APPLICATION OF TREE IMPROVEMENT TO MINI-, MIDI-, AND MAXI-ROTATION MANAGEMENT

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INTRODUCTION

When I finish this talk, you probably will decide that this was essentially an argument for more intensive silviculture; and you will be right. And, if you think that I am sticking my neck out, you are also correct; but remember the turtle--it makes progress only when its neck is all the way out.

Why have I taken this approach? Because silviculturists, particularly in the Northeast, either have not recognized the possibilities or have not dared to advocate intensive, short-rotation management with genetically improved trees.

Genetics is one of the sciences essential to the art of silviculture (to the geneticist, of course, the most important); and silvicultural methods will seldom be accepted by management unless they guarantee a profitable return. But,first we must know what is biologically possible. Forest research ideas are too often nipped in the bud--before the possible economic returns have been determined--with the remark that they would not pay off.

In a paper titled "Mini-Rotation Forestry" (Schreiner, 1970), I predicted that much greater effort must be directed toward more intensive--and more expensive--silviculture; and that a major requirement for maximum success of such intensive silviculture will be genetically improved planting stock. Obviously, mini-rotation management is not the only answer to the future production of fiber and timber in the Northeast. There are at least three broad approaches that would fit the changing environment of forest management; these are designated as mini-, midi-, and maxi-rotation management (Fig. 1).

MINI-ROTATION MANAGEMENT

In the paper on mini-rotation forestry, I briefly discussed the apparent trend in available forest land and woods labor, and the need for intensive short-rotation forestry; and I outlined the possibilities for intensive short-rotation management. I suggested the term mini-rotation forestry to include the production of fiber on rotations of 1 to 4 or 5 years (mini-rotation fiber production); boltwood for fiber, particle-board, or other uses on rotations of 6 to 15 years (mini-rotation boltwood production); and lumber and veneer logs on rotations of 15 to 30 years (mini-rotation timber production).

Mini-rotation forestry will require: (1) maximum use of growing space on lands with the highest potential for tree growth; (2) machine site preparation, planting, cultivation, and harvesting; (3) intensive culture; (4) utilization of small stem-wood and, if possible, branch-wood; and (5) rapid-growing species, <u>natural or synthetic</u> varieties, or hybrids.

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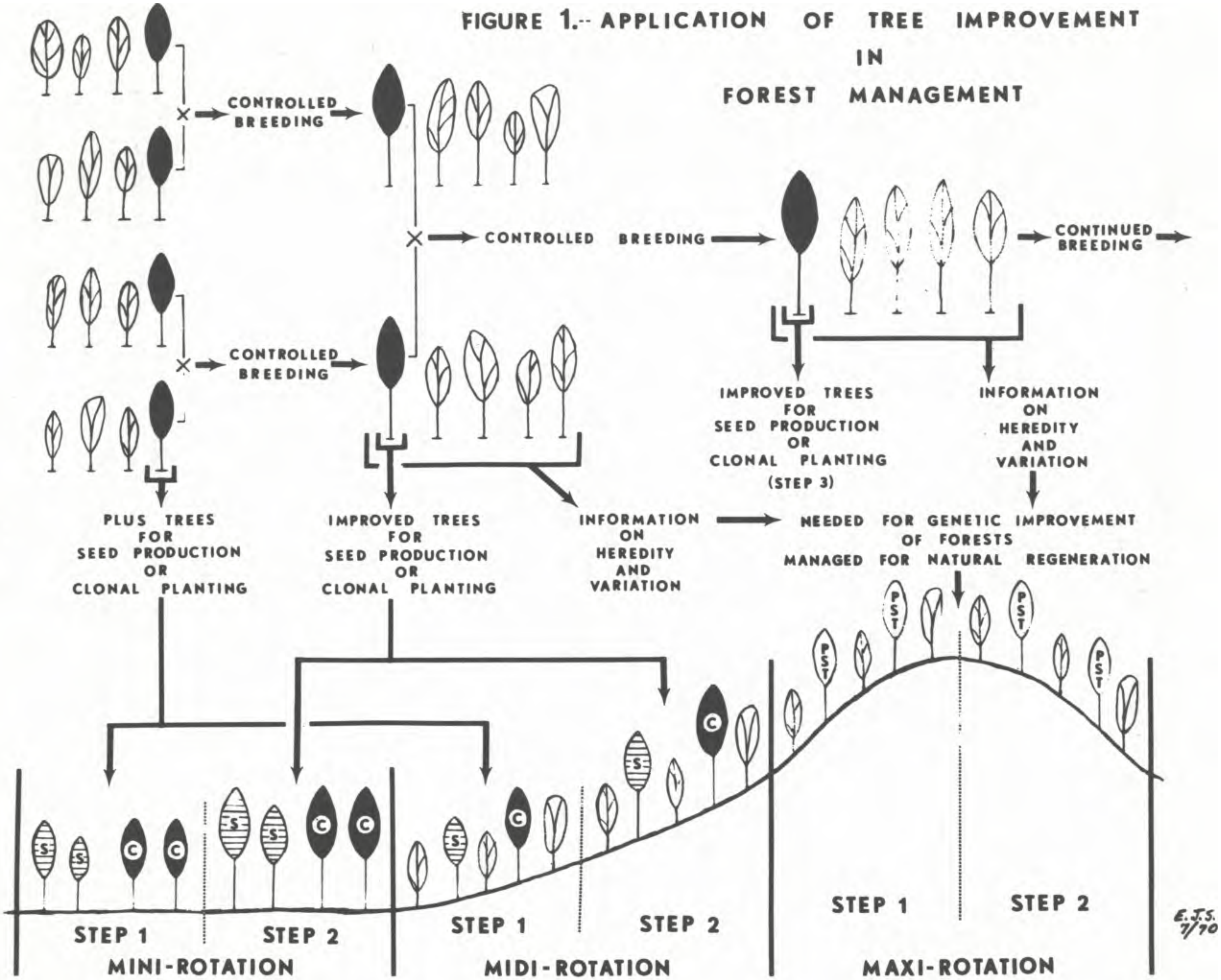
FIGURE 1.-- APPLICATION OF TREE IMPROVEMENT IN FOREST MANAGEMENT



S = Seedling planting stock; C = Clonal planting stock; PST = Plus Seed Trees

The importance of maximum stocking to obtain maximum yield of eastern white pine on lands of high tree-growth potential is apparent (Tables 1 and 2).

Table 1.--Eastern white pine yields per acre at age 20, to a 3.0-inch top i.b. in Maine, Massachusetts, and New Hampshire (Applies to overstory pine trees 3.0 inches d.b.h. and over)

Site index	Stocking percent 40		70		100		130	
	Cu.ft.[1]	Cords[2]	Cu.ft.[1]	Cords[2]	Cu.ft.[1]	Cords[2]	Cu.ft.[1]	Cords[2]
6o	892	9.9	1,477	16.4	2,039	22.7	2,583	28.7
7o	1,044	11.6	1,730	19.2	2,387	26.5	3,025	33.6
8o	1,223	13.6	2,026	22.5	2,796	31.1	3,543	39.4
90	1,432	15.9	2,373	26.4	3,274	36.4	4,149	46.1

[1]Excerpt from Leak et al., 1970; table 3.
[2]Converted for this paper on the basis of 90 cubic feet per cord.

Table 2.--Eastern whiteyine board-foot yields per acre to a 6.0-inch top i.b., age 40, site index 80[1] (Applies to overstory pine trees 9.0 inches d.b.h. and over)

State	Stocking percent 50	70	100	120
Maine	13,411	15,669	18,478	20,104
Massachusetts	16,011	19,302	23,531	26,039
New Hampshire	14,134	14,878	15,710	16,153

[1]Excerpt from Leak et al., 1970; tables 4, 5, and 6.

The cubic-foot yields for eastern white pine are based on boltwood sizes (3.0-inch top i.b.) (Table 1). At 20 years on site index 60, the reported yield is 9.9 cords with 40 percent stocking in contrast to 28.7 cords (1.4 cords per acre per year) with 130 percent stocking. For site index 90, the yields are 15.9 cords with 40 percent stocking and 46.1 cords (2.3 cords per acre per year) with 130 percent stocking. The effect of stocking is also apparent in the board-foot yields at age 40, to a 6.0-inch i.b. top, of trees 9.0 inches and over in d.b.h. (Table 2).

Establishment, culture, and harvesting of intensively managed stands can be handled by machines; this was discussed briefly in my paper on mini-rotation forestry.

There have been many reports over the years on the beneficial effect of site preparation, particularly deep plowing. Recently, Althen (1970) has reported that plowing and tilling improved 3-year height growth of white spruce and white pine by 37 and 40 percent, respectively. For sugar maple and locust, the average growth on plowed plots was three and four times greater than on scalped plots; for ash, the ratio was nearly 9 to 1.

Forest fertilization is receiving increasing attention. In Althen's (1970) studies, fertilization improved growth of all species, but the favorable response was much greater in the plowed plots than in the scalped plots. Although intensified rates of application increased growth, the improvement was not proportional to the increase in dosage. FAO (1969) has reported that growth increases have been recorded that range from 15 to 200 percent more than unfertilized areas of similar species composition and on similar sites; and that experience in Scandinavia indicates that increases in periodic annual increment of between 30 and 50 percent are easily obtained.

In 1945 I reported on the need for plowing and fitting land before planting hybrid poplars, and on the need for weeding during the first year. I also noted that many forest species will respond to elimination of grass, to the fertility effect of sod turned into the soil, and to weeding--though not necessarily in the same degree as hybrid poplars. The need, on a relatively fertile soil, for turning under the sod for maximum growth (and, in fact, for successful growth) of hybrid poplars, indicated that the sod on old fields might supply the organic material needed to tip the biological balance in favor of tree growth.

> "From the evidence on the complexity of the soil condition so easily referred to as 'fertility' it has become more and more obvious that the importance of organic matter in soils cannot be gauged simply on the basis of its bulk or of its nutrient components. Its effect on plant growth must also be measured in terms of biological change; a little bit in the right place and at the right time can result in astounding improvement of soil fertility." (Schreiner, 1945).

There has been very little effort to utilize very small 3- to 4-year-old stems for fiber or particle-board. But there has been progress toward the utilization of small trees for lumber and veneer. FAO has reported that recent developments in manufacturing methods for veneer make it possible to utilize much smaller material. This advantage is partly achieved by using a kind of telescopic spindle to hold the log in place while it is being rotated. As the log is peeled, the outer casings are withdrawn, leaving a small spindle, sometimes with a diameter as small as 5 cm. (FAO, 1969).

There are at least 16 hardwood and 10 conifer species that could be used immediately for pilot-scale trials of mini-rotation management in the Northeast (Schreiner, 1970). The earliest and maximum progress in the application of genetically improved trees to forest management will be through synthetic multi-clonal hybrid varieties. By clonal propagation, the breeder can multiply superior individuals immediately for commercial use without alteration of the genotype and without determining their ability to transmit the desirable qualities or characteristics to their seedling progenies (Schreiner, 1966).

Superior clones of hybrid poplars, such as clones NE-300 (Populus cv. Betulifolia X P. trichocarpa) and NE-264 (Populus cv. Angulata X P. cv. Volga), are available for pilot-scale trials. The estimated 4-, 9-, and 15-year volume production of these clones in 100-tree plots, established with dormant cuttings spaced 4 x 4 feet on two upland sites in Williamstown, Massachusetts, is shown in the following tabulation:

Clone	Upland site	Mean volume-cords per acre		
		4 years	9 years	15 years
NE-300	Terrace	6	14	36
	Slope	7	13	46
NE-264	Terrace	4	7	38
	Slope	1	3	22

A 4-year mini-rotation for fiber production would require closer than 4- by 4-foot spacing. Evidence from many nursery plantings of the Northeastern hybrids has indicated that the volume of the average 4-year-old trees in the 4- by 4-foot clonal trial can also be attained at 1- by 4-foot spacings. For this reason, the 4-year volume per acre was calculated on the basis of 7,623 trees per acre (70% survival at 1- by 4-foot spacing) and the volume of the average tree (computed as a cone).

The 9-year and 15-year volumes were estimated on the basis of the number of residual trees and the total volume of the average tree.

Clone NE-300 is an early starter that could be used for mini-rotation fiber, boltwood, and timber production. Clone NE-264, a slower starting but disease resistant hybrid, would be most useful for boltwood and timber mini-rotations.

Clonal planting stock of plus trees would give the greatest uniformity (trees labeled "C" in figure 1); seedling planting stocks (trees labeled "S") would be more variable. For seedling stock it will be most desirable to use half-sib progenies derived from seed of plus trees until genetically improved seed-orchard stocks become available. Planting stock derived from rogued seedling or clonal seed-orchards will provide families and individuals genetically superior to the plus-tree progenies. Step 2 (Fig. 1) indicates the use of planting stocks (clones or seedlings) that are genetically superior to those used in step 1.

MIDI-ROTATION MANAGEMENT

I suggest midi-rotation management on forest lands that are not economically suitable for intensive mini-rotation forestry for various reasons, such as soils with inferior tree-growth potential, excessive stoniness or topography that would not permit intensive machine culture, distance from markets, and forest stands that cannot be clearcut and must be managed under some modified system, such as strip or patch cuttings.

Most silvicultural prescriptions in the Northeast, and particularly in New England, have been for long-rotation management, based on natural regeneration and the concept of individual tree selection. The silviculturists have failed to recommend, or even to mention, the possibilities of genetic improvement conversion by in-planting improved varieties or better natural species (for midi-rotation management).

A schedule of intermediate treatments for management objectives of sawlogs and veneer logs of paper birch, paper birch boltwood, and mixed timber of high-value products is shown in table 3. These recommendations call for considerable investment in cleaning and precommercial thinnings in naturally reproduced stands.

Table 3.-- Schedule of intermediate treatments (at stand age in years) Excerpt from Marquis et al., 1969; table

Treatment	Management objective					
	Paper birch sawlogs and veneer logs		Paper birch boltwood		Mixed timber of high-value products	
	Site 70 +	Site < 70	Site 70 +	Site < 70	Site 70 +	Site < 70
Cleaning	5-101	--	5-101		5-10	[1]--
Pruning	--	--	--	--	15-201	--
Precommercial thinning	25	301	25	301	25	301
Precommercial thinning	35	--	--	--	35	--
Thinning	45	50	35	50	45	50
Thinning	55	60	--	--	55	60
Harvest (paper birch) [2]	65	70	45	60	65	70
Thinning	--	--	--	--	85	95
Thinning	--	--	--	--	100	115
Harvest (other hardwoods	--	--	--	--	120	135

1 Use these cultural treatments only if stand conditions require them. See prescriptions.

[2] Clearcutting, seed tree cutting, or strip cutting.

[3] Clearcutting, seed tree cutting, strip cutting, or patch or shelterwood cutting where clearcutting is not desired.

I suggest that this much investment in silvicultural treatments would justify "Genetic Improvement Conversion" by replanting clearcut areas and by in-planting partial cuttings with better species or improved varieties.

For our 1957 Conference in Maine, we prepared a 1-acre field demonstration to illustrate "Genetic Improvement Conversion" in the spruce-fir type (Schreiner, 1958).

This was an attempt to demonstrate improvement of the "genetic stand potential" by in-planting trees with more desirable inherent qualities than those in the existing stand; better races of the native species, better native or exotic species, and, when available, improved strains or clones. The quickest genetic improvement conversion on the demonstration site would be to clearcut and replant with the best stocks available. However, experience had indicated that in the spruce-fir type, clearcutting is often an unwarranted economic risk because the hardwoods, shrubs, and weeds that normally take over are very expensive to control. This is still true, and there are additional reasons for partial cuttings, particularly the attitude of the public.

The original stand is shown in figure 2. Partial cutting was used to provide for mass selection through natural regeneration of white spruce and eastern white pine, and for in-planting of better species or varieties without exposing the forest floor to the inroads of weed and brush species. Seven of the best phenotypes of white spruce and eastern white pine were left in the residual stand for seed trees (Fig. 3).

From 50 to 100 trees per acre of species, races, or hybrids considered or known to be adapted to the site, and to be better than the local white spruce or white pine, were to be planted in the openings within a year after this first, and after each successive partial cutting. Sufficient residual basal area (51.07 square feet) and volume (1,016.6 cubic feet) was left to make at least one, and possibly two commercial cuts to release the in-planted trees and superior white spruce and white pine regeneration.

Genetic improvement conversion to better species or varieties through in-planting would reduce the 50- to 125-year rotations based on natural regeneration. In the 1957 demonstration, we used patch cuttings and included plus seed-trees. For midi-rotation management, now and in the future, I would suggest strip cutting and would omit plus-tree selection for natural regeneration. The cleaning and the two precommercial thinnings scheduled as intermediate treatments (Table 3) would be sufficient to release the in-planted improved trees from wild-stock competition. Fertilization of the in-planted stock should also be considered.

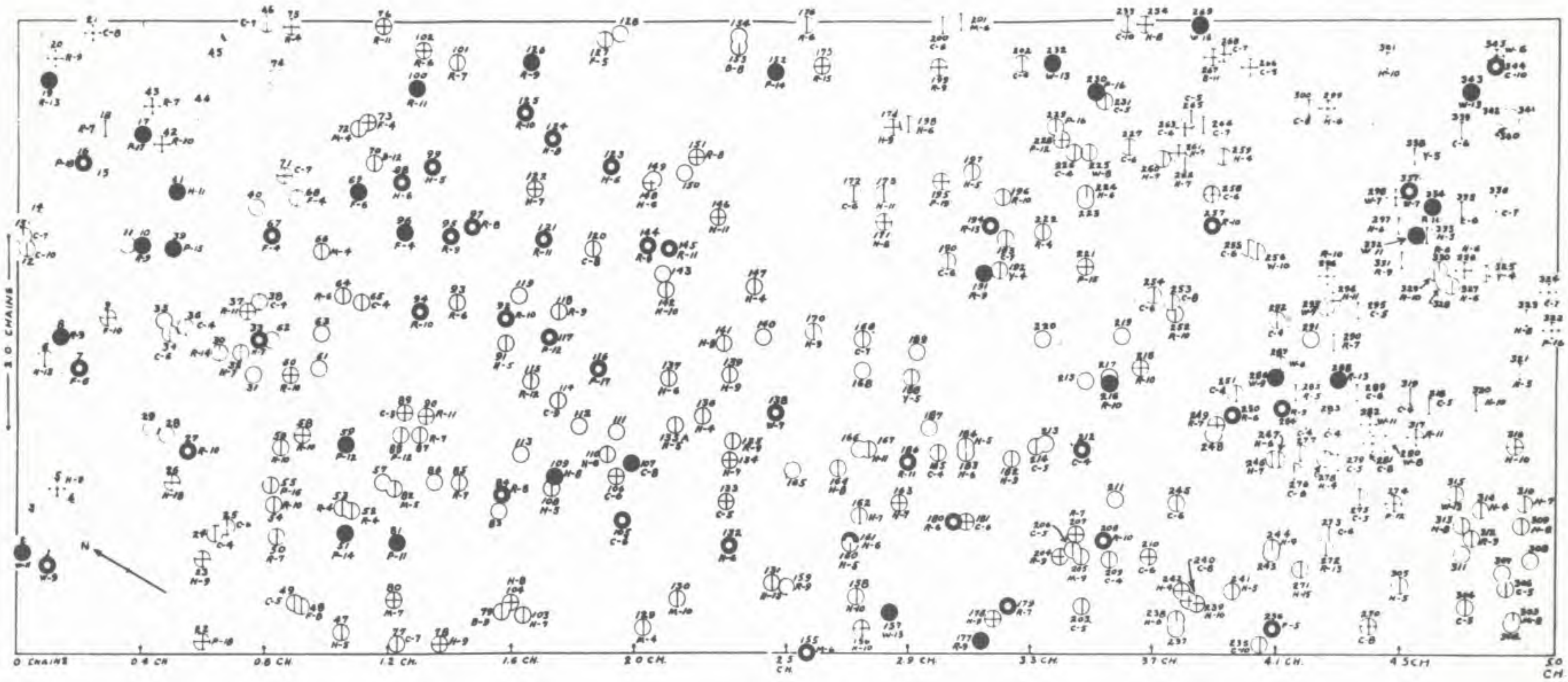
As in the case of mini-rotation management, step 1 (Fig. 1) would utilize seedlings or ramets of plus trees; step 2 would utilize improved planting stock derived from a controlled breeding program, either through half-sib or full-sib breeding. Step 3 and beyond would continue the improvement procedure.

MAXI-ROTATION MANAGEMENT

Maxi-rotation based on natural regeneration has been, and still is, the generally recommended and accepted forest management procedure in this and most other regions. An example of such long-rotation management--100 to 125 years for high-quality sawtimber--is the proposal by Foster (1964) for eastern white pine. His proposal was to start management with stands that have reached about 1/3 rotation age, by selecting the outstanding crop trees for pruning to heights of as much as 50 feet during the second-third of the rotation; he suggested removal of the unpruned trees in two or more cuttings.

> "Where 6-log trees are anticipated with approximately 75 percent of their volume in the first three logs, it would be short-sighted to prune less than 50 feet. One-log pruning for such trees would be ridiculous. Two-log pruning to 35 feet is likely to be

Figure 2.--Original stand - Before logging (Trees in the 5-inch d.b.h. class and up)



Legend:
- B = Paper birch
- C = Northern white-cedar
- F = Balsam fir
- H = Eastern hemlock
- M = Red maple
- P = Eastern white pine
- R = Red spruce
- W = White spruce
- Y = Yellow birch

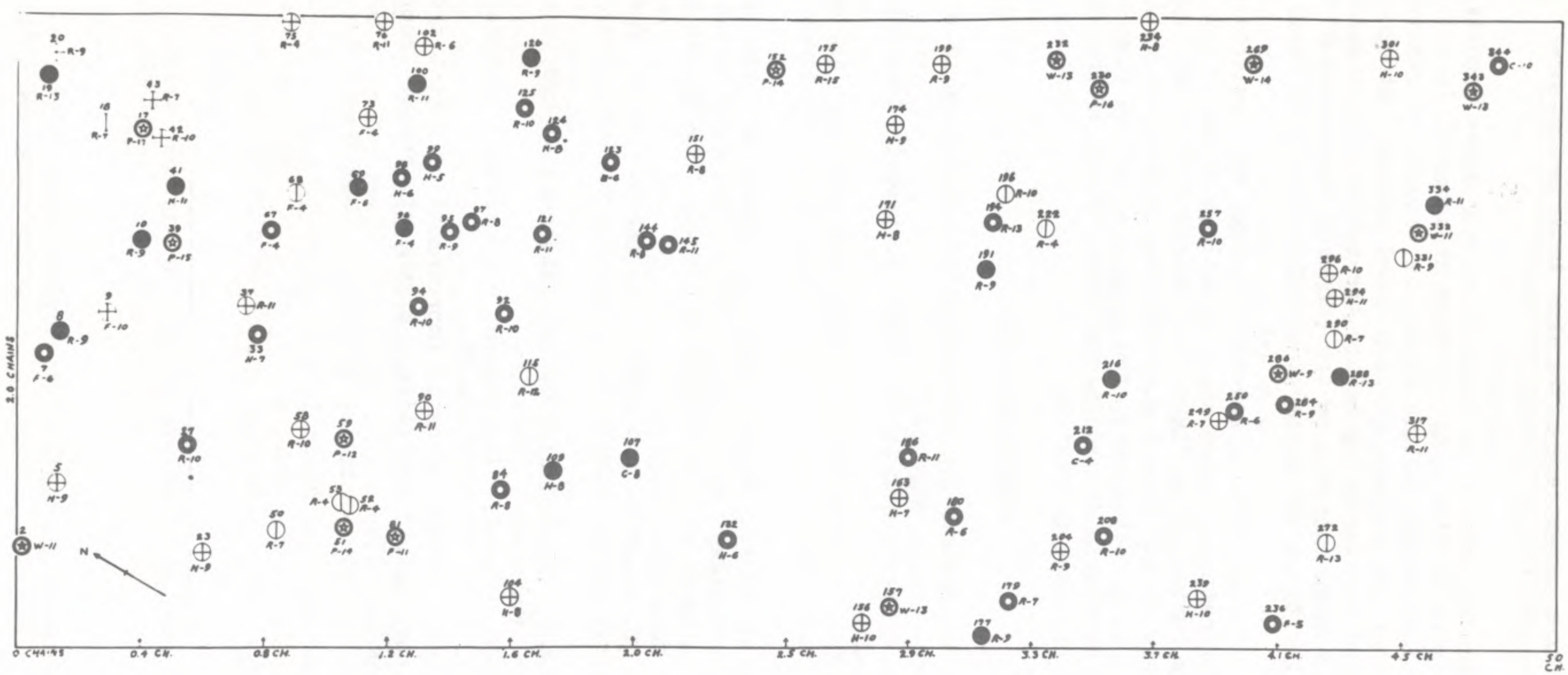
Legend (continued)

1, 2, 3, etc. = Tree numbers

Tree ratings ● = 1 ◎ = 2 ⊕ = 3 ⦶ = 4 ○ = 5

Letters indicate species; number following letter (w-9) is the d.b.h. class in inches. Species and diameter class designations are omitted for cull trees.

Figure 3.-- Residual stand - After logging (Trees in the 5-inch d.b.h. class and up)



Legend: C = Northern white-cedar
F = Balsam fir
H = Eastern hemlock
P = Eastern white pine
R = Red spruce
W = White pine

Legend (continued)

1, 2, 3, etc. = Tree numbers

Tree ratings ⊛ = 1 W ⊛ = 1 P ● = 1 ◉ = 2 ⊕ = 3 ⦶ = 4

Letters indicate species; number following letter (w-9) is the d.b.h. class in inches.

"employed in most cases on average sites when total height near maturity is not expected to go beyond 100 feet."

Maxi-rotation management should be considered only under conditions where genetic improvement conversion (for midi-rotation management) is not economically feasible. These conditions would include infertile, steep, or remote sites; and lack or high cost of labor for release of in-planted improved stock. Improved trees could be in-planted to eventually reduce the rotation; but without any culture, success would depend entirely on the inherent vegetative fitness, particularly the superiority of the inherent growth-rate of the in-planted stock.

The application of forest-tree improvement through mass selection to stands that must be managed for natural regeneration by selecting plus seed trees (maxi-rotation management) is indicated in figure 1. Improvement of the genetic potential of the stand will be very slow. Step 1 must utilize the best trees in the existing stand. Step 2 will not be possible until the <u>progenies</u> of the plus seed trees selected in step 1 are available for additional improvement of the stand through the plus seed trees of this new generation.

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