A Silvicultural Guide for SPRUCE-FIR in the Northeast

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ABSTRACT

A practical guide to the silvicultural treatment of spruce-fir stands for timber production in New England and New York. Both even-aged and uneven-aged management are considered, covering both the establishment of new stands and the culture of existing stands. Includes a set of prescriptions describing specific treatments for a range of stand conditions and management objectives.

ACKNOWLEDGMENT

Full recognition is made of the contributions of Arthur C. Hart in the initial preparation of the material contained in this guide. At the time of his death, Mr. Hart was in charge of the research program for spruce-fir silviculture in Orono, Maine.

A major portion of his professional career was spent in northern New England, where he was considered by many to be an expert in spruce-fir forestry. Many of his research findings and observations are contained in this guide. The process of preparing this publication was made easier because of his work.

The authors are proud to dedicate this publication to the memory of Arthur C. Hart.

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INTRODUCTION

THIS PUBLICATION was developed to answer the need for a silvicultural guide to the management of spruce-fir types in the spruce-fir region of northern New England and New York. Such types occupy 13.4 million acres of land, of which all but 5 percent are privately owned. This guide was designed not only to supplement professional knowledge, but also for the benefit of the many laymen who will find it informative.

The silviculture prescribed is based on achieving maximum production of timber of the desired species and size. This can be done by maintaining stands that fully use the growing capacity of the site, by regular timber-stand-improvement operations, by periodic harvests to achieve rapid growth, and by regeneration methods that will secure adequate reproduction quickly (fig. 1). The guide applies to sites that are reasonably capable of developing naturally into stands containing at least 50 percent of their basal area in spruce-fir. It is not designed for plantations, and caution is advised when applying this guide to pure upland red spruce stands or to pure stands of black spruce.

Silvicultural methods that are compatible with the many land uses other than timber production may require adjustment of the prescriptions in this guide. No general rules are possible because of the variety of circumstances that may be encountered. Each case must be considered individually.

The information contained in the guide is based on a review of literature, current research, consultation with forest managers, and observation. It is not the last word in silvicultural practice; the results of research now

Figure 1.—Spruce and balsam fir reproduction in a small opening in the stand, a common occurrence in the spruce-fir forest.

under way or being contemplated may require future modification.

Similar guides for the silvicultural management of paper birch may be found in USDA Forest Service Research Paper NE-130 (*Marquis et al. 1969*); guides for the silviculture of northern hardwoods may be found in USDA Forest Service Research Paper NE-143 (*Leak et al. 1969*).

SPRUCE-FIR TYPES AND SPECIES

Pure stands of spruce-fir occur on the poorly drained soils of swamps and flats adjacent to lakes and streams and on the thin soils of upper slopes. Above the flats, where the soils are deeper and better drained, the proportion of hardwood species is greater.

The spruces—red (*Picea rubens* Sarg.), white (*P. glauca* (Moench) Voss), and black (*P. mariana* (Mill.) B.S.P.)—and balsam fir (*Abies balsamea* (L.) Mill.) are the major components of the spruce-fir cover types in the Northeast. The important types include balsam fir, red spruce, red spruce—balsam fir, paper birch—red spruce—balsam fir, and white spruce—balsam fir—paper birch.

Other softwood species are also found in these forest types, principally eastern hemlock (*Tsuga canadensis* (L.) Carr.), eastern white pine (*Pinus strobus* L.), northern white cedar (*Thuja occidentalis* L.), and occasionally tamarack (*Larix laricinia* (DuRoi) K. Koch). Associated hardwoods include sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.), yellow birch (*Betula alleghaniensis* Britton), paper birch (*Betula papyrifera* Marsh.), American beech (*Fagus grandifolia* Ehrh.), poplar (*Populus* spp.) and ash (*Fraxinus* spp.).

Occurrence

In the Northeastern United States, the spruces and fir occur from the Canadian border through New England and New York. At the higher elevations in the mountain areas, red spruce occurs as far south as Tennessee and North Carolina, but white spruce extends only into New York. Balsam fir reaches into Virginia and West Virginia, and black spruce reaches into Pennsylvania. The principal commercial range includes northern New England and New York.

The soils where spruce-fir grow are mostly acid podsols with a thick mor humus and a well-defined A_2 horizon—characteristics commonly associated with abundant rainfall, cool climate, and softwood cover. Many of the glacial till soils have a compact layer averaging 18 inches below the surface.

Pulpwood is the principal product of the spruce-fir region. More than two-thirds of the annual harvest of spruce and fir is for pulpwood, although sawlogs have a higher value per cubic foot.

Balsam fir and black spruce are generally grown to a maximum size of 10 to 12 inches d.b.h.; red and white spruce are grown as large as 14 to 16 inches for pulpwood and 18 to 20 inches for sawlogs.

Stand Establishment

The basic requirements for successful natural spruce-fir regeneration are: an adequate seed supply; proper seedbed; and light, temperature, and moisture conditions that are conducive to seed germination and seedling survival. Seed production may begin when trees are about 15 years old, but significant production usually does not begin until the trees are 25 to 30 years old or later. Very few viable seeds are stored in the forest floor for more than 1 year. Some of the silvical characteristics of the several species are given in table 2, appendix (*Fowells 1965*).

Mineral soil is an excellent seedbed for germination. Generally ample moisture is available, and soil temperatures are moderate. Litter and humus are poorer seedbeds because they are likely to be drier and hotter than mineral soil. Severe competition makes heavy sod the poorest seedbed.

Favorable seedling development is greatly affected by light, temperature, and moisture conditions. Initially the light requirements conducive to early establishment seem not to exceed 10 percent of full sunlight (*Vezina and Peck 1964*). But as the seedling develops, light intensities of 50 percent or more are necessary for optimum growth (*Shirley 1943*).

Soil surface temperatures between 115°F. and 130°F. result in the mortality of most young conifer seedlings even when they are exposed for very short periods of time (*Baker 1929*). Damage caused by late frost to leaders and new lateral growth is seldom severe.

Although seedlings of spruce and fir are similar in many respects, spruce is weaker and more fragile, and grows slower during the establishment period.

Seedlings that have obtained a height of about 6 inches can be considered as being established. Once a seedling becomes established, early growth is determined largely by the amount and character of overhead competition. Dense growth of bracken fern, raspberry, and hardwood sprouts are the chief competitors of seedlings on heavily cutover lands; but both balsam fir and the spruces will survive many years of suppression and still respond to release.

Site Classification

The shade tolerance of spruce and fir and the multiple-aged condition of the stands in which they normally occur make determination of site index difficult. In addition, spruce and fir do not have as wide a range in site index as do many other tree species that grow well on a wide variety of sites. For these reasons, site index as a method of site classification is not used in this guide. However, Meyer's (*1929*) site-index values for various stand types are illustrated below. The figures are based on the average height of dominant and codominant trees at 50 years:

Stand type	*Site-index range*
Primary softwood site:	
Spruce swamp	24 to 35
Spruce flat	27 to 39
Upper spruce slope	up to 35
Old farmland	31 to 44 or more
Secondary softwood site:	
Lower spruce slope	27 to 47
Old farmland	less than 39 to 50

Despite the wide variety of these sites, they can be placed in one of two general classes—primary softwood sites or secondary softwood sites (*Westveld 1941*). These classes are meaningful in terms of potential stand composition, growth, and reproduction.

Primary softwood sites occur under conditions of poor or impeded drainage in the so-called spruce-fir swamps, flats, and other lower topographic positions. Spruce-fir—particularly red spruce—also is common on the thin soils of upper slopes. Characteristic shallow rooting on these soils makes open stands susceptible to windthrow. These sites are composed mostly of softwood species. Hardwoods comprise less than 25 percent of the stand and are mostly paper birch, yellow birch, aspen, red maple, and an occasional beech or sugar maple. Feather mosses, ferns, and numerous herbs make up the low ground vegetation characteristic of these sites.

Secondary softwood sites occur on the better-drained sites of higher topographic positions and on medium-elevation ridge lands. Hardwoods may comprise from 25 percent to as much as 70 percent of stands on these sites, often competing harshly with spruce-fir. However, the tolerant red spruce and balsam fir may become established in the understory, responding to release if the overstory is removed. On such sites, the hardwoods usually are beech, sugar maple, and yellow birch. Herbaceous vegetation is less common than shrubs such as witch hobble (*Viburnum alnifolium* Marsh.), striped maple (*Acer pensylvanicum* L.), and mountain maple (*Acer spicatum* Lam).

Principal Damaging Agents

Many insects and diseases damage spruce and fir. However, spruce is relatively free from these destructive agents until it matures. Fir, at all ages, is more subject to insect and disease attack. Only the more important insects and diseases are mentioned here.

One of the most serious insects is the spruce budworm (*Choristoneura fumiferana* Clemens), a defoliator that attacks both spruce and fir, but prefers fir. Vast outbreaks of this insect in the past have killed millions of cords of pulpwood, primarily in stands containing mature and overmature fir.

The balsam woolly aphid (*Adelges piceae* Ratzeburg), which attacks fir, is an intro-

duced insect that seems to be becoming increasingly serious in the Northeast. The salivary injections of the aphid kill or deform fir trees.

Most silvicultural theories proposed to minimize the impact of insect outbreaks have not been put into practice on a scale large enough to test their effectiveness against epidemic populations. Some degree of success has been achieved with biological control and aerial spraying.

The important diseases of spruce include red ring rot (*Fomes pini*), which enters through dead branch stubs, and red brown butt rot (*Polyporus schweinitzii*), which enters largely through basal wounds. They are usually confined to overmature or damaged trees. Thus a stand that is maintained in a healthy, vigorous condition will be less susceptible to infection.

One fungus (*Stereum sanguinalentum* Fr.) causes over 90 percent of all trunk rot in living balsam fir trees. Often referred to as "red heart", this disease enters the tree through broken tops, broken branches, and other injuries.

Infections of balsam fir by other fungi cause various butt and root rots, which are not as serious as the trunk rot disease. However, these rots weaken the trees, making them susceptible to wind damage.

In stands where these diseases are serious, commercial thinning should begin when tree diameters are about 8 inches. But other timber-stand-improvement measures should be taken as soon as problems warrant immediate attention. The pathological rotation of fir is 50 to 60 years along coastal areas in Maine and near southern extremes in the spruce-fir region. In the interior and more northern areas, final harvest should take place at 70 to 90 years.

The frequency of occurrence of the various types of rot in balsam fir does not vary greatly between sites. However, the important trunk rots seem to be slightly more prevalent on primary softwood sites (*Basham et al. 1953*).

Spruce and fir are shallow-rooted. Most of the feeding roots are in the duff and the top few inches of mineral soil. Because of their shallow root systems, thin bark, and flammable needles, trees of all ages are easily killed by fire. Their shallow root systems also mak them subject to windfall. Caution is necessar in stands subjected to harvesting operations i areas where windfall is known to be a problen Damage can be reduced by leaving uncut por tions along the windward edges of the stanc Depth of these protective strips should be a minimum of one-half the height of the trees t be harvested.

Some injury and mortality of spruce and fi is caused by animals and birds. These pests in clude porcupine, bear, deer, hares, and yel low-bellied sapsuckers. However, there is littl that can be done silviculturally to prevent this kind of damage.

MANAGEMENT OBJECTIVES

Traditionally, the major objective of timber management has been to grow the most of a given timber product that the land is capable of producing, either in the shortest time or at the least expense. And it is important to define a specific objective, because without a definite course of management, the full potential of the land cannot be realized. The four objectives that follow are framed to meet most needs although specific objectives may be quite different and require modification.

Objective 1.—Maximum production of spruce-fir pulpwood. In terms of this guide, objective 1 is stated for timberland owners who desire to grow only pulpwood.

Objective 2.—To produce a maximum proportion of spruce-fir veneer logs or sawlogs and a minimum proportion of pulpwood. In terms of this guide, objective 2 is stated for timberland owners who depend on others for markets and for sawmill and veneer mill owners who will usually want to grow sawlogs or veneer logs to supply their mills. If possible, these owners will usually market smaller trees from intermediate harvests or improvement operations as pulpwood. But the availability and reliability of markets will determine both the products and species toward which these owners slant their management.

Objective 3.—The maximum production of the highest value timber products of all spe-

cies present or adapted to the site. This objective is similar to objective 2, except that where markets are available for associated species of high value, management will be aimed at maximum returns from all species. However, in this guide, management of mixed species is limited to stands in which at least 50 percent of the basal area is spruce-fir. For many stands with less spruce-fir, the silvicultural guides for northern hardwoods or paper birch should be used.

The first three objectives are applicable when timber is the primary product. The fourth objective is necessary because other forest uses—recreation, water, wildlife, esthetics—may be considered primary products rather than byproducts of timber management. Although timber management is normally compatible, these uses of forest lands readily visible from tourist routes and scenic highways, in places adjacent to recreation areas, in roadside and waterside strips, and in watersheds, may well be considered the primary objective.

Objective 4.—Maximum production of the desired product other than timber, including recreation, water, wildlife, and esthetics by silvicultural methods that are compatible with some degree of timber production. To achieve objective 4, considerable adjustment of the prescriptions in this guide will usually be required, especially for even-aged silviculture. State service foresters or consulting foresters can be consulted for additional advice as specific cases are encountered.

SPECIES COMPOSITION GOALS

In stands where balsam fir is susceptible to insect and disease attack, the goal should be to decrease the proportion of fir in spruce-fir stands. This may be hard to do because fir tends to increase in proportion to spruce in second-growth stands. But foresters have been aware for years that the best way to achieve a better balance between spruce and fir is to reduce the amount of fir by harvesting it for pulpwood before it deteriorates. In general, spruce can be held in at least equal ratio to the less desirable fir only if a continuous forest cover and sources of spruce seed are maintained. If the site is producing fast-growing, high-quality fir, then the decision to favor spruce is less absolute. Product objective now enters into the decision-making. And for some uses, fir may even be encouraged.

In spruce-fir stands where hemlock is a significant component, it may be desirable to favor hemlock over fir. Hemlock is less susceptible to insects and diseases and is longer-lived.

Unfavorable site conditions retard the growth of hardwoods more than they retard the growth of spruce and fir. Therefore, on primary softwood sites, spruce and fir should be favored over the hardwoods. On secondary softwood sites, the difference in growth is not so great. On these sites, the greater value of the hardwoods for veneer or sawlogs becomes an important factor; and it may be desirable to favor hardwoods over spruce and fir.

In the final analysis, the forester should work toward creating and maintaining the species composition that best meets the owner's objective within biological and economical limitations.

SILVICULTURAL SYSTEMS

Silvicultural systems for spruce-fir stands lead to either uneven-aged stands or to even-aged stands.

Uneven-aged stands are those in which the trees are of at least three distinct age classes irregularly mixed in the same area (*Society of American Foresters 1950*). Except for very old stands, uneven-aged stands are distinctly irregular in height; and there is great variation in tree size (fig. 2). These stands are developed or maintained by relatively frequent harvests made throughout the rotation. The distribution of diameters in a balanced uneven-aged stand will plot into a characteristically inversed J-shaped curve.

Even-aged stands are those in which the difference between the oldest and the youngest trees does not exceed 10 to 20 years or 25 percent of the length of the rotation. Trees in these stands tend to be rather uniform in height, but they frequently cover a wide range

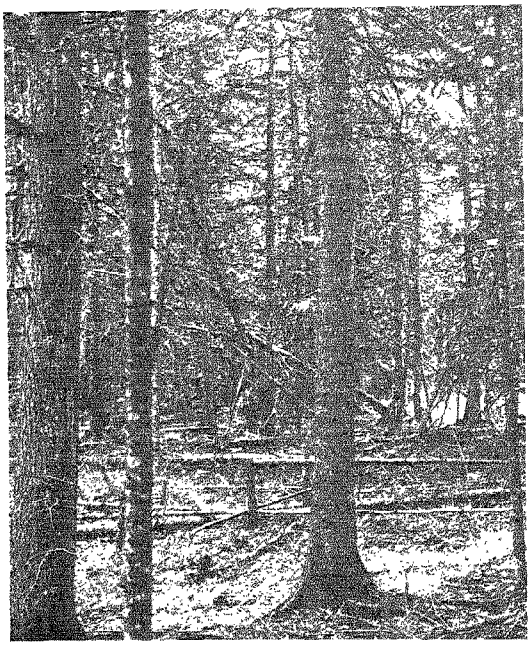


Figure 2.—An unmanaged, uneven-aged spruce-fir stand with a large component of hemlock.

of diameter classes (fig. 3). These stands usually develop after the sudden removal of the previous stands through logging, fire, or other cause. A plotting of diameters will usually result in a curve resembling a bell-shaped form.

It is not always an easy task to decide whether or not a particular stand should be considered uneven-aged or even-aged. This is especially true for types of stands possessing only two age classes. This question is commonly answered when the forest manager considers the kind of management he intends to apply to the forest property. The age of the stand is ignored and its character is developed by the silvicultural method being used in the management of the property.

Uneven-aged Silviculture

The term selection system is applied to any silvicultural program aimed at the creation or maintenance of an uneven-aged stand and includes some form of periodic harvesting.

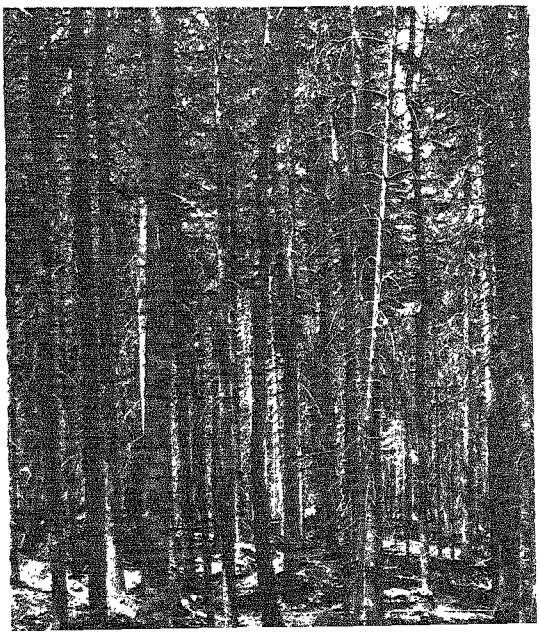
Because spruce and fir are usually able to regenerate and grow under overhead shade, truly uneven-aged stands will develop in areas not drastically disturbed by nature or man. Thus the selection method is well adapted to the management of a spruce-fir stand. The periodic harvests maintain a continuous forest cover, and the retention of spruce seed trees can favor the regeneration of this species. These harvests may also increase the proportion of spruce by removing the shorter-lived balsam fir.

Uneven-aged silviculture has other advantages. The growing space on each acre is more fully utilized in the vertical plane. The environmental conditions are more stable, and the plant and animal populations of the stand are more stable. Fire hazard from slash accumulations is less. In general, there is less chance of losing an entire stand at once through insect attack, infectious disease, or other natural catastrophe. And the area may appear more attractive to the esthetic-conscious public.

However, there are some disadvantages too. Management is more complicated because all operations are conducted in mixtures of different age classes. Harvesting operations are usually more difficult and expensive, and a larger area must be covered to get a given volume. Logging damage to and death of reserved trees is difficult to prevent.

Under ideal uneven-aged silviculture, the mature trees are removed as scattered individuals or small groups at relatively short intervals. The interval is based on growth rate, stand condition, and the size of the desired

Figure 3.—An unmanaged even-aged white spruce-balsam fir flat.



harvest; but in all cases, the eventual goal is a sustained yield of products. Trees should be marked before harvesting. In the initial applications of silvicultural treatments to previously unmanaged stands, the marked trees are usually the undesirable trees that do not meet the quality standards for veneer logs or sawlogs now or prospectively.

The percentage of these undesirable trees diminishes with succeeding harvests. Generally, this is the marking priority: (1) poor-risk trees or those assumed to be doomed before next harvest; (2) poor-quality trees; (3) slow-growing trees; (4) trees of less desirable species; (5) trees whose removal will improve spacing in the reserve stand; and (6) mature trees of good quality, good risk, desirable species, and fast growth. And to make optimum use of growing space, the marking should leave a reasonably even distribution of acceptable trees. These trees are classed as crop trees or potential crop trees and meet product requirements now or are expected to in the future.

Table 3 (appendix) is a suggested tree classification for red spruce and balsam fir that may be used to select trees to be harvested or to be retained. It takes into consideration crown class, vigor, and live-crown ratio and shows the average 10-year diameter growth for trees in each class. Vigor-class definitions are also given in the appendix.

Each periodic operation is a combined harvest, intermediate thinning, and timber-stand improvement because trees in all size classes are included. Therefore there are usually no separate non-commercial thinning operations as in even-aged management, although initial harvest may be unprofitable if a large percentage of defective trees are cut.

When properly employed, the selection method perpetuates a well-stocked stand of the more vigorous, fast-growing, and well-formed trees distributed among all size classes (fig. 4).

Operating Interval

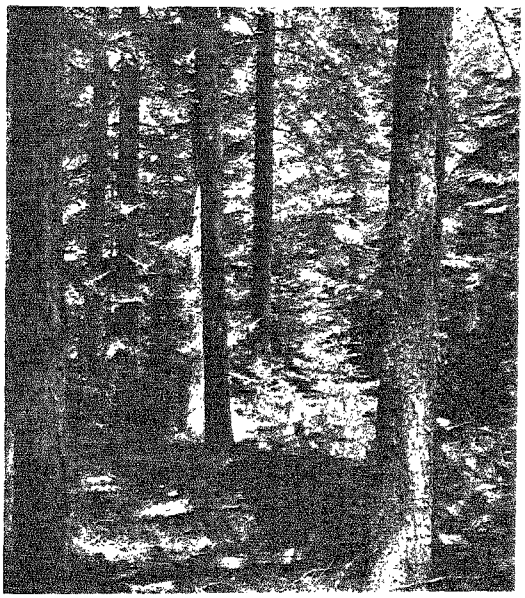
On the better sites and on accessible areas, the operating interval should not exceed 10 to 15 years, especially if the stand runs heavy to balsam fir. On the poorer sites and on less accessible areas, economic considerations may cause the operating interval to be as long as 20 to 25 years, although losses to mortality and defect may be relatively high.

Stocking and Stand Structure

Little research information is available for determining the best stocking and stand-structure goals to work toward in any specific forest situation. Selection of these goals is largely a matter of judgment. Probably there is little difference in growth of stands ranging from less than 75 square feet of basal area to as much as 150 square feet of basal area per acre in trees over 0.5 inches d.b.h. Dense stands heavily thinned to about 50 percent of initial basal area often continue to grow at a rate approximating former growth. Residual trees in these stands usually respond to release and can double and even triple former performance.

Balanced uneven-aged stand structures are presented as tentative goals in table 4 (appendix).

Figure 4.—A well-stocked stand of well-formed trees being perpetuated by the selection method of silviculture.



Growth and Yield

Management practices have the strongest influence on net growth. Any practice that increases the percentage of softwood species will also increase net growth. Spruce and fir make major contributions to net growth in all stand types. Safford (*1968*) found that the average net annual growth that can be expected from stands receiving a minimal silvicultural input is about 50 cubic feet per acre in softwood stands (66 to 100 percent softwood species) and 40 cubic feet per acre in mixed-wood stands (21 to 65 percent softwood species). Table 5 (appendix) shows average net annual growth per acre by individual species.

Net growth during the first 10 years after partial stand removal in primary softwood stands ranged from 47 to 82 cubic feet per acre annually in several experimental areas in northern Maine. However, in primary softwood stands on rather poor sites on the Penobscot Experimental Forest in Maine, where unmanaged stands are being converted to managed stands, 10-year periodic results indicate a net annual growth of only 45 to 56 cubic feet per acre. Similar data for secondary softwood sites are not available.

Trends from experimental data have shown that well-managed stands on reasonably ductive sites can produce nearly twic much merchantable wood as unman stands over the course of a rotation, prim because of the anticipation and salvage of ural mortality.

Even-aged Silviculture

Even-aged silviculture involves a serie intermediate operations followed by regen tion harvests at the end of each rotat There may be a single final harvest as in cl cutting or more than one harvest as in shelterwood method or in the seed- method.

Natural Regeneration Methods

Clearcutting is a good method to apply mature or overmature stands or where par removal would result in considerable dam or mortality to the residual trees. Stands which mechanical harvesters are to be u usually must be either clearcut or subjected a strip clearing operation (fig. 5). If the str are narrow—no wider than half the height the trees being harvested—the method can

Figure 5.—Large machines can operate in relatively narrow strips. Few residuals are left standing within the strip, and damage to edge trees need not occur.

considered a variant of the shelterwood method.

Clearcutting for regeneration requires that all trees down to 1 or 2 inches in diameter are felled. Because of the large volume of wood removed, this method entails the lowest cost for temporary logging improvements per unit of volume. When properly distributed, clearcutting increases the capacity of the forest property to support wildlife by increasing available browse.

However, clearcut land may be left with limited means for regeneration unless advance reproduction is present, a seed source is available, or immediate planting is carried out. A harsh micro-environment can develop, making regeneration difficult. Slash may smother advance reproduction or hinder the establishment of new seedlings. Slash can also increase the fire hazard. However, slash problems on mechanized operations having a high degree of utilization are minimized because the slash is more evenly distributed and piles containing large materials are not accumulated. Esthetically, a clearcut area may present an unattractive appearance to some people until it greens up with a ground cover of herbs, shrubs, and trees. This process usually takes 2 or 3 years but begins the same year as the harvest.

Some of these disadvantages can be minimized by clearcutting in either alternate or progressive strips or in patches. Openings wider than one tree height are suggested for areas where environmental conditions within the openings will not become too severe for successful regeneration. In these areas, the distance that the seeds are disseminated often regulates the width of the opening. For balsam fir and black spruce, openings should be no more than 2.5 to 3.0 chains wide; and for red spruce and white spruce, they should be no more than 6.0 chains wide.

On hot dry sites and on areas subjected to excessive wind damage, narrow strips or small patches of a width not exceeding half the height of the trees being harvested are necessary to obtain maximum shelter from the residual stand. This procedure should improve seedling survival by providing more moderate surface temperatures and higher soil moisture.

After the initial openings in the stand are regenerated, adjacent areas can be cleared. The second operation will normally take place 3 to 10 years after the first operation. Uncut residual strips or patches should be at least 1 chain wide and preferably wider to help insure windfirmness in the residual trees.

Another desirable procedure for obtaining natural regeneration is the shelterwood system. In this method, at least two harvests are made. The first harvest, made to establish reproduction, should be made in a good seed year. About one-third to one-half of the basal area of the stand should be removed at this time, and the cut should be uniformly distributed. Harvests greater than this might leave the stand susceptible to wind damage. This harvest should remove the least desirable trees, leaving the larger and more vigorous trees of desirable species to provide seed. Factors to consider in tree selection are: susceptibility to wind damage; reduction of seed sources of less desirable species; and the spacing, vigor, and quality of the reserve stand. When the regeneration is well established, the remainder of the original stand can be harvested in one or more operations (fig. 6).

Figure 6.—Shelterwood system being employed in a spruce-fir stand. When the area has regenerated, the residual trees will be harvested.

Because the spruces and fir are shallow-rooted species, the seed-tree method of regeneration is not recommended because of potential wind damage.

Artificial Regeneration

In areas where natural regeneration is inadequate or unlikely to develop in a reasonable length of time, it may be necessary to resort to direct seeding or planting. Spruce is presently recommended over fir.

Artificial regeneration should be limited to areas where the environmental conditions are satisfactory for seed germination and seedling survival. Only the best seed or planting stock should be used. And when genetically improved stock is available, it should be used. This possibility in itself is a major advantage of clearcutting followed by planting.

When either seeding or planting are planned, the need for site preparation must be considered. Seeding on scarified seedbeds and planting on sites free of vegetative competition will allow new seedlings to survive and grow more rapidly. This is important because they will then be better able to compete with any natural regeneration that might develop.

Site Preparation

Generally the spruces and fir regenerate best on a mineral-soil seedbed because of more favorable temperature and moisture conditions. However, relatively little mineral soil is exposed during a harvesting operation, except in the skidroads. Logging operations conducted in the summer will, in some instances, expose more mineral soil than those done in the winter. Thus, in some situations, supplemental measures may be needed if seedbeds favorable for spruce-fir regeneration are to be provided.

Scarification should be only deep enough to mix the top 2 or 3 inches of mineral soil with the humus. A seedbed such as this not only will improve germination, but also will favor more rapid growth.

Some site-preparation work may also be needed before planting. Heavy accumulations of slash in clearcut areas may make the use of mechanized planting equipment impossible and hand-planting slow and laborious. Cleaning the planting site of slash may be necessary. Several methods of treating slash are possible, ranging from crushing and chipping to removal from the site altogether.

In areas where seeding or planting of spruce or fir is planned, silvicides may be used to eliminate hardwood competition.

Intermediate Operations

A requirement of even-aged silviculture is the conduct of intermediate operations during the development of the stand. These include cleanings, thinnings, and intermediate harvests. Unlike stands being managed under the principles of uneven-aged silviculture, where each periodic operation can be a combination of timber-stand improvements as well as a harvest, even-aged silviculture often requires distinct and separate operations. And each intermediate operation is necessary if the full potential of the site is to be realized.

CLEANINGS

Cleaning is done in young stands not past the sapling stage. The objective is to free potential crop trees from other individuals of less desirable species or form that overtop or are likely to overtop the potential crop trees. This is also the time to rid the stand of unwanted holdovers from the previous stand.

Cleaning is the silvicultural tool that not only reduces the length of the rotation, but it is also the first attempt after the establishment of a new stand to alter species composition. Growth of merchantable trees is increased and wind-damage risk is reduced because of better development of crown and roots.

The need for cleaning in young spruce-fir stands depends on the intensity of competition. This in turn depends on site. On the primary softwood sites—poorly drained and shallow soils—spruce and fir are usually predominant and suffer little competition from hardwoods. Here, cleaning is usually not needed unless thickets have developed or if spruce is to be favored over fir and other softwoods.

On secondary softwood sites—deeper and

better drained soils—hardwoods are more aggressive. Much effort is required to bring the spruce and fir through this competition. A management decision must be made about whether to fight these hardwoods or to include them in the next timber crop. The landowner's objective, the relative value of the species involved, and the cost of cleaning operations are factors that enter into this decision. A single cleaning about 8 years after final harvest or when average height is 10 to 12 feet is usually enough to insure softwood dominance and improve individual tree growth, but occasionally follow-up treatments will be needed. Crop-tree spacing should be between 5 and 7 feet. Use the growing-stock guide for sapling stands to estimate the number of crop trees to release.

Current height growth of the spruce-fir is a good indicator of the need for cleaning. As long as terminal growth is greater than 6 inches annually, cleaning is not urgently needed (*Westveld 1953*).

Where spruce and fir are desired and hardwoods are not, spraying with an approved selective silvicide is suggested. This should be done after current spruce-fir growth has hardened off and winter buds have developed, but when the leaves on the hardwoods are still functioning.

Where both softwoods and hardwoods are desired, broadcast spraying of silvicides cannot be used. Treatment of individual stems, either by cutting or by application of approved chemicals, will be necessary to accomplish the cleaning job. Cleaning operations may take from 2 to 8 man-hours per acre, depending on the age of the stand, its composition, and its density.

Stand improvement with the use of mechanized equipment has been tried in other timber types with some success (*Dosen et al. 1958, Lotan 1967, Tackle and Shearer 1959*). The limited experience to date suggests that such an operation is best done in stands with trees between 10 and 20 feet tall. If the minimum width of strips cleared in this way is at least equal to the tree height, then a satisfactory growth response may follow in spruce-fir stands. However, because the techniques are not yet fully developed, specific recommendations cannot be made.

THINNINGS AND INTERMEDIATE HARVESTS

Thinning shortens the time it takes to bring trees to rotation size and also salvages a portion of trees that otherwise would be lost through mortality. Thinning begins with the selection of crop trees or potential crop trees to be carried through to maturity. These trees should be of the most desirable species and of the highest quality. They should be evenly distributed through the stand.

With even-aged management, stands will probably need an initial thinning at 25 to 35 years of age, followed by periodic thinnings or intermediate harvests at 10- to 20-year intervals. When planning these operations, use the B-level in the growing-stock guide (fig. 7)—depending on mean stand diameter—to determine the minimum reserved stocking.

Stands with a high proportion of fir should be thinned first. Those having a high proportion of spruce can be delayed unless competition is severe. The first thinning may be a pre-commercial one, but succeeding thinnings should yield commercial harvests (at least 5 cords per acre). Remove fir and retain spruce if the quality of fir is below that of the spruce or if spruce is being favored over fir. In stands containing hemlock, favor hemlock over fir if the quality of the fir is poor.

Timber removals for thinnings or for intermediate harvests on primary softwood sites should not exceed 10 to 40 percent of the total basal area. For secondary softwood sites, 30 to 50 percent may be removed at any one time. Removals in excess of these amounts may result in substantial wind damage. Amounts to remove vary with conditions of the site. These percentages should take precedent over removals specified by the B-level in the growing-stock guide.

Growth responses to thinning in white spruce trees approaching maturity are significant when trees are released on at least three sides to a distance equal to crown diameter of the tree being released (*Frank 1973*). Similar thinning regimes are recommended at this time for other spruce and for fir.

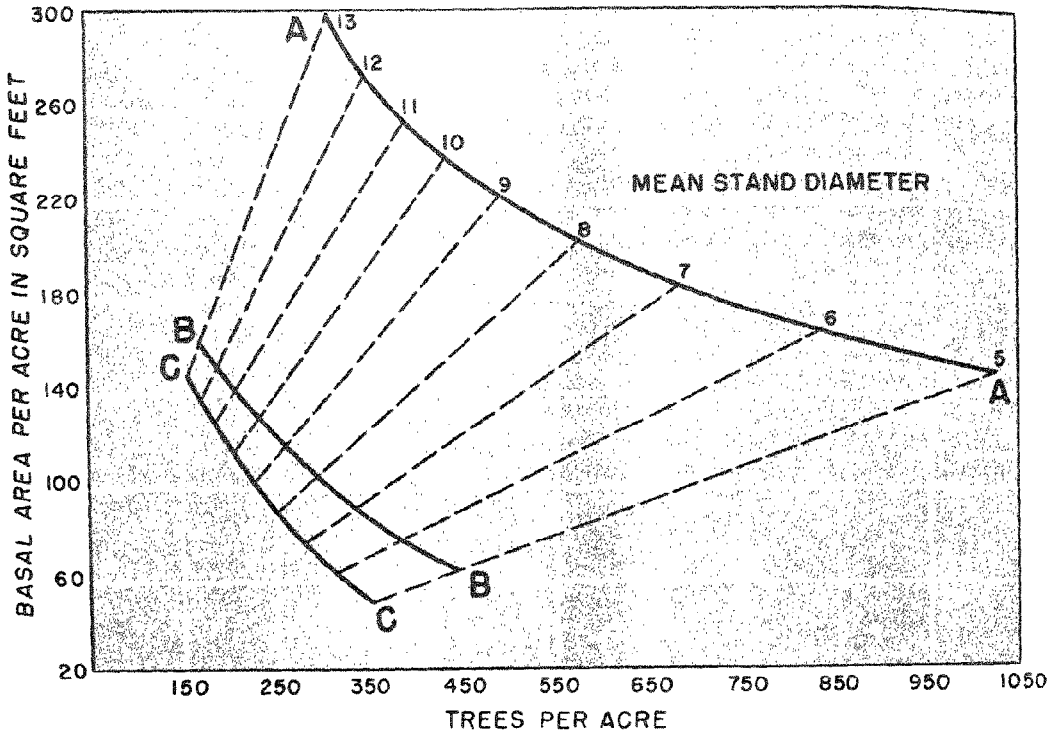


Figure 7.—Growing-stock guide for even-aged spruce-fir, based on the number of trees in the main canopy, average diameter, and basal area per acre. The area above the A-level represents overstocked stand conditions. Stands between the A- and B-levels are adequately stocked. Stands between the B-and C-levels should be adequately stocked within 10 years or less. Stands below the C-level are understocked.

Growing-Stock Guides

Growing-stock guides for even-aged spruce-fir stands with a mean stand diameter of at least 5 inches are given in figure 7. They apply to the trees in the main crown canopy and include the intermediate to dominant trees.

These guides are based on the number of trees per acre, the basal area per acre, and the mean diameter of the stand. The B-level represents minimum growing stock for adequate growth. The C-level represents the point where 10 years of growth will raise the stand to the B-level. The A-level represents an unmanaged stand on an average site. Stands above the A-level are overstocked; those between the A-level and B-level are adequately stocked; those between the B-level and C-level are potentially adequately stocked; and those below the C-level are understocked.

For unmanaged even-aged sapling stands, average numbers of acceptable stems of growing stock required to produce at least a B-level stocking of crop trees are (*Westveld 1941*):

Mean stand diameter (inches)	*Acceptable stems per acre (number)*
1	1,660
2	1,345
3	1,075
4	850

Yields

Cubic foot yields per acre from fully-stocked, even-aged stands of second-growth

red spruce in the Northeast are given in table 1 (*Meyer 1929*). Because the yield relationship between sites and for stands within sites is not distinct, there is an overlapping of various sites and stand types for specific yield values. The yield values in table 1 are given for four combinations of sites and stand types. These yields are from so-called normal unmanaged stands. Yields from stands under a management scheme including periodic harvests or thinnings would be substantially higher over a rotation.

In general, stands fully stocked to spruce-fir on secondary softwood sites will yield greater volumes of wood than will similar stands on primary softwood sites.

SILVICULTURAL PRESCRIPTIONS

Stand Diagnosis

Before silvicultural prescriptions can be written for a stand, the management objective must be decided upon, and the stand must be described.

The limits of the stand to be considered and treated as separate entities must be delineated. The area included should be small enough to have reasonably similar stand and site conditions throughout, yet large enough to permit efficient harvesting.

Once the boundaries are known, then the stand diagnosis can be made.

Reproduction Stands

These stands are made up of stems at least 6 inches tall, but the mean stand diameter is less than 0.5 inches. Stems may be of seedling or sprout origin.

Percentage of stocking is needed for diagnosis. To determine the percentage of stocking in stands 10 acres and larger, locate randomly or systematically at least one milacre plot (3.72 feet in radius or 6.6 feet square) per acre. In stands smaller than 10 acres, locate a minimum of 10 milacre plots.

Tally each of these sample plots in one or more of the following stocking classes:

Stocking class 1.—Stocked with at least two spruce or fir trees.

Stocking class 2.—Stocked with at least one spruce or one fir and one other commercial species or stocked with at least two other commercial species.

Stocking class 3.—Not stocked.

In a reproduction stand, a stocked plot is one in which there is a minimum of two stems. For a plot to be tallied in stocking class 1, both stems must be spruce-fir, otherwise the tally will be in stocking class 2. A plot will be tallied as stocking class 3 if the above requirements are not met.

To determine the percentage of stocking, divide the number of plots in each stocking class by the total number of milacre plots and multiply by 100. A tally sheet for recording this information is given as figure 8 (appendix).

Table 1.—Cubic-foot yield per acre of fully stocked, even-aged stands of second-growth red spruce[a] in the Northeast by stand age, site, and stand type

Age (years)	Secondary softwood site (lower slopes, old farmland)	Primary softwood site (flats, old farmland); and secondary softwood site (lower slopes, old farmland)	Primary softwood site (swamps, flats, upper slopes, old farmland); and secondary softwood site (lower slopes)	Primary softwood site (swamps, upper slopes)
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
40	1,650	1,110	600	138
50	3,770	2,760	1,670	480
60	5,550	4,200	2,750	940
70	6,620	5,150	3,470	1,400
80	7,280	5,700	3,920	1,670
90	7,650	6,000	4,160	1,800
100	7,870	6,190	4,310	1,900

[a] Based on the merchantable cubic-foot volume in trees in the 4-inch and larger diameter classes from a 1-foot stump to a top of 3 inches inside bark.

Sapling Stands

A sapling stand is one in which the mean stand diameter is between 0.5 and 4.5 inches. To diagnose these stands, determine the mean d.b.h. of the trees in the main crown canopy for spruce, fir, and all other commercial tree species. This can be estimated or based on a few measurements. Number of milacre plots per acre is similar to those required for reproduction stands.

In sapling stands, a stocked plot is one in which at least one of the diameter classes listed below has the indicated number of potential crop trees of spruce-fir (stocking class 1) or other commercial species (stocking class 2).

Diameter class (inches)	*Acceptable stems per plot (number)*
0.5 to 1.4	2
1.5 to 2.4	1
2.5 to 3.4	1
3.5 to 4.4	1

A plot with only a single 1-inch spruce or fir but with a 1-inch tree of some other species will be tallied in stocking class 2. A plot not meeting any of these requirements will be classed as not stocked (stocking class 3).

To determine the percentage of stocking, divide the number of plots in each stocking class by the total number of milacre plots and multiply by 100. Use the tally sheet (fig. 8) for recording this information.

Poletimber and Sawtimber Stands

These are stands with average diameters of 4.5 inches and larger. To diagnose these stands, you need to know the number of trees per acre and the basal area per acre. For even-aged stands, you also need to know the mean diameter of the stand.

First, classify the stand as even-aged or uneven-aged and as whether it occurs on a primary or secondary softwood site. Indicate if even-aged or uneven-aged management is planned. Use the tally sheet (fig. 9, appendix) for recording these data.

Then in stands 10 acres and larger, locate randomly or systematically at least one sample point per acre. In stands smaller than 10 acres, locate a minimum of 10 sample points. Use a prism or an angle gauge at each point to determine the trees of commercial species to be measured and recorded. A 10-factor instrument is recommended. Distances to borderline trees should be measured. A listing of distanes for instruments having a factor of 10 is in table 6 (appendix).

When all sample points have been measured, compute the number of trees per acre.

To determine the number of trees per acre by diameter classes, divide the tree count in each diameter class by the total number of sampling points and then multiply by the conversion factor on the tally sheet.

EVEN-AGED MANAGEMENT

Determine whether the stand is mature or immature and record these data on the tally form (fig. 9, appendix). In a mature even-aged stand, more than 50 percent of the total basal area is in trees of the size being managed for, in fir trees that have reached pathological rotation, or in a combination of both. In an immature stand less than 50 percent of the basal area is in trees of this kind. Visual observation can be used for this determination. Otherwise, use data from sample points supplemented with increment borings from fir for determination of age.

For even-aged management, the tree count should include only those intermediate to dominant trees that make up the main crown canopy.

Basal area per acre is found by dividing the total tree count by the total number of sampling points and multiplying by the prism or gauge factor.

The mean d.b.h. of an even-aged stand can be estimated from the growing-stock guide (fig. 7), using the basal area per acre and the number of trees per acre.

In addition, in mature stands only, estimate the stocking of reproduction and sapling stems. To do this, use the sample point as the center of a milacre plot and record whether these plots are stocked with spruce-fir, stocked with other commercial species, or not stocked. Use the tally form (fig. 9, appendix) for recording these data.

If an estimate of volume is desired, apply an

appropriate local volume table to the number of trees per acre by species and diameter class as shown on the tally sheet.

Next, complete the stand-diagnosis form (fig. 10, appendix). Then refer to the key to find the suggested prescription.

UNEVEN-AGED MANAGEMENT

Tally all trees in the 1-inch and larger diameter classes. If uneven-aged stands are being converted to even-aged strands, an estimate of reproduction and sapling stems is also required. Use the tally form (fig. 9) for recording these data.

Next, transfer the number of trees per acre by diameter classes from the tally sheet (fig. 9) to the stand-diagnosis form (fig. 11, appendix). Determine basal area per acre by diameter class and enter in the stand-diagnosis form. Also enter the data from the proper columns in table 4 for the operating interval desired. Be sure to use the data for the appropriate management objective.

Finally, use the following key to find the suggested prescription. For prescriptions 7, 8, 9, and 10, the differences by d.b.h. class that are excess may be harvested or removed in a timber-stand-improvement operation. But the total amount removed should not exceed the total differences between the stand estimate of basal area and the goal. Nor should the amount removed result in a stand susceptible to excessive wind damage.

THE KEY

I. Reproduction and Sapling Stands

Mean Stand Diameter Less Than 4.5 Inches

Stand Condition	*Prescription*
A. Mean stand diameter less than 0.5 inches	
B. Primary softwood site	
C. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	1
CC. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction	2
BB. Secondary softwood site	
D. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	3
DD. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction but total stocking is 50 percent or more	4
DDD. Total stocking of reproduction is less than 50 percent	2
AA. Mean stand diameter between 0.5 and 4.5 inches	
E. Primary softwood site	
F. 50 percent or more of milacre sample plots are stocked with spruce-fir saplings	5
FF. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir saplings	2
EE. Secondary softwood site	

Stand Condition	*Prescription*
G. 50 percent or more of milacre sample plots are stocked with spruce-fir saplings	6
GG. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir saplings but total stocking is 50 percent or more	4
GGG. Total stocking of saplings is less than 50 percent	2

II. Poletimber and Sawtimber Stands

Mean Stand Diameter 4.5 Inches and Larger

A. Uneven-aged stand	
B. For maintaining uneven-aged stand condition	
C. Primary softwood site	
D. Commercial harvest feasible of at least 5 cords per acre	7
DD. Commercial harvest not feasible	8
CC. Secondary softwood site	
E. Commercial harvest feasible of at least 5 cords per acre	
F. Spruce-fir represents at least 50 percent of total basal area	7
FF. Hardwoods represent more than 50 percent of total basal area	9
FFF. Spruce-fir and hardwoods each representing less than 50 percent of total basal area and other softwoods (principally hemlock) accounting for remainder	7
EE. Commercial harvest not feasible	
G. Spruce-fir represents at least 50 percent of total basal area	8
GG. Hardwoods represent more than 50 percent of total basal area	10
GGG. Spruce-fir and hardwoods each representing less than 50 percent of total basal area and other softwoods (principally hemlock) accounting for the remainder	8
BB. For converting to even-aged stand condition	
H. Primary softwood site	

Stand Condition	*Prescription*
I. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
II. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction	12
HH. Secondary softwood site	
J. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
JJ. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction but total stocking is 50 percent or more	13
JJJ. Total stocking of reproduction is less than 50 percent	12
AA. Even-aged stand	
K. For maintaining even-aged stand condition	
L. Primary softwood site	
M. Mature stand	
N. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
NN. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction	
O. Growing stock above the B-level	12
OO. Growing stock below the B-level	14
MM. Immature stand	
P. Growing stock above the B-level	15
PP. Growing stock below the B-level	16
LL. Secondary softwood site	
Q. Mature stand	
R. 50 percent or more of milacre sample plots are stocked with spruce-fir reproduction	11
RR. Fewer than 50 percent of milacre sample plots are stocked with spruce-fir reproduction but total stocking may be 50 percent or more	
S. Growing stock above the B-level	13
SS. Growing stock below the B-level	17

Stand Condition	*Prescription*
QQ. Immature stand	
T. Spruce-fir represents at least 50 percent of total basal area	
U. Growing stock above the B-level	15
UU. Growing stock below the B-level	16
TT. Hardwoods represent more than 50 percent of total basal area	
V. Growing stock above the B-level	18
VV. Growing stock below the B-level	19
KK. For converting to uneven-aged stand condition	
W. All stands	20

The Prescriptions

1. This stand should develop naturally into a spruce-fir stand. Consider eliminating competing vegetation, including hardwoods. Otherwise do nothing now. Examine in 5 years.
2. This stand may not develop within 5 years into a stand satisfactorily stocked with spruce-fir reproduction or saplings. Consider preparing the site and direct-seed or plant spruce and fir on those areas not stocked with spruce-fir, but only if the non-stocked areas have potential for spruce-fir. Otherwise do nothing now. In either case, examine in about 5 years.
3. Begin a cleaning operation to eliminate the competing vegetation, including hardwoods, if the management decision is to favor spruce-fir. If the spruce-fir is in competition with other softwoods, do nothing now. If the decision is to manage for all species, begin a cleaning operation to favor potential crop trees of any species. In all cases, examine in 5 years.
4. This stand may not develop within 5 years into a stand satisfactorily stocked with spruce-fir reproduction or saplings. If the management decision is to regenerate spruce-fir, prepare the site and direct-seed or plant spruce or fir on areas not stocked with spruce-fir reproduction, but only if the non-stocked areas have potential for spruce-fir. If the decision is to manage for all species, begin a cleaning operation to favor potential crop trees of any species. In either case, examine in about 5 years. If northern hardwoods account for a stocking of more than 50 percent, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.
5. This stand should naturally develop into a spruce-fir stand. If competition from other species appears to be slowing stand development or if a spruce-fir thicket is developing or has developed, begin a cleaning operation. Use growing-stock guide for number of acceptable stems per acre. Examine in 5 years.
6. Begin a cleaning operation to eliminate the competing species if the management decision is to favor spruce-fir. If the decision is to manage for all species, begin a cleaning operation to favor potential crop trees of any species. Use growing-stock guide for number of acceptable stems per acre. In either case, examine in 5 years.
7. Use the stand-diagnosis form (see fig. 11, appendix) to determine if any of the diameter classes are overstocked. Mark heavier in these classes, keeping spacing in mind, and using the marking guides and table 3, appendix. If practical, the

commercial harvest should be conducted in a good spruce or fir seed year. The seed crop can take advantage of the opening of the stand and of any seedbed scarification that has occurred. Depending on site, the harvest should not remove more than 10 to 50 percent of the total basal area per acre; and at least 80 to 120 square feet of basal area per acre should be retained. If this minimum amount of residual growing stock is not possible because of poor quality, consider converting to even-aged silviculture. Examine again at the end of the operating interval.

8. Consider timber-stand improvement to favor crop trees of desired species. Examine in about 10 years.
9. If the management decision is to favor spruce-fir and the spruce-fir growing-stock component is adequate for management, use the stand-diagnosis form (fig. 11, appendix) to determine what diameter classes are overstocked. Mark heavier in these classes and keep spacing in mind, using the marking guides and table 3, appendix. Examine in about 10 years. If the spruce-fir growing stock component is not considered adequate, convert to even-aged silviculture. If the decision is to manage for all species, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.
10. If the management decision is to favor spruce-fir, begin a timber-stand-improvement operation to favor crop trees of desired species and to remove undesirable trees. Examine in about 10 years. If the spruce-fir component is not considered adequate, convert to even-aged silviculture. If the decision is to manage for all species, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.
11. Harvest all merchantable trees and fell all other trees 1 to 2 inches and larger in diameter. The size and shape of the clearings selected should provide environmental conditions suitable for natural regeneration. Examine in about 5 years.
12. To obtain spruce-fir regeneration, apply the first harvest of a shelterwood cutting or clearcut narrow strips. If artificial regeneration is necessary, clearcut and prepare the site; and direct-seed or plant spruce or fir on those areas not stocked with spruce-fir. In either case, examine in about 5 years.
13. If the management decision is to regenerate spruce-fir, remove a portion of the trees by applying the first harvest of a shelterwood cutting or clearcut narrow strips. Consider preparing the site, and direct-seed or plant spruce or fir on areas not stocked with spruce-fir reproduction. Hardwood sprouts may have to be controlled. Examine in about 5 years. If the decision is to manage for all species, harvest all merchantable trees and fell all other trees 1 to 2 inches and larger in diameter. The size and shape of the clearings selected should provide environmental conditions suitable for natural regeneration. Examine in about 5 years. If hardwoods account for 50 percent or more of the stocking in reproduction, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.
14. To obtain spruce-fir regeneration in a reasonable period of time, artificial methods are probably necessary. Clearcut, then prepare the site and direct-seed or plant spruce or fir on areas not stocked with spruce-fir. Examine in about 5 years.
15. Begin a periodic harvest program if a commercial harvest is feasible. Otherwise consider a timber-stand-improvement operation. Examine in about 10 years or at the next operating interval.
16. Consider a timber-stand-improvement operation. Otherwise do nothing now. Examine in about 10 years. If growing stock is below the C-level, consider preparing the site; and direct-seed or plant spruce or fir on areas not stocked with spruce-fir. Examine in about 5 years.
17. If the management decision is to regenerate spruce-fir, harvest all merchantable trees and fell all other trees 1 to 2 inches and larger in diameter. Then prepare the

site and direct-seed or plant spruce or fir on areas not stocked with spruce-fir reproduction. Examine in about 5 years. If the decision is to manage for all species, harvest all merchantable trees and fell all other trees 1 to 2 inches and larger in diameter. Examine in about 5 years. If hardwoods account for 50 percent or more of the stocking in reproduction, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.

18. If the management decision is to favor spruce-fir, begin a periodic harvest program if a commercial harvest is feasible. Otherwise consider a timber-stand-improvement operation. In either case, examine in about 10 years. If the decision is to manage for all species, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.
19. Conduct a timber-stand-improvement operation if the mangement decision is to favor spruce-fir. Examine in about 10 years. If growing stock is below the C-level, consider preparing the site and direct-seed or plant spruce or fir on areas not stocked with spruce-fir. Examine in about 5 years. If the decision is to manage for all species, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.
20. Make a series of partial harvests or conduct timber-stand-improvement operations at intervals not exceeding 5 to 10 years. These cuttings should remove small groups of several trees scattered through the stand to stimulate regeneration. The trees to be removed should be marked. The objective is to develop a diameter distribution that will plot as an inversed J-shaped curve. Consider preparing the site and direct-seed or plant spruce or fir on areas not stocked with spruce-fir. If hardwoods represent more than 50 percent of the basal area and the decision is to manage for all species, see the Silvicultural Guide for Northern Hardwoods in the Northeast or for Paper Birch in the Northeast.

LITERATURE CITED

Baker, Frederick S.
1929. Effect of excessively high temperatures on coniferous reproduction. J. Forest. 27: 949-975.

Basham, J. T., P. V. Mook, and A. G. Davidson.
1953. New information concerning balsam fir decays in Eastern North America. Can. J. Bot. 31: 334-360.

Dosen, R. C., J. H. Stoeckeler, and F. G. Kilp.
1958. Mechanized thinning in jack pine saplings. J. Forest. 55: 201-204.

Fowells, H. A.
1965. Silvics of forest trees of the United States. U. S. Dep. Agr., Agr. Handbk. 271. 761 p.

Frank, Robert M.
1973. The course of growth response in released white spruce—10-year results. USDA Forest Serv. Res. Pap. NE-258. 6 p.

Leak, William B., Dale S. Solomon, and Stanley M. Filip.
1969. A silvicultural guide for northern hardwoods in the Northeast. USDA Forest Serv. Res. Pap. NE-143. 34 p.

Lotan, James E.
1967. Eleven-year results of strip-thinning by bulldozer in thirty-year-old lodgepole pine. USDA Forest Serv. Res. Note INT-69. 6 p.

Marquis, David A., Dale S. Solomon, and John C. Bjorkbom.
1969. A silvicultural guide for paper birch in the Northeast. USDA Forest Serv. Res. Pap. NE-130. 47 p.

Meyer, Walter H.
1929. Yields of second-growth spruce and fir in the Northeast. U. S. Dep. Agr. Tech. Bull. 142. 52 p.

Safford, Lawrence O.
1968. Ten-year average growth rates in the spruce-fir region of Northern New England. USDA Forest Serv. Res. Pap. NE-93. 20 p.

Shirley, Hardy L.
1943. Is tolerance the capacity to endure shade? J. Forest. 41: 339-345.

Society of American Foresters.
1950. Forestry terminology. Soc. Amer. Forest., Washington. D. C. 93 p.

Tackle, David, and Raymond C. Shearer.
1959. Strip-thinning by bulldozer in a young lodgepole pine stand. Mont. Acad. Sci. Proc. 19: 142-148.

Vezina, P. E., and G. Y. Peck.
1964. Solar radiation beneath conifer canopies in relation to crown closure. Forest Sci. 10(4): 443-451.

Westveld, Marinus.
1941. Yield tables for cut-over spruce-fir stands in the Northeast. USDA Forest Serv. NE. Forest Exp. Sta., Occas. Pap. 12. 18 p.

Westveld, Marinus.
1953. Empirical yield tables for spruce-fir cut-over lands in the Northeast. USDA Forest Serv. NE. Forest Exp. Sta., Sta. Pap. 55. 64 p.

Westveld, Marinus.
1953. Ecology and silviculture of the spruce-fir forests of Eastern North America. J. Forest. 51: 422-430.

APPENDIX

Vigor Class Definitions*

gor I

Crown well developed, usually symmetrical; no ead branches in live crown. *Branches* long and ender, up-turned at least 15 degrees from hori- ntal except near bottom of crown; recent ter- inal and lateral growth good (at least 8 inches id averaging 10-12 inches except in heavy seed ear). *Needles* long and lustrous, bluish-green for and slightly yellowish-green for spruce, grow- g densely on twigs; and on fir up-turned instead flat on twigs. *Bark* on fir light gray, tight, nooth, and shiny, with many pitch blisters; on ruce, reddish and shredded on young trees, in rge, thin, loose plates on mature trees.

igor II

Crown of poorer form than in Vigor I but giving ie general impression of being healthy without aking rapid growth; if large, crown may be fairly pen, but if small, should be fairly dense; dead ranches in crown limited to a few small ones. *ranches* may be shorter and less slender than in igor I but not stubby and heavy; horizontal or ightly drooping except may be slightly up-turned ear top; terminal and lateral twig growth last few ears usually fair to good (3 to 8 inches, except omewhat less during heavy seed years) although low growth is admissible if crown form is other- ise good. *Needles* flattened on fir twigs and a eeper green with less bluish cast and not so dense n twigs as in Vigor I; spruce needles shorter, less lustrous and not so closely spaced on twigs. *Bark* on fir usually smooth, dirty gray, not shiny, pitch blisters less conspicuous; on spruce, rougher and more brownish on young trees, darker brown and with plates smaller and tighter than on Vigor I trees.

Vigor III

Crown of poor form (open, one-sided or thin), but not dying; may have dead branches in live crown. Branches may be short and stout, or if slender, foliage very sparse, horizontal or more commonly drooping, especially at tips; terminal and lateral growth very poor (less than 3 inches), except may occasionally be fair on trees with otherwise poorly developed crowns. *Needles* flat on fir twigs, widely spaced, often dull, unhealthy color; on spruce, short, not lustrous, and frequently yellowish, very slender and brittle, and appearing sparse or scattered on twigs. *Bark* on fir dark gray or almost brown, thick, rough and often broken into small scales on old trees, dirty dull gray on young trees, never smooth and shiny, pitch blisters inconspicuous or lacking; on spruce, dark brown to almost black, with scales smaller and heavier on young trees, thick, ridged, and fissured, and often reddish brown on old trees.

* McLintock, T. F. 1958. A tree classification for red spruce and balsam fir. U. S. Forest Service NE. Forest Exp. Sta. office report, 33 p.

Table 2.—Some silvical characteristics of balsam fir and the spruces

Species	Relative shade tolerance	Relative growth rate	Good cone crop frequency	Effective seed dispersal
			Years	*Feet*
Balsam fir	Very tolerant	Fast	2-4	100
Black spruce	Tolerant	Slow-medium	4	100
White spruce	Tolerant	Fast	2-6	300
Red spruce	Tolerant to very tolerant	Medium	3-8	200

Table 3.—Tree classification for red spruce and balsam fir*

Tree class	Rating as growing stock	Vigor	Crown class	Crown ratio	Average 10-year diameter growth
			RED SPRUCE		
					Inches
A	Superior	I	Dominant & intermediate	0.6+	1.8
B	Good	I	Dominant & intermediate	.3-.5	1.3
C	Acceptable	II	Overtopped	0.6+	
			Intermediate	0.6+	.9
			Dominant	0.3+	
D	Inferior	II	Intermediate	.3-.5	.6
		III	Dominant	0.3+	
E	Undesirable	III	Intermediate	0.3+	.2
			All other trees with a crown ratio of under .3		
			BALSAM FIR		
A	Superior	I	All classes	0.7+	2.4
B	Good	I	All classes	.5-.6	1.8
		II	All classes	0.7+	
C	Acceptable	I	All classes	.3-.4	1.2
		II	All classes	.3-.6	
D	Inferior	III	Dominant & intermediate	0.5+	.8
E	Undesirable	III	Overtopped	0.5+	.4
			All other trees with a crown ratio of under .3		

* McLintock, T. F. 1958. A tree classification for red spruce and balsam fir. USDA Forest Serv. NE. Forest Exp. Sta. office report. 33 p.

Table 4.—Stocking goals for uneven-aged stands at the start of 5-, 10-, and 20-year operating intervals, by management objective, number of trees per acre, and basal area per acre

D.b.h. class (inches)	Management objective 1: Pulpwood product; Operating interval						Management objectives 2, 3, and 4: Multiple product; Operating interval					
	5-year		10-year		20-year		5-year		10-year		20-year	
	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area
	No.	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*	*No.*	*Sq. ft.*
1	514	3	459	2	370	2	173	1	153	1	122	1
2	343	8	306	7	246	5	135	3	118	3	96	2
3	229	11	204	10	164	8	104	5	92	5	74	4
4	152	13	136	12	110	10	80	7	70	6	57	5
5	102	14	91	12	73	10	61	8	54	7	44	6
6	68	13	60	12	49	10	47	9	41	8	33	7
7	45	12	40	11	32	9	36	10	32	9	26	7
8	30	10	27	9	22	8	28	10	25	9	20	7
9	20	9	18	8	14	6	21	9	19	8	16	7
10	13	7	12	7	10	5	16	9	14	7	12	6
11	9	6	8	5	6	4	13	8	11	7	9	6
12	6	5	5	4	4	3	10	8	9	7	7	6
13	4	4	4	3	—	—	7	7	6	6	5	5
14	3	3	2	3	—	—	6	6	5	6	4	4
15	2	2	—	—	—	—	4	5	4	5	3	4
16	—	—	—	—	—	—	3	5	3	4	2	3
17	—	—	—	—	—	—	3	4	2	4	—	—
18	—	—	—	—	—	—	2	3	2	3	—	—
19	—	—	—	—	—	—	1	3	—	—	—	—
Total	1,540	120	1,372	105	1,100	80	750	120	660	105	530	80

Table 5.—Average annual net growth per acre by species

Species	Softwood stands		Mixedwood stands	
	Cu. ft.	*Pct.*	*Cu. ft.*	*Pct.*
Pine	1.5	3	0.2	1
Spruce	25.0	51	15.8	39
Balsam fir	17.1	35	31.1	32
Hemlock	2.3	5	4.3	10
Cedar	2.0	4	2.0	5
Tamarack	.1	([a])	([b])	([a])
All softwoods	48.0	98	35.5	87
Sugar maple	([b])	([a])	0.8	2
Red maple	1.5	3	3.7	9
Yellow birch	−.8	−2	−.1	([a])
Paper birch	.4	1	1.0	2
Beech	.1	([a])	.1	([a])
Aspen	.1	([a])	.2	([a])
Other hardwoods	([b])	([a])	−.1	([a])
All hardwoods	1.3	2	5.6	13
All species	49.3	100	41.1	100

[a] Less than 0.5 percent.
[b] Less than 0.05 cubic feet.

Table 6.—Horizontal distances to borderline trees when using a 10-factor prism or angle gauge for trees 0.5 inches d.b.h. to 19.4 inches d.b.h.

D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)	D.b.h. (inches)	Distance (feet)
0.5	1.37	4.3	11.82	8.1	22.27	11.9	32.72	15.7	43.17
0.6	1.65	4.4	12.10	8.2	22.55	12.0	33.00	15.8	43.45
0.7	1.92	4.5	12.37	8.3	22.82	12.1	33.27	15.9	43.72
0.8	2.20	4.6	12.65	8.4	23.10	12.2	33.55	16.0	44.00
0.9	2.47	4.7	12.92	8.5	23.37	12.3	33.82	16.1	44.27
1.0	2.75	4.8	13.20	8.6	23.65	12.4	34.10	16.2	44.55
1.1	3.02	4.9	13.47	8.7	23.92	12.5	34.37	16.3	44.82
1.2	3.30	5.0	13.75	8.8	24.20	12.6	34.65	16.4	45.10
1.3	3.57	5.1	14.02	8.9	24.47	12.7	34.92	16.5	45.37
1.4	3.85	5.2	14.30	9.0	24.75	12.8	35.20	16.6	45.65
1.5	4.12	5.3	14.57	9.1	25.02	12.9	35.47	16.7	45.92
1.6	4.40	5.4	14.85	9.2	25.30	13.0	35.75	16.8	46.20
1.7	4.67	5.5	15.12	9.3	25.57	13.1	36.02	16.9	46.47
1.8	4.95	5.6	15.40	9.4	25.85	13.2	36.30	17.0	46.75
1.9	5.22	5.7	15.67	9.5	26.12	13.3	36.57	17.1	47.02
2.0	5.50	5.8	15.95	9.6	26.40	13.4	36.85	17.2	47.30
2.1	5.77	5.9	16.22	9.7	26.67	13.5	37.12	17.3	47.57
2.2	6.05	6.0	16.50	9.8	26.95	13.6	37.40	17.4	47.85
2.3	6.32	6.1	16.77	9.9	27.22	13.7	37.67	17.5	48.12
2.4	6.60	6.2	17.05	10.0	27.50	13.8	37.95	17.6	48.40
2.5	6.87	6.3	17.32	10.1	27.77	13.9	38.22	17.7	48.67
2.6	7.15	6.4	17.60	10.2	28.05	14.0	38.50	17.8	48.95
2.7	7.42	6.5	17.87	10.3	28.32	14.1	38.77	17.9	49.22
2.8	7.70	6.6	18.15	10.4	28.60	14.2	39.05	18.0	49.50
2.9	7.97	6.7	18.42	10.5	28.87	14.3	39.32	18.1	49.77
3.0	8.25	6.8	18.70	10.6	29.15	14.4	39.60	18.2	50.05
3.1	8.52	6.9	18.97	10.7	29.42	14.5	39.87	18.3	50.32
3.2	8.80	7.0	19.25	10.8	29.70	14.6	40.15	18.4	50.60
3.3	9.07	7.1	19.52	10.9	29.97	14.7	40.42	18.5	50.87
3.4	9.35	7.2	19.80	11.0	30.25	14.8	40.70	18.6	51.15
3.5	9.62	7.3	20.07	11.1	30.52	14.9	40.97	18.7	51.42
3.6	9.90	7.4	20.35	11.2	30.80	15.0	41.25	18.8	51.70
3.7	10.17	7.5	20.62	11.3	31.07	15.1	41.52	18.9	51.97
3.8	10.45	7.6	20.90	11.4	31.35	15.2	41.80	19.0	52.25
3.9	10.72	7.7	21.17	11.5	31.62	15.3	42.07	19.1	52.52
4.0	11.00	7.8	21.45	11.6	31.90	15.4	42.34	19.2	52.80
4.1	11.27	7.9	21.72	11.7	32.17	15.5	42.62	19.3	53.07
4.2	11.55	8.0	22.00	11.8	32.45	15.6	42.90	19.4	53.35

Note: Borderline distances for trees larger than 19.4 inches d.b.h. can be calculated by multiplying d.b.h. by 2.75.

TALLY SHEET AND STAND-DIAGNOSIS FORM

FOR REPRODUCTION AND SAPLING STANDS

Stand size class:

☐ Reproduction

☐ Sapling

Softwood site:

☐ Primary

☐ Secondary

Mean stand diameter in inches _____

Stocking Class	Plot count	Percent
1. Stocked with spruce-fir		
2. Stocked with other commercial species		
Total stocking		
3. Not stocked		
TOTAL, ALL CLASSES		100

Prescription: _____

Figure 8.—A tally sheet and diagnosing form for reproduction and sapling stands.

TALLY SHEET FOR

POLETIMBER AND SAWTIMBER STANDS

Stand Condition:

☐ Even-aged

☐ Mature

☐ Immature

☐ Uneven-aged

Type of Management:

☐ Even-aged management

☐ Uneven-aged management

Softwood site:

☐ Primary

☐ Secondary

D.b.h. class	Fir	Spruce	Other softwood	Paper birch	Other hardwood	Tree count	Conversion factor	Number Trees per acre
1							1,833	
2							458	
3							204	
4							115	
5							73	
6							51	
7							37.4	
8							28.6	
9							22.6	
10							18.3	
11							15.2	
12							12.7	
13							10.8	
14							9.4	
15							8.2	
16							7.2	
17							6.3	
18							5.7	
19							5.1	
20							4.6	
21							4.2	
22							3.8	
23							3.5	
TOTAL								

No. of sample points: _____

Milacres stocked:*	No.	%
Spruce-fir		
Other species		
Total stocked		
Milacres not stocked		
Total milacres		

*Milacres stocked should be tallied when: (a) uneven-aged stands are to be placed under even-aged management; (b) even-aged management is to be maintained in mature even-aged stands.

Figure 9.—A tally sheet for poletimber and sawtimber stands.

STAND-DIAGNOSIS FORM FOR EVEN-AGED MANAGEMENT

Management objective: _____

Number of trees per acre: _____

Basal area per acre: _____ sq. ft.

Mean diameter of stand: _____ inches

Milacres stocked:

Stocked with spruce-fir: _____%

Stocked with other commercial species: _____%

Total stocking: _____%

Required basal area per acre at B-level: _____sq. ft.

Basal area per acre above B-level: _____sq. ft.

Available for harvest: _____sq. ft. (some or all above B-level depending on the windfirmness of the stand.)

Prescription: _____

_____

_____

_____

_____

Figure 10.—A stand-diagnosis form for even-aged management.

STAND-DIAGNOSIS FORM FOR UNEVEN-AGED MANAGEMENT

Management objective: _____

D.b.h. class (inches)	Number of trees per acre			Sq. ft. of basal area per acre		
	Tally sheet	Table 4 goal	Difference + -	Tally sheet	Table 4 goal	Difference + -
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
TOTAL						

Computed amount of growing stock to be removed: _____ sq. ft. per acre

Prescription: _____

Figure 11.—A stand-diagnosis form for uneven-aged management.