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STRIP CLEARCUTTING TO REGENERATE NORTHERN HARDWOODS

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The Great Lakes' northern hardwood forests are a collection of various combinations of species occurring on a broad spectrum of sites, but inevitably dominated by sugar maple and/or beech. These forests have natural resilience to disturbance, and normally maintain themselves whether a single tree or an entire canopy is lost. These attributes permit use of a variety of regeneration techniques, both all-aged or even-aged.

Clearcutting has been the least successful method of regenerating northern hardwoods to date (Metzger and Tubbs 1971). Yet, a workable method of clearcutting could alleviate the problem of sugar maple and beech dominating the reproduction by improving conditions for germination and establishment of other northern hardwood species.

It is intuitively appealing to clearcut in strips rather than larger blocks, because microclimates of strips can be better manipulated to meet regeneration requirements of individual species. Northern hardwood species have better germination and seedling height growth for up to 5 years under partial shade than in the open (Logan 1965, 1966, 1973; Godman and Krefting 1960; Marquis 1966; Tubbs 1969). However, moderately shaded to open conditions usually provide the greatest increases in root and shoot weights (Logan 1965, 1966, 1973).

Varying strip width and orientation changes the timing, duration, and amount of solar radiation reaching the ground and consequently the microclimate. Berry (1964), Marquis (1965), and Brown and Merritt (1971) have shown how manipulating strips affects shadow patterns. Other factors that can be influenced are exposure to prevailing winds, cold air drainage, diurnal and seasonal periods of subfreezing temperatures, and downward penetration of winds. Manipulating strip layout can influence snow accumulation and melting on level terrain (Clausen and Mace 1972). Thus the strip microclimate could be modified to provide a more suitable germination and growth environment than that of larger block clearcuts.

A number of objectives must be met when regenerating northern hardwoods by strip clearcutting. Adequate stocking and growth of a desirable species mix are basic requirements. Also important is the potential for development of quality boles because northern hardwoods are normally managed for saw- and veneer-log production. Future bole quality is influenced early by both stand environment and reproduction characteristics. Strip clearcutting also has advantages in wildlife habitat and watershed management, requiring other criteria.

In 1959 a series of strip cutting trials was begun to compare early establishment and development of reproduction under two orientations, two widths, and with or without herbicide treatment of advance reproduction.

METHODS

Stand Conditions

The two types in the northern hardwood forest included in the trials are SAF type 25 (sugar maple-beech-yellow birch, referred to hereafter as northern hardwood) and SAF 24 (hemlock-yellow birch, referred to hereafter as hemlock-hardwood). In all, four separate stands were studied: two northern hardwood stands and one hemlock-hardwood stand on the Upper Peninsula Experimental Forest (UPEF), 15 miles southeast of Marquette, Michigan; and one hemlock-hardwood stand on the Argonne Experimental Forest (AEF), 22 miles northeast of Rhinelander, Wisconsin. All four were old-growth stands containing large, overmature trees (table 1).

Table 1.—*Density, basal area stocking and volumes of original stands in clearcutting trials on the Upper Peninsula and Argonne Experimental Forests (based on all trees 5 inches d.b.h. and larger)*

Type and stand	Density	Basal area stocking	Volumes	
	Trees/acre	Sq.ft./acre	Net MBF/acre	Cords/acre
Northern Hardwood:				
UPEF 1	120	120	8.8	15.6
UPEF 2	133	118	NA[1]	NA[1]
Hemlock Hardwood:				
UPEF	177	179	11.4	11.7
AEF	208	161	6.0	24.4

[1]NA = not available.

Only light salvage cuttings had been made in the several decades preceding the study.

All of the stands are on relatively level till plains. Soils on the UPEF site are usually sandy loams, free of rock; they vary from well drained to somewhat poorly drained in the northern hardwood stands, and from somewhat poorly to poorly drained in the hemlock-hardwood stand. Soils at AEF are silt loams, with numerous large stones at or near the surface; they range from moderately well drained to somewhat poorly drained. The better drained UPEF soils frequently have fragipans or in some cases bedrock within 24 inches of the surface.

Seedlings were present in all stands prior to cutting. Their development and stocking were best in the northern hardwood stands, where 75 percent of the quadrats were stocked and sugar maple dominated. The AEF hemlock-hardwood stand had the most poorly developed seedling layer, dominated by sugar maple. The advance reproduction in the UPEF hemlock-hardwood stand was a more diverse mixture of species with red maple most common, but had the poorest stocking (51 percent).

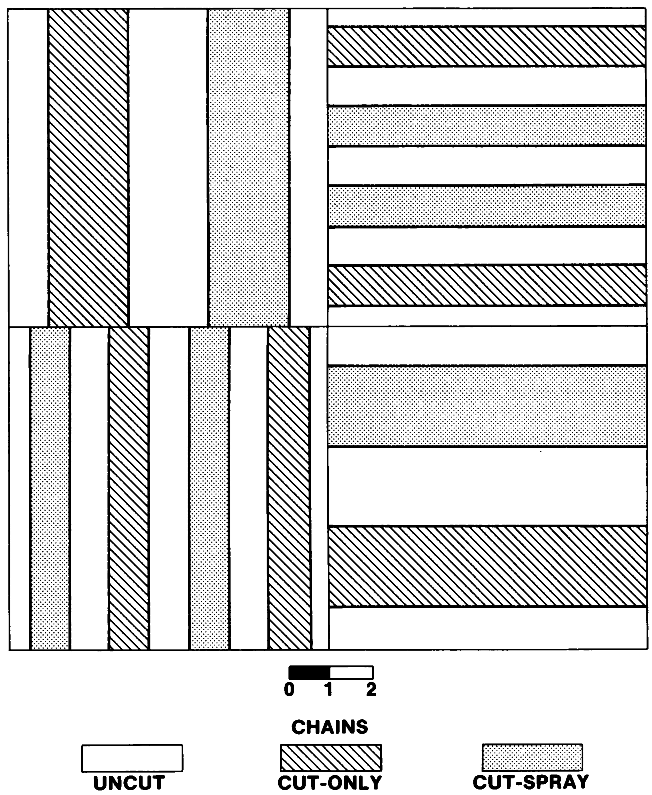

Figure 1.— *Generalized layout of clearcut strips in a UPEF stand.*

Silvicultural Treatment

At UPEF, strips were clearcut by commercial operators and were 1 or 2 chains wide by 8 chains long with the long axis oriented either east-west or north-south (fig. 1). Uncut strips of equal width alternated with the cut strips. All trees over 4 inches d.b.h. were cut and the merchantable material removed. Strips were cut in the northern hardwood stands in the winter of 1959-60 (stand 1) and in the winter of 1960-61 (stand 2). Strips in the hemlock-hardwood stand were cut the winter of 1964-65. Each winter two strips of each orientation of 2-chain width and four strips of each orientation of 1-chain width were cut.

In the AEF hemlock-hardwood stand, all strips were oriented east-west to parallel an 8-percent slope of west aspect. Because most strips exceeded 8 chains in length, the study was confined to the central 8-chain portion. Saplings were cut in addition to the larger trees. During each of the winters of 1964-65 and 1965-66 two 2-chain and four 1-chain-wide strips were cut.

Herbicides were used to eliminate advance reproduction on half of the strips in each combination of widths and orientations. They were sprayed the summer following logging. Northern hardwood stands were treated with 2,4,5-T in a water-oil carrier at 8 and 4 lbs. of herbicide in 100 gals. of carrier in stands 1 and 2, respectively. Tordon 101 (Picloram and 2,4-D) was used in the hemlock-hardwood stands at a strength of 2.5 lbs. per 100 gals. of water. Herbicides were applied until they dripped from the foliage.

Stumps in the UPEF sprayed strips were also treated separately with a stronger solution of herbicide in an oil carrier. Northern hardwood stand 1 was treated with 2,4,5-T at 20 lbs. per 100 gals., stand 2 with a mixture of 2,4,5-T and 2,4-D at 30 lbs. per 100 gals., and the hemlock-hardwoods with 2,4,5-T at 16 lbs. per 100 gals.

Survey Procedures

Reproduction on uncut and cut-only strips was first measured one or two seasons after cutting; a second measurement was made six or seven seasons after cutting. Reproduction on cut-sprayed strips was measured the first or second season after spraying and again in the fifth or sixth season. Seedlings were recorded by species, height class, density class, and origin (seedling or sprout); the species and height class of the tallest or dominant stem was also determined. Quarter-milacre quadrats spaced at 10-link intervals on transects crossing the strip perpendicular to the long axis were used. Between five and nine transects per strip were run. The second survey of hemlock-hardwood strips used actual counts of reproduction instead of density classes and assessed the dominant stem on milacre and ninetieth-acre quadrats. Each milacre quadrat was centered over a quarter-milacre quadrat. Three ninetieth-acre quadrats were installed per chain of transect. The large quadrats sampled reproduction that had the best opportunity of becoming one of approximately 90 final crop trees per acre.

RESULTS

Stand Establishment

Cut-only strips were generally well stocked with reproduction 6 or 7 years after cutting. In the three UPEF stands, each cut-only strip had more than 17,000 stems per acre (table 2), and 73 percent or more of the quarter-milacre quadrats contained at least one tree (table 3). The cut-only AEF hemlock-hardwood strips were not as well stocked. They averaged 9,000 seedlings per acre and 60-percent stocking of the quadrats.

Reproduction on cut-sprayed strips was much more variable. Best results were obtained in UPEF northern hardwood stand 1 and in the UPEF hemlock-hardwood stand. Each had in excess of 25,000 seedlings per acre and 66 percent stocking of reproduction on quadrats 6 years after spraying (tables 2 and 3). Northern hardwood stand 2 at UPEF averaged only 9,000 stems per acre and 63 percent stocking. The herbicide-treated AEF strips had the poorest reproduction, averaging only 4,000 stems per acre and 30 percent stocking.

Neither strip width nor orientation consistently led to increased reproduction (tables 2 and 3). Much of the variation within stands was due to factors unrelated to strip layout, such as soil moisture, original overstory, and advance reproduction.

Desirable hardwoods—sugar maple, red maple, yellow birch, beech, white ash, and basswood—of seedling or seedling-sprout origin occurred on an average of 95 percent of the quarter-milacre quadrats that were stocked with any species or form of tree reproduction at UPEF. Again, the cut-sprayed strips of northern hardwood stand 2 were the exception; the proportion of stocked quadrats with a desirable hardwood declined to an average of 72 percent on the 2-chain-wide strips. Somewhat poorer results also occurred at AEF, where 87 and 57 percent of the stocked quadrats had desirable hardwoods on the cut-only and cut-sprayed strips, respectively.

Effects of advance reproduction

Regeneration success on cut-only strips depended on the presence of large advance reproduction. Stocking percentages 6 to 7 years after cutting were positively correlated ($r^2 = .70$) with the percent of quadrats stocked with advance reproduction over 4 feet tall at the time of cutting. All successfully regenerated cut-only strips originally had more than 9 percent of their quadrats stocked with reproduction over 4 feet tall.

Table 2.—*Number of seedlings per acre, by cutting treatment and strip width and orientation*[1]*, 5 to 7 years after strip clearcutting on the Upper Peninsula and Argonne Experimental Forests*

(In thousands of seedlings per acre)

Type and stand	Cut-only					Cut-sprayed					Uncut				
	1-NS	1-EW	2-NS	2-EW	Mean	1-NS	1-EW	2-NS	2-EW	Mean	1-NS	1-EW	2-NS	2-EW	Mean
Northern Hardwood:[2]															
UPEF 1	26.3	28.0	28.3	27.9	27.6	40.8	29.1	35.5	25.3	32.7	29.1	24.2	21.4	17.2	23.0
UPEF 2	25.9	17.5	30.1	35.5	27.3	8.7	11.2	7.8	9.8	9.4	21.7	20.7	28.6	22.9	23.5
Hemlock-Hardwood:[3]															
UPEF	26.1	27.7	34.5	22.3	27.7	31.5	30.9	50.9	32.0	36.3	16.5	19.4	13.3	19.6	17.2
AEF	—	9.8	—	8.4	9.1	—	4.7	—	3.4	4.0	—	26.2	—	19.6	21.5

[1]1-NS = 1 chain wide, oriented north-south, etc.
[2]Estimates are "minimum populations" because counts for each species, size-class terminated at five on each quadrat.
[3]Estimates are based on counts of all seedlings on quadrats.

Table 3.—*Quarter-milacre quadrats stocked with one or more seedlings by cutting treatment and strip width and orientation*[1]*, 5 to 7 years after strip clearcutting on the Upper Peninsula and Argonne Experimental Forests*

(In percent)

Type and stand	Cut-only					Cut-sprayed					Uncut				
	1-NS	1-EW	2-NS	2-EW	Mean	1-NS	1-EW	2-NS	2-EW	Mean	1-NS	1-EW	2-NS	2-EW	Mean
Northern Hardwood:															
UPEF 1	89	91	95	99	93	99	91	96	89	94	96	95	91	85	92
UPEF 2	79	73	89	91	83	62	59	63	66	62	86	78	90	79	83
Hemlock-Hardwood:															
UPEF	81	81	91	77	82	66	87	83	88	81	71	62	56	76	66
AEF	—	59	—	60	60	—	30	—	30	30	—	88	—	78	81

[1]1-NS = 1 chain wide oriented north-south, etc.

Other related parameters, such as desirable hardwood stocking 6 to 7 years after cutting, stocking of advance reproduction over 2 feet tall, and numbers of advance reproduction instead of stocking percentages, yielded significant correlations but reduced coefficients of determination. The initial stocking of all sizes of advance reproduction was poorly correlated with stocking 6 to 7 years later ($r^2 = .10$).

Stump sprouting

Stump sprouts were limited to the cut-only strips because spraying effectively minimized them. Most species sprouted to some degree, but only red maple did so prolifically. Red maple sprouts were not well distributed, yet due to their rapid growth and large number per stump they occupied much growing space and readily overtopped other reproduction. They were most abundant on UPEF hemlock-hardwood cut-only strips, where they made up 6 percent of the dominants on milacre quadrats and 21 percent of the dominants on ninetieth-acre quadrats.

Time of establishment

Seedling age data showed most yellow birch and red maple seedlings originated after spraying in the UPEF hemlock-hardwood stand (93 percent of the birch and 85 percent of the maple). Establishment continued over 4 years following spraying. In the first season a third of both species became established. Birch establishment peaked the second year with half the birch seedlings becoming established then. Twenty percent of the maple seedlings became established in each of the next 2 years.

Effects on quality

The degree of crown competition within northern hardwood stands affects development of stem quality. Thus, two factors affecting crown competition were considered: variation in height and distance to nearest competitor (tree at least two-thirds as tall) for the dominant tree on the ninetieth-acre quadrat. Cutting only trees larger than 4 inches d.b.h. in the hemlock-hardwoods at UPEF resulted in more variation in height among dominants than at AEF, where trees over 2 inches d.b.h. were cut (table 4). Spraying at UPEF did not reduce this variability because a number of conifer and larger hardwood saplings were unaffected by the herbicide. Spraying at AEF, however, created more variation in height than occurred on the cut-only strips. The majority of dominants on cut-only strips had a competitor within a distance not exceeding the dominant's crown diameter. On cut-sprayed strips, half or fewer of the dominants had a competitor within this distance.

Stand Development

Reproduction developed best in the cut-only strips in both stands and in the cut-sprayed strips in stand 1 in the northern hardwoods at UPEF. There were substantial increases in quadrats stocked with reproduction over 4 feet tall through the first 6 to 7 years after cutting (table 5). The hemlock-hardwood stands did not develop as well, particularly at AEF. All the UPEF hemlock-hardwood strips had the potential to improve, however, because many quadrats had gained seedlings between 2 and 4 feet tall. The AEF strips had the poorest prospects for improvement.

Poor development of reproduction as a stand at AEF and on cut-sprayed strips in UPEF stand 2 was not due to poor growth rates of the surviving trees, but due to loss of existing stocking and poor establishment of new reproduction. Growth rates on these units (0.71 feet/year) were comparable to the overall average (0.73 feet/year). Height growth was calculated as the difference between the two surveys in the weighted averages of class midpoints for the tallest seedling per quadrat.

Neither strip width nor orientation affected reproduction growth rates (table 6). Differences were usually caused by other factors, often the proportion of fast-growing pioneer species present.

Additional support for the conclusion that strip width did not affect height growth came from analyzing reproduction height across the strips for individual species. Heights did not improve with distance from the timbered edge, although the opposite impression was apparent in the field, since the taller pioneer species— quaking aspen, paper birch, and pin cherry— were more abundant in the central portion of the strip.

Species Composition

Cut-only strips

Strip clearcutting in the northern hardwood type had little effect on species composition in the regenerated stand. Composition on cut strips was very similar to that on adjacent uncut strips (table 7). Sugar maple comprised most of this reproduction and its preponderance reduced species diversity of the reproduction below that of the original overstory.

Table 4.—*Characteristics of dominant trees on ninetieth-acre quadrats in hemlock-hardwood clearcut strips at the Upper Peninsula and Argonne Experimental Forests, 5 to 6 years after treatment*

Stand and treatment	Height			Dominants with competitor[1]	Mean distance to competitor	Mean crown diameter of dominant
	Mean	Range	Coefficient of variation			
	-------- Feet --------		------------- Percent	-------------	----------------- Feet	-----------------
UPEF:						
Cut-only	18.6	4-67	59	63	6.7	7.2
Cut-sprayed	11.4	4-46	58	50	6.1	4.3
AEF:						
Cut-only	10.2	4-15	24	75	3.7	4.3
Cut-sprayed	7.2	3-17	36	42	5.7	2.5

[1]Percent of quadrats where dominant tree has a competitor (tree at least ⅔ height of dominant) not more than dominant crown diameter away.

Table 5.—*Height of tallest reproduction stem on quarter milacre quadrats by cutting method and year after clearcutting or spraying on the Upper Peninsula and Argonne Experimental Forests*

(In percent of quadrats stocked)

Type and stand	Year	Cut-only: Nonstocked & 0-2′	Cut-only: 2-4′	Cut-only: 4′+	Cut-sprayed: Nonstocked & 0-2′	Cut-sprayed: 2-4′	Cut-sprayed: 4′+
Northern hardwood:							
UPEF 1	1-2	64	22	14	96	2	3
	6-7	15	16	69	15	29	55
UPEF 2	1-2	66	25	9	96	2	2
	5-6	25	17	58	65	21	15
Hemlock-hardwood:							
UPEF	2	77	14	10	98	2	<1
	6	32	30	38	30	45	25
AEF	1-2	91	8	1	98	1	1
	5-6	50	16	34	76	12	12

Table 6.—*Average annual height growth[1] of dominant reproduction in the 4- to 5-year period following treatment by strip width and orientation[2] on the Upper Peninsula and Argonne Experimental Forests*

(In feet per year)

Type and stand	Cut-only: 1NS	1EW	2NS	2EW	Means: 1	2	NS	EW	All	Cut-sprayed: 1NS	1EW	2NS	2EW	Means: 1	2	NS	EW	All
Northern hardwoods:																		
UPEF 1	0.67	0.79	0.66	0.69	0.73	0.68	0.66	0.74	0.70	0.88	0.73	0.93	0.60	0.81	0.77	0.90	0.67	0.79
UPEF 2	.75	.84	.94	.86	.79	.90	.85	.85	.85	.44	.53	.74	.74	.48	.74	.59	.64	.61
Hemlock-hardwoods:																		
UPEF	.42	.66	.55	.62	.54	.58	.49	.64	.56	.65	.79	.80	.86	.73	.84	.74	.83	.78
AEF	—	.74	—	.74	—	—	—	—	.74	—	1.09	—	.47	—	—	—	—	.79

[1]See text for method of derivation

[2]Strip width: 1 = 1 chain wide, 2 = 2 chains wide; orientation: NS = north-south, EW = east-west.

Table 7.—*Comparison between species composition of the original stand and of the reproduction 5 to 7 years after strip clearcutting on the Upper Peninsula and Argonne Experimental Forests*

Species	Original stand: ≥ 5 inches d.b.h. Percent of basal area	Original stand: ≥ 5 inches d.b.h. Percent of numbers	Regenerated stand: ≥ 6 inches tall — Percent of number of seedlings: Leave	Cut-only	Cut-spray	Regenerated stand: ≥ 6 inches tall — Percent of dominant stems: Cut-only	Cut-spray
NORTHERN HARDWOOD-UPEF Stand 1							
Sugar maple	50	43	74	66	60	51	44
Red maple	3	5	7	10	3	13	4
Yellow birch	14	10	6	16	33	17	47
Other hardwoods[1]	25	35	13	8	3	18	5
Conifers	8	7	1	1	1	1	0
NORTHERN HARDWOOD-UPEF Stand 2							
Sugar maple	63	61	86	88	64	76	57
Red maple	1	([2])	1	1	2	1	2
Yellow birch	20	13	5	6	12	7	9
Other hardwoods[1]	13	19	8	6	22	15	32
Conifers	3	7	1	1	1	1	1
HEMLOCK HARDWOOD-UPEF							
Sugar maple	3	4	10	10	1	9	1
Red maple	22	28	37	52	6	51	15
Yellow birch	22	24	45	31	84	21	39
Other desirable hardwoods	1	2	1	1	1	2	1
Pioneer hardwoods	0	0	1	1	9	4	41
Conifers	53	42	6	5	1	14	3
HEMLOCK HARDWOOD-AEF							
Sugar maple	16	14	78	56	13	37	18
Red maple	5	5	9	11	5	19	9
Yellow birch	21	14	9	12	28	8	13
Other desirable hardwoods	6	7	1	3	1	3	1
Pioneer hardwoods	1	([2])	1	13	53	32	57
Conifers	52	60	1	4	1	1	2

[1]Includes pioneer hardwood species, other desirable hardwood species, and ironwood.
[2]Less than 1 percent.

Sugar maple's importance in the new stand may decline; allowing diversity to increase over time if the composition of the new stand shifts toward that of seedlings dominating the quadrats. Even so, the new stand will probably not reach the diversity of the parent stand. Offsetting the decline of sugar maple would be one or more species of the group of other hardwoods (beech, ironwood, quaking aspen, black ash, basswood, and American elm), which as a group make up a larger proportion of dominants than of all reproduction. Conifers made up a minor proportion of the new stand and probably will continue to do so. Red maple and yellow birch reproduction was inconsistent; these species were more abundant than in the original overstory and the uncut strip reproduction in stand 1, but were about the same or declining in relation to these populations in stand 2. The net effect was that no important changes occurred in these two species due to strip cutting.

The hemlock-hardwood stands at both UPEF and AEF underwent considerable change in character as hemlock-dominated overstories were replaced by hardwood-dominated reproduction. The change was not solely due to cutting, since the uncut and cut-only strips were more comparable to each other than to the original overstory (table 7). These stands would have probably reverted to hardwoods naturally, through attrition of overmature conifers over time and poor regeneration of hemlock.

Sugar maple became the most common reproduction species on both uncut and cut-only strips in the AEF hemlock-hardwood stands. However, cutting reduced the proportion of sugar maple compared to the uncut strips, while increasing the proportion of pioneer species (quaking aspen, paper birch, and pin cherry). This trend may continue, since the amounts of sugar maple and pioneer hardwood dominants were almost equal.

On the UPEF hemlock-hardwood cut strips, red maple became the most common species and should remain so. It benefitted from cutting, as did the pioneer species, while most other species remained unchanged or declined in relative abundance. These strips had the only significant amount of hemlock advance reproduction. Because it was well developed, it was often dominant.

Cut-sprayed strips

Spraying herbicides in combination with cutting was only partially effective in creating desired changes in species composition of the reproduction. Sugar maple, although relatively less abundant on cut-sprayed than on cut or uncut strips in all four stands, still comprised about the same proportion of the new stand as it did in the original overstory (table 7).

The proportion of yellow birch increased after spraying in all four stands, but real increases in numbers and stocking were attained in only two. In northern hardwood stand 1, yellow birch became the leading dominant, with over 10,000 seedlings per acre. It was also the most abundant species in the UPEF hemlock-hardwood stand, where its 30,000 seedlings per acre made up 84 percent of the reproduction, but only 39 percent of the dominants. Higher proportions of yellow birch in the other two stands were caused by fewer stems of other species rather than by a gain in birch numbers. In these two stands, yellow birch numbers and stocking percentages were similar on cut-sprayed, cut-only, and uncut strips.

Establishment of pioneer hardwood species (mostly quaking aspen, but including pin cherry and paper birch) was highly variable following spraying. They were a minor component of the reproduction in only the UPEF northern hardwood stand 1. In the remaining stands they ranked either first or second in abundance and proportion of dominants (table 7). In both hemlock-hardwood stands they were the most common dominants.

Red maple was the only other species present in significant amounts in the cut-sprayed strips. It was relatively less abundant than in the other strips, but it remained at levels comparable with its position in the original overstories.

Effect of strip design

Changing strip width and orientation had little effect on the performance of desired species. Sugar maple was the only desired hardwood species to respond to changes in strip layout, but this occurred only in the cut-only strips of one stand. In this case sugar maple stocking was 12 percent greater on 1-chain than 2-chain strips and 9 percent greater on north-south than east-west strips. The pioneer species generally exhibited the opposite behavior, being better stocked on the more exposed cut-sprayed strips and AEF cut-only strips. Overall, pioneer hardwoods in the 2-chain strips averaged 12 percent and the east-west strips 5 percent better stocking than in the 1-chain and north-south strips, respectively. These trends would probably have been better expressed if other factors affecting seedling establishment had been more uniform throughout each stand.

Effects of parent stand and site

Species composition of reproduction was related to the composition of the original overstory and site factors, especially on the cut-only strips. The abundance of either sugar or red maple in the reproduction was positively correlated to its abundance in the overstory, but often negatively correlated to the abundance of the opposite species (table 8). Abundance of beech or hemlock in the overstory and red maple in the reproduction were positively correlated, while the opposite was often true for sugar maple in the reproduction. Yellow birch reproduction responded similarly to red maple reproduction, being positively associated with overstory red maple but negatively with sugar maple. Abundance is the same as the ecologists' importance value for a species; it represents the mean of relative density and relative stocking for a reproduction species and the mean of relative density and relative basal area for each overstory species.

There were fewer significant relations between reproduction and original overstory species in the cut-sprayed than in the cut-only strips (table 8). In northern hardwood stands, yellow birch reproduction was associated with overstory red maple, beech, and hemlock, but along with quaking aspen and pin

Table 8.—*Correlation coefficients for occurrence of species in reproduction and in overstory by strips, or segments of strips (see text for method of computing coefficients)*

Reproduction species	Cut-only strips					Cut-sprayed strips				
	Overstory species									
	Sugar maple	Red maple	Yellow birch	Hemlock	Beech	Sugar maple	Red maple	Yellow birch	Hemlock	Beech
NORTHERN HARDWOOD-UPEF STANDS 1 & 2										
Sugar maple	71[1]	–89[2]	38	–91[2]	–77[1]	32	–61	33	–53	–40
Red maple	–77[1]	96[2]	–24	91[2]	74[1]	–46	24	–16	16	77[1]
Yellow birch	–53	76[1]	–28	70	65	–79[1]	87[2]	–29	88[2]	86[2]
HEMLOCK HARDWOOD-UPEF										
Sugar maple	87[1]	–37	72	–64		87[1]	–14	39	–29	
Red maple	–31	90[2]	18	–29		85[1]	–31	32	–17	
Yellow birch	–41	–43	–46	57		47	37	52	–51	
Quaking aspen	–52	–32	–38	60		–85[2]	–6	–46	38	
HEMLOCK HARDWOOD-AEF										
Sugar maple	78[2]	–41[1]	–4	–58[2]		27	5	–12	–21	
Red maple	–41[1]	52[2]	19	20		–1	8	27	14	
Yellow birch	–55[2]	34	0	40		13	–4	–5	–2	
Quaking aspen	–25	–18	–10	33		–6	–17	–6	–2	
Pin cherry	–55[2]	13	–2	44[1]		–51[1]	11	8	51[1]	

[1]Correlation coefficient of 95 percent acceptance.
[2]Correlation coefficient of 99 percent acceptance.

cherry it was negatively related to overstory sugar maple.

Soil moisture gradients within the stips also affected species composition. Sugar maple was most abundant on mesic sites, and red maple on somewhat poorly drained sites; yellow birch was slightly more common on somewhat poorly drained than on better drained sites.

Lesser vegetation

A dense layer of shrubs, herbs, and grasses followed cutting and cutting-spraying, initially dominating reproduction on many hemlock-hardwood strips (fig. 2). A similar vegetation survey was not made in northern hardwood stands. By the fifth to the seventh year, reproduction dominated the lesser vegetation in most stands, yet this lesser vegetation remained an important component of the total plant cover. The cut-sprayed strips at AEF and UPEF stand 2 continued to be dominated by lesser vegetation on the majority of quadrats even after 5 years.

Raspberry was the most common shrub on mesic sites. Wetter sites had a mixture of shrubs, usually with mountain maple an important component. Other species of shrubs and small trees occurring in the strips were pin cherry, red-berried elder, blackberry, beaked hazel, and willow. Sedge-grass communities proliferated after spraying on wetter sites and on many of the AEF strips.

DISCUSSION

These trials demonstrated the great potential of strip clearcutting for re-establishing well-stocked stands of high-value hardwoods. Simultaneously, the poor results obtained served as a reminder that misapplication of the method can result in failure (Metzger and Tubbs 1971). Obviously, strip clearcutting must be very carefully prescribed and used. The inconsistent results of these trials provide some leads toward improving our understanding of where and under what conditions the method is likely to succeed.

Most strips in these trials had the potential to produce a fiber crop, in that the numbers and distribution of stems within the strips appear adequate to assure utilization of the site. Stocking on several of the cut-sprayed strips, however, was low, with much

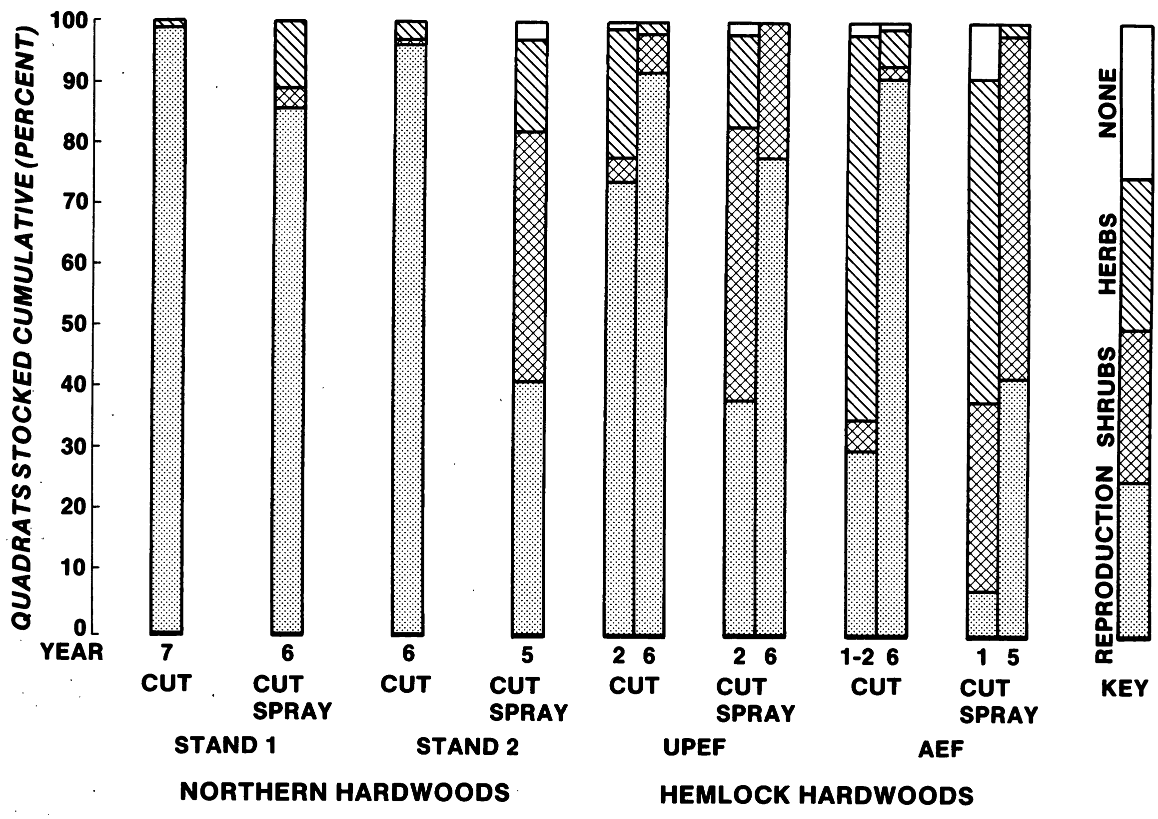

Figure 2.— *Form of vegetation dominating quadrats on clearcut strips on the Upper Peninsula and Argonne Experimental Forest.*

reproduction subordinate to lesser vegetation. In these cases, the well-established shrub and grass-sedge communities appeared likely to continue domination of sizeable areas for some time (Levy 1970, Metzger and Tubbs 1971).

The good distribution of desirable hardwoods in competitve positions on all strips at UPEF except the cut-sprayed strips in stand 2 create the potential for producing saw and veneer logs as well as fiber. The outlook for developing high-quality boles in these stands is not as readily apparent, but depends on maintaining high levels of crown competition to reduce branch and fork caused bole defects (Godman and Books 1971). Achieving both vertical and horizontal competition among crowns requires well-spaced reproduction of uniform height in recently reproduced stands. Cutting to a 5-inch d.b.h. limit at UPEF left many potential wolf trees and considerable variation in height, even after spraying. Had the stands been weeded, residual density and distribution should have resulted in crown closure, thus promoting higher stem quality. However, until research provides minimum stocking standards in relation to potential stem quality, the impact of stocking on quality can only be speculated upon.

Poorer stocking and competitive positions of desirable hardwoods in the AEF cut-only strips and UPEF cut-sprayed strips of stand 2 make the prospects of obtaining high-quality yields very marginal. Furthermore, these stands' crown structure, needed to promote stem quality, is not anticipated to develop for some time. Cut-sprayed strips at AEF are so severely understocked that there is no question of their failure.

One frequently cited advantage of clearcutting is its potential to increase species diversity of regenerated stands. On the contrary, these clearcutting trials without supplemental treatment reduced diversity. Clearcutting released reproduction established before cutting, whose superior competitive position prevented establishment of any significant amounts of new reproduction that could have increased diversity. Sugar maple was usually the most abundant species of advance reproduction, but beech, red maple, and hemlock were important in a few situations. The use of herbicides also failed to increase species diversity, although the advance regeneration was effectively eliminated or set back. Single species tended to dominate the regenerated stand, although the species varied from stand to stand depending on seed availability and site conditions.

This study did not identify an optimum width or orientation for strips, since little of the variation in results could be associated with strip layout. Ringger and Stearns' (1972) microclimatic data for AEF openings suggest why stocking differences for many species are slight between 1- and 2-chain strips. A number of microclimatic parameters remain relatively constant until opening diameters exceed twice the height of the border trees, then change abruptly. In these trials, the ratio of strip width to border tree height was less than 2. Larger openings increase the risk of lower temperatures for longer periods and increase the drought stress brought about by a combination of longer durations of high temperatures, higher wind speeds, and increased direct solar radiation. There is considerable uncertainty about the successful establishment of key species in wider strips, and added trials are warranted.

When advance reproduction was released by strip clearcutting, its success in the new stand depended on its ability to withstand major changes in light, heat, moisture, and competition. If the reproduction can withstand release, the size of area released apparently has little effect. Wider cut-only strips might be successful, because composition in these trials resembled that in larger clearcuts in Canada (Winget 1968, Boivin 1971) and in northeastern United States (Nyland and Irish 1971, Richards and Farnsworth 1971).

Reproduction height proved to be a good measure of its capability of withstanding overstory removal in the strips as well as in shelterwoods (Jacobs 1974). Site and climatic conditions also affect the outcome, so no single minimum stocking standard for widespread use is advisable. This study's results would apply to sites with low plant moisture stress similar to UPEF; a minimum of 15-percent stocking (a 50-percent safety factor has been added) of advance reproduction over 4 feet tall is recommended in such cases. In situations with relatively high potential moisture stress, Jacobs' (1974) recommendations developed for shelterwood release at AEF would be more appropriate (5,000 well distributed 2- to 4-foot-tall seedlings per acre). When these levels are not attainable, an alternative cutting method should be used; if an even-aged stand is desired, a shelterwood to promote further development of advance reproduction before final release is necessary (Godman and Tubbs 1973).

Species composition of the overstory and soil drainage had a greater influence on composition of reproduction on cut-only strips than did cutting or strip design. Sugar maple reproduction was most aggressive under its own canopy and on moderately well-drained to well-drained sites. On sites with less than well-drained soils, where red maple, yellow birch or hemlock were abundant in the overstory, reproduction of red maple and yellow birch increased in relative abundance or became the dominant species. These results are generally contrary to the hypotheses of Fox (1977) and Forcier (1975) that different species tend to replace overstory species in climax forests.

Successful regeneration from seed on the herbicide-treated cut strips depended on an adequate seed supply, elimination of advance reproduction, and a favorable environment. The importance of seed supply was indicated by the successful establishment of reproduction following bumper crops of sugar maple and yellow birch seed. Conversely, reproduction establishment declined drastically after crop failure or poor crops. It is also important that the seed is available the first season after spraying. Bumper crops of yellow birch occurred 2 and 3 years after spraying, but did not contribute measurably to the new stand. Rapid develpment of competing vegetation probably limited the chances of later seedling establishment.

Herbicide spraying proved to be especially beneficial to the establishment of yellow birch in two stands by successfully eliminating the advance reproduction. Sugar maple rebounded after spraying in the northern hardwood stands and became an important component of the reproduction again. Also benefitting from spraying were the pioneer species—quaking aspen, paper birch, and pin cherry. The pioneer species' abundance on the strips was probably less than what would be more commonly expected. This was partially due to the lack of pioneer species in the original stand (except for one paper birch per acre on the AEF), which meant there was no vegetative reproduction or seed available from adjacent uncut strips. There also would have been little seed available in the litter layer, because these stands had been undisturbed for 200 or more years (Graber and Thompson 1978). The source of seed was, therefore, in areas away from the strips, and in 2 of the 3 years of establishment at AEF, seed crops of quaking aspen and paper birch were failures (Godman and Mattson 1976). Pioneer species' increased abundance on the wider or more open strips suggests that these species would be favored by even larger strips.

Establishment of many other desirable species was hampered by too few trees, poor seed crops, or low seed mobility. For some, additional silvicultural practices may be needed. Basswood at AEF is an excellent example. Its reproduction was lacking despite good stocking in the overstory and plentiful seed. Supplemental treatments may be needed to overcome seed dormancy and to provide protection from decay and rodent predation (Godman and Mattson 1976).

Adequate dispersal of seed from the uncut border was no problem on the 1- and 2-chain-wide strips used. Benzie (1959) found high numbers of seeds from sugar maple and yellow birch up to 5 chains from their sources.

The generally poorer regeneration at AEF suggests the environmental differences between AEF and UPEF are important and should be considered in any future applications of strip clearcutting. A combination of factors leads to increased moisture stress at AEF. The climate at AEF is more continental than at UPEF, which is in close proximity to Lake Superior. Also contributing to greater stress at AEF are a boulder layer near the soil surface that reduces moisture-holding capacity, and the westerly aspect of the strips which may have increased evapotranspiration at the site. The other extreme, excessive soil moisture, caused reproduction failures of certain small areas at UPEF. Areas of high water tables throughout the growing season regenerated poorly.

Successful strip clearcutting trials at UPEF were comparable in many respects to shelterwood (Tubbs and Metzger 1969) and seed tree (Godman and Krefting 1960) trials also conducted there. These trials all became fully stocked after cutting and sugar maple stocking did not vary greatly among the different cutting methods. Yellow birch establishment on the successfully regenerated sprayed strips exceeded the results obtained in shelterwood trials with either seedbed scarification or seedbed scarification plus herbicide treatment (Tubbs and Metzger 1969).

Results of strip clearcutting in the hemlock-hardwood stand at AEF were similar to those from an earlier study of strip and block clearcutting in immature northern hardwood stands there (Metzger and Tubbs 1971). Reproduction in both trials was marginal to unacceptable. Stocking often declined when the stand was heavily disturbed—that is, when larger areas were cut, when cutting diameter limits were lowered, or when strips were sprayed. Desired shifts in species composition were not obtained.

Browse yields from shrubs and reproduction on clearcut strips at AEF reached 500 pounds per acre 7 years after cutting (Stearns 1969). Other benefits to wildlife from strip cutting are the interspersion of various stand structures, creation of edges and the increase in important food and cover species absent in mature northern hardwood stands.

SUMMARY

Strip clearcutting with or without supplemental treatments is a workable silvicultural option for even-aged management of northern hardwoods. It is not a technique that can be applied indiscriminately, because an error in application can result in long-term loss or reduction of tree cover and development of a community of lesser vegetation. Each situation requires careful evaluation, and strip clearcutting should be used only when it is the logical means to achieve management objectives.

Strip clearcutting to release advance reproduction should only be done when the stocking of reproduction capable of withstanding exposure is adequate. Guidelines for stocking should be more conservative on sites subject to greater moisture stress. This method does not allow significant manipulation of species composition in the regenerated stand.

Strip clearcutting combined with herbicide treatment should be even more judiciously prescribed and is subject to more constraints. Our experience revealed that treatments must effectively eliminate the advance reproduction and seed must be available. Experience shows that at least good or better seed crops of yellow birch, sugar maple, and red maple are needed to restock clearcut areas. Good crops of other species, except the pioneer hardwoods, did not successfully establish them. Soil moisture availability at the site influences regeneration results but our limited data do not warrant specific recommendations regarding soil moisture and stocking levels.

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COMMON AND SCIENTIFIC NAMES OF TREES AND SHRUBS MENTIONED

Ash, black	*Fraxinus nigra* Marsh.
white	*Fraxinus americana* L.
Aspen, quaking	*Populus tremuloides* Michx.
Basswood	*Tilia americana* L.
Beech	*Fagus grandifolia* Ehrh.
Birch, paper	*Betula papyrifera* Marsh.
yellow	*Betula alleghaniensis* Britton
Blackberry	*Rubus* (subgen. *eubatus* Focke)
Cherry, pin	*Prunus pensylvanica* L. f.
Elder, red-berried	*Sambucus pubens* Michx.
Elm, American	*Ulmus americana* L.
Hazel, beaked	*Corylus cornuta* Marsh.
Hemlock, eastern	*Tsuga canadensis* (L.) Carr
Ironwood	*Ostrya virginiana* (Mill) K. Koch
Maple, mountain	*Acer spicatum* Lam.
red	*Acer rubrum* L.
sugar	*Acer saccharum* Marsh.
Raspberry	*Rubus idaeus* L.
Willow	*Salix* spp. L.

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Metzger, Frederick T.

1980. Strip clearcutting to regenerate northern hardwoods. U.S. Department of Agriculture Forest Service, Research Paper NC-186, 14 p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Describes results of strip clearcutting trials in mature northern hardwood and hemlock-hardwood stands in the Lake States. Two strip widths and orientations were tested, with and without herbicide treatment of the advance regeneration. Establishment, growth, and species composition of the regeneration were assessed.

KEY WORDS: Sugar maple, yellow birch, red maple, eastern hemlock, even-aged silvicultural systems, herbicides, Michigan, Wisconsin.

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Nature is beautiful...leave only your footprints.