

**HARDWOOD SILVICULTURE AND MANAGEMENT:
AN INTERPRETIVE LITERATURE REVIEW FOR THE CANADIAN MARITIME PROVINCES**

by

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ABSTRACT

The current state of hardwood inventory and management in New Brunswick and Nova Scotia is described. The review acknowledges three major source works about hardwoods and incorporates contemporary research literature on hardwood silviculture and management pertinent to the Canadian Maritime Provinces.

The silvics of seven major and eight minor species with which the forest manager must deal are discussed together with the silvicultural implications of species characteristics.

Silvicultural operations appropriate to stated management objectives, and guides to management using optimum stocking levels are then reviewed. In conclusion, recommendations for management research and development are made. There are 104 references.

RESUME

L'auteur décrit l'état actuel des inventaires et de l'aménagement des feuillus au Nouveau-Brunswick et en Nouvelle-Ecosse. Il prend note de trois travaux de base sur les feuillus et groupe la documentation contemporaine sur la sylviculture et l'aménagement des feuillus dans les Maritimes.

Il discute des pratiques sylvicoles concernant sept espèces importantes et huit espèces mineures avec lesquelles le gérant forestier doit composer. Il étudie aussi les implications sylvicoles des caractères des espèces.

Puis il passe en revue les opérations sylvicoles appropriées à des objectifs définis d'aménagement, outre les guides d'aménagement utilisant le boisement optimal. En conclusion il formule des recommandations en vue de la recherche et du développement en matière d'aménagement. Il y a 104 références.

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INTRODUCTION

This review of literature is an early step in beginning hardwood research and development programs which are being prepared and implemented jointly and concurrently by the Maritimes Forest Research Centre and the New Brunswick Department of Natural Resources, and the Maritimes Forest Research Centre and the Nova Scotia Department of Lands and Forests.

Hardwood and mixedwood forest sections in the Acadian Forest Region, described by Rowe (1972), follow natural physiographic and climatic site types, not political boundaries. The research

programs proposed and underway, therefore, deal with problems in hardwood forest management and silviculture which may be socio-economic or political in origin, but which must be solved in the context of natural vegetation distributions, and the hardwood forest resource wherever it is located. Loucks (1962) in his report "A forest classification for the Maritime provinces" describes seven forest zones and 11 ecoregions. Hardwoods are found in each one (Table 1). Rowe (1972) describes 13 forest sections with an important hardwood component in 11 of these.

In the Maritimes, foresters and forest ecologists recognize a range of "mixedwood" cover types, based on the proportions of the hardwood and softwood

Table 1. Distinctive features of the zones and ecoregions

Zone	Ecoregion	Characteristic species	Associated climate
Sugar maple-Ash		sM,Be,wAs*	Warm, dry
	(1) St. John River	sM,Be,l,wAs,Bu,Ba	Warm, dry
Sugar maple-Hemlock-Pine		sM,Be,wP,eH,yB	Mod. warm, mod. dry
	(2) Restigouche-Bras d'Or	sM,Be,bF,yB,wP,wS	Mod. cool, mod. dry
	(3) Magaguadavic-Hillsborough	sM,Be,wP,eH,bF,rS	Mod. warm, mod. dry
Sugar maple-Yellow birch-Fir		sM,yB,bF,Be	Cool, moist
	(4) Maritime Uplands	sM,yB,bF, Be,wS,rS,rM	Cool, moist
Red spruce-Hemlock-Pine		rS,bF,eH,wP,rM	Mod. warm, mod. dry
	(5) Clyde River-Halifax	rS,wP,eH,rO, rM,bS,Be	Warm, dry
	(6) Maritime Lowlands	bF,rS,bS,eH,wP,rM,jP,wS,Be	Mod. cool, mod. dry
Spruce-Fir Coast		wS,bF,wB	Cool, wet
	(7) Fundy Bay	rS,bF,wB,wS,bS,yB,Mo	Cool, wet
	(8) Atlantic Shore	wS,bF,bS,wB	Cool, wet
Fir-Pine-Birch		bF,wB,wS,wP	Cool, moist
	(9) New Brunswick Highlands	bF,wB,wP,tA,wS,bS,jP,rS	Cold, mod. dry
	(10) Gaspé-Cape Breton	bF,wB,wS,bS	Cold, wet
Spruce Taiga		bS,bF,wS	Cold, wet
	(11) Cape Breton Plateau	bS,bF,wS,wB,Mo	Cold, wet

* Abbreviations of tree names are those adopted by the C.I.F., For. Chron., 1952.

stand components, and only a few "hardwood" types. Forest disturbance by logging and burning, however, has resulted in an increase in the predominantly hardwood cover type in "mixedwood" areas and the persistence or increase of hardwoods in mixtures. The tolerant and sometimes more valuable hardwoods (sugar maple, yellow birch, white ash and beech¹) are threatened by forest disturbances, and the intolerant and often less valuable hardwoods (trembling aspen, balsam poplar, white birch, grey birch, red maple and red oak) may be stimulated to seed, sucker and sprout following logging or fire.

Use of softwoods in the Maritimes is at, or near, capacity. Use of hardwoods is only one-third of the overall calculated capability. Under-utilization of an increasing area of pioneer hardwoods, and gross over-usage through high-grading of quality hardwoods during the past 200 years and continuing to this date have created the current need for better forest management.

In management of softwood for fibre production, the ability of pioneer hardwood tree and shrub species to colonize disturbed sites and to compete successfully with softwood regeneration for survival and growth are problems which have called for intensive silvicultural treatment. Expensive treatments to remove hardwood residuals, such as tree crushing and poisoning, are common in Maritimes silviculture. In quality hardwood management there is both a challenge and an opportunity for species selection through canopy manipulation and better silviculture. The problems of softwood management are thus seen to be problems of hardwood management also, (West 1976).

THE CURRENT SITUATION

Professor G.L. Baskerville in his 1976 report to the Maritimes Forest Research Centre² traces the development of the management problem as he sees it in New Brunswick and in Nova Scotia:

¹ Nomenclature follows Rowe (1972).

² Hardwood research in the Maritimes. G.L. Baskerville — 1976 report to the Maritimes Forest Research Centre. 49pp. Unpubl.

New Brunswick

The Forest

"There are more or less 60 million cunits of hardwood in the New Brunswick forest. The principle species are the maples and birches and these together could theoretically yield an annual cut of .98 million cunits (Table 2). There is no coherent information on the stand mixtures in which these species occur. Typically, pure hardwood stands contain various proportions of these species with spruce, fir and the other softwoods. Poplar occurs as nearly pure stands and in mixture with the softwoods.

The distribution of the productive forest area by broad cover types shows that 13% supports "hardwood" stands, 20% supports mixed "hardwood-softwood" (Table 3). Two thirds of the hardwood forest is on freehold land. In terms of volume, slightly more than two thirds is on freehold land (Table 4). The fact that the total volume in Table 4 does not agree with that given in Table 3 is typical of the data base problem. These are derived separately and could not be reconciled.

There is a paucity of information on the growth of hardwoods. The most reliable data are in the form of an average for all forests in the province — 7.9 net cubic feet of hardwoods per acre per year (Table 5). Such an average figure, however, is no indication of the performance of hardwood stands.

For the province as a whole the current annual hardwood harvest amounts to 45% of the annual allowable cut of 1.4 million cunits (Table 6). Over the five Wood Processing Regions this ranges from 22% to 118%. That is, the hardwood resource is on the average under-utilized but is locally harvested in excess of the calculated allowable cut.

Variations in harvesting practice are startlingly broad. In areas where hardwood is felled for pulpwood using the Chipharvester at roadside virtually no residual stand is left. At the other extreme, remote from hardwood pulpmills, the sawlog harvest may run as low as one cunit per acre. In one HS stand near Edmundston, for which data were taken in the summer of 1975, there were 14 cunits of hardwood standing after a "clear cut" for softwood pulp and hardwood sawlogs (Table 7). In addition there were nearly 8 cunits felled and left on the ground as waste.

Table 2. Merchantable volume by species and size class for province of New Brunswick¹⁾.

Species	Diameter Group			total	AAC ²⁾	Harvest ³⁾
	4-5	6-9	10+			
	(000,000 cubic feet)					
sugar maple	102	231	827	1160		
red maple	307	609	504	1420	60.28	?
yellow birch	55	198	448	701	37.82	?
white birch	168	316	263	747		
beech	116	244	454	814	12.78	?
poplar	124	409	490	1023	28.67	?
other	50	59	68	177	3.52	?
Total	922	2066	3054	6042	143.07	61.7

1) New Brunswick inventory, 1968.

2) AAC = allowable annual cut from "Sandwell" report.

3) harvest = cut projected for 1975 by Department of Economic Growth.

Table 3. Stocked area by tenure class and cover type, New Brunswick¹⁾.

	<u>Crown</u>	<u>Large freehold²⁾</u>	(Acres)	<u>Small freehold</u>	<u>Total</u>
S ³⁾	2,839,600	1,181,400		1,587,400	5,608,400
SH	1,768,000	750,200		1,118,900	3,637,100
HS	1,251,400	722,600		800,900	2,774,900
H	<u>545,100</u>	<u>540,300</u>		<u>670,500</u>	<u>1,755,900</u>
Total	6,404,100	3,194,500		4,177,700	13,776,300

	<u>Crown</u>	<u>Large freehold</u>	(%)	<u>Small freehold</u>	<u>Total</u>
S	21	9		11	41
SH	13	5		8	26
HS	9	5		6	20
H	<u>3</u>	<u>4</u>		<u>6</u>	<u>13</u>
Total	46	23		31	100

	<u>Crown</u>	<u>Large freehold</u>	(%)	<u>Small freehold</u>	<u>Total</u>
S	51	21		28	100
SH	49	21		30	100
HS	45	26		29	100
H	31	31		38	100

	<u>Crown</u>	<u>Large freehold</u>	(%)	<u>Small freehold</u>	
S	44	37		38	
SH	28	23		27	
HS	20	23		19	
H	<u>8</u>	<u>17</u>		<u>16</u>	
Total	100	100		100	

1) compiled from New Brunswick Inventory, 1968.

2) Large freehold = 5000 acres or larger.

3) S = > 75% softwood by volume.
 SH = 50 – 75% softwood by volume.
 HS = 25 – 50% softwood by volume.
 H = < 25% softwood by volume.

Table 4. Merchantable hardwood volume by tenure class and cover type, New Brunswick¹⁾.

	<u>Crown</u>	<u>Large freehold²⁾</u>	(cunits)	<u>Small freehold</u>	<u>Total</u>
S ³⁾	3,275,700	1,847,100		2,077,500	7,196,400
SH	5,868,600	3,631,600		3,721,400	13,221,600
HS	7,767,900	6,988,600		7,324,700	22,081,200
H	4,841,400	6,134,400		4,789,700	15,765,500
Total	21,753,600	18,601,800		17,909,300	58,264,700

	<u>Crown</u>	<u>Large freehold</u>	(%)	<u>Small freehold</u>	<u>Total</u>
S	6	3		3	12
SH	10	6		7	23
HS	13	12		13	38
H	8	11		8	27
Total	37	32		31	100

	<u>Crown</u>	<u>Large freehold</u>	(%)	<u>Small freehold</u>	<u>Total</u>
S	45	26		29	100
SH	44	28		28	100
HS	35	32		33	100
H	31	39		30	100

	<u>Crown</u>	<u>Large freehold</u>	(%)	<u>Small freehold</u>	
S	15	10		12	
SH	27	20		21	
HS	36	38		41	
H	22	32		26	
Total	100	100		100	

1) compiled from New Brunswick Inventory, 1968.

2) Large freehold = 5000 acres or larger.

3) S = > 75% softwood by volume.
 SH = 50 – 75% softwood by volume.
 HS = 25 – 50% softwood by volume.
 H = < 25% softwood by volume.

Table 5. Volume growth averages from New Brunswick from provincial forest inventory 2nd and 3rd remeasurements of permanent sample plots.

	Spruce	Fir	Spruce	Other Softwood	Total Softwood	Hardwood	All Species
Original Volume (cu ft/ac)	439	374	813	174	987	402	1389
Cubic Feet Per Acre Per Year							
Net Growth	12.4	9.5	21.9	4.7	26.6	7.9	34.5
Mortality	4.9	8.1	13.0	1.4	14.4	6.3	20.7
Gross Growth	17.3	17.6	34.9	6.1	41.0	14.2	55.2
Ingrowth	1.9	3.0	4.9	0.9	5.8	2.7	8.5
Accretion	15.4	14.6	30.0	5.2	35.2	11.5	46.7
Percent of Original Volume							
Net Growth	2.8	2.5	2.7	2.7	2.7	2.0	2.5
Mortality	1.1	2.2	1.6	0.8	1.5	1.5	1.5
Gross Growth	3.9	4.7	4.3	3.5	4.2	3.5	4.0
Ingrowth	0.4	0.8	0.6	0.5	0.6	0.7	0.6
Accretion	3.5	3.9	3.7	3.0	3.6	2.8	3.4

Table 6. Annual allowable cut and drain by wood processing region and species group for 1975, New Brunswick ¹⁾.

	WPR1 ²⁾		WPR2		WPR3		WPR4		WPR5		Totals	
	SW	HW	SW	HW	SW	HW	SW	HW	SW	HW	SW	HW
(000s cunits)												
Annual Allowable cut	804	237	684	218	650	250	501	245	1010	480	3649	1430
Drain												
sawmills	208	36	126	8	230	62	122	28	258	6	944	140
pulpmills	409	88	446	33	417		56	254	914	85	2242	460
veneer								6				6
particleboard			9	6					16	5	25	11
plywood			30								30	
TOTAL	617	124	611	47	647	62	178	288	1188	96	3241	617
AAC – Drain	187	113	73	171	3	188	323	(43)	(178)	384	408	813
Ratio Drain/AAC	.76	.48	.89	.22	1.00	.25	.36	1.18	1.18	.80	.89	.43

¹⁾ Source: compiled by Resource Utilization Division - N.B. Department of Economic Growth.

²⁾ WPR = wood processing region.

³⁾ SW = softwood,
HW = hardwood.

Table 7. Summary of residual stand and felled waste after softwood pulpwood harvesting and hardwood sawlog harvesting in an HS stand near Edmundston ¹⁾.

	Standing volume by d.b.h. class			
	5	6-9	10+	Total
	(cunits/ac)			
Sugar maple	.14	1.13	8.45	9.81
Yellow birch	—	.91	1.51	2.42
Beech	—	.35	1.57	1.92
Total	.14	2.39	11.62	14.15
	Felled waste volume by d.b.h. class			
	5	6-9	10+	Total
	(cunits/ac)			
Sugar maple	—	.10	6.00	6.10
Yellow birch	—	.09	1.03	1.12
Beech	—	.08	.58	0.66
Total		.27	7.61	7.88

¹⁾ Special survey by J. Levesque and R. West, 1975.

The Problem

The hardwood problem in New Brunswick is fundamentally one of utilization. It is difficult to justify active management when less than one half of the estimated allowable cut is being taken. Indeed this suggests that the hardwood forest is building up. Such seems to be the case for volume, but there is considerable doubt as to whether or not the quality of the forest is improving.

The question of quality is of transcending importance in discussing hardwood management. The annual allowable cut was calculated by Hanzlik's formula, an algorithm devised explicitly to handle the conversion of an essentially old growth forest to a managed, balanced age distribution. It deals in terms of volume and in essence spreads the liquidation period (of the old forest) out over an appropriate period to permit formation of a balanced age distribution. Although there are no age data for New Brunswick forests, it is widely held that this was an appropriate use of Hanzlik's formula. A fundamental assumption of the formula in terms of conversion to a managed forest is the complete removal of the forest and regeneration to a uniform age class at each harvesting.

Although the allowable annual cut is 1.43 million cunits, in practice quality rules utilization and the .62 million cunit harvest is determined by the availability of "quality" hardwood. It is generally held that if the forest run quality was higher in terms of saw and veneer logs, utilization would readily rise to the allowable cut.

There is a distinct possibility that the present considerable undercut in terms of volume is in fact an overcut with respect to quality! That is, the better quality material is being removed from the forest faster than the present forest structure permits development of material of this quality. If this is the case then quality of the forest is declining while the volume is increasing. It is not possible to document this notion because of the absence of quality data on the standing forest. However, one or two simple calculations serve to suggest the need for care here. If New Brunswick harvested hardwood at the allowable annual cut rate then the average age of each cunit in inventory would be 41 years (i.e. inventory divided by cut). Based on current drain, the average age of each cunit of inventory is 95 years. These are "ages from merchantability", but even after allowing a liberal time for stands to reach merchantable proportions it is clear that such a forest would be yielding much younger trees than the two-century-old veterans currently considered to be top quality. Left to itself the forest will only produce trees of 200-year stature when harvested every 200 years. If we use a shorter rotation we must either take silvicultural action to increase the tree size, or accept smaller trees.

In general there is no compelling reason to manage a

forest until it is under full utilization. Indeed, it can be argued that money expended on silviculture before full utilization is reached is wasted cunits per annum at which point management will be both necessary and mandatory. There are at least two critical dangers inherent in such an obvious solution. Firstly, if indeed New Brunswick is already harvesting at or beyond the level of quality renewal, an increase in utilization would be disastrous. It would not be sustainable, even in the short run. Secondly, because of the present forest structure such an increase would have to be based on low quality material because it is too susceptible to market fluctuations.

Clearly the hardwood problem requires more than superficial analysis if a workable solution is to evolve. Attempts to go beyond the superficial, however, quickly reveal the impossibility of rational analysis of the hardwood problem under existing conditions. The reason for this is the devastating absence of critical information. The lack of a hardwood policy is decried, but such a policy is not possible in the absence of fundamental data on the resource to be managed. Particularly:

- 1) The distribution of the hardwoods throughout the province is not known either by type, area or by species.
- 2) There is no accepted standard of quality hence the distribution of quality throughout the province is not known.
- 3) The volume growth of hardwoods is not known by cover type and species.
- 4) The quality growth of hardwoods is not known except in a few scattered instances.
- 5) The developmental pattern on cut over land is not known and it is necessary to assume that future growth will be similar to past growth.
- 6) The age distribution of the hardwood forest is not known.
- 7) The level of utilization by species is not known either for the province or by ownership class.

The information listed above is fundamental to the formulation of the most primitive management policy. Without such information New Brunswick can only expand utilization on the assumption that growth of quality is equal to drain in quality. Without this information it is not possible to determine a reasonable hardwood policy or even a reasonable set of goals. That is, the silvicultural management appropriate for the forest resource and the economic development for utilization would be self evident.

Simple goals such as "get as much high quality hardwood as possible" are worse than no goal at all. With such undefined goals it is never possible to tell when, or if, you get there or even if you are progressing in the proper direction. Similarly pious notions of sustained yield are equally misleading. These must, at present, assume the growth of forest in both quantity and quality is equal to drain in quantity and each

year (a byproduct of moving from an "old" to a "managed" forest) there is some doubt that even the present level of quality harvest can be sustained without silvicultural input. This is not a catastrophic situation but rather an ever declining ramp-function which makes it much easier to rationalize inaction. It is a virtual certainty that an unmanaged forest will not yield 1.43 million cunits per year in the current quality mix for any period of time. The yield of 1.43 million was calculated to liquidate existing old stands with no consideration of quality. Yet the present quality mix is widely held to be inadequate.

Nova Scotia

The Forest

There are some 27 million cunits of hardwood in Nova Scotia. The distribution of this volume by species is given in Table 8. The principal species are the maples and birches (54% and 28% of the volume respectively), but there are nine other species including substantial amounts of aspen and beech. Best quality pure hardwood stands typically contain sugar maple, both birches and beech while mixedwood stands contain various combinations of all but the most intolerant hardwoods along with the softwood species.

The distribution of the 10.7 million acres of forested land in the province is 17% hardwood, 30% mixedwood and

53% softwood (Table 9). Only one-quarter of the hardwood forest is on crown land and fully one-half is on small free holdings. The proportions in terms of volume are essentially the same (Table 10).

Growth data from the provincial inventory indicate a net growth of hardwood species (all cover types) of 8.8 cubic feet per acre per year (Table 11). Growth data are available by age class and tenure for each inventory subdivision with the highest hardwood growth rates occurring in the North Central, South Central and Eastern Subdivisions (Table 11).

The current annual harvest of hardwoods for the province as a whole is of the order of 150,000 cunits. This amounts to 5.4 cubic feet per acre per year based on the hardwood land only or 3.3 cubic feet per acre per year based on the hardwood land plus one-half the mixedwood land. In either case the cut represents only a fraction of the current growth (40-60%). Nova Scotia has not calculated an allowable cut for hardwoods but the available data all suggest the hardwood resource is underutilized except in very local areas.

Because of the light utilization there are wide variations in harvesting practice. Areas cut to supply the hardboard plant are often clear felled while hardwoods are left standing in most softwood pulpwood 'clear cuts'. Throughout the rest of the province these residual stands pose considerable problems in that they hinder management for the softwood component but are of sufficient quality to make cut-over clearing appear to be a wasteful practice. While there are

Table 8. Merchantable volume by species and size class for the province of Nova Scotia¹⁾.

	Diameter group			Total
	4-6	7-9	10+	
	(000,000 cubic feet)			
sugar maple	57	88	208	353
red maple	280	401	434	1,115
yellow birch	61	120	349	530
white birch	91	95	59	245
oak	21	29	30	80
aspen	43	65	75	183
grey birch	18	2	0.5	20.5
white ash	6	9	11	26
black ash	0.6	1	1.7	3.3
cherry	0.7	0.5	0.2	1.4
elm	0.2	0.5	2.8	3.5
beech	42	54	66	162
balsam poplar	—	—	—	trace
Total	620.5	865	1237.2	2722.7

¹⁾ Nova Scotia Inventory, 1971.

Table 9. Stocked area by tenure class and cover type, Nova Scotia¹⁾.

	<u>Crown</u>	<u>Large²⁾ freehold</u>	<u>Small freehold</u>	<u>Federal</u>	<u>Total</u>
	(Acres)				
Softwood ³⁾	1,420,930	1,168,930	2,942,940	188,290	5,721,200
Mixedwood	677,570	688,450	1,748,450	58,010	3,172,600
Hardwood	459,060	416,440	953,070	20,850	1,858,490
Other forest	3,950	2,120	3,220	—	9,310
Total	2,561,620	2,275,990	5,647,750	276,220	10,761,670

	<u>Crown</u>	<u>Large freehold</u>	<u>Small freehold</u>	<u>Federal</u>	<u>Total</u>
	(%)				
Softwood	13	11	27	2	53
Mixedwood	7	7	16	—	30
Hardwood	4	4	9	—	17
Other forest	—	—	—	—	—
Total	24	22	52	2	100

	<u>Crown</u>	<u>Large freehold</u>	<u>Small freehold</u>	<u>Federal</u>	<u>Total</u>
	(%)				
Softwood	25	20	52	3	100
Mixedwood	21	22	55	2	100
Hardwood	25	22	51	2	100
Other forest	42	23	35	—	100

	<u>Crown</u>	<u>Large freehold</u>	<u>Small freehold</u>	<u>Federal</u>	
	(%)				
Softwood	55	52	52	68	
Mixedwood	27	30	31	21	
Hardwood	18	18	17	11	
Other forest	—	—	—	—	
Total	100	100	100	100	

1) Nova Scotia Inventory, 1971.

2) large freehold = 1000 acres or larger.

3) softwood ≥ 75% softwood by volume.
 mixedwood 20–74% softwood by volume.
 hardwood ≤ 25% softwood by volume.

Table 10. Merchantable hardwood volume by tenure class, Nova Scotia¹⁾

<u>Crown</u>	<u>Large²⁾ freehold</u>	<u>Small freehold</u> (000,000 cubic feet)	<u>Federal</u>	<u>Total</u>
621	659	1,388	54	2,722
23%	24%	51%	2%	100%

1) Nova Scotia Inventory, 1971.

2) large freehold = 1000 acres or larger.

Table 11. Volume growth averages for the province of Nova Scotia¹⁾.

<u>Ownership</u>	<u>Net growth</u>		<u>Mortality</u>	
	<u>softwoods</u>	<u>hardwoods</u>	<u>softwoods</u>	<u>hardwoods</u>
	(cu ft/ac/yr)			
crown	21.2	6.6	11.2	1.5
large freehold	20.2	10.8	10.2	1.8
small freehold	26.4	9.5	6.0	2.2
Federal	17.9	1.1	5.4	6.4
Provincial average	23.4	8.8	8.2	2.0
<u>Subdivision</u>				
Cape Breton	23.7	5.9	11.5	1.5
Eastern	28.4	9.4	7.3	1.5
North Central	30.0	15.7	5.0	3.1
South Central	22.8	12.1	6.3	1.4
Valley	23.9	5.8	7.3	3.6
South Shore	25.0	5.5	7.4	3.0
Southwestern	8.1	6.0	11.8	12.6

1) Nova Scotia Forest Inventory section, 1974.

certainly local variations, the inventory data do not suggest a successional trend away from softwood towards mixedwood and from mixedwood towards hardwood following harvesting. There is some suggestion, however, of a declining trend in the presence of sugar maple and yellow birch, two of the more valuable species.

Despite the fact that the hardwood forest is increasing in volume (i.e. it is undercut) it is generally conceded that the quality of the forest is declining. This is not a readily demonstrable fact, but derives from observation and from inventory data which show that the proportion of the volume in trees of the largest size class is decreasing. The reason for the decline in quality appears to be the prevalence of high grading the hardwood resource. This procedure, of course, causes an immediate decline in quality, but also results in a forest structure that is unsuitable to the development of quality material. Thus, the loss in quality with high grading tends to be **persistent**. Inventory data suggest that the small freehold forest has suffered most in this respect.

The Problem

Hardwood management in Nova Scotia faces the double problem of oversupply and low quality. It is, at best, difficult to manage in the face of oversupply. The problem is monumental when the excess material is of low quality. Nova Scotia appears committed to a policy of non-conversion in that they wish to maintain the hardwood forest rather than convert it to softwoods. Their reasoning for this is sound. They argue that hardwoods are essential to maintain site quality and that conversion runs too many risks with respect to other forest values. The most valuable stands and the 'place to start' have been tentatively identified as the young tolerant hardwoods on upland sites. The objective here would be related to enhancing the quality of these stands. However, because of the preponderance of volume on small freehold and its poor (relatively) quality it is regarded as essential to acquire increased industrial capacity to use lower quality hardwoods.

While the information base is more complete than in New Brunswick, the policy analysis steps still have to be explicitly followed to reach both an active management program and to permit research planning."

In this way, Baskerville introduces the management problems and so the research needs.

Lack of orderly use of the hardwood forest resource for production, protection, and amenity; low demand levels; unreliability of markets; distance between quality hardwood use and quality hardwood stand; or between low quality hardwood use and

pulpwood stand are recurring features of problem analyses (Tweeddale 1974; Atlantic Area Consultants 1965; Baskerville 1976; Dickinson 1976; West 1976). There are at the same time, expanding uses of hardwoods, new technologies and increasing demands for other hardwood forest values. Among these are:

Production forestry;

- Fuelwood for electric power,
- Charcoal for energy and industrial use,
- Conventional sawtimber,
- Mining timbers and railroad ties,
- Shortwood logs for furniture components,
- Fibreboards,
- Waste products for fuel,
- Waste products for poultry bedding and fertilizer,
- Sugarbush management,

Protection forestry;

- Watershed management for quality and yield,
- Wildlife management for large and small game, fish and birds,
- Site and soil improvement,

Amenity forestry;

- Parks and recreation,
- Tourism,
- Highway landscaping,
- Disturbed land reclamation,

Short-term production demands on Maritimes hardwoods are unpredictable. Short-term utilization of even the traditional forest products depends on widely fluctuating markets, transportation costs, and costs of woods operations. Long-term demands can only be ranked along with vague predictions of unprecedented world consumption of all forest products, increases in use of other forest resources, and the impact of spruce budworm on softwood supplies. More complete utilization in the Maritimes will depend on better management of the forest to ensure volume supplies and to improve the forest resource. Thus, there are management and silvicultural problems associated with the existing, often decrepit, hardwood forest and also associated with the new forest to be established for the next and future rotations.

The review of literature which follows is designed to guide the reader to material relevant to his interest in Maritimes hardwood management and silviculture. It may help in decision-making but it is not in itself decisive.

SILVICS OF THE SPECIES

The tree species with which Maritimes Forest Managers are mainly concerned are, in approximate increasing order of tolerance,

trembling aspen	<i>Populus tremuloides</i> Michx.
largetooth aspen	<i>Populus grandidentata</i> Michx.
grey birch	<i>Betula populifolia</i> Marsh.
white birch	<i>Betula papyrifera</i> Marsh.
red oak	<i>Quercus rubra</i> L.
white elm	<i>Ulmus americana</i> L.
white ash	<i>Fraxinus americana</i> L.
yellow birch	<i>Betula alleghaniensis</i> Britton
red maple	<i>Acer rubrum</i> L.
sugar maple	<i>Acer saccharum</i> Marsh.
American beech	<i>Fagus grandifolia</i> Ehrh.

Hardwoods generally grow in mixed stands in the Acadian forest region (Rowe 1972). Forest sections are located as illustrated in Figures 1 a, b, and c. Where site and soil conditions are severe, the pioneer hardwoods such as grey birch, white birch, and the poplars are found in association with softwoods such as white spruce, black spruce, and jack pine. Thus, softwoods predominate in the New Brunswick Uplands (A.1), the Eastern Lowlands (A.3), the South Atlantic Shore (A.5a), the East Atlantic Shore (A.5b), the Cape Breton Plateau (A.6) and the Atlantic Uplands (A.11), because of elevation, exposure and coastal winds. At lower elevations, on well-drained but moisture rich slopes, and in sheltered locations further inland in both Nova Scotia and New Brunswick, tolerant hardwoods are common. Mixed softwood/hardwood stands and tolerant hardwoods occur predominantly therefore in the Upper Miramichi-Tobique (A.2), Carleton (A.4), Southern Uplands (A.10), Central Nova Scotia Lowlands (A.12), Cobequid (A.13) and the Cape Breton - Antigonish (A.7) Sections. The Fundy Coast (A.9) Section is variable and it is difficult to interpret existing forest cover because of the very significant disturbance of this accessible forest.

On disturbed sites, contemporary clearcuts, abandoned agricultural land and on repeatedly burned-over areas, the poplars, grey birch, white birch, and red maple colonize even potentially productive areas since the seed source for other species has been removed. Associated pioneer softwoods are common in mixture. The more valuable and more tolerant hardwoods, sugar maple, yellow birch, white ash, and beech

occur in association with red spruce, white pine, Eastern hemlock, and Eastern white cedar. Hardwoods are usually absent on the poorly-drained acid soils where only black spruce and tamarack can survive. Silvicultural implications of species characteristics are often far-reaching and always significant in the achievement of management objectives. Site and soil preferences, regeneration requirements, survival and growth rates, competitive abilities, and tolerance of limiting factors contribute to the more or less satisfactory performance of any species under a management regime.

The species and associated forest cover types, limits to growth, and major enemies are described in detail in "Silvics of Forest Trees of the United States" by H.A. Fowells (ed. 1965)³. Details of seeds, seeding, and propagation are described in "Seeds of Woody Plants in the United States"⁴ by C.S. Schopmeyer (ed. 1974), and the "Hardwood Nurseryman's Guide"⁵ by R.D. Williams and S.H. Hambs (1976). With ready access to these source works, the forester can begin to assess constraints to growth. Additional information presented here is extracted from other recent reports.

WHITE ASH

The Maritime Provinces represent the extreme north and east of the range of white ash (Wright 1959). The northern ecotype has been identified as winter hardy, diploid, with distinctive purple fall leaf color. It is described (Fowells 1965) as the largest, commonest, and most useful of the ashes and is a component of some mixedwood (white pine - hemlock - red spruce) and many hardwood stands in association with sugar and red maple, beech, and yellow birch. Demanding in its site requirements, ash is not a vigorous competitor in mixture, requiring shade (about 45% of full sunlight) and shelter in the early stages of growth, and increasing light from sapling stage to maturity (Logan 1973). Thus, it responds to thinning from above. It is a moisture-loving species which tolerates periodic flooding, though not swampy areas. A prolific stump sprouter,

³ Agriculture Handbook 271. USDA Forest Service 762 pp.

⁴ Agriculture Handbook 450. USDA Forest Service 883 p.

⁵ Agriculture Handbook 473. USDA Forest Service 78 p.

Figure 1a

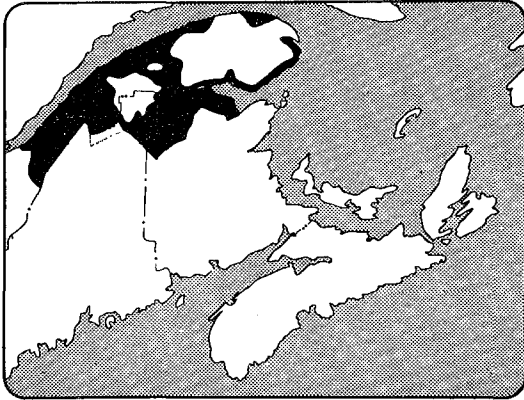
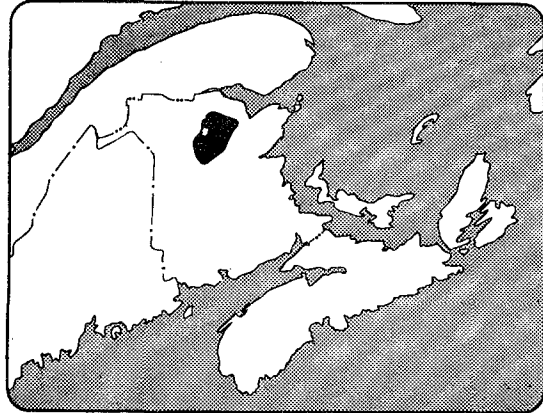
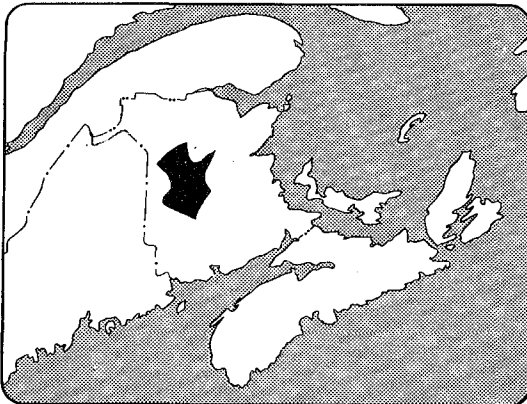
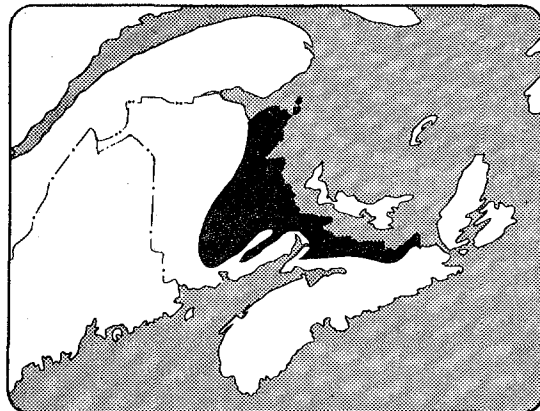
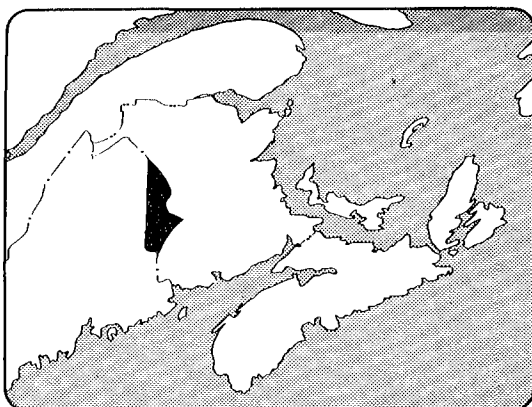
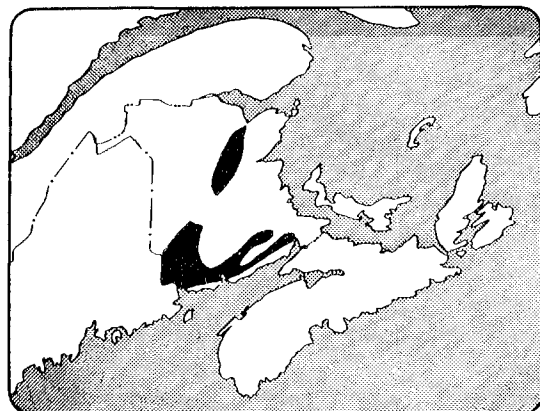
L.6 — Temiscouata-Restigouche**A.1 — New Brunswick Uplands****A.2 — Upper Miramichi-Tobique****A.3 — Eastern Lowlands****A.4 — Carleton****A.10 — Southern Uplands**

Figure 1b

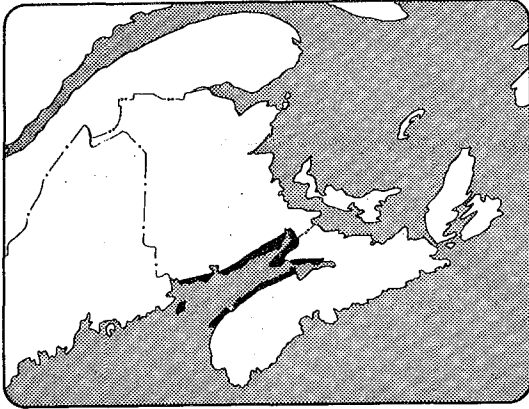
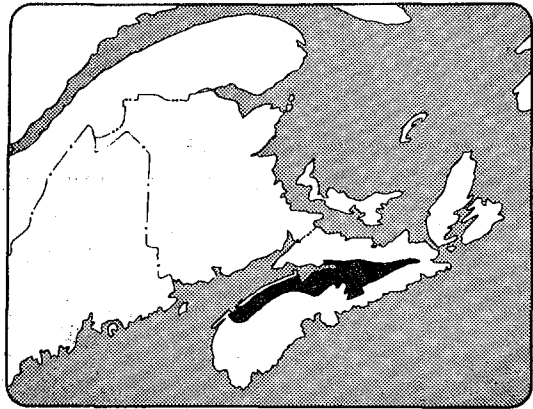
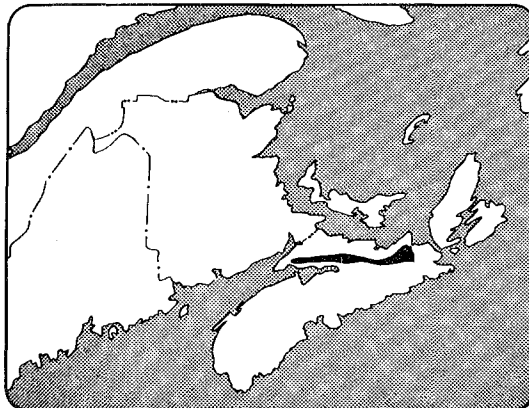
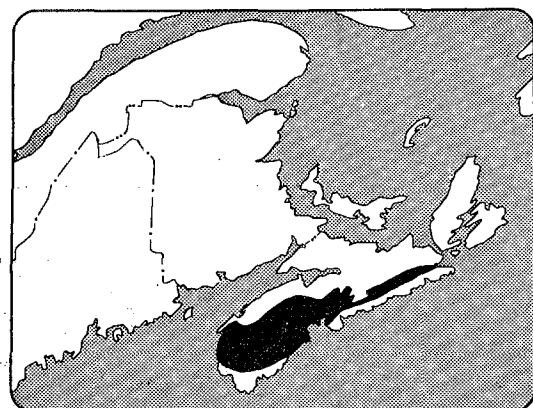
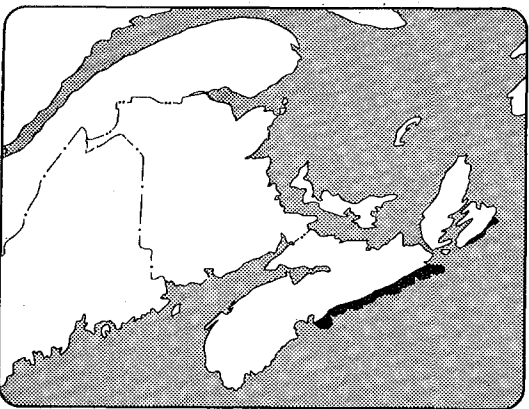
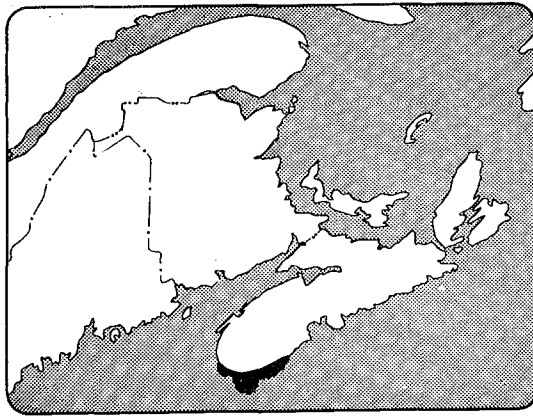
A.9 — Fundy Coast**A.12 — Central Lowlands****A.13 — Cobequid****A.11 — Atlantic Uplands****A.5b — East Atlantic Shore****A.5a — South Atlantic Shore**

Figure 1c

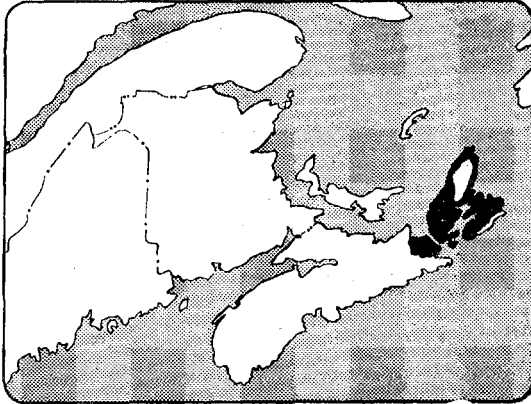
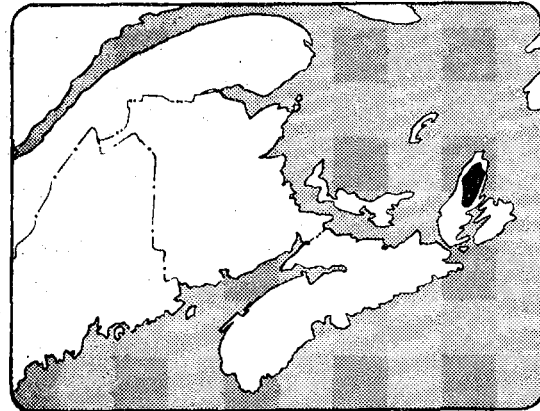
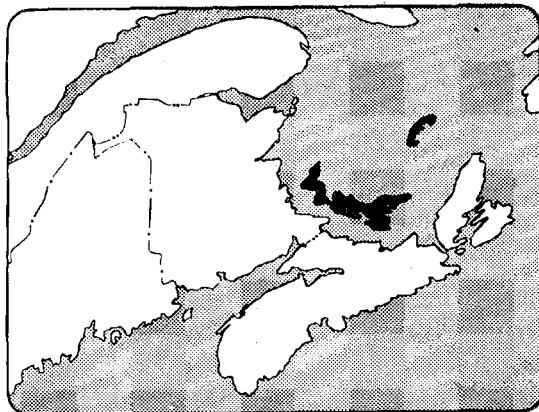
A.7 — Cape Breton-Antigonish**A.6 — Cape Breton Plateau****A.8 — Prince Edward Island**

Figure 1.
Major Forest Sections in the Maritimes
Reproduced from "Forest Regions of
Canada" by J.S. Rowe, 1972.

it is a favorite deer browse species. The value of ash for both wood fibre (pulp) and for custom sawing stock is such that silvicultural treatments to favor ash in hardwood stands may be well worthwhile (Cope 1948). In mixed stands, ash also fulfills the role of soil improver.

Occurrence

White ash is found in the Carleton (A.4), Atlantic Uplands (A.1), and Central (N.S.) Lowlands (A.12) forest sections, and almost always in association with sugar maple, yellow birch, and red maple.

Delayed and vigorous germination of covered white ash seeds observed by Leak (1963a) suggests a site preparation technique which incorporates ash seed with organic matter. Ash regeneration is favored under a shelterwood of 40 to 80 sq ft basal area/acre or in small clearcuts of 0.05 to 0.1 acre. White ash self-prunes well in dense stands. Yield tables for tolerant hardwoods in Ontario (Plonski 1974) predict mean annual increment of 2.4 m³/ha per year or 34 ft/acre per year. White ash productivity will compare favorably with these estimates yet as Drinkwater (1957) points out, white ash in Nova Scotia seldom forms a significant proportion of the stand basal area. It is a species worth promoting.

Silvicultural Implications

Group selection silviculture and narrow strip clearcutting with shelterwood cutting in leave strips appear to suit the characteristics of white ash.

YELLOW BIRCH

Yellow birch is a very valuable component of hardwood and mixedwood stands in the Maritimes.

Occurrence

Yellow birch is a component of stable forest communities in all but three of Rowe's forest sections in the Acadian Forest Region the South Atlantic Shore (A.5a), East Atlantic Shore (A.5b), and Fundy Coast (A.9). Associated species are sugar maple, red maple, beech, white birch, white ash, red spruce, eastern white pine, and eastern hemlock. It often attains veneer qualities and grows to, at least, saw-

log sizes. A thin-barked species, yellow birch is easily damaged during partial cutting, and logging wounds expand. Damage to the stump/root system causes discoloration of the most valuable butt log. Shigo and Larsen (1969) describe yellow birch as particularly susceptible to the advance of decay organisms. Sap sucker damage is common. Because clear wood is so valuable in this species each treatment to improve quality is worth considering. Natural pruning followed by thinning promotes healing of branch stubs, (Solomon and Blum 1977). A pruning treatment immediately after thinning will take advantage of increased vigor and rapid diameter growth to heal pruning wounds. Clear wood means logs of veneer quality and an opportunity to increase stand value by as much as 6%. Patch clearcuts (0.1 - 0.6 acres), slightly larger than for white ash, are suitable for natural regeneration of yellow birch. Seedlings are taller and heavier when grown in 45% of full light (Logan 1965). Loucks (1962) places yellow birch mainly in the Maritimes Uplands ecoregion and describes the climate as cool and moist. He notes the abundance and vigor of competing ground vegetation in this ecoregion and intensive site preparation is required to promote yellow birch on these sites. Dieback of yellow birch is a recurring phenomenon in the Maritimes. Stillwell, (1954), and Drinkwater (1957) cautiously suggest sanitation cutting in yellow birch where dieback is evident. Since many affected crowns may recover, only moribund stems (that is, with many secondary infections) need be removed.

At the Birch Symposium held at the University of New Hampshire in Durham, New Hampshire in 1969, 29 papers were presented. At that time, the joint chairmen, P.E. Bruns and W.J. Doolittle, said:

"From a review of the papers prepared for presentation at this meeting it is evident that we already know much about how to grow and utilize the birches especially those that regenerate naturally. We know enough to do a much better job of managing our birch stands than we are doing now. Nevertheless, even for natural stands we still have much to learn about spacing and thinning and about birch nutrition and fertilization. It is in artificial regeneration and plantation management of the birches that our knowledge is most woefully weak."

Doolittle and Bruns go on to say;

"Top grade birch veneer logs and sawlogs are now scarce. The situation will probably result in

making the birches even more valuable in the future and since there are practically no birch plantations in existence today it means that we shall have to manage the existing natural stands intensively with emphasis on thinnings, fertilization, and utilization to see us through for at least 30 years when we hope we will be able to begin utilizing some plantation-grown birch."

At the same time, they say, we must keep in mind that the birches, paper birch in particular, are prized for their aesthetic value in public forests and parks and in private woodlands and as ornamental trees in cities and around homes. More and more forest land is being set aside each day for special uses other than for timber production. Aesthetics, recreation, water, and sanctuaries for wildlife are uses that may be assigned individually or in some combination with each other or with timber production.

Thus, forest managers in the Maritimes may have some breathing space to improve the quality and growth of birch since it is with second-growth natural stands of birch that they are concerned. Operational scale trials of yellow birch seedling culture in greenhouse, nursery, and plantation are underway.

In a paper entitled "Natural regeneration of yellow birch in Canada", Burton, Anderson, and Riley (1969) at the Birch Symposium said:

"Though regional differences in soils and climate occur east of Ontario, yellow birch appears to prefer a rather exacting ecological niche in Quebec (Lemieux 1963) and the Maritimes (Drinkwater 1957) in a somewhat similar order of magnitude".

The authors indicate that this implies deep moist soils enriched with humus. Filip, Marquis, and Tubbs in contributions to the Proceedings (1969) recommend clearcutting and shelterwood for white and yellow birch rather than the unmanaged single stem selective cutting of the past. Summer logging operations may provide ground disturbance and a receptive seedbed, but no freedom from vegetation competition. Seedbed scarification is recommended.

The silviculture guides prepared for paper birch in the northeast by Marquis, Solomon, and Bjorkbom, (1969) integrate the sorts of information available at the symposium and present them in a form suitable for the forest manager. Importantly, silvicultural prescriptions are based on 1) management objectives, 2) silvics of the species, and 3) stand

dynamics. The paper birch guide was soon followed by prescriptions for northern hardwoods (Leak, Solomon, and Filip 1969).

Silvicultural implications

Shelterwood silviculture is favored in the references from United States of America; narrow strip clearcutting in Quebec. Yellow birch seems suited to some form of shelterwood or narrow strip clearcutting which may create a sort of shelterwood.

WHITE BIRCH

White birch occurs in association with other hardwoods in all the Maritime mixedwood and hardwood cover types. It is a true pioneer species and produces abundant seed. The small winged white birch seed is widely dispersed from the parent tree and is noticeable on disturbed seedbeds in the fall and on top of snow throughout the winter. On disturbed sites, the seed germinates and grows on mixed soil seedbeds that have an abundant moisture supply. Seedlings thrive in full light conditions (Logan 1965) and early growth is rapid. White birch also sprouts from cut stumps and after fire. At the end of the rotation however, white birch seedlings which may have germinated successfully on a receptive seedbed do not thrive in the shade of longer-lived competitors (Filip 1969). In the Maritimes where stand disturbance has been more or less continuous and where clearcutting is common, white birch is an increasing component of mixedwood. It is a major hardwood component in stands in the New Brunswick Uplands (high elevation) South Atlantic Shore (exposure), East Atlantic Shore (exposure, poor soil drainage), Cape Breton Plateau (exposure), Nova Scotia Central Lowlands (disturbed and cleared sites), and along the Fundy Coast (disturbed sites). White birch is capable of producing sound straight stems provided spacing is not too open. It does not respond to thinning as well as yellow birch, and only to thinning from below. In their silvicultural guide for paper birch in the Northeast, Marquis, Solomon, and Bjorkbom (1969) recommend narrow strip or small patch clearcutting for white birch regeneration. A scarified seedbed, they say, is more important than any other factor. Shelterwood cutting may also be used. In the Maritimes, white birch seems to have adapted

more to the role of pioneer. Logan (1965) records that white birch seedlings preferred 45% and more of full light and so partial cutting or small clear-cuttings may lead to the successful regeneration of other more tolerant species, especially red maple.

Occurrence

White birch is a significant stable component of stands in all but three of Rowe's forest sections in the Acadian Forest Region; Carleton (A.4), Prince Edward Island (A.8) and Cobequid (A.13).

Silvicultural implications

White birch is suited to clearcutting. In mixed-woods, seedbed scarification is needed to provide a receptive seedbed and to take advantage of the abundant seed fall. A few seed trees (4 per acre) may be left to ensure adequate seed distribution. The combination of summer logging, seed trees, and fill-in scarification is recommended by Marquis, Solomon and Bjorkbom (1969).

SUGAR MAPLE

A similar symposium in 1968 featured sugar maple. Papers presented included: species characteristics in stands, enemies, appropriate silviculture, economics, utilization (i.e. wood not sap utilization), and appropriate management systems.

Occurrence

Sugar maple is a persistent component of many forest types and is lacking only in the East Atlantic Shore (A.5b) South Atlantic Shore (A.5a), Cape Breton Plateau (A.6) and the Atlantic Uplands (A.12). Common associates are beech, yellow birch, white birch, red maple, white ash, white pine, red spruce, white spruce, and balsam fir.

Fayle (1965) comparing the root systems of sugar maple and yellow birch draws attention to the development of strong peg lateral roots in birch. In most soils, the dense central root mass of maple creates a large ball which resists overturning by wind. Both are wind-firm species. Yellow birch with well-developed extensive lateral roots and a less intensive central rooting mass is more suited to shallow soils but roots of yellow birch will also penetrate

deeper soils. Thus, yellow birch may be more adaptable to a range of soil depth conditions than sugar maple.

The persistence of sugar maple in many northern hardwood forests after years of high grading is dependent on its silvical characteristics and absence of severe stand disturbance. That is, high grading on a single stem or group basis has favored seedling regeneration firstly because of the consistently high seed production. Pole-sized stands of sugar maple produce some seed, while mature stands consistently disperse more than a million seeds per acre. Counts exceeding 8 million seeds per acre have been recorded (Tubbs 1968). Within a stand, seed distribution from sugar maple is remarkably uniform, thereby ensuring an adequate source for the regeneration of seedlings in naturally developed or cut openings. Shade tolerance ensures that it is the first colonizer in small openings, and advanced growth of sugar maple is a characteristic of almost all stands where this species occurs. The abundant seed dispersal is balanced by low germination. Where seeds do germinate, initial growth is vigorous and radicals are able to penetrate the hardwood leaf mat. Among the northern hardwoods, sugar maple is unique in its ability to reproduce on undisturbed forest litter. Yellow birch in the same mixed stands, although also a prolific seeder, produces a germinant which does not have the capability of penetrating a leaf mat. Mechanical site preparation is thus a typical silvicultural prescription. The sprouting characteristics of sugar maple also help in the colonization of mixedwood stands. Stump sprouts, root suckers, and the resprouting of damaged saplings are characteristics of the species (Fayle 1965). Browsed sugar maple will resprout and colonize the understory of many mixedwood stands.

Another characteristic of sugar maple is its high tolerance to suppression. This may be considered to be a tolerance to low light conditions but seems also to have components of other competitive features, such as an ability to adapt rooting to a variety of soil types, and at the end of a suppression period to respond to release. Sugar maple is also a long-lived species and will replace red maple, white and yellow birch in mixed stands when these are reduced by decadence and breakup of the canopy. Logan (1965), in a series of light experiments, determined that the growth of established sugar maple seedlings in only 13% of full sunlight was 87% of the growth in 100% sunlight. This contrasts

markedly with the performance of an intolerant species, white birch. White birch at 13% of full sunlight produced only 26% of the growth produced at 100% full light. In thinning, sugar maple crop trees respond to fairly heavy release treatments. Six years after thinning, diameter growth rate was 60% higher than on control plots with only moderate release according to Drinkwater's (1960) study in Nova Scotia.

Sugar maple is a valuable species well-adapted to intensive silvicultural treatment, such as the preparation of a stand for seeding, the creation of openings for the initial regeneration establishment, the subsequent enlarging of openings to encourage sapling growth, and following establishment of a new stand responds to thinning in increased growth and yield. Staining of the timber during closing of pruning wounds is a concern but most studies indicate that the species responds quickly to wound healing and that provided the pruning is carried out on thinned trees, the vigor of the release helps in closing the wound and in adding clear lumber.

Maple syrup production is an important value of the species in private woodlot management. Guidelines for silviculture in sugar bush management have been prepared by the Ontario Ministry of Natural Resources and edited by C.F. Coons, Division of Forest Management. This guidebook, published in 1975, sets out in some detail and in practical terms the appropriate silviculture for maximum sugar bush value. Since the biological factory which produces maple syrup is to a large extent dependent on the leaf area of the crown, silvicultural treatments such as thinning, and pruning are aimed at maximizing crown surface area. The sugar-bush tree is often short-boled with a spreading crown, and stems are widely spaced (80/acre). Nevertheless, the sugar bush can be managed for timber production as well as maple syrup production. The Ontario handbook describes thinning the young sugar maple to increase diameter to tapping size (23 cm dbh), the thinning of the tapped sugar bush to increase sap production, and thinning to remove competing species. Thus, a thinned sugar bush is a stand of vigorously growing trees without the competition of unwanted non-sap producing species or low-sap producers. The guidebook discusses enemies of the sugar maple, insects and fungal diseases, and outlines a procedure for transplanting sapling sugar maple. Reference may also be made to "Common pest problems of sugar maple in the Maritimes",

by Renault, Magasi and Marks (1975). A silvicultural guide for developing a sugarbush has been prepared by Lancaster *et al* (1974) at the Northeastern Forest Experiment Station, U.S.D.A. Silvicultural treatments to regenerate and improve sugar maple stands are part of the research program of the George D. Aiken sugar maple laboratory at Burlington, Vermont. Rooted maple cuttings from desirable parent trees are reared in the greenhouse and tested in outplanting. Superior sap producing genotypes will improve syrup yields from sugar maple plantations.

Silviculture implications

Sugar maple is suited to the selection system of silviculture and has persisted in stands which have been "selectively" cut or high graded for several rotations. Under proper management selection silviculture is the system of choice.

RED MAPLE

Because of its regular seed supply, prolific sprouting capability, and intermediate tolerance rating, red maple is an increasing component of the mixedwood stands in the Maritimes. This is particularly a result of continued partial cutting or high grading in mixedwood stands. A light residual stand of merchantable softwoods with a component of red maple stems and cut stumps sets the scene for rapid colonization by sprouts, suckers, and seedlings. Red maple is described by Morison (1938) as occurring "here and there" in the forests of New Brunswick, but Baskerville's 1976 figures indicate that red maple is on the increase and is the most abundant hardwood species in Nova Scotia.

Occurrence

Red maple is an aggressive component of almost all forest sections in the Maritimes and is found in mixture with most species. It is a colonizer of disturbed sites but is only a successional species which gives way to more tolerant followers. Drinkwater (1957) describes red maple as rarely absent from any stand but abundant only on less fertile and poorly drained sites where sugar maple is less aggressive. It associates, he says, mainly with yellow birch. Favorable light intensities afforded by thinned birch crowns, combined with the fact that it is a prolific

seeder with strong sprouting ability, enable red maple to maintain itself. Following partial cutting, red maple stump sprouts are a conspicuous component of regeneration stocking. Leak, Solomon, and Filip in their 1969 Silvicultural Guide bring together the characteristics of the species which they feel are most important. These are: shade tolerance; relative growth rate; frequency of good seed crops; effective seed dispersal distances; minimum seedbed requirements; sprouting vigor; and delayed germination characteristics, (a "buried seed strategy").

Silvicultural implications

Red maple may be managed under group selection or strip clearcutting systems. Groups should be large enough and strips wide enough to stimulate height growth of this intermediate to shade intolerant species.

POPLARS

Another group of hardwood species important in the Maritimes forests is the poplars.

Occurrence

Poplars, trembling aspen, largetooth aspen and balsam poplar occur on disturbed sites throughout the Maritimes, especially where abundant light can reach the forest floor. There soil warming takes place and roots produce the familiar sucker sprouts. The poplars are prominent on the Cape Breton Plateau (A.6), Cape Breton-Antigonish (A.7), Fundy Coast (A.9), Southern Upland (A.10) and Atlantic Upland (A.11) sections. These pioneer species are on the ascendancy following extensive logging and partial cutting in mixedwood stands. The poplars are very prolific seeders and sprouters. Aspen sprouts from both high cut stumps and from root suckers. For some forest managers, this presents a problem in the establishment and growth of conifers or more valuable hardwoods. For others, it provides an opportunity to raise bulk wood fibre over a very short rotation. The growth of aspen root sprouts is inhibited by overstory shading and when even one or two residual parent trees are left standing. The aspens as a group do not feature in the prescriptions in the silviculture guide of Leak, Solomon and Filip (1969), but an indication of their potential for the Canadian forestry

scene is presented in "Growth and Utilization of Poplars in Canada" by Maini and Cayford (1968). The Table of Contents of this report includes: Silvics and ecology of *Populus* in Canada; The silviculture and management of natural poplar stands; Poplar breeding; The silviculture and management of poplar plantations, an account of insects and diseases; and Decay as a limiting factor in poplar utilization. There are major sections on the wood chemistry and wood technology of poplar for plywood, lumber, fibreboard, particleboard, pulp and paper. Hybridization of poplars provides an opportunity in tree breeding for improvement of productivity and yield of this important group of species. Zsuffa *et al.* (1977) predict pulpwood rotations of 6-8 years for successful clones and for some hybrids.

Silvicultural implications

Poplars should be managed under a clearcutting system of silviculture.

BEECH

Beech occurs in the Miramichi - Tobique (A.2), Carleton (A.4), Cape Breton-Antigonish (A.7), Southern Uplands (A.10), Atlantic Uplands (A.11), Central (N.S.) Lowlands (A.12), and Cobequid (A.13) forest sections. Common associates are sugar maple, yellow birch, and red maple. The most tolerant hardwood in the mixture, beech has long been prized for its sawlog and veneer quality timber. Because of its value, it has been logged-over such that the best stands containing beech and sugar maple have been removed from production. Only in the most lightly cutover mixedwood stands is beech a significant component of regeneration. In heavily cutover stands, beech growth is poor, sapling quality is low, and immature stands are the subject of a variety of ailments including frost crack, sun scald, and the beech scale insect/bark canker composite. Where present in mixed stands, it is still valued for furniture wood. Day in his 1958 University of New Brunswick Masters thesis, "A Study of the Ecology of Beech" records its distribution in New Brunswick. The species, he finds, is concentrated in the Saint John River valley and in the northern and central uplands. Only a few representative stands occur along the Fundy coast. Of 1330 ground sample plots examined by Day, 255 contained beech. Only two contained beech without

maple and 567 contained maple alone. Stump sprouting of beech is a concern because of the low quality and poor form of the available parent stems. Beech is shade tolerant or "shade demanding". Logan's (1973) study of seedling growth indicated that more than 45% of full sunlight reduced height growth and total weight.

Silvicultural implications

Beech should be managed under a group selection or shelterwood system of silviculture. Only sound stems of good quality should be left as parent trees and regeneration should be complete before the residual stems pass from maturity to over-maturity.

MINOR SPECIES

Description of minor species noted below are usually found in texts of dendrology and less often in texts about silvics (species characteristics and the sites they occupy). They all have an importance in silviculture and some are now featured in re-appraisals as a source of energy.

Grey birch (*Betula populifolia* Marsh): The poplar-leaved birch is an aggressive pioneer which regenerates vigorously from cut and burned stumps, and after abundant seedfall. Seedbed disturbance following logging and/or fire, creates conditions suitable for grey birch seed germination.

Occurrence

Grey birch is a component of unstable disturbed forest communities and is common on such sites in the Fundy Coast (A.9), Southern Uplands (A.10), Eastern Lowlands (A.3) and Central (N.S.) Lowlands (A.12). Associated species are the poplars, red maple, and white birch.

Dense stands of juvenile grey birch constitute a considerable biomass which may be attractive as a source of wood fuel (Young 1977) but which is not at all attractive to the forest manager whose objective is conifer management or hardwood sawlogs. Grey birch sap in Quebec (O'Farrell 1976) has been found to yield approximately 50% more sugar when compared with maples, and the resulting sugars (xylitol) are now in demand because of chemical properties important in control of tooth decay and their compatibility with certain diabetic conditions.

The poor form of grey birch in the Maritimes may be attributed to species characteristics and the colonization of harsh sites (shallow soils, wetlands, and exposure to salt sea winds). Further south, in the United States of America on protected sites, it is commonly used as a secondary timber species and in landscaping of exposed areas (Collingwood and Brush 1964). Grey birch stands are an increasing component of the Maritimes forest scene. The species may preform an important role as a nurse to more sensitive and shade tolerant softwood and hardwood species which follow successionaly.

American elm (*Ulmus americana* L.): The American elm is a long-lived mid-tolerant species of the moisture-rich protected site. Once an important timber species because of its strength and durability (e.g. underwater), it has had to be removed from the lists of desirable species in regeneration because of Dutch elm disease. Remnant groups of elm, single stems and sometimes vigorous sprouts of elm may occupy a niche in mixedwood stands on the more fertile soils.

American red oak (*Quercus rubra* L.): American red oak appears in stands of coastal eastern Nova Scotia and in valleys in northern Cape Breton Island and coastal southern New Brunswick. It is a sprouting species and survives severe browsing by both wild and domestic animals. It has a reputation of tolerating moderately infertile soils and the abuses of urban landscaping but has not been tested under production management at this northern extreme of its range.

Basswood (*Tilia americana* L.): A tall tree with desirable shade tree characteristics and soft easily-worked wood, basswood is demanding of site quality and sheltered environment. A vigorous sprouter, it has often been found in association with red oak and red maple, but the sprouts of basswood are more susceptible to decay and it is not competitive with its associates.

Occurrence

Basswood occurs sporadically in New Brunswick in sheltered locations among tolerant hardwoods in the Carleton (A.4) forest section and perhaps sporadically in Nova Scotia. It is a rare component of the mixed tolerant hardwood forest. It is now thought that many recorded specimens in Nova Scotia are the introduced *Tilia Europea* while the scattered groups or individuals in New Brunswick are the native *T. americana* (Goldsmith 1977)⁶.

⁶ Goldsmith, F.B. Pers. Comm., Dept. of Biology, Dalhousie University, Halifax, N.S.

Ironwood (*Ostrya virginiana* (Mill.) K. Koch): Ironwood frequently forms an understory in mixed hardwoods and persists following logging. It is a vigorous stump sprouter and often a prolific seeder. Therefore, it is one of the problem hardwood species that occupies the regeneration period of more valuable species. It is unlikely to form closed cover and is a true "pucker brush" species (Young 1977).

Striped maple (*Acer pensylvanicum* L.): Moosewood is an understory species which persists for a short time following logging and sprouts vigorously from cut stumps. In closed stands of even-aged sapling hardwoods, striped maple may reach pole size. It is of no consequence in mature stands but may compete severely with conifer reproduction.

Pine cherry, (*Prunus pensylvanica* L.) has been identified by Marks (1974) as having a "buried seed" strategy which enables it to colonize even small openings in the forest canopy. That is, the regular abundant seed production (an edible drupe) may be stored in the hardwood litter on the ground each year until conditions for successful germination prevail. This property is shared by sugar maple and white ash.

Therefore, in openings and after cutting, buried pin cherry seed may germinate. It is widely dispersed by animals and birds. Seedlings of pin cherry compete successfully with advance growth of tolerant tree species, with sprouts of cut stems, and effectively suppress ground vegetation such as raspberry.

In dense stands of pin cherry, where no hardwood regeneration or only softwood regeneration is present, it may completely dominate the site. In mixed hardwood regeneration where pin cherry is more scattered, it forms a useful stabilizing influence on succession.

It is present for only the first 25 years of secondary succession (as illustrated by Marks) and serves as a nurse crop. That is, it completes the regeneration stocking of the site and inhibits the development of heavy lateral branching of competing tree species. After a short period in this useful role, it recedes from the stand, allowing canopy closure by the more commercially desirable species.

Thinning prescriptions in juvenile mixed hardwood stands should recognize the role of pin cherry as a nurse crop. It is a useful competitor for co-dominant and dominant stems of commercial species and it should be carefully appraised before being removed from competition with intermediate stems.

Where distribution of commercially desirable stems is patchy, it may often be necessary to leave

cull stems or unmerchantable species standing to hinder the development of epicormic branching or sunscald on the better stems. This would be particularly important along the exposed edge of the leave strip in corridor thinning. Here, pin cherry may be favored.

Mountain maple (*Acer spicatum* Lamarck): A serious deterrent to satisfactory regeneration of spruce and fir in northern New Brunswick and Quebec, mountain maple is a persistent occupant of cutover sites. It is a strong competitor for light, moisture, and nutrients and although it is reported to be an understory species further south, it may form a complete ground cover on northern cutovers. Most silvicultural treatments have been directed at attempts to control or eliminate mountain maple and Post (1969) describes cutting, burning, poisoning, and, more successfully, bulldozing with a root rake. Site preparation with the root rake is recommended because it interrupts the branch layering, not sprouting habit of mountain maple. Burning of logging slash among maple thickets is also effective. Perala (1971) describes the control of hazel, aspen suckers, and mountain maple with "Pickloram" an organophosphate which also may control balsam fir.

Conclusion

In 1974, the Canadian Forestry Service, in a hardwoods management workshop, reviewed the research and development status of hardwoods in Canada. Much of the material covered at the symposium was a review of existing information gleaned from the literature, together with a description of active Canadian Forestry Service research projects (Stiell 1974). The material presented at the workshop covered several aspects of hardwood management, including amenity forestry. Hardwood forests make a valuable contribution to the amenities and they are a feature of our parks and recreation programs. Without the form and color of hardwood species, this amenity would be considerably reduced. Not only visitors, but residents enjoy the value of hardwood forests. Ninety percent of the people of Quebec live in the hardwood forest region. The same is true of Ontario and perhaps the Maritimes. The hardwood soils are often the most fertile forest land and much of it is privately owned. A useful summary of silvical characteristics of some northern hardwoods (Table 12) was presented by Leak, Solomon, and Filip (1969).

ROLE OF PIN CHERRY IN NORTHERN HARDWOODS

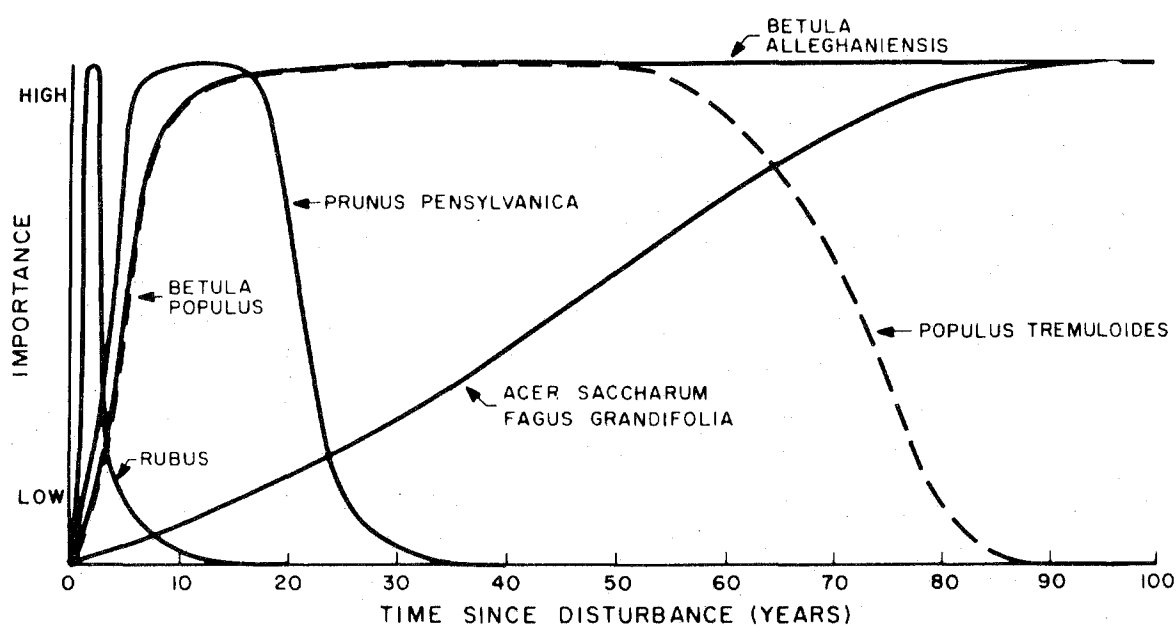


FIG. 2. Diagrammatic representation of the importance of different species along a time sequence following disturbance of a typical northern hardwood forest.

Reproduced from: "The role of pin cherry in the maintenance of stability in northern hardwood ecosystems" by P.L. Marks. *Ecol. Monogr.* 44(1): 73-88.

Table 12. Silvical characteristics of the important species in the beech-birch-maple and associated types*

Species	Shade tolerance	Relative growth rate	Seeding frequency, good crops	Effective ¹ seed dispersal	Minimum seedbed requirements	Sprouting vigor	Delayed germination
			<i>Years</i>	<i>Tree heights</i>			
Sugar maple	Tolerant	Medium	2–5	2–3	Light litter	Moderate	Possibly a small proportion
American beech	Tolerant	Medium	2–3	0–1	Light litter	Abundant root suckers	None known
Yellow birch	Intermediate	Slow to medium	2	2–4	Mineral soil or mixed mineral-humus	Very low	None known
Paper birch	Intolerant	Fast	2	2–4	Mineral soil or mixed mineral-humus	Moderate to low	None known
White ash	Intermediate	Medium to fast	3–5	2–3	Light litter	Moderate to high	Up to three-fourths germination second spring
Red maple	Intermediate	Medium to fast	1	2–3	Light litter	Very high	Small proportion germinate second spring
Aspen	Intolerant	Fast	4–5	—	Continuous moisture	Abundant root-suckering	None
Red spruce	Tolerant	Medium	3–8	2–4	Moist humus or mineral	—	None known
Eastern hemlock	Tolerant	Medium	2–3	2–4	Moist humus or mineral	—	None known

¹ Effective seed dispersal means that roughly 50 to 75 percent of the seed falls within the given distance.

* Reproduced from "A silvicultural guide for northern hardwoods in the Northeast" with permission of the authors.

SILVICULTURAL OPERATIONS

Species characteristics, which have been considered here as a complement to those established in the authoritative references cited, help us to understand and to predict responses to silvicultural treatment. But there are few, if any, pure stands of one hardwood species in the Maritimes, and it is with behavior and responses in mixed stands that the forest manager is concerned, the interaction of species characteristics. This is much more difficult to predict, and so the reviewer must look to experience elsewhere to help understand responses. The literature of the New England States, and Ontario, and Quebec Provinces is rich in experience with mixed stands. Although this information has not been generated entirely independently, there is a historical and geographical separation which provides some interesting comparisons in a review of harvest cutting, site preparation, and young growth tending. Openings in the forest canopy, in thinning and partial cutting, control the representation of parent trees. By canopy manipulation in clearcutting, shelterwood, and selection silviculture, regeneration of species in mixture may be favored or inhibited. The management objective in many of the referenced works has been the improved quality of selected species for sawlogs. Only the poplars and the "pucker brush" species have been considered for total fibre production. Much has been written about sap production, but less about watershed, wildlife, and amenity values. The hardwood forest cover provides many benefits and can be managed to maximize them. Permanent forest cover using the selection system of silviculture on sensitive watersheds or important park areas is an example. Narrow strip and patch clearcutting to provide wildlife cover and browse are others. One has to read "between the lines" about silvicultural operations and their effectiveness, to appreciate how they might help to achieve a range of management objectives important in the Maritimes because these benefits of one or other system were not often recognized by the forest production manager, and subsequent gains may have been only fortuitous. Harvesting mature and merchantable hardwoods has been carried out in the northeastern United States and the Maritime Provinces of Canada in a variety of ways. Cutting methods have set the scene for some severe regeneration problems but not all have been unsuccessful. High quality tolerant hardwoods have generally been harvested by some sort

of high grading system. Individual stem, small patch, and block clear cutting have been the pattern because of the distribution of groups of merchantable species and individual stems. Low quality hardwoods, intermediates, and intolerants, have been successfully harvested and regenerated in the United States of America using the shelterwood system, and more recently in Ontario and Quebec using selection systems and narrow strip clearcuts.

Shelterwood harvest cutting in many cases results in the release of an existing understory or in the more rapid establishment of regeneration present as advance growth. Filip (1973) has discussed and recommended the selection system of silviculture, instead of high grading, to harvest quality species for sawlog production. Where selection systems are used tolerant species are favored, for example, sugar maple may be favored over birch especially where site preparation is omitted. Tubbs and Metzger (1969) and Godman and Tubbs (1973) have recommended shelterwood cutting for intermediate species such as yellow and paper birch. Clearcutting has not been widely recommended for hardwood species, but where merchantability of the stand is high or where pioneer species such as white birch and poplar are present, clearcutting is possible. The question then becomes — what size and shape of clear cut will be used?

Clearcutting

Where harvest cutting is compatible with the regeneration requirements of the species to be harvested, the reestablishment of a new productive stand is facilitated by clearcutting. Where it is not, severe ecological problems are created and silvicultural repairs are expensive. Marquis (1965a) reports successful natural regeneration in small clear cuttings (1/10—2/3 acre) made in both second-growth and old-growth hardwood stands. In such small clear cuttings, yellow birch and paper birch seedlings became established in large numbers in all patch sizes. Birch seedlings on disturbed seedbeds are in a better competitive position than those on undisturbed seedbeds although competition from sprouting and suckering of other non-commercial species is severe. Patch size can be used to manipulate shade and to control species representation in the regeneration, (Marquis 1965b).

Marquis (1967) reports, for example, on a larger (22 acre) clear cut on the Bartlett experimental forest in New Hampshire. Regeneration there following logging in 1937 has now developed into a 40-year-old

stand and this provides an opportunity to examine the case history of a large complete clear cutting. The mixed northern hardwood species included beech, yellow birch, sugar maple, red maple, white ash, paper birch, and striped maple. At 25 years of age in 1962, 56% of the basal area stocking was to intolerants, 18% to intermediates, and 26% to tolerants. In the 30-year stand development period following clear cutting, several marked changes have taken place. The raspberries, blackberries, and other herbaceous species which dominated the area along with stump sprouts, root suckers, and a massive influx of pin cherry, have given way to a stand of aspen, paper birch, and white ash as the dominant species, and red maple, yellow birch, sugar maple, and beech are now present as co-dominants or understory species. Establishment and growth of these species have been so successful that thinning was necessary and a thinning response study was established in the area when the stand was 25 years old. Stand mortality over the 5-year period, 25 years from cutting to 30 years from cutting, in the absence of thinning, amounted to 35% of the number of stems and resulted in a stem diameter/number curve that conforms to the inverse J-shaped curve more typical of uneven-aged stands. Marquis pointed out that the short-lived pin cherry is already dying out. Aspen can be expected to follow at 40-60 years of age; paper birch at 80 years of age; and red maple and white ash to survive past 100 years. Finally, the stand will be dominated by the original long-lived climax species, beech and sugar maple, with small amounts of yellow birch. Therefore, harvesting of this mixedwood stand by complete clear cutting has resulted in some dramatic changes in species representation and a trend has been established towards the replacement of the original stand structure, (complete clearcutting in this instance meant all hardwoods 1.6 inches in diameter and larger, and all conifers 4.5 inches dbh and larger). A few scattered white ash have been left as seed trees.

Competition for light is an important factor in choosing patch size, although it is not the only environmental factor affected. Marquis (1965b) further investigated the amount of light reaching the ground in small clearcuttings. Strip systems of clear cutting lend themselves well to cutting in a planned series with the direction of the strips aligned to maximize conditions for establishment of regeneration and to control the amount of light reaching the ground. Marquis demonstrates how to calculate the amount and duration of sunshine reaching strips in

several orientations of various shapes and sizes. Two examples are shown here (Figs. 3 & 4). When combined with known light requirements, (Logan 1965, 1973) **these guides are useful prediction tools.**

Roberge (1977b) describes thinning and clear-cutting in mixed hardwood stands in Quebec to encourage yellow birch regeneration. The thinned and clear-cut plots were subsequently scarified and seeded or planted to yellow birch. Ten years later in the clear-cut plots intolerant and semi-tolerant species tended to replace tolerant species within the first five growing seasons, while climax species tended to replace non-climax species during the next five year period. The percentage representation of yellow birch increased throughout. Sugar maple regeneration, reports Roberge, responded well to thinning, to patch clear cutting and to ground scarification. Sugar maple, striped maple, and mountain maple reestablished aggressively in patch clearcuts.

Clearcutting in the Maritimes is almost "complete" wherever stand merchantability is high. In some mixedwood cutting agreements, there are regulations which require residual standing hardwood stems which are unmerchantable, to be cut and left lying. Under these conditions, abundant sunlight reaches the cutover area and vegetation response to increased sunlight and soil temperature is immediate. Complete clearcutting usually implies ground disturbance as well, and so there is a response to the then receptive seedbed. The successful colonizers of complete clearcuts are trembling aspen, (sprouting from the root systems), red maple, white and grey birch, and sometimes white ash (sprouting from cut stumps), seedling establishment of yellow and white birch, and severe competition from an influx of shrub species and weed tree and shrub species such as raspberry, willow, hazel, mountain maple, and pin cherry. Clearcutting is compatible with production forestry (sawlog and pulpwood) and only with care and planning can it be integrated with amenity and wildlife management.

Shelterwood cutting

Harvest cutting by partially cutting to a merchantable diameter limit or removing only merchantable softwoods from mixedwood stands results in an increase in the representation of hardwoods. Representation of weed species and competition from ground vegetation are dependent upon the residual stand density (Leak and Solomon 1975). Shelterwood

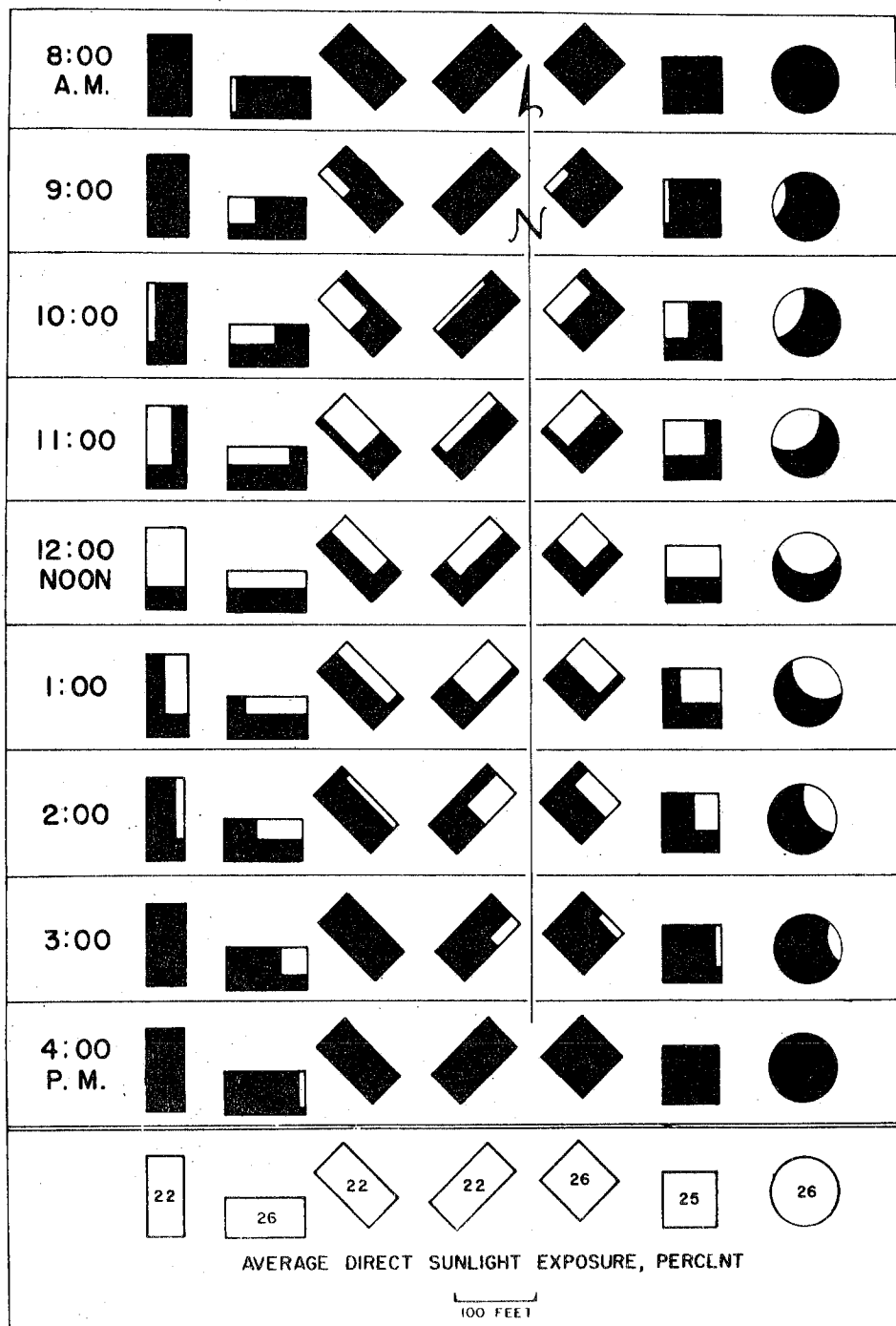


Figure 3.—Patterns of light and shade in various 1/10-acre patches—June 7, latitude N. 44°, at different times of day.

Reproduced with permission from "Controlling light in small clearcuttings" by D.A. Marquis, U.S. Forest Service Res. Pap. NE-39, 1965.

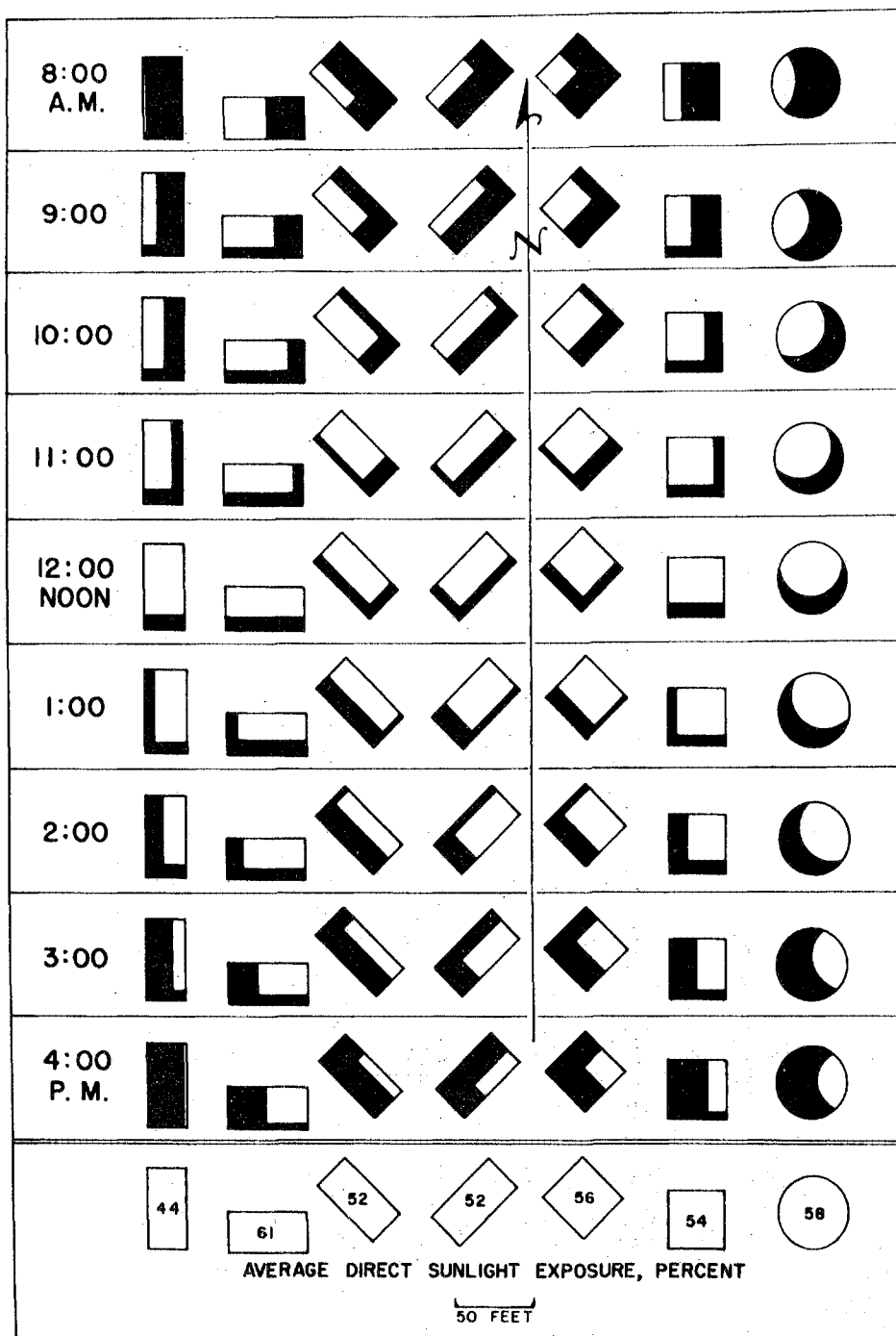


Figure 4.—Patterns of light and shade in various 1/2-acre patches—June 7, latitude N. 44°, at different times of day.

Reproduced with permission from "Controlling light in small clearcuttings" by D.A. Marquis. U.S. Forest Service Res. Pap. NE-39.

can be used to control the species representation in the residual stand and the representation of commercially valuable species as advance growth and in the understory. It is the harvest cutting method recommended by Tubbs and Metzger (1969) for yellow birch in mixed stands and can be compared to the narrow-strip clearcutting recommended by other workers (Roberge 1977a, Robitaille 1977) where strip width and orientation are used to control species representation in the cut strips. The shelterwood system of silviculture, however, is the one recommended by Godman and Tubbs (1973) for mixed tolerant hardwoods. The general rules they have developed are presented here. Shelterwood cutting is compatible with production forestry (sawlog and pulpwood) and with care can be integrated with amenity and protection forestry.

SUMMARY OF RECOMMENDATIONS FOR APPLYING TWO-CUT SHELTERWOOD IN NORTHERN HARDWOOD STANDS

General Rules for Tolerant Species

1. Stands selected should be moderately well stocked with advanced regeneration of desirable species. At the minimum, stands should average at least 8 inches dbh.
2. Marking must be from below. Leave 60% crown cover at regular spacing. All trees left must be considered part of the residual crown cover.
3. Initial logging should be done only when the ground is snow covered to minimize seedling loss.
4. The overstory can be removed when the reproduction attains a height of 3 to 4 feet. Log when the ground is snow covered, removing all stems. Lopping of slash should be minimized and restricted to aesthetic or access areas.

Modifications to Favor Yellow Birch

1. Attempts to regenerate yellow birch should focus on cool, moist, (hemlock-hardwood) sites.
2. Marking should tend to discriminate against sugar maple in the residual overstory. Leave no more than 70% crown cover of the most vigorous trees.
3. Scarify 50% or more of the surface area after leaf fall and prior to logging. Scarification should aim at mixing the humus and mineral soil and

destroying advance regeneration. Kill advanced regeneration prior to cutting on sites too difficult to scarify.

4. Make the first cutting during moderate or better seed year, or direct seed before mid-winter at a rate of at least $\frac{1}{4}$ pound per acre on the scarified area. One seed tree per acre may be left for insurance.

Selection cutting

Harvest cutting by a selection process has been traditionally used in the Maritimes for sawlog and custom log production. However it has been unmanaged and unplanned and dependent upon market availability and merchantability of stems, Baskerville (1976). Quality has decreased in mixedwood stands. The appropriate management objective which the selection system of silviculture can fulfill, however, as exemplified by the recommendations of Leak and Filip (1977), is an increase in stand quality, stem quality, and quality species representation. Selection silviculture is compatible with production forestry (sawlogs) and can be integrated with amenity and protection forestry in watershed and wildlife management.

But in the Maritimes, clearcutting has resulted in the reestablishment of pioneer and sprouting hardwood species. Shelterwood cutting has resulted in an increase in the representation of hardwoods in mixed stands; and harvesting by a selection process, either single stem, small group, or patch has resulted in the reduced quality of hardwood and mixedwood stands. Summarizing the impact of harvest cutting methods on old-growth northern hardwoods, Leak and Wilson Jr. (1958) have said that the selection method of harvesting favors tolerant species, chiefly beech and sugar maple; that patch cuttings of 1/10 to 1/6 of an acre are conducive to the establishment of the intermediates (yellow birch and white ash), as well as the tolerants, and that clearcuttings in areas of 5 acres or larger allow the establishment of the intolerant paper birch and aspen. Reaction by northern hardwoods to several harvest cutting methods is now quite well understood. Problems in species representation after regeneration establishment are clear. Management objectives and trends in the Maritimes are less clear, or not stated, but once these can be established and a pattern of harvest cutting and system of silviculture selected, the scene is set for subsequent silvicultural treatments designed to fulfill the management objective. Tests of silvicultural

treatments that may be useful in the Maritimes context are reviewed in the following six sections.

Site Preparation

In the northern hardwood forest, yellow birch in mixture with other species is at a disadvantage during the regeneration period. The selective type of harvesting which has been carried out in quality hardwoods has resulted in successful regeneration particularly of the shade tolerant species, sugar maple and beech. In more heavily cutover stands, red maple and trembling aspen are significant components of the new stand. Yellow birch is a valuable species producing high quality veneer logs and large diameter sawlogs. But it is only on disturbed seedbeds that natural seedlings of yellow birch become established. Furthermore, yellow birch does not seem to tolerate shade and competition from ground vegetation. It is not a sprouting species, whereas the pioneer grey birch and white birch often regenerate from cut stumps.

Hatcher (1966) lists some of the site preparation treatments that have been used in mixed hardwood stands. These include soil discing, litter burning, bulldozer scarification, scarification with girdling of residual trees, uniform partial cutting, and clear-cuttings of a variety of sizes. Small canopy openings or narrow strip clear cuttings appear to be the most promising techniques available to control canopy cover. The major constraint to the establishment of yellow birch, however, is not canopy opening size but seedbed receptivity. Thus, on all scarification treatments, regardless of cutting method, Hatcher discovered an improvement in yellow birch regeneration. Thus yellow birch responds to intensive site preparation. Comparable seedbed preparation methods used by Bjorkbom (1967) for paper birch resulted not only in an increase in paper birch seedling stocking but also in a marked increase in the number of paper birch sprouts. Site preparation by discing and burning in the summer reduced the number of stump sprouts from those levels produced by winter logging alone. Bjorkbom concludes that summer logging in mixed stands will result in the satisfactory stocking of paper birch, and that winter logging may result in an abundance of stump sprouting. Only where the proportion of paper birch in the species mix should be increased will the forest manager be required to scarify the seedbed.

The treatment recommended for white ash by

Leak (1963b) is a scarification treatment which mixes white ash seed into the seedbed. His study in the White Mountains of Vermont compared sown and then scarified, with scarified and then sown treatments. With the sown and then scarified seedbed treatment, there were no significant differences between 40% cutting, 20% cutting, and an uncut residual stand. The seedbed treatment was more important than the cutting treatment for this species. The silvical characteristics of white ash indicate that this species should be regenerated under a shelterwood or very narrow clear-cut system. The heavy seeds falling from parent trees are incorporated into organic material by site preparation beneath the overstory and may be already present as stored seed on the ground.

Where clearcutting has been used and where vegetation competition is severe, especially from such species as mountain maple, pin cherry and raspberry, site preparation for regeneration may involve the removal of these unwanted species. There are many references, in the research literature to trials of herbicides and silvicides.

Marks' (1974) paper (previously reviewed under "minor species") on the role of pin cherry in maintaining stability in northern hardwood ecosystems describes the "buried seed strategy" of the species. An accumulation of between 100,000 and 200,000 buried seeds per acre is common. Pin cherry is particularly well suited for efficient colonization of large gaps. Because of the accumulative effect of seed production and seed storage, the presence of pin cherry in even small gaps represents a potential for rapid colonization of any clearcut. The silviculturist must decide whether to control competition from pin cherry, or to consider it as a useful stage in succession where pin cherry will ultimately give way to more valuable species already present in seedling and sprout form on the cut-over area.

Stump sprouting

Stump sprouts are a very visible component of hardwood regeneration stocking in the Maritimes. Common sprouting species are red maple, sugar maple, white ash, and beech. Yellow birch less commonly sprouts from cut stumps and regenerates mainly from seedlings. White birch sprouts sporadically and grey birch is sometimes a very vigorous sprouter. Striped maple, although often an understory species with weak sprouts, will sprout vigorously from stumps cut in openings.

Red maple stump sprouts are perhaps the most familiar component on recent clearcuts where machine harvesting has resulted in a complete cut. Where white ash is present, first growing season sprouts are commonly 5 feet high, but are preferred deer browse.

The behavior of stump sprouts and their role in stand formation are not well understood. In their 1967 report, "Stump sprouting of four northern hardwoods", Solomon and Blum trace the development of sprouts of sugar maple, red maple, yellow birch, and white birch cut in the dormant season. Sprout numbers per stem and height growth are related to parent stem diameter and vigor (radial increment). Smaller, faster growing stumps produce more vigorous (taller) sprouts. The older the parent tree, the less vigorous the sprout of the same age. Paper birch sprouts were reported to be sensitive to overhead shade (from the residual stand) and yellow birch was "essentially non-sprouting". Stump sprouts are more drought tolerant than seedlings.

Wendel (1975) describes sprouting of the more traditional "coppice shoot" species of oaks (white, red and chestnut oak) and black cherry. Low stumps produce healthier sprouts, and immature trees sprout more vigorously than mature stems. Lamson (1976) examined 8- and 12-year-old sprouts. The interval since cutting was long enough to determine that dominance in Appalachian hardwood sprouts was quickly established and that thinning was possible among weaker sprouts to relieve wasteful competition on the stump. Crop tree sprouts (vigorous, good form) almost always originated low on the stump close to groundline. The rapid decline of weaker sprouts is reported by several authors and after 10 growing seasons, Bjorkbom (1972) reports means of 6 sprouts per stump for red maple and white birch, 4 for beech and 9 for grey birch. Tatler (1973) suggests that sprout red maple can be thinned to minimize defects by; (1) selecting only sprouts with small well-healed branch stubs, (2) rejecting sprout clumps with extremely defective bases, and (3) leaving one or two dominant sprouts in each clump. Decay of sprout red maple does not pass through the stump base from one sprout to another (Shigo 1965).

Trials of coppice shoot management at Acadia Forest Experiment Station, New Brunswick (Thomson 1952) and at Nuttby Mountain, Nova Scotia indicate a potential for rapid stand establishment, but also indicate that sprouts are favorite deer browse (Drinkwater 1958). The opportunity for management of

hardwood stands using stump sprouts is apparent because many stands harvested today are themselves of stump sprout origin. The basal sweep of hardwood butt logs is a good indicator. Current regeneration is therefore the second rotation of stump sprouts. Perhaps it is in stump sprout form that species sensitive to competition, such as white ash, can best be managed.

Plantation establishment

For a review of planting potential and possibilities for 14 hardwood species we must turn to the works of von Althen whose 1964 report reviews the hardwood literature on planting in eastern Canada to that date. In his first report and in subsequent ones in 1972 and 1977, and in the proceedings of the Canadian Forestry Service hardwoods management workshop in 1974, von Althen underlines the importance in the establishment of hardwood plantations of the following important steps;

1. selection of the planting site;
2. site preparation or cultivation;
3. seed and planting stock quality;
4. planting method;
5. the control of woods;
6. fertilizer application;
7. the control of rodent damage;
8. the use of hardwood species in mixtures to provide nurse crops.

The most important single factor in the successful establishment of hardwood plantations is the selection of a satisfactorily drained, deep, fertile soil. The A and B soil horizons together should be at least 18 inches deep and most hardwood species, says von Althen, never produce high quality timber when they are planted on dry sites, on exposed slopes or ridges, or where the topsoil is shallow, or consists of heavy compacted clay. To prepare sites for hardwood plantation, von Althen recommends both ploughing and disking. The cultivation destroys all the weeds including the deep-rooted perennials and by improving soil aeration and soil structure and water status, cultivation stimulates microbiological activity. Following complete mechanical site preparation, the application of herbicides in dosages small enough to be tolerated by highly susceptible hardwood seedlings can be successfully used. Where deep complete cultivation of the total area is not feasible because of existing forest cover or poor soil types, site preparation may be carried out in strips which may be

plowed and then chemically treated. However, where there is a residual strip, competition from tree species on the edges and from invading weed species may be so severe as to make the plantation worthless.

In direct seeding, von Althen recommends the use of species with large seeds. Small-seeded species tend to have much lower establishment and survival rates. Planting stock should be sturdy with a well-branched root system. Seedling size is more important than seedling age since large young seedlings perform better than smaller older planting stock. Root collar diameter has proved to be as important as total height of seedlings. In planting hardwood seedlings, the recommended much-branched root system demands a large planting hole. Trials with planting augers have been quite successful.

The next concern is weed control, and after several years of extensive research and selection, Simazine, which is a pregermination herbicide that controls a large number of broad-leaved weeds and grasses, is recommended. It is most effective when applied to weed-free surfaces in early spring, before the weed growth has started and since each tree species has its own Simazine tolerance, von Althen has established levels for all the commonly planted hardwood species and is now testing the suitability of new herbicides such as "Kerb" and "Roundup". Fertilizer compositions, however, have been less effective than either weed control and/or cultivation of the site.

Microbiological activity in the soil, improved by cultivation, releases nutrients which are otherwise unavailable to the planted stock. Removal of weed competition also increases the availability of nutrients. These results are confirmed by the work of other researchers especially that of Yawney and Carl (1970) in sugar maple culture in Vermont. That is, the growth of sugar maple seedlings, for example, improves in relation to the degree of weed control achieved by the cultural treatments.

Von Althen's species requirements for successful planting and his planting guide of 1964 are reproduced here (Tables 13 and 14).

An account of silvicultural research on hardwoods in Quebec by Robitaille and Roberge (1976) indicates that work on strip clearcutting with hardwood planting is underway in that province. Fertilizer treatment studies are also listed. In a study entitled, "The conversion of a degraded mixed stand of sugar maple and yellow birch to production forestry", Robitaille lists among the work done: scarification

with planting of 10,000 trees; planting of 13,500 trees without site preparation; scarification with artificial seeding; fertilizer application with NPK in part of the plantations; and trials with combinations of N, P, and K fertilizers. There have also been some weeding and cleaning; manually, mechanically, and chemically. A control section will allow observation of establishment of natural regeneration without site amelioration. Precommercial thinnings and other stand treatments are also underway. These are new studies and research results are not yet available.

Precommercial thinning

In his research report entitled, "Crown Release of Young Sugar Maple", Drinkwater (1960) describes a precommercial thinning treatment conducted in Nova Scotia. Drinkwater has said,

"there are over ½ million acres of tolerant hardwood, that is, sugar maple, sugar maple-beech and sugar maple-beech-yellow birch associations (in northern Nova Scotia). Heavy cutting and the incidence of insects and disease have so degraded the stands and reduced the amount and quality of saw timber that there is not enough left to support an industry. At the same time, the volume of small low quality hardwood has continued to increase. If these stands are to produce saw timber, cultural treatments and thinnings are needed to improve the growth rate and the quality of the trees that remain".

Thus, Drinkwater was concerned with thinning of material which at that time (1950) was unmerchantable for sawlog sizes. The stands were about 35 years old and mean stem diameter was 1 to 5 inches. Total height was 23 feet. Trees were thinned to 5, 6, and 8 foot spacing between crown projections. The greater degree of release produced greatest increment in basal area for the period 1951 to 1957. The stands were composed of a mixture of sugar maple, yellow birch, and beech but since the beech were badly infected with *Nectria* canker and the yellow birch were quite scattered, the sugar maple were favored in these treatments. The largest trees gave the greatest percentage response in basal area. Release treatment had no special effect upon height growth, natural pruning, or the incidence of epicormic branching. The treatment is recommended for the management of sawlog stands.

TABLE 13. Species Requirements for Successful Planting

Tree Species	Trees Suitable for Planting on						Planting Stock				Stand Composition			Site Preparation		Planting Method		Cultivation After Planting	
	Eroded Land	Shelterbelts	Abandoned Agricultural Land	Poorly Drained Areas	Intermediate Soils	Undisturbed Hardwood Soils	Seeds	Cuttings	1-0 Nursery Stock	2-0 Nursery Stock	Pure Plantations	In Mixture with other Hardwoods	Suitable for Underplanting	Essential	Beneficial	Machine Planting	Hand Planting	Essential	Beneficial
Black Locust	x	x	x		x	x			x	x	x	x			x	x	x		x
Black Walnut						x	x		x	x		x		x			x	x	
Poplar spp.						x		x			x			x			x	x	
White Ash						x			x	x			x		x		x		x
Green Ash		x		x	x	x			x	x	x	x			x		x		x
Yellow Poplar						x			x	x		x		x			x	x	
Red Oak					x	x	x		x	x	x	x			x	x	x		x
White Oak						x	x		x	x		x			x	x	x		x
Bur Oak		x	x		x	x	x		x	x		x			x	x	x		x
Black Cherry					x	x			x	x		x		x		x	x	x	
Sugar Maple					x	x			x	x		x	x	x		x	x	x	
Silver Maple				x	x	x			x	x		x	x		x	x	x		x
Basswood					x	x			x	x		x	x		x	x	x		x
Sycamore				x	x	x			x	x		x			x	x	x		x

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TABLE 14. PLANTING GUIDE

Tree Species	Purpose of Planting	Climatic Range in Canada	Where to Plant	Where not to Plant	Age of Planting Stock
Black Locust	Erosion control or pioneer planting.	Not a native tree in Canada but has been planted successfully from southern Quebec to southern Manitoba.	May be planted anywhere; trees will not grow well, but will persist and improve the site for subsequent plantings.	On excessively dry or very wet sites.	1-0 or 2-0 seedlings.
	Fencepost and timber production.	Same as above	For optimum growth plant only deep, fertile, moist but well drained loamy soils, preferably of limestone origin.	On dry or very wet, poorly aerated compacted sites.	1-0 or 2-0 seedlings.
Burr Oak	Shelterbelts, reforestation of poor dry sites.	Southwestern New Brunswick to southern Saskatchewan.	Best growth is found in bottomlands, but will grow on heavy textured, poorly aerated and drained prairie soils.	On exposed, stoney ridges and very wet areas.	Stratified acorns or 1-0 or 2-0 seedlings.
Green Ash	Shelterbelts, reforestation of wet areas.	Southwestern Quebec to eastern Alberta	Along rivers and creeks and areas which may be flooded up to 40 percent of time during the growing season. On moist uplands soils with neutral to alkaline reactions.	On exposed dry ridges and soils with a light claypan at depth of less than 24 inches.	1-0 or 2-0 seedlings.
American Sycamore	Reforestation of areas of wet muck land, shallow peat soils and river banks.	Native in southern Ontario but has been planted successfully as far north as Ottawa.	For optimum growth plant in rich bottomland soils, along creeks and rivers. Will also grow in wet muck land, shallow peat soils and moist upland sites. Is tolerant to wet soil conditions and flooding.	On exposed or excessively dry ridges or dry sand plains.	1-0 or 2-0 seedlings.
Northern Red Oak	Timber production.	Cape Breton to southwestern Ontario.	For optimum growth plant in deep, moist, well drained soils of medium texture. Will also grow on soils ranging from clay to loamy sands to shallow, rocky soils, but tree growth and form will be poor on these sites.	In open fields or abandoned pastures. On excessively dry or wet soils. Young seedlings prefer protective overstorey.	Seeding acorns in fall or spring or 1-0 or 2-0 seedlings.

How to Plant				Evaluation
Species Composition	Site Preparation	Method of Planting	Cultivation after Planting	
Pure plantations.	Ploughed strips or preparation of planting spots by spading and elimination of weeds.	Machine planting or manual planting by spade.	Ploughing between rows or hoeing around each tree for at least the first two years.	A very valuable tree for erosion control planting and soil improvement through nitrification.
Pure plantation or in mixture with other hardwoods.	Same as above	Same as above	Same as above.	The most vigorous trees develop highest resistance to locust borer attack.
In mixture with black locust and green ash.	Ploughed strips or preparation of planting spots 12 x 12 inches.	Machine planting or manual planting by spade.	Will tolerate heavy competition but ploughing or hoeing will be beneficial.	Very drought hardy, good resistance to smoke and gas injury. Of minor value as a wood producing tree.
In mixture with black locust, silver maple, poplar spp., and aspen.	Ploughed strips or planting spots at least 12 x 12 inches.	Machine planting or manual planting by spade.	Will tolerate heavy competition but cultivation for the first two growing seasons is beneficial.	Very hardy to climatic extremes. Major fault is poor form. Good tree for reforestation of wet areas and shelterbelts.
Always in mixture with green ash, poplar spp. red maple, silver maple and Manitoba maple.	Ploughed strips or planting spots at least 12 x 12 inches.	Generally manual planting by spade.	Will tolerate moderate competition but cultivation for the first two growing seasons will be beneficial.	Not a valuable timber tree but preferred for reforestation of wet, poorly drained areas. Planted extensively as an ornamental.
In pure stands or in mixture with white ash basswood American beech, black cherry hickory and maple spp.	Ploughed strips or planting spots at least 12 x 12 inches.	Machine planting or manual planting by spade.	Will tolerate moderate competition but cultivation for the first two growing seasons will be beneficial.	An important timber tree, grows rapidly on a wide variety of sites and is also planted extensively as an ornamental.

TABLE 14. PLANTING GUIDE (Continued)

Tree Species	Purpose of Planting	Climatic Range in Canada	Where to Plant	Where <i>not</i> to Plant	Age of Planting Stock
White Oak	Timber production.	Southern Ontario to southern Quebec.	On higher bottomland where the soil is deep and moist with good drainage.	In open fields or abandoned pastures, on very dry or very wet sites, or in mixture with softwoods.	Seeding of acorns in fall or spring or 1-0 or 2-0 seedlings.
Silver Maple	Timber production.	Southwestern New Brunswick to southwestern Ontario.	For optimum growth plant in bottomland with a moist, deep soil and along borders of swamps and rivers. Will also grow on poorer sites, but requires high soil moisture.	In open fields or abandoned pastures, on shallow, dry soils or exposed ridges. In mixture with softwoods.	1-0 or 2-0 seedlings.
Sugar Maple	Timber production and source of maple syrup and maple sugar.	Nova Scotia to western Ontario.	For optimum growth plant on moist, rich, well drained soils as found on lower slopes and in valley bottoms. On poor, dry soils the growth is generally slow and the form is poor.	In open fields or abandoned pastures, on shallow, dry soils, or on exposed ridges.	1-0 or 2-0 seedlings.
Poplar spp.	Maximum wood production for timber or pulpwood.	Wide distribution over nearly all parts of Canada.	For optimum growth plant only on soils rich in minerals, especially lime, moist but well drained and well aerated soils as found in valley bottoms, along creeks and rivers and moist, but well drained fields.	On sites with heavy, compacted, poorly aerated, dry, shallow or mineraly depleted soils, and in swampy areas with stagnant water.	Cuttings or rooted cuttings.
White Ash	Timber production.	Cape Breton Island to the lower end of Lake Superior	For optimum growth plant on deep, moist, well drained soils which have a high nitrogen content. These soils are generally found on bench lands in river valleys and on lower slopes.	On abandoned, infertile, open fields or pastures on eroded land or dry, exposed ridges.	1-0 or 2-0 seedlings.

How to Plant				Evaluation
Species Composition	Site Preparation	Method of Planting	Cultivation after Planting	
In mixture with basswood, white ash, black cherry, hickories and northern red oak.	In ploughed strips or planting spots at least 12 x 12 inches.	Manual planting by spade.	Will tolerate moderate competition but cultivation for the first two growing seasons will be beneficial.	An important timber tree, but very difficult to plant.
In mixture with white ash, red maple, American Sycamore, and green ash.	In ploughed strips or planting spots at least 12 x 12 inches.	Manual planting by spade.	Will tolerate moderate competition but cultivation for the first two growing seasons will be beneficial.	A very rapidly growing tree. Its greatest disadvantage is poor form due to heavy sprouting at the base. Used extensively as an ornamental.
In mixture with locust, beech, red oak, red maple and hickories.	In ploughed strips or planting spots at least 18 x 18 inches.	Manual planting by spade.	Clear cultivation must be maintained for at least the first two growing seasons.	A valuable timber tree. Seedlings are highly susceptible to frost damage and browsing. At present little is known about best planting procedures.
In pure plantations only.	Complete, deep cultivation or preparation of planting spots at least 4 x 4 feet.	Cuttings are planted by planting stick. Rooted cuttings by spade in holes of 2 x 2 x 2 feet.	Clear cultivation must be maintained for at least the first two growing seasons.	When planted on proper site and properly cared for, poplar will produce the greatest volume of wood in the shortest period of time.
In mixture with black locust, basswood, oak, beech and maple spp.	In ploughed strips or planting spots at least 18 x 18 inches.	Machine planting or manual planting by spade. May be planted under protection of nurse crop.	Will tolerate moderate competition but cultivation for the first two growing seasons will be beneficial.	An excellent timber tree of high value. Suitable for underplanting if released later.

TABLE 14. PLANTING GUIDE (Continued)

Tree Species	Purpose of Planting	Climatic Range in Canada	Where to Plant	Where <i>not</i> to Plant	Age of Planting Stock
Black Cherry	Timber production.	Western Nova Scotia to Lake Superior.	For optimum growth plant on rich, deep, moist, but well drained soils as found in river valleys and on lower slopes. It will grow on drier upland soils, but growth is generally slow.	In abandoned, infertile, open fields or pastures on eroded land or dry, exposed ridges or on swampy ground.	1-0 or 2-0 seedlings.
Basswood	Timber production, source of honey.	Western New Brunswick to southern Manitoba.	For optimum growth plant on deep, moist but well drained soils with a high nitrogen content as found in river valleys and on lower slopes. On drier upland soils the growth is generally slow.	In abandoned infertile, open fields or pastures, on eroded land or dry, exposed ridges or on swampy ground.	1-0 or 2-0 seedlings.
Yellow Poplar	Timber production.	Southern Ontario.	For optimum growth plant on deep, moist but well drained soils with a high nitrogen content and a loose texture as found in river valleys and on lower slopes.	In abandoned, infertile, open fields or pastures, on eroded land or dry, exposed ridges or on swampy ground.	1-0 or 2-0 seedlings.
Black Walnut	Timber production.	Southern Ontario on protected sites as far north as Ottawa.	For optimum growth plant only on deep, fertile, moist but well drained soils of alluvial origin as found in river valleys, protected coves and lower slopes.	In abandoned, infertile, open fields or pastures, on even slightly eroded land or dry exposed ridges.	Seeds or 1-0 or 2-0 seedlings.

How to Plant				Evaluation
Species Composition	Site Preparation	Method of Planting	Cultivation after Planting	
In mixture with black locust, sugar and red maple, white ash and basswood.	Complete cultivation or preparation of planting spots at least 18 x 18 inches.	Manual planting by spade.	Clear cultivation must be maintained around the seedlings for at least the first two growing seasons.	A valuable timber tree in mixed hardwood stands. At present little is known about best planting procedures.
In mixture with white ash, black cherry, hickory spp. and black walnut.	In ploughed strips, or planting spots at least 18 x 18 inches.	Manual planting by spade.	Will tolerate moderate competition but cultivation for the first two growing seasons will be beneficial.	A valuable timber tree and an important source of honey. At present little is known about best planting procedures.
In mixture with black locust, black walnut basswood and black cherry Suitable for underplanting.	Complete deep cultivation or preparation of planting spots at least 18 x 18 inches.	Manual planting by spade. Fleshy roots are susceptible to planting injury.	Clear cultivation must be maintained around the seedlings for at least the first two growing seasons.	A valuable timber tree but of little economic importance in Canada due to small range. Planted frequently as an ornamental.
In mixture with black locust, yellow poplar, white ash and basswood.	Complete deep cultivation or preparation of planting spots at least 18 x 18 inches.	Manual planting by spade.	Clear cultivation must be maintained around the seedlings for at least the first two growing seasons.	One of the most valuable timber trees, but difficult to grow due to its very high soil requirements.

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McCauley and Marquis (1972) report on investment in precommercial thinning of northern hardwoods in a 25-year-old stand. Cost estimates were prepared by a study of previous reports on this work, (Marquis 1969). Of approximately 400 crop trees selected per acre, 50% were white birch and 50% yellow birch, white ash, sugar maple, red maple, and beech. The thinning methods that involve least effort in tree marking, such as the selection of fixed diameters or the removal of only certain species, are much cheaper to carry out than individual tree marking throughout a large diameter range and among several species, including softwoods. High quality products such as large and small boltwood can be grown over a long enough rotation to produce large trees of high quality and to justify the investment in a precommercial thinning which yields a 6% or greater return on the investment. Precommercial thinnings, say the authors, are particularly attractive on areas where timber production is the major land use. The highest rate of return on thinning investment was 10.6% where species were simply selected, and 9.9% return where light thinning to diameter limits was carried out. The report of Erdmann, Godman, and Oberg (1975) describes precommercial crown thinning in a 16-year-old mixed hardwood stand. Five degrees of crown release were studied and yellow birch saplings were favored. Epicormic branching of yellow birch was a feature of all thinning treatments. However, during the three years following treatment, 74% of existing old epicormic shoots and 4% of the new epicormic shoots died. The diameter growth rate of the pole-sized trees could be doubled by thinning and, since sawlog material was the objective, the low incidence of epicormic branching was encouraging. The release treatment allowed the intermediate yellow birch stems to maintain their crown position among more tolerant species. Further release treatment will be necessary but if these trends continue, birch saw and veneer log rotations in the Lake States can be cut in half by using crown release among codominant and subdominant stems.

Erdmann, Godman, and Mattson (1975) discussed the effects of crown release and fertilizer on small sawlog-sized yellow birch. Their study was conducted in 65-year-old even-aged stands of yellow birch, sugar maple, red maple, and other mixed hardwoods. Yellow birch were favored in the thinning treatments. After three growing seasons diameter growth did not respond to the addition of fertilizer, but foliar analysis indicated that N, P, and K had

been taken up into the system. The previously untended 65-year-old codominant yellow birch trees responded well to crown release.

These precommercial release treatments follow traditional silvicultural practice. Costs and benefits, however, are not often available and must be more carefully considered before management recommendations are made. Thus, the report of McCauley and Marquis (1972), which synthesizes the experience of previous studies seems to provide dependable costs and projected returns and is a useful reference work.

The effectiveness of fertilizer applications to established hardwood stands is not clearly indicated and depends on local sites and soil nutrient status. Fertilizers are further discussed in the following section on thinning.

Thinning

The objective of thinning in mixed hardwood stands has traditionally been to improve sawlog quality. Thus, crop-tree thinning has been most widely used. In this operation, trees which have the potential to form the final sawlog crop are selected early in the rotation and are favored in one or two thinnings throughout the cycle. Species, as well as diameter classes, can be favored. The 1959 report of Conover and Ralston entitled, "The results of crop tree thinning and pruning in northern hardwood saplings after 19 years", is an example of a traditional thinning cycle. The thinning responses of American elm, white ash, basswood, and sugar maple are compared. Growth responses among crop trees selected during the first thinning were favorable over the 19-year period. Among non-crop trees, negative growth is reported since many non-crop trees are removed by subsequent thinnings. Total stand production, however, including growth on crop and non-crop trees shows a favorable increase over the unthinned control stand. Ninety-six percent of the total merchantable volume in the thinned stands is in crop trees, compared to 69% of the merchantable volume in the control plots on trees which had been identified as potential crop trees but not thinned. Conover and Ralston report that trees in the dominant and codominant crown classes made the best growth, except for white ash which grew well regardless of its position in the crown canopy. Stump sprouting following thinning was a serious factor in competition for the remaining trees. In marking such young stands, the authors caution

that responses to thinning may include forking, epicormic branching, the lack of natural pruning and increased growth responses in trees in the non-crop diameter sizes.

Thinning has also been used successfully to reclaim high-graded mixedwood stands. For example, in 1936, near Thurso, Quebec, thinnings were begun in decrepit hardwood residuals (MacLean 1950). In mixed stands of white pine and tolerant hardwoods, white pine had been logged 50 or more years previously and hardwoods then dominated the canopy. Since that time, the hardwoods had been repeatedly logged and the forest was left in a "very unproductive condition", with between 800 and 2000 stems per acre including about 600 to 1200 stems of the commercially valuable birch, maple, basswood, and oak. The residual stand consisted of scattered very large wolf trees of poor form, and an understory of younger trees with good growth potential but in serious competition with unmerchantable species.

Target stocking was 500 stems per acre of merchantable species. Girdling was used to remove trees more than 4 inches dbh. Others were felled. Thinning was heavy, removing up to 30% of stems and up to 48% of the total standing volume. Beech was heavily thinned (29-99%) and yellow birch was favored. By 1947, it could be determined that periodic mean annual increment was approximately 37-74 cu ft/acre on upper slopes, 60 cu ft/acre on lower slopes and 31-63 cu ft/acre on ridges compared to control levels of 25-30 cu ft/acre. Yellow birch responded favorably to release. MacLean has shown that improvement can be made in derelict mixedwood stands using simple marking rules to favor valuable species and to improve stem quality. Greatest gains were made on protected valley sites with deeper soils.

Roberge in 1975 reported on the effect of thinning on the production of high quality wood in northern Quebec. The experiment was initiated in 1963 in an even-aged sugar maple-yellow birch-beech stand. Yellow birch made up as much as 40% of the total number of trees 9 cm dbh and over, and about 28% of the standing basal area. There were two degrees of thinning, the first removed 20% of the unthinned stand basal area and the second, 40%. Sugar maple and yellow birch both responded to the thinning, sugar maple more than birch. The rate of diameter growth of yellow birch was increased by 2% in the 20% thinning and 12% in the 40% thinning. Both thinning intensities were successful although they

somewhat favored the sugar maple at the expense of yellow birch. Thinnings in mixed hardwood stands, as reported by Robitaille and Roberge (1976), indicate that thinning with fertilization provides better growth responses than either thinning or fertilizing alone. Thinning has a greater influence on stand growth than fertilizing.

Thinning is recommended and successfully used in sugar bush management to achieve optimum spacing, to remove unwanted species and poor quality sugar maple. Guidelines are available to the sugar bush operator for optimum spacing to maximize sap production (Coons 1975). The forest manager can thin to specified stand densities and basal areas using guide curves for sugar bush management (Lancaster *et al.* 1974).

Mechanization of thinning in northern hardwood pole stands is described by Biltonen *et al.* (1976). There were five thinning treatments: (1) strip thinning, mechanical felling and skidding; (2) selection thinning, chain saw felling and no skidding; (3) selection thinning, mechanical felling and skidding; (4) strip thinning with selection thinning between strips, mechanical felling and skidding to landing; (5) shelterwood thinning, mechanical felling and skidding to landing. Strip thinning was carried out in strips 10 feet wide. Major equipment used was a feller buncher, a grapple skidder, and a whole tree chipper. The thinning treatments were carefully costed. The advantages and disadvantages of the thinning treatments as described by the authors are presented here.

Advantages and Disadvantages of Thinning Treatments

Selection thinning. —Silviculturally, selection thinning is superior to strip thinning but is more difficult to mechanize because:

1. The feller-buncher and skidder must both operate in the stand, creating a higher risk possibility for injury to the remaining trees.
2. A good felling and removal system is difficult to coordinate because both machines tend to interfere with one another — bunches felled in uncut areas must be removed before felling can be continued.
3. Skidder operators are often not experienced enough to decide the least damaging route out of the woods each time they pick up a load.

Strip thinning. —Strip thinning is easy to mechanize but silviculturally less satisfactory because there is no possibility of choosing between individual trees. All trees within the strip should be cut. In addition, the 10-foot-wide strips were not adequate to maximize production as previously discussed. Residual stand damage was high because the feller-buncher must always place the cut material into the uncut stand.

Strip thinning with selection — the best method. —Strip thinning with individual tree selection between strips was good compromise because it was reasonably productive and was acceptable silviculturally. It was also preferred by the equipment operators and adopted by the logger as the system to use on his own woodlands.

Initially, the feller-buncher starts cutting a 10-foot-wide strip, laying all bunches to the right. As soon as the end of the strip (660 feet in this case) is reached, the operator would go to his left and begin selectively thinning the between-strip space up to where the next strip will be (70 feet). The trees from the selective area would be bunched in the previously cut strip, thereby minimizing damage and also concentrating all of the cut material either in the cut strip or adjacent to it. After the operator has finished the selective cutting, he is back at his starting point and has one cut strip and a 70-foot-wide band of selectively thinned area. He then moves 70 feet to the left, and begins a new strip, again laying bunches to the right and into the thinned area he just finished cutting. As he progresses in this manner to his left, he can cut many acres of material and never interfere with the skidder. With all the material being concentrated on a strip, the skidder operator, experienced or not, can easily follow the cutting pattern without having to make any skidding route decisions.

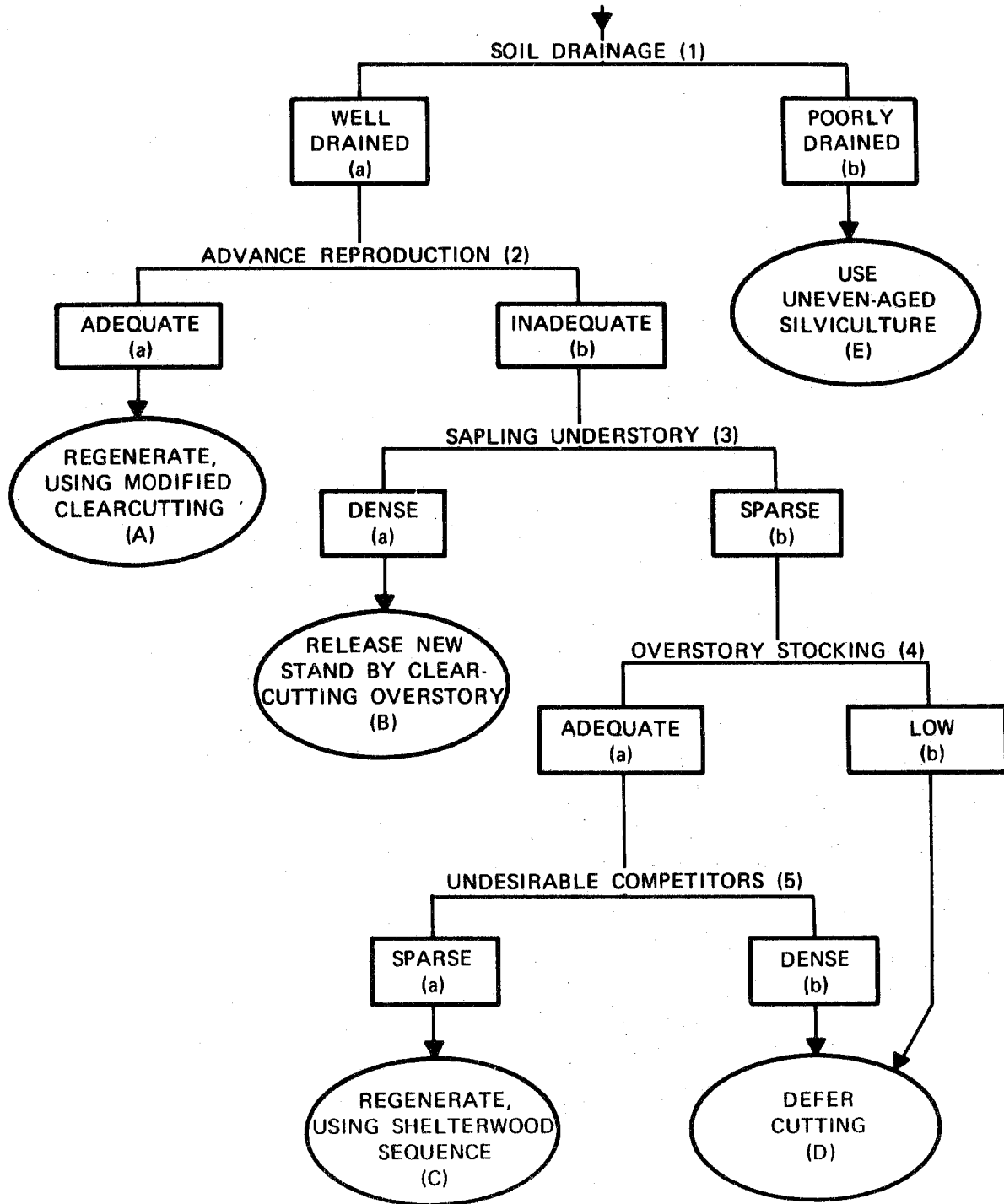
In stands which are less than fully stocked, thinning should be done only in the patches where overcrowding leads to competition and mortality. In most cases, the first thinning may be non-merchantable or, as we have described previously, precommercial. However, if any of the thinnings can be sold, this should be encouraged and markets should be researched. The authors of "A silvicultural guide to the hard maple yellow birch and hemlock working group in Ontario", Bruce and Heeney (1974), caution against thinning too early and thinning before the trees have a clean stem of about 26 ft. The second thinning, the Ontario authors say, should be a revenue producer; that is, hardwood stands at middle age will likely have developed clearly identifiable potential crop trees and followers. Among the followers, thinning is carried out to provide post, pole, and sawlog material (cf. the crop tree and non-

crop tree responses of Conover and Ralston 1959). Where pulpwood markets are close-by, an opportunity exists for subsequent thinnings, but in most cases two thinnings would be a maximum for one rotation. In many current examples only one, and only a commercial thinning, can be considered. Yet, where other land values e.g. parks and recreation, are considered, repeated thinning may be justified. If pruning is to be carried out, it should be done only on crop trees and following thinning so that expensively pruned trees are not subsequently thinned. Good quality stems and adequate regeneration of quality species can be obtained under the shelterwood system of silviculture. Thinning in the early stages of the creation of the shelterwood should be geared to stand improvement and should set the scene for successful preparatory or seeding cuts. Thus, the Ontario authors suggest that in stands of as much as 100 years of age, the removal of the merchantable material of sawlog size will result in an improvement in understorey stems.

Preparatory felling

Preparatory felling provides the forest manager with an opportunity to create conditions suitable for regeneration of commercially valuable species. Where advance growth is present in satisfactory quantities, no preparatory cutting may be necessary to encourage regeneration in advance of final harvest cutting. Some sort of shelterwood cutting is usually necessary. Marquis *et al.* (1975) in "An interim guide to regeneration of Alleghany hardwoods" describe stand analysis by which a decision to clearcut or to use preparatory cutting can be made. The process is called "stand diagnosis" and the components are: (1) the identification and sampling of stand units; (2) the evaluation of the overstorey; (3) the evaluation of the understorey; and (4) the establishment of regeneration stocking levels. From this information and from stocking guides prepared for Alleghany hardwoods, a decision-making is begun which is illustrated in Fig. 5. Limiting factors which must be assessed include: undesirable competitors; soil drainage; and the presence or absence of adequate advanced reproduction. Thus, the preparatory felling may be used to modify the species mixture and provides an opportunity to remove undesirable stems of poor form. For example, Leak and Solomon (1975) examined the influence of residual stand density on regeneration of northern hardwoods. If we assume that the

Figure 5.— Guides to Allegheny hardwood regeneration.



Reproduced with permission from "An interim guide to regeneration of Allegheny hardwoods" by D.A. Marquis, T.J. Grisez, J.C. Bjorkbom and B.A. Roach. U.S. Forest Service, Tech. Rep. NE-19, 1975.

residual stand densities are the result of "preparatory felling", we can predict the reaction of regeneration of a variety of species to different preparatory cutting intensities. These were: 40, 60, 80, and 100 sq ft basal area per acre of residual stand, for the Bartlett Experimental Forest, N.H. where the study was carried out. Stocking of regeneration, after nine years, was higher where the initial residual basal area was lower. Zero residual density, (i.e. clearcutting) favored intolerant species. Forty square feet basal area favored intermediate species and more than 60 sq ft basal area per acre favored tolerant species.

The preparatory felling operation in shelterwood silvicultural systems is a most important step in controlling the composition of the resulting natural regeneration, (Metzger and Tubbs 1971; and Godman and Tubbs 1973). Damage to advance growth by removal of the shelterwood overstory is discussed by Jacobs (1974). With careful planning and cooperation from the logging contractor, damage to residual stand and to existing reproduction can be minimized. The success of applied research trials on an operational scale substantiates these claims.

Utilization concerns

There are many uses for hardwoods, some traditional, others very recent and innovative. There are fewer markets for hardwoods and this creates a serious problem in the supply/demand situation. The list of uses for hardwood timber is a long one. The use for hardwood fibers and reconstituted fibers is increasing, but the outlets for these products are often temporary. There is a continuing demand for high quality hardwood lumber but there is an increasing proportion of low quality hardwoods in the forests of the Maritimes because of high grading. Logging for quality hardwoods generates twice as much low quality material which may have to be left in the forest. Oldham (1976) in a report to the Maritimes Section of the Canadian Institute of Forestry pointed out that, to produce one cunit of quality hardwood in New Brunswick generates 2.3 cunits of poor quality wood under a clear-cut harvesting system. West (1976) reporting to the same meeting says that, residual standing volume following cutting in mixedwood types is about 3 cunits per acre where softwoods were predominant in the type; while in the hardwood-softwood type, with hardwoods predominant, residual volume is about 10 cunits per acre. A further 2 or 3 cunits per acre may be lying broken on the ground as we have described

before (Introduction, Table 7). West summarizes the main elements of the hardwood utilization problem as follows;

1. excessive supply,
2. the distribution of the hardwood user in relation to the distribution of the hardwood resource,
3. the scarcity of high quality hardwood,
4. the big distances between high quality and low quality users of the resource,
5. effect of a large volume of residual hardwood on subsequent softwood regeneration,
6. high cost of removing residuals for site preparation purposed for conifer management and,
7. the tendency of the Acadian forest to regenerate following a harvest with a larger proportion of hardwoods than was found in the original stand. While the capability in the Maritimes to use low grade hardwoods for pulp fiber increases, the supply of low grade material far outweighs the current and predicted demand.

The hardwood logging residue left behind following conventional hardwood sawlog operations is described in a case-study in the Appalachians by Craft (1976). This example will serve to illustrate the sorts of materials generated by conventional logging in hardwoods:-

After the merchantable timber (12 inches dbh and over) was felled and removed, a typical acre within the 18-acre sample block was selected for close study. The first treatment was the removal of all topwood residue. All sound material that would give a straight or nearly straight piece at least 6 inches in diameter by 4 feet 3 inches long or longer was removed and decked for sawing. The remaining topwood material was stored for chipping. The second treatment was the felling and skidding of all residual trees that were 6 inches diameter at breast height or larger. The final treatment was the felling and skidding of all trees below 6 inches dbh which were weighed and piled for chipping. The total weight of all residues recovered from one acre was 69.3 tons. Topwood residue yielded 11 tons of sawable logs. Residual trees yielded 14.9 tons of sawable bolts and the weight of merchantable logs harvested from the 18 acre unit was about 40 tons per acre. Thus, for every ton of merchantable logs harvested about 1.8 tons of residue remained. The test sawing operation produced 8.2 tons of chippable slabs and edgings and 2.6 tons of sawdust. The chip yield was not assessed.

The problem of generating logging residue in hardwood and mixedwood stands is so serious that Martin in 1976 prepared a logging residue yield table.

Martin reports that the independent variables; type of cut, products removed, basal area per acre, and stand age explain 95% of the variation in residue volume per acre. So, a yield table was prepared to show the probable residue volumes for different cutting practices at various levels of basal area per acre of residual stand, and stand age.

In a hardwood stand, for example, of 100 years of age, with a basal area per acre of 100 sq ft, an improvement cut would yield 321 cu ft per acre of logging residue, a selection cut 584 cu ft per acre, a sawlog clearcut 2122 cu ft per acre and a clearcut with other products removed 341 cu ft per acre, (that is, pieces 4 inches or more in diameter at the small end, more than 4 feet in length, and at least 50% defect free).

There is a wide range of products that can be manufactured from residual hardwoods, and utilization techniques are far advanced. What is lacking is an effective collecting, processing, and distributing system through viable markets.

Young (1977) describes how hardwoods, both main crop species and "pucker-brush" species, fit well within the "complete tree" concept. Pucker-brush pulping studies (Chase, Hyland, and Young 1971, 1973) show that usable pulp can be made from the wood and bark of both stems and branches of the smaller successional hardwoods (grey birch, pin cherry, red maple, and aspen). Residual parts of mature hardwoods can be used in quantities suitable for a pulpwood operation. The resulting increase in fiber production is about 100% (not including the stump/root systems which might add a further 34 oven-dry tons per ha).

While these systems are being refined, markets must be found for the products generated. Alternate uses for hardwoods, reports Young (1977), include pulp, sap, livestock feed using hardwood leaves, xylitol (a sugar from birches), bark for poultry litter, poultry manure and bark mixed as an agriculture fertilizer, and a long list of hydrocarbons providing plastic materials and fuel, (energy in both solid wood, liquid, and gaseous form).

Flann (1977) examines opportunities in hardwood utilization from two approaches, (1) improved roundwood allocation and (2) more efficient processing techniques. Flann stresses that there is a need to make the best use of a diminishing quality of resource. Improved conversion efficiency is the hardwood utilization opportunity with which the report is mainly concerned. Helpful information is available in

improved-hardwood utilization in a report entitled "Felling and Bucking hardwoods — How to Improve your Profits", by Petro (1971). Petro points out that one cut in bucking hardwood logs affects the quality of two logs, above and below the cut. In the recommended bucking technique, cross cutting begins at defects and works outwards to clear lumber. Defects are isolated by jump cutting and the use of a greater range of log lengths. In an example presented and illustrated by Petro, lumber value increases, through careful bucking, from \$143.44 per thousand bd ft net scale to \$177.57. Such gains from effective bucking can be demonstrated easily in the field.

New uses for hardwood logging residues are suggested by Schneider (1977) in his report on "Energy from Forest Biomass". Both wood and bark should be considered as a source of fuel, and Schneider outlines the processes leading to both gas and liquid fuels.

The reports of Young, Flann, Petro and Schneider, indicate that more efficient and better use can be made of the hardwood resource through an integrated utilization plan. Better utilization means a better woods operation and better silviculture.

GUIDES TO MANAGEMENT

Site Index, Stocking and Yield

Curtis and Post (1962a) prepared "Site index curves for even-aged northern hardwoods in the Green Mountains of Vermont". A reference age of 75 years at breast height was chosen because it is at this stage in the rotation that height/volume relationships stabilize for hardwoods. In a subsequent publication Curtis and Post (1962b) compared site indices for four species (sugar maple, white ash, white birch, and yellow birch). Then the site capability for one species could be predicted from the measurement of any others available on the site. The resulting comparison is presented here (Fig. 6). Curtis and Post (1964) then related basal area stocking, diameter, and volume to site indices. Comparison was also made by Foster (1959) between white pine and red maple. Red maple was the species present and white pine was the desired alternate species. It is important to note that these comparisons were originally based on second or third growth even-aged, managed stands, but that they have been found useful in both New York State and New Hampshire in uneven-aged stands. A series of site index curves for 36 species is complete for the eastern United States (Hampf

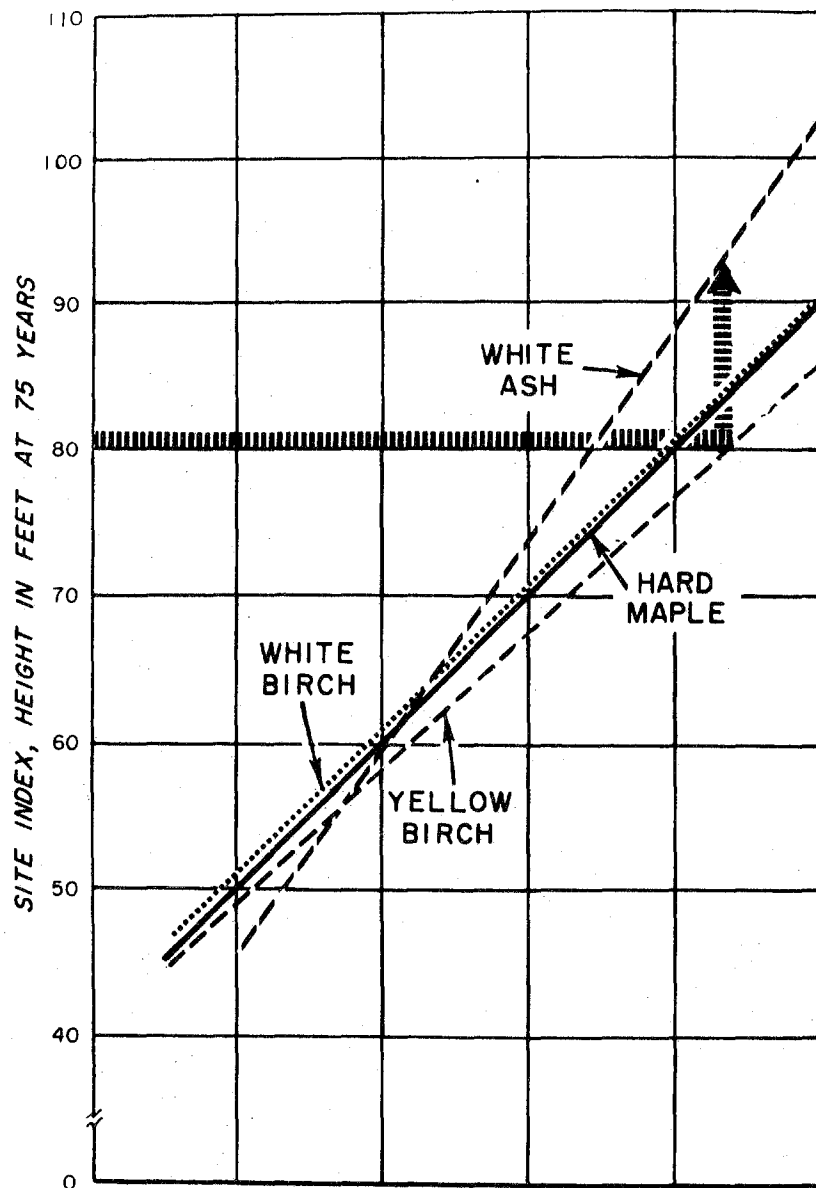


Figure 6. — Comparative measured site indices for four northern hardwood species on acid till soils in the Green Mountains of Vermont. Base age used was 75 years at breast height. If the site index of one species is known for a given piece of land, the site index of any of the other three species can be estimated.

For example, if the site index for yellow birch is 80, and you want to know site index for white ash: start at 80 on the site-index scale and read right to the yellow birch curve, then read straight up to the white ash curve, and read left to get site index — 93.

1965). The information is drawn from a variety of sources and each is acknowledged on the appropriate figure.

Stocking guides for upland hardwood forests in the Central States were prepared by Gingrich (1967). These are directed to the production of hardwood sawtimber. Full stocking, for example, of 10-inch trees is 115 sq ft basal area per acre, and 210 stems per acre. Full stocking of larger trees, or of smaller pole size trees could be less, or more stems per acre with only a small change in basal area. Once the management objective has been determined, sawlogs or pulpwood, the silviculturist enters the stocking guide with stand data (age, mean stand diameter, and basal area per acre), which will determine the resulting prescription. This paper, which appeared in *Forest Science*, provides a full and valuable account of the nature of "density" and "stocking" distributions in hardwood stands. Gingrich in 1971 goes on to set down definitive stocking guides complete with yield tables for managed and thinned stands. For upland hardwoods the conversion period from unmanaged to managed stands may be long (e.g. 40 years) and may incorporate several thinings 10 years apart.

In preparation of "A silviculture guide for northern hardwoods" Leak, Solomon, and Filip (1969) have advanced the concept of the stocking guides used by other contemporary researchers.

Solomon and Leak (1969) presented a paper at the Birch Symposium which illustrates how site index curves and basal area growth curves can be used for both even-aged and uneven-aged mixed hardwood stands. The stocking curves finally appeared in a definitive form in the 1969 silvicultural guide. Age and height, that is site index, determine the site class. Basal area per acre determines the stocking factor, and thus the volume and increment.

Detailed stocking charts are presented for even-aged stands of pure paper birch and mixed northern hardwoods showing basal areas, numbers of trees, and mean stand diameters that represent overstocked, adequately stocked, and understocked conditions. Thinning is then prescribed to maintain basal area increment within the guidelines for the appropriate diameter classes.

After heavy thinning in 25-year-old even-aged northern hardwoods, diameter growth rates of paper birch increase by nearly 30%, and yellow birch by over 75%. In older stands past age 65 yr, the response of both birches to thinning is considerably less.

Yields from an average well-balanced uneven-aged stand are estimated at about 200 bd ft of sawlogs per acre per year plus 15 cu ft of pulpwood, equivalent to a total of at least 0.5 cords/acre per year. Since current logging economics dictate a minimum cut per acre of 6 to 10 cords, the appropriate cutting cycle is 12 to 20 years (Leak and Filip 1975). Preliminary estimates are that intermediate cuttings will as much as double the final yield from even-aged stands.

The stocking guides of Solomon, Leak, and Filip, and of Gingrich are presented (Figs. 7, 8) for comparison. Upland hardwood stands in the Central States lack the high proportion of small diameter stems present in the more tolerant hardwood stands of the northeast. Their application in the Maritimes hardwood stands should be carefully tested. Perhaps the New England curves are more suitable.

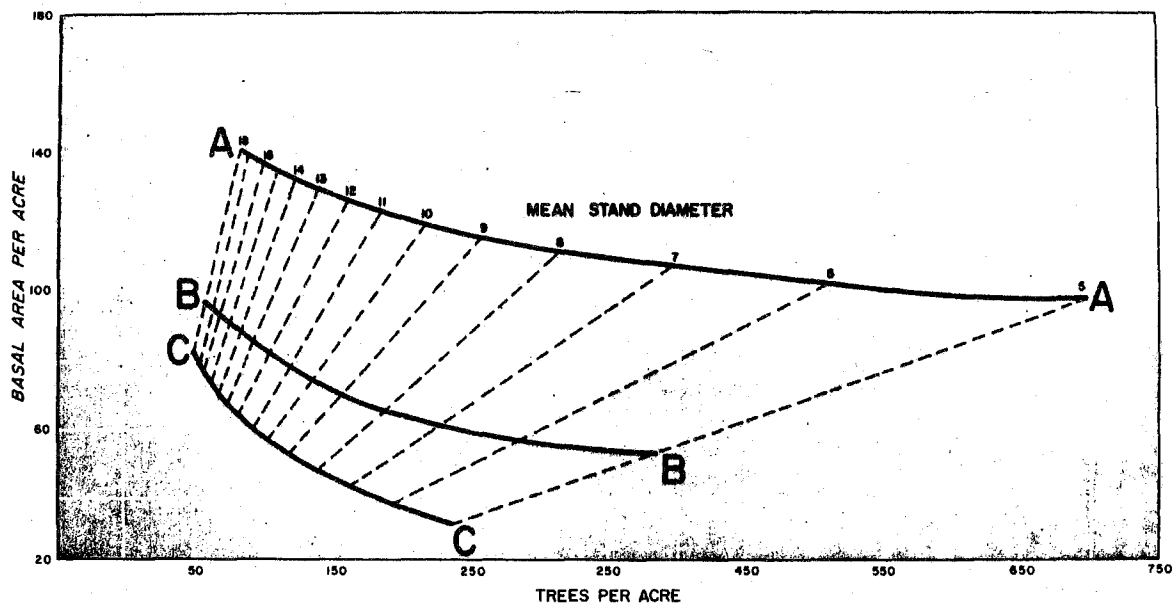
In their report "A silvicultural guide for developing a sugarbush", Lancaster *et al.* (1974) also use basal area control.* Heavier thinning and wider spacing are required to promote the development of good sugar maple stems. Large crowns mean satisfactory leaf area, and sugar and carbohydrate production. The stocking chart developed by the authors is illustrated (Fig. 9). To the overstocked, fully stocked, and understocked classes has been added a further low-density class for sugarbush management. Minimum levels range from 50 to 150 trees per acre and from 20 to 60 sq ft basal area per acre, for stem diameters from 5 to 18 inches dbh. A sugar maple stand of 75, 10-inch trees per acre might provide 70–90 tapholes and 15–25 gallons of maple syrup per season (Coons 1975).

A silvicultural guide comparable to that of Leak, Solomon, and Filip has been prepared for the hard maple, yellow birch, and hemlock "working group" in Ontario by Bruce and Heeney (1974). In an orderly presentation, they discuss habitat conditions, the life history of the species, some miscellaneous characteristics, damaging agents, management objectives, harvesting methods, regeneration techniques, stand improvement through tending, and they also discuss some special situations, such as high-graded stands, stands with several crown classes and stands on difficult shallow soils.

A section on "management objectives" introduces a discussion of silvicultural systems. It is reproduced

* For worked examples of diagnostic tally sheets see Appendix.

Figure 7.—Stocking guides for even-aged northern hardwoods, based on number of trees in the main canopy, average diameter, and basal area per acre. Stands above the A line are overstocked. Stands between the A and B lines are adequately stocked. Stands between the B and C lines should be adequately stocked within 10 years. And stands below the C line are definitely understocked.



Reproduced with permission from: "A silvicultural guide for northern hardwoods in the northeast" by W.B. Leak, D.S. Solomon, and S. M. Filip. U.S. Forest Service Res. Pap. NE-143, 1969.

Upland hardwoods on a *poor* site.

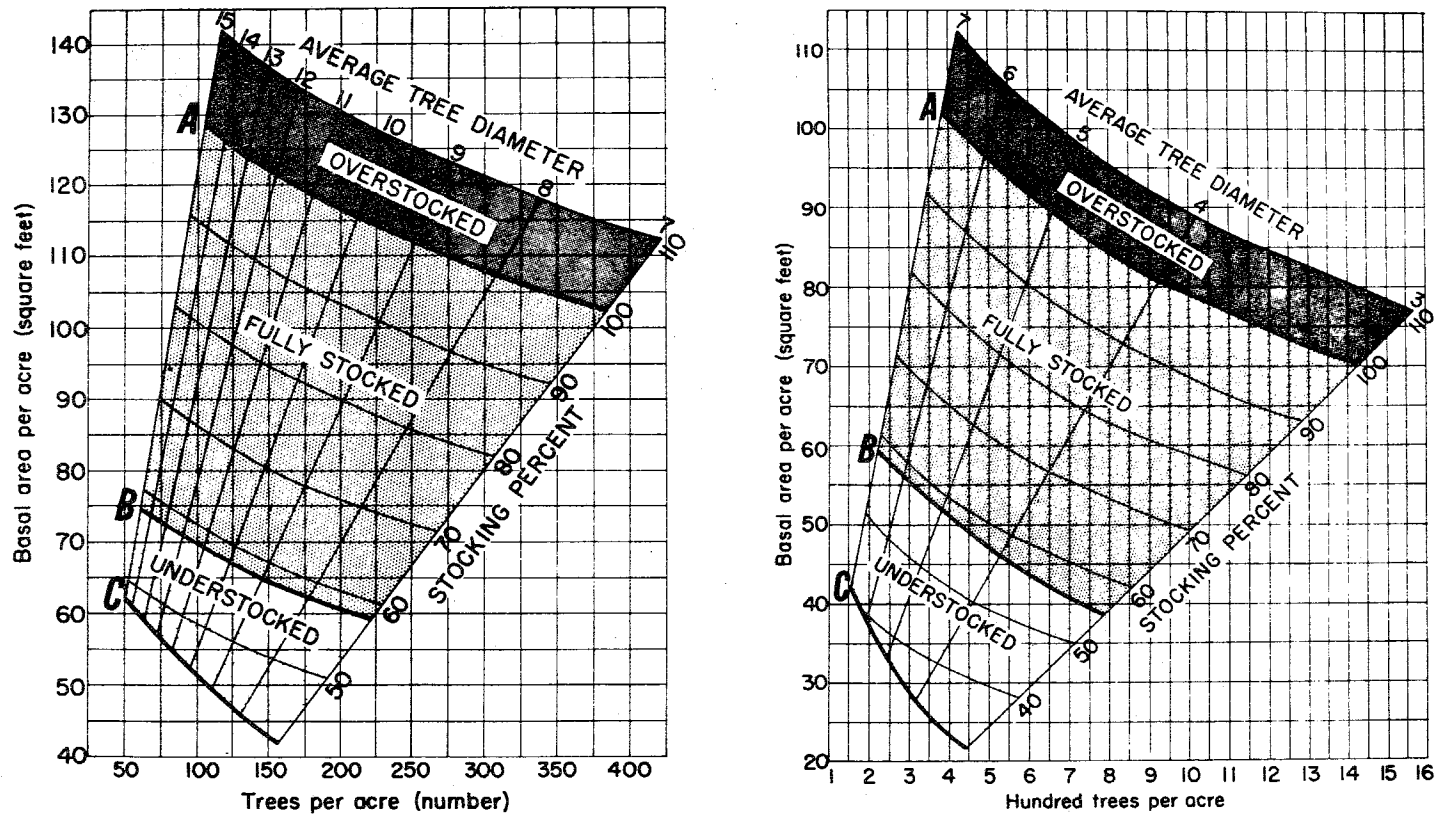
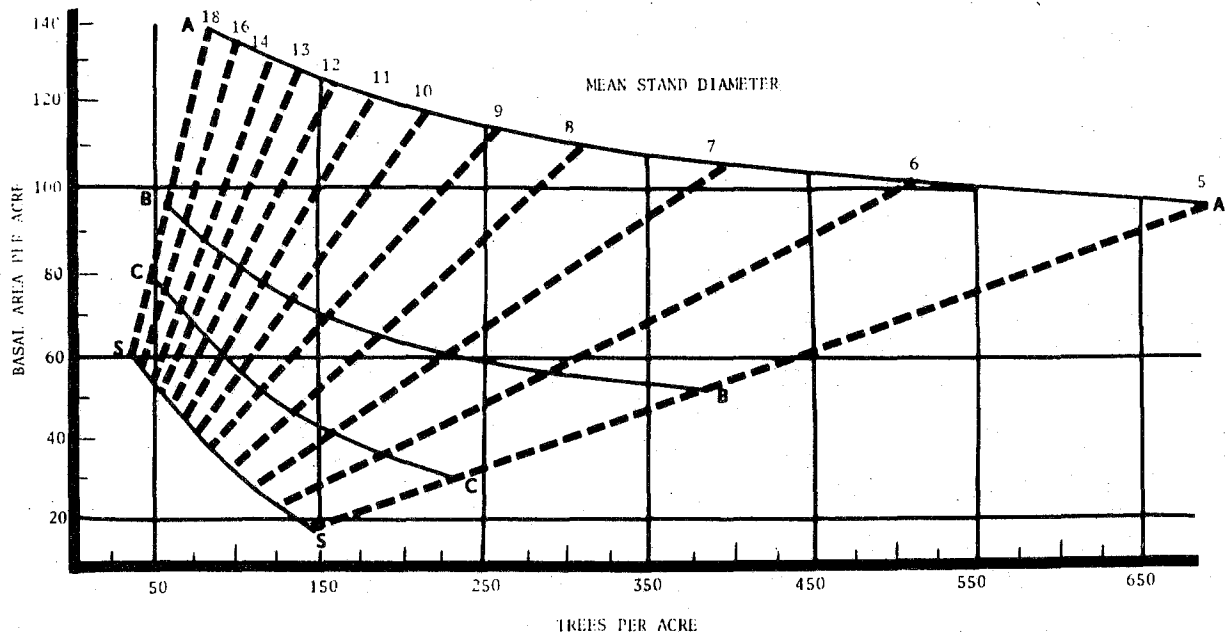


FIGURE 8.—Relation of basal area, number of trees, and average tree diameter to stocking percentage for upland central hardwoods. Tree-diameter range is 7–15 inches in chart at left; 3–7 inches in chart at right. The area between curves A and B on both charts indicates the range of stocking where trees can fully utilize the growing space. Curve C shows the lower limit of stocking necessary to reach the B level in 10 years on average sites. (Average tree diameter is the diameter of the tree of average basal area.)

Reproduced with permission from: "Measuring and evaluating stocking and stand density in upland hardwood forests in the Central States" by S.F. Gingrich. For. Sci. 5:279-291 1959.

Figure 9.—Stocking chart for even-aged northern hardwoods, based on number of trees in the main canopy, average diameter, and basal area per acre. For timber objectives, stands above the A line are overstocked. Stands between A and B lines are adequately stocked. Stands between B and C line should be adequately stocked within 10 years. Stands below the C line are definitely understocked. For sugarbush management, maple stands at the S line are at minimum stocking levels.



Reproduced with permission from: "A silvicultural guide for developing a sugar bush" by K.F. Lancaster, R.S. Walters, F.M. Laing and R.T. Foulds. U.S. Forest Service, Res. Pap. NE-286, 1974.

here together with the more general discussion of "harvesting methods". Appendices to the report include sections on rotation age determination, silvicultural systems compatible with multiple use (especially recreation), stand composition goals, species mix, wildlife needs, and an example of an all-age control table for the selection system, (a common prescription) (Table 15).

MANAGEMENT OBJECTIVES

The principal species of the Tolerant Hardwood Working Group will be managed to produce a continuing supply of quality hardwood logs and veneer bolts from the better forest sites. Where markets exist, pulpwood will be produced from logging residue and from intermediate cuttings in the stand.

The requirements of the major species of birds, game, and fur-bearing animals for wildlife habitat will be considered when selecting management techniques for the major species. Deer management will require modification of regeneration and tending procedures to ensure adequate food and cover in the winter months.

Aesthetics is an important consideration in this working group especially adjacent to travel routes, recreation areas, parks, natural areas, lakes, and rivers. Reserves or vegetative screens should be managed to ensure continuity and prevent decadence.

Site Protection is not normally considered a serious problem in this working group. It responds well to management under silvicultural systems (selection and shelterwood) which afford maximum site and aesthetic protection. Care in the location and construction of roads, landings, and skidding trails is required especially when operating in rolling topography or soils subject to erosion.

HARVESTING METHODS

GENERAL

There is no one harvesting method which will achieve all of the objectives listed above but depending on the priorities of use in the given area, modifications in silvicultural practices will occur to achieve specific results.

In general, where commercial timber production is required, either one of the shelterwood systems or the selection system will be used. Both have the advantage of dispersing the cut-over and meeting the requirements of wildlife for shelter and open space.

Clearcutting in strips or patches may be used where regeneration of intolerant species is required and where site

protection and recreation potential are minimal. Large clear cuts (over 50 acres) are not permitted.

Where game management is important or when the efficiency of timber production is required, the system to be used will be the strip shelterwood.

In areas where site protection or recreation requirements impose use restrictions, the uniform shelterwood can be used to modify the appearance of the harvested stands or areas.

In other situations where aesthetics are important or where intensive management practices are required, the selection system may be applied.

This silvicultural guide makes good use of the research of Trimble (1970), Leak and Filip (1975) Blum and Filip (1963), Leak, Solomon, and Filip (1969) Marquis (1967) von Althen (1964) and McQuilkin (1970). Strip shelterwood, group shelterwood, uniform shelterwood and selection systems of silviculture are presented and discussed in the light of a range of management objectives.

Regeneration techniques include site preparation, selection of appropriate equipment, prescribed fire, light requirements for seedlings, regeneration stocking for natural regeneration, and a discussion of artificial regeneration and plantation establishment.

Control of stocking is based on the changing space requirement of individual stems. Basal area control is one of the guides to stand development. Stocking standards are high. Acceptable regeneration stocking is more than 80% by milliacre quadrat survey, number of stems per acre more than 5000. Thus, the management guides are based on very dense stocking in the early stages of development and imply a series of thinnings.

Filip's 1973 paper, "Cutting and cultural methods for managing northern hardwoods in the Northeastern United States", is a further development of the 1969 hardwood management guide. It describes the experimental program which led to the preparation of the guide and advises the forest manager to begin by making the important decision of whether the growing stock will yield top-grade products, such as veneer logs, sawlogs, and millwood, or yield mostly pulpwood and other bulk products. Another basic decision, says Filip, is whether to go for a high proportion of shade tolerant species, intermediates, or intolerants. These would determine the appropriate silvicultural system. Definitively Filip then goes on to illustrate, using the stocking chart, how a stand distribution might be achieved for intermediate or intolerant species. A stocking table is used which has diameter classes, number of trees per

Table 15. All aged control table for the selection system structure of desired stand*

1" Classes			2" Classes			10 Year Cycle				Volume Removed 10 Years				
DBH	No.	BA	DBH	No.	BA	Cut or Remove	Resid. No.	BA Removed	Resid. BA	HT in FT	GTCF	NMCF	Net CF Merch Pulp	Net CF Merch Logs
(1)	(2)	1 tree (3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1	171	.0054								10	—	—	—	—
2	132	.0218	1-2	303	3.80	124	179	1.56	2.24	30	—	—	—	—
3	101	.0491								44	117	64	64	—
4	78	.0873	3-4	179	11.77	73	106	4.81	6.96	53	161	129	129	—
5	60	.1364								58	165	146	146	—
6	46	.1964	5-6	106	17.21	43	63	7.01	10.20	63	159	146	66	80
7	36	.2673								68	158	148	40	108
8	27	.3491	7-8	63	19.05	26	37	7.85	11.20	71	73	69	12	57
9	21	.4418								73	239	227	27	200
10	16	.5454	9-10	37	18.01	15	22	7.25	10.76					
11	12	.6600												
12	10	.7854	11-12	22	15.77	9	13	6.44	9.33					
13	7	.9218												
14	6	1.0690	13-14	13	12.86	6	7	5.97	6.89					
15	4	1.2272												
16	3	1.3963	15-16	7	9.10	2	5	2.62	6.48					
17	3	1.5763												
18	2	1.7671	17-18	5	8.26	5	—	8.26	—					
Total	735			735	115.83	303	432	51.77	64.06		1072	929	484	445

Note:— Q = 1.3 Diameter groups = 2 inches
Average 10 year diameter growth = 2 inches (all groups)
Height-diameter relationship from FRI Report 25
Volumes from standard volume tables — Division of Forests

* Reproduced with permission from: "A silvicultural guide to the hard maple, yellow birch and hemlock working group in Ontario" by D.S. Bruce and C.J. Heeney, OMNR, For. Manag. Br. 1974.

hectare, and basal area per hectare, with a goal of 18.4 m² per ha or 80 sq ft per acre. Filip also discusses the improved aesthetics of the selection system of silviculture for shade tolerant species. Research is needed, he says, in greenhouse rearing schedules for artificial regeneration, and in the application of fertilizer for stand improvement. Filip is obviously satisfied with the stocking guide curves and their application in the New England States.

Management of uneven-aged hardwood stands for quality is perhaps the most demanding management objective. Leak and Filip (1975, 1977) recommend selection systems to achieve the desired stem diameter class distribution. Northern hardwoods become financially mature not larger than 22 inches dbh. Optimum residual stocking lies somewhere between 70 and 80 sq ft of basal area per acre. Stand structure is projected by the authors for "Q", the quotient between adjacent 2-inch diameter classes, from 1.3 to 1.0 in an example (Table 16) which is shown here. These are the options presented to the forest manager. If Q increases, the number and proportion of small trees increase. Within one stand, different Q values can be applied to sawtimber and pole sizes. The stand structure follows a typical reverse J form and the appropriate choice is Q = 2.0 (Table 17).

Stand structure, response to partial cutting and the production of quality sawtimber are the subjects of a recent report by Solomon (1977). In 70- to 90-year-old second growth northern hardwoods (beech, yellow birch, sugar maple, red maple, white birch, and white ash) with some red spruce and a significant hemlock component, partial cutting and girdling were carried out in 1963. Residual basal areas were 100, 80, 60, and 40 sq ft per acre. Within each residual basal area level were three levels of stand structure: 30, 45, and 60% sawtimber (>10.5 dbh). Sawtimber sizes tended to be overstory trees with pole timber sizes in the understory. As sawtimber density increased, sawtimber increment decreased because of overstocking in the upper canopy. Stem number curves (12) are compared in the report for each treatment and sawtimber class combination. Tables of diameter and basal area increment by species and treatments are presented. Solomon says in summary:

"A 60-square foot treatment with about 45 to 60 percent sawtimber seem reasonable for fairly intensive uneven-age management where some cultural or marginal work could

be done in the poletimber to improve quality and species composition. A treatment of 80 square feet with about 45 percent sawtimber should be appropriate for less intensive even-age management where little work will be done in the poletimber size. The q-ratio for 45 percent sawtimber is about 1.7 or a little higher while the q for 60 percent sawtimber is about 1.5. These growth data should be useful in making specific predictions of stand response to various levels of density and structure, and they provide some general guidelines for management to achieve optimum basal area growth. Notice that stand growth response will depend upon species composition, since certain species such as hemlock grow much faster in diameter and maintain ingrowth rates better than other species. Since these data were taken from a 70- to 90-year-old stand, caution should be used in applying these results to younger or older stands."

These guidelines will be invaluable to the forest manager and woodlot owner in the study region.

The rate of diminution (Q) between diameter classes is also known as de Liocourt's coefficient (1898)¹. Knuchel in his book, "Planning and Control in the Managed Forest" translated from German by Mark L. Anderson in 1953, points out that the ideal fully stocked constitution of the selection forest can be provided from the stem/number curve. Once there is a graphical representation which simulates the proposed forest structure, cutting can begin in the appropriate diameter classes. Knuchel presents examples of de Liocourt's coefficient for Q equal to 1.3, 1.35, 1.4 and 1.5, and the appropriate diameter class/stem number values.

Leak and Filip (1977) consider the concept of an "allowable harvest" made up of adjustment in all merchantable diameter classes. Changes may be made to the structural goal of the residual stand once cutting cycles are begun. In many cases, it may be possible to work towards a smaller "Q", i.e. a higher percentage of sawtimber in successive cycles. Having selected a suitable value(s) of Q, several future stand structures can be projected and, thus, future yields predicted. The stem/number curve is, in fact, a mathematical model from 1898.

¹ de Liocourt, F. 1898. De l'Amenagement des sapinières. B.S.F. p. 396-409.

Table 16. Residual stand structures designed for 70 square feet of residual basal area per acre up through the 20-inch class, and between 70 and 80 square feet up through the 22-inch class*

Dbh class (inches)	q = 1.3		q = 1.4		q = 1.5		q = 1.6		q = 1.7		q = 1.8		q = 1.9		q = 2.0	
	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area
	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>
6	26.8	5.25	35.3	6.91	44.2	8.67	53.8	10.55	63.5	12.45	73.2	14.34	82.8	16.22	92.0	18.04
8	20.7	7.22	25.2	8.78	29.5	10.30	33.6	11.73	37.3	13.03	40.6	14.18	43.6	15.20	46.0	16.06
10	15.9	8.67	17.9	9.78	19.7	10.72	21.0	11.45	22.0	11.98	22.6	12.31	22.9	12.49	23.0	12.54
12	12.2	9.61	12.8	10.05	13.1	10.30	13.1	10.31	12.9	10.14	12.5	9.84	12.1	9.47	11.5	9.03
14	9.4	10.03	9.1	9.78	8.7	9.35	8.2	8.77	7.6	8.13	7.0	7.45	6.4	6.79	5.8	6.14
16	7.2	10.08	6.6	9.15	5.8	8.13	5.1	7.15	4.5	6.24	3.9	5.41	3.3	4.67	2.9	4.01
18	5.6	9.82	4.7	8.25	3.9	6.86	3.2	5.67	2.6	4.64	2.2	3.80	1.8	3.11	1.4	2.54
20	4.3	9.32	3.3	7.28	2.6	5.64	2.0	4.36	1.5	3.37	1.2	2.61	.9	1.02	.7	1.57
22	3.3	8.67	2.4	6.29	1.7	4.56	1.2	3.30	.9	2.40	.7	1.76	.5	1.29	.4	.95
Total	105.4	78.7	117.3	76.3	129.2	74.5	141.2	73.3	152.8	72.4	163.9	71.7	174.3	71.3	183.7	70.9

* Reproduced with permission from: "Uneven-aged management of northern hardwoods in New England" by W.B. Leak and S.M. Filip. U.S. Forest Service Res. Pap. NE-332 1975.

Table 17. Examples of the basal areas and volumes removed per acre for two residual stocking alternatives*

Dbh class (inches)	Initial stand		q = 2.0				q = 1.6			
			Residual		Cut		Residual		Cut	
	Trees	Basal area	Trees	Basal area	Basal area	Volume	Trees	Basal area	Basal area	Volume
	<i>No.</i>	<i>Sq. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>Sq. ft.</i>	<i>Bd. ft.</i>	<i>No.</i>	<i>Sq. ft.</i>	<i>Sq. ft.</i>	<i>Bd. ft.</i>
6	94.7	18.56	92.0	18.04	0.52	—	73.2	14.34	4.22	—
8	53.9	18.81	46.0	16.06	2.75	—	40.6	14.18	4.63	—
10	27.0	14.72	23.0	12.54	2.18	—	27.6	12.31	2.41	—
12	27.2	21.35	11.5	9.03	12.32	1,539	12.5	9.84	11.51	1,441
14	16.1	17.21	5.8	6.15	11.06	1,638	7.0	7.45	9.76	1,447
16	7.2	10.05	2.9	4.01	6.04	968	3.9	5.41	4.64	742
18	4.9	8.66	1.4	2.54	6.12	1,054	2.2	3.80	4.86	813
20	1.6	3.49	.7	1.57	1.92	339	1.2	2.61	.88	151
22	.5	1.43	.4	.95	.48	47	.7	1.76	—	—
All	233.1	114.3	183.7	70.9	43.4	5,585	163.9	71.7	42.9	4,594

* Reproduced with permission from: "Unevenaged management of northern hardwoods in New England" by W.B. Leak and S.M. Filip. U.S. Forest Service Res. Pap. NE-332, 1975.

The impact of stand density and stocking on selected species groups, (pioneer, intermediate, or climax) must be understood before accurate stand predictions based on the coefficient of diminution can be made. The recommendations of Leak and Filip (1975) are based on the study plots within stands actually cut to projected specifications together with silvicultural systems prescribed for sawtimber production and the improvement of stem and stand quality.

A special report on hardwoods in Quebec (Volume 1, The resource) edited by Robert Lefrance (1976) and prepared for COGEF¹ is a good example of management problem analysis and silviculture prescription based on the results of research. The table of contents includes a Problem statement, an Assessment of gross merchantable volume, Log quality, The percentage of merchantable material by product class, The net merchantable volume, Recreational resource use, Silviculture research, and Silviculture prescriptions. Appended to the report is a list of current management and silvicultural research projects in the province of Quebec.

Management problems which are described include; a reduction in hardwood quality, a conversion in species representation from tolerant to intolerant hardwoods, increase in the size of clearcut and the intensity of partial cutting with attendant problems of site preparation and seedling establishment in the face of increasing invasion by ground vegetation, such as raspberry, pin cherry, and mountain maple. These concerns are shared by the management forester in the Maritime provinces.

The management recommendations contained in the table "Methods of harvesting recommended for hardwood and mixedwood stands" are divided into utilization classes, sawlog operations, sawlog, fibre-board and pulpwood. For good and poor quality stems, cutting prescriptions are presented for mature stands, immature stands, and stands in the regeneration phase. Thinnings, improvement cuttings, and harvest cuttings are recommended as appropriate. Many options are presented.

Good quality stands are to be harvested to preserve the sawlog potential. Poor quality stands are recommended for clearcutting and replacement as soon as possible with higher quality species. Diameter limit cutting, the authors suggest, can be used for both sawlog and pulpwood stands. The diameter limits fixed for sawlog or for pulpwood, they say, should be variable

and are a function of region, site, stand, and stem groupings within the stand, so that never more than 30 or 40% of the volume is cut. However, at least all the trees which have reached their economic maturity should be cut. Where this would amount to more than 30 to 40% of the original volume, a change to clear-cutting is recommended. This is almost always the case in poplar stands of a mature even-aged form. Thinning is directed towards harvesting trees that have reached economic maturity and then those trees that are in competition with crop trees. In "clearcutting" all trees more than 3.6 inches dbh which can be profitably utilized (whether for sawlogs, pulpwood, or other uses) are cut and harvested. Those which cannot be used are left standing. The "complete clearcut" (*coupe totale*) consists of harvesting all stems more than 1 inch dbh and includes the tops. The use of such a cut is strongly limited by competition from raspberry, pin cherry, mountain maple, and stump sprouts, which frequently invade the whole cutting area, (c.f. Roberge, 1977)

Strip clearcutting discourages this invasion because of the shade of the leave strips, and allows the development of more tolerant and valuable species. It is suggested that choice of harvesting methods should also be based on the needs of wildlife species, of recreationists, and of watershed protection. The report, in fact, covers a range of options in classical silviculture and recommends the alignment of silvicultural techniques with local site conditions, with utilization needs, and with management objectives.

Thirty-five silvicultural research projects of the federal and provincial governments are listed in an appendix. In reviewing the direction of this research the authors have put together several concrete recommendations and in summary suggest a change from commercial diameter limit cutting towards strip clear-cutting. By restricting diameter limit cutting so that certain species and qualities of stems are favored, and by having an individual diameter limit, the hardwood forest will gain in quality.

CONCLUSIONS AND RECOMMENDATIONS

It is evident from a review of the literature such as this that there is helpful information available. Management problems which have been defined in the New England States, in Ontario and Quebec are comparable to those outlined by Baskerville and others in the Maritimes. Options in silviculture are available to meet management objectives and several of these have

¹ Conseillers en gestion des forêts.

been tested. Selection silviculture has been recommended for certain stand types with quality hardwoods in New England, shelterwood further west and in Ontario. Narrow-strip clearcutting has been found useful in Quebec. Hardwood plantation management is common in Ontario while natural regeneration is encouraged in New England. Both natural and artificial regeneration are used and under investigation in Quebec.

In the Maritimes we have seen a change from single stem and group "selective" cutting (high grading) to better utilization and more use of clearcutting or a partial cutting which may resemble shelterwood operation.

Hardwood management research and development

More intensive forest management and silviculture create demands for more information. In his report to the Canadian Forestry Service, Baskerville (1976) recommended a stepwise approach to hardwood research in the Maritimes which begins with a description and statement of the problem. These have been presented in the Introduction to this review. Research must now be carried out to advance knowledge in a management context which is relevant to real problems and close cooperation is needed between research workers and forest managers.

Information generated will help to meet such objectives as:

1. Better and more complete utilization of the hardwood forest resource through integrated woods operations and multiple product use.
2. Provision of more options for management by use of appropriate cutting techniques, reforestation of selected species and stand improvement treatments, i.e. better silviculture.
3. Improved quality of hardwood stands through better management and appropriate cultural treatments.

Comparable concerns and research plans appear in "Timber management research priorities in the Northeast" a report prepared by Tryon and Roach (1976)¹ for the Timber Management Subcommittee U.S.F.S. Northeastern regional planning committee.

Objective: To develop improved methods for increasing the value and yield of northern hardwood forests of the Northeast (U.S.A.).

¹ Unpublished.

Research needs:

1. Yield prediction
2. Stand and population dynamics; competitive relationships.
3. Vegetation — site relationships.
4. Stand regeneration.
5. Intermediate stand treatment.
6. Management options.

Objective: To develop the knowledge and methods needed to ensure the survival and development of artificially established hardwood species in the Northeast (U.S.A.).

Research needs:

1. Basic environmental studies.
2. Develop systems for field planting.
3. Seed sources for immediate use.
4. Propagation of quality planting stock.

In response to such acknowledged research needs in the Maritimes, agreement and agreement-in-principle have been reached on a program of joint hardwood research between the Canadian Forestry Service, Maritimes Forest Research Centre and the Nova Scotia Department of Lands and Forests, and between MFRC and the New Brunswick Department of Natural Resources.

The essential elements of these programs are:

1. Hardwood site classification.
2. Hardwood inventory update and quality assessment.
3. Current demand survey.
4. Utilization opportunities.
5. Improved yield prediction for major sites.
6. Regeneration response to current harvesting.
7. Development of silvicultural prescriptions to fulfill a range of management objectives in production, protection, and amenity forestry.
8. The role of stump sprouting in hardwood regeneration.
9. Regeneration ecology of white ash.
10. Role of hardwoods in soil nutrient status on sensitive sites.
11. Costs and benefits of silvicultural treatments.
12. Demonstrations of successful silvicultural treatments.

The Maritimes Forest Research Centre has assumed responsibility for:

1. Advisory services in hardwood silviculture
- Objective: To provide technical advice and assistance on hardwood silviculture and management to forestry agencies in the region.

2. Development of silvicultural prescriptions for Maritime hardwoods

Objective: To develop silvicultural prescriptions for hardwoods which will fulfill a range of management objectives.

3. The role of hardwood stump sprouts in reforestation of cut-over land

Objective: To determine the occurrence, development and fate of hardwood sprouts following cutting.

4. The regeneration ecology of white ash
- Objective: To identify environmental factors limiting the regeneration of white ash and to develop silvicultural prescriptions to promote white ash regeneration.

Responsibility for other research studies has been assumed by the provincial forestry agencies especially for site classification, inventory, quality assessment and utilization opportunities; and by cooperating federal government departments especially for some economic aspects.

The results of research and development programs completed and underway will be shared through publication, discussion forums and demonstrations in the field. Progress of the research, and alignment of research priorities with research capabilities will be greatly assisted by hardwoods research working groups which are being developed.

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Figure 10.

Hardwood stem quality classes are presently being developed in the Maritimes (photos: Carlin, NB DNR).



Figure 11,
Sawlogs selected.



Figure 12 .
Tops are often left
behind.



Figure 13 ,
Rejected stems
remain standing
(photos: West
NB DNR).



Figure 14.
Short pieces left
at a landing.



Figure 15 ,
Short hardwood,
wasted after bucking
(photos: West, NB DNR)



Figure 16.
Sawlogs at
the mill
(photo: West
NB DNR).

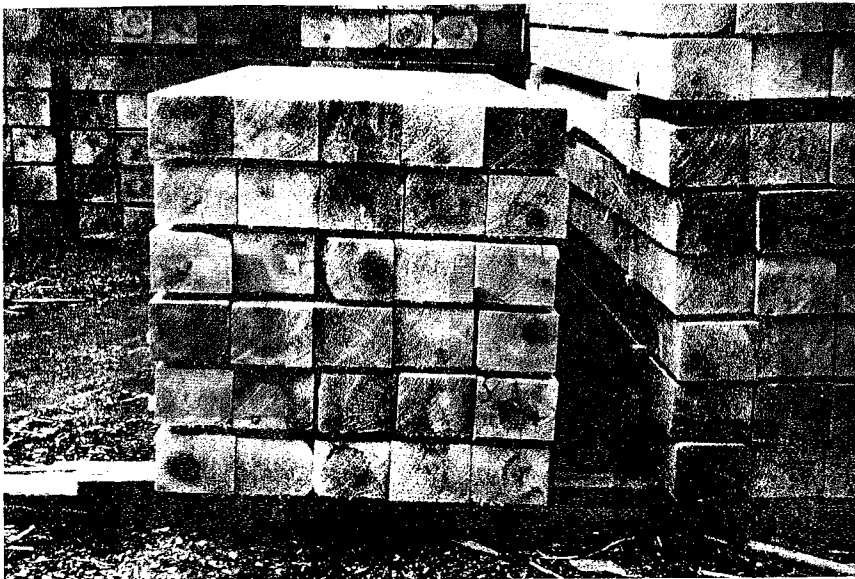


Figure 17.
Railway ties cut
from heart wood
(photo: Carlin
NB DNR).



Figure 18.
Clear sapwood
pieces make short
furniture compo-
nents (photo:
West NB DNR).



Figure 19.

Cutting in
"pucker brush"
of stump sprout
origin.



Figure 20.

"pucker brush"
decked for
chipping for
charcoal pro-
duction.

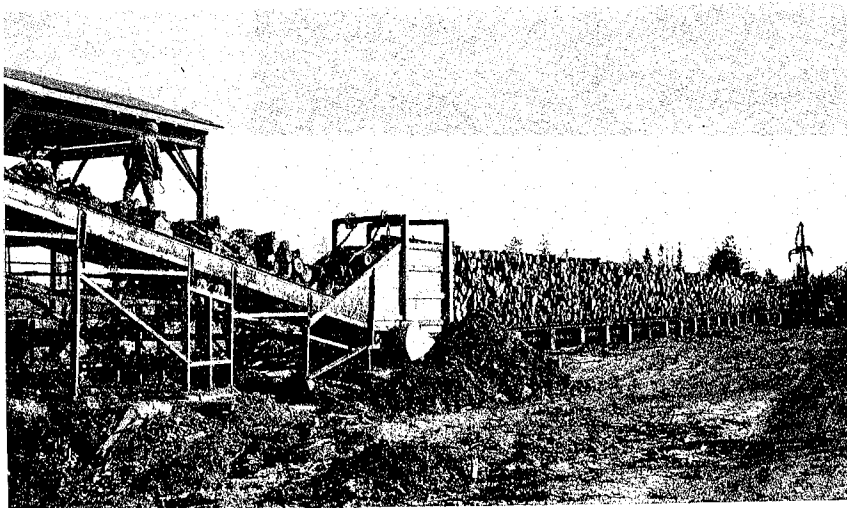


Figure 21,

Short pieces for
flakeboard pro-
duction (photos:
West, NB DNR).



Figure 22.
Sprouting, one
year after the
pucker brush cut.
(photo: West,
NB DNR)

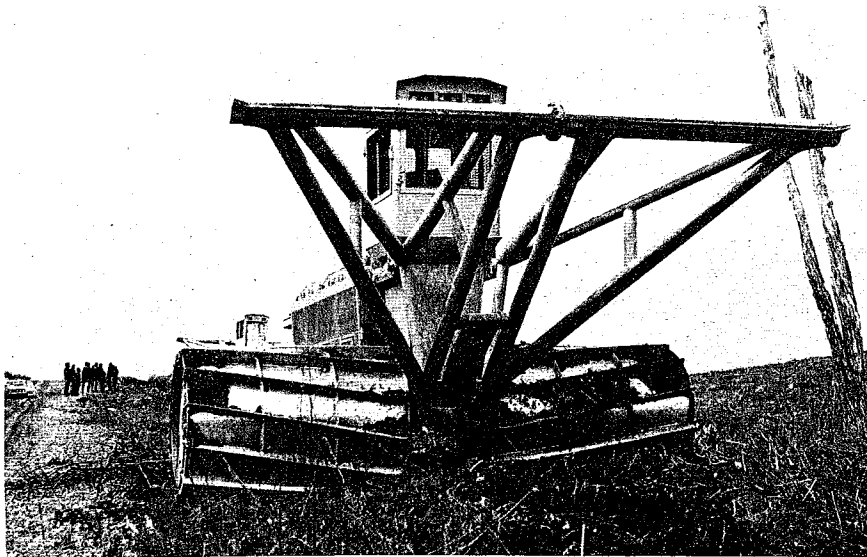


Figure 23,
Tree crusher to
eliminate hard-
wood residuals and
to prepare for soft-
wood plantation
(photo: Lees, CFS)

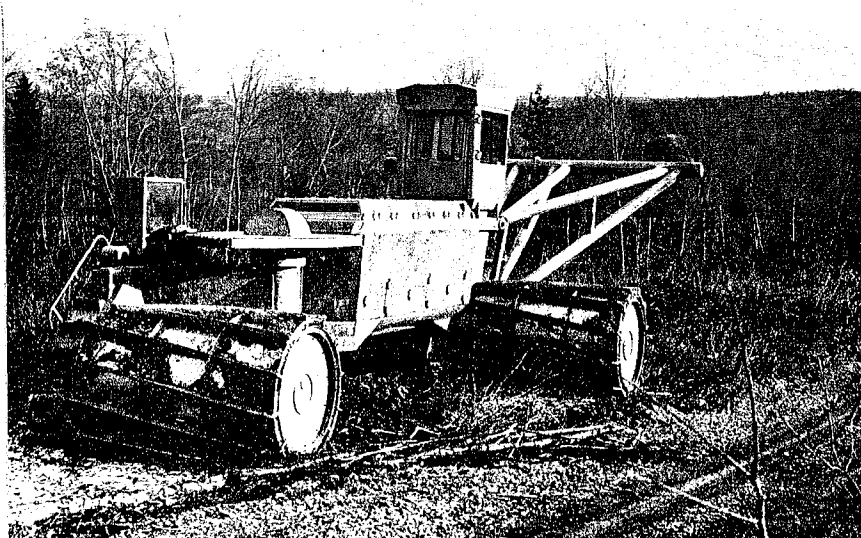


Figure 24.
Residual hard-
woods to be
crushed (photo:
Lees, CFS)

APPENDIX

Example of use of the diagnostic tally sheet for sugarbush stands

[For the determination of the number of trees per acre, average stand diameter, stocking, and spacing for sugarbush management]

Dbh (inches)	Number of trees tallied														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	458	917	1375	1834	2292	2750	3209	3667	4125	4584	5042	5501	5959	6417	6876
4	115	229	344	458	573	688	802	917	1031	1146	1260	1375	1490	1604	1719
6	/ 51	O 102	/ 153	/ 204	X 255	/ 306	/ 357	/ 407	458	509	560	611	662	713	764
8	/ 29	/ 57	/ 86	/ 115	/ 143	/ 172	X 201	/ 229	258	287	315	344	372	401	430
10	/ 18	/ 37	O 55	/ 73	/ 92	/ 110	128	147	165	183	202	220	238	257	275
12	/ 13	/ 25	/ 38	51	64	76	89	102	115	127	140	153	165	178	191
14	9	19	28	37	47	56	65	75	84	94	103	112			
16	O 7	/ 14	21	29	36	43	50	57	64	72	79	86			
18	6	11	17	23	28	34	40	45	51	57	62	68			
20	5	9	14	18	23	27	32	37	41						
22	4	8	11	15	19	23	27	30	34						
24	3	6	10	13	16	19	22	25	29						
26	3	5	8	11	14	16	19	22	24						
28	2	5	7	9	12	14	16	19	21						
30	2	4	6	8	10	12	14	16	18						

Tally Legend

/ Maple
O Birch
X Other species

Number of
plots

No. of trees/acre

$\therefore = 4$

$\frac{798}{4} = 200$

Total Number of Trees Per Acre.—Add the last figures checked on each line and divide by the number of point samples tallied.

$$407 + 229 + 110 + 38 + 14 = 798 \div 4 = 200$$

BA Per Acre.—Add the total number of entries in each size class, multiply by 10 and divide by the number of point samples tallied. (BA factor = 10)

$$27 \times 10 = 270 \div 4 = 68$$

STAND DESCRIPTION:

Number of trees per acre 200

BA per acre 68

Average stand dbh 7.9

Trees per acre at C level 140
(or level selected for management)

BA at C level 45
(or selected level)

STAND PRESCRIPTION:

Mark for cutting
or girdling 60 trees = 23 BA
(Total minus C or selected level)

Average crop tree
spacing 18 feet

**DIAGNOSTIC TALLY SHEET FOR NORTHERN HARDWOODS
POLETIMBER & LARGER STANDS**

Cumulative Tally - Number of Trees Per Acre (B.A. Factor 10).

DBH	Number of Trees															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	458	917	1375	1834	2292	2750	3209	3667	4125	4584	5042	5501	5959	6417	6876	7334
4	115	229	344	458	573	688	802	917	1031	1146	1260	1375	1490	1604	1719	1833
6	51	102	153	204	255	306	357	407	458	509	560	611	662	713	764	815
8	29	57	86	115	143	172	201	229	258	287	315	344	372	401	430	458
10	18	37	55	73	92	110	128	147	165	183	202	220	238	257	275	293
12	11	22	33	44	55	66	77	88	99	110	121	132	143	154	165	176
14	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112
16	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
18	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
20	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
22	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
24		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
26			1	2	3	4	5	6	7	8	9	10	11	12	13	14
28				1	2	3	4	5	6	7	8	9	10	11	12	13
30					1	2	3	4	5	6	7	8	9	10	11	12
Total																

Total Number of Trees Per Acre - Add the last figure used in each block and divide by the number of point samples tallied.

B.A. per acre - Add the total number of entries by class, multiply by 10, and divide by the number of point samples tallied.

Site Index Trees:

Age

Height

Site Index

Mean Stand Diameter

Basal Area: "B" level _____ "C" level _____

Stand Class:

Even-aged ☐

Uneven-aged ☐

Commercial Cutting

Feasible ☐

Not Feasible ☐

Volume per acre - (25 * (No. 16' logs*) (50) (B.A.) = Board Feet

(.037 * (No. 8' sticks*) (.053) (B.A.) = Cords

*Average stand height in number of 16' logs or 8' sticks whichever is applicable.

PRESCRIPTION:

Stocking guides for even-aged northern hardwoods based on number of trees in the main canopy, average diameter, and basal area per acre. Stands above the A-line are overstocked. Stands between the A- and B-line are adequately stocked. Stands between the B- and C-line should be adequately stocked within 10 years. Stands below the C-line are definitely understocked.

