Ecology and Silviculture of the Spruce-Fir Forests of Eastern North America[1]

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Using the climax forest as a guide to growing the species best suited to the climate and the site, the author offers a silvicultural system for managing the spruce-fir forests of eastern North America. Based on ecological principles, such silviculture is aimed to bring about forests that are inherently healthy and have a natural resistance to insects and disease.

THE LAW of supply and demand has done much in recent years to lift timber growing into the category of a paying enterprise. Nevertheless the business of growing timber is still attended by many hazards.

Some of these have their origin in economic disturbances over which the timber-land owner has little control. Other hazards, however—particularly those of climatic or biologic origin such as insects, disease, windthrow, and fire—the timberland owner can do much through intelligent silviculture to circumvent. But the plain facts are that through inept manipulation of the forest he often does the very things that tend to perpetuate and intensify the hazards.

This is strikingly evident in the spruce-fir region. Poor logging practices, abetted by fire and other destructive forces, have seriously impaired the forests' productive powers and resistance to forest pests. Ill-conceived cutting practices have brought about radical changes both in composition and stand structure; often incoming stands are only remotely related in composition to the original forest. Such forests are often subject to rapid deterioration and are frequently prey to disease and insect epidemics.

The poorly stocked, deteriorated, pest-ridden forests of today are essentially the result of yesterday's failure to evolve a spruce-fir silviculture based on truly sound ecological principles.

Origin of the Spruce-Fir Forests

The eastern spruce-fir belt extends from Newfoundland westward to the great plains of Manitoba and Dakota, a distance of more than 2,000 miles. For 1,200 miles or more it straddles the boundary line between Canada and the United States. It sends long tongues far to the south—but only along the high ridges and lofty summits of the Appalachian ranges. To the north, fingers of spruce follow the relatively warm north-flowing streams well into the treeless, moss-covered tundra.

The commercial spruce-fir belt averages about 300 miles in depth. A wide strip of nearly pure coniferous forests occupies its upper portion. Below it lies the transition zone. Admixtures of hardwoods, largely intolerant species, occur here. In the lower strip of this zone tolerant hardwoods tend to supplant the intolerant ones. Still farther south, spruce and fir give way to forests of deciduous hardwoods.

The silvicultural significance of the spruce-fir climax types becomes more evident when viewed in terms of their geological origin. The present pattern of spruce-fir types is linked with the last great ice sheet that invaded the spruce-fir region from the north. This phenomenon profoundly affected the topography and soil. In some places the ice swept the surface practically clean of soil. Over the region as a whole, however, it dropped a mantle of heterogeneous debris, spreading it indiscriminately over hills, mountains, plains, and valleys to varying depths.

This glacial debris, consisting of clay, sand, gravel, rock, and boulders, sometimes filled valleys to a depth of 300 feet or more. Often the drift was pushed up in great heaps and windrows. It piled up in dams across valleys to form lakes and ponds. It created kames and eskers, outwash plains and terraces, enormous terminal moraines, and great boulder belts. Ice gouged out depressions to form swamps and muskegs.

When the ice made its final retreat some 10,000 years ago, the forests again moved northward. But glaciation, by changing the topography, soil, and drainage, had created a pattern of sites quite different from what prevailed in the preglacial era. This forced a redistribution of species within the region. The effects of these changes are expressed in today's pattern of climax forest associations.

Following the retreat of the ice sheet, pure coniferous forests of spruce, balsam fir, and jack pine—or combinations of these species—reclothed the shallow soils of the north and the thin soils of steep mountain slopes. Spruce, balsam fir, and cedar—often with admixtures of white birch and aspen—took over the flats; black spruce, tamarack, and cedar invaded the swamps and muskegs. But on the deeper soils of the lower slopes, benches, and low-lying ridges to the south, conifers shared the sites with such hardwoods as beech, birch, and maple.

Essentially these forests are expressions of the fundamental laws that govern distribution and growth of vegetation. In their climax stage they represent Nature's verdict, based on thousands of years of experimentation, of the species or combinations of species that are best adapted to the sites.

The Climax Forest as a Guide

For managing today's spruce-fir forests, the forester needs a simple yet dependable guide that will enable him to direct his silviculture toward the production of those species best suited to the climate and the soil. Such a guide can be found in climax forest associations.

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The stable tree associations that characterize such forests are best adjusted to meet the impact of diseases, insects, and other antagonistic forces.

Climax forest associations are in complete harmony with the soil and the plant and animal life they support. They are inherently healthy.

My thesis is that by using climax forests as silvicultural guides it will be possible to prevent the development of conditions within the forest that make the business of growing timber both costly and hazardous. In essence this is "preventive forestry," analogous to "preventive medicine." This type of approach promises thriftier, healthier, more resistant forests—thus more productive ones.

A fact of great significance to foresters is that climax forests are integral biological units. Each such unit is characterized by a distinctive climatic-edaphic complex. Environmental differences are of sufficient magnitude between units to effect pronounced differences in growth behavior.

This is clearly expressed by marked differences in composition, growth capacity, ease of regeneration, factors of competition, and liability to windthrow, disease, and insect pests. These basic differences dictate to a large degree the type and intensity of silviculture to be employed for most efficient management. Thus, climax forests provide a sound and natural basis around which to build a successful regimen of silviculture.

The Goal of Spruce-Fir Silviculture

Owners of spruce-fir forests in the eastern United States and Canada usually have as their primary goal the production of pulpwood—preferably spruce and fir. Because spruce has been the top-ranking pulpwood species, it is the favored tree for management.

Where these goals conflict radically with the principle of striving for stand compositions and structures characteristic of the respective climax groups, goals should be altered so this silvicultural principle can be achieved.

In this paper I am attempting to show a level of silviculture considered optimum for the existing sites and the requirements of the tree species that characterize them. The measures prescribed are aimed to maintain an acceptable proportion of spruce and balsam fir and to promote healthy, rapid-growing forests, thereby attaining maximum sustained increment and quality production.

These objectives may involve curtailing present profits in the interest of greater future returns. Thus, high-order silviculture is implied. The measures are based on the findings and experience of numerous agencies and individuals working in the field of spruce-fir management both in Canada and the United States. Existing literature dealing with the ecology and silviculture of spruce and balsam fir has been freely drawn upon.

The extent to which high-order silviculture will be applied will be influenced in a large measure by economic conditions and the quality of the forest sites. Because of remoteness from markets, poor transportation development, low potential productivity, character of timber, etc., only extensive forestry will be justified for certain portions of the region. On the other hand, productive lands close to markets justify intensive forestry practices.

The Problems in Silviculture

Depleted and Deteriorated Stands

To attain spruce-fir management goals, the measures employed must restore depleted and deteriorated stands and forestall the creation of such conditions in the future. The need for refined and often costly cultural measures to bring vast areas into a satisfactory producing state is plain indication of failure in the past to properly correlate cutting practices to silvicultural requirements.

Through proper cutting methods it is possible to forestall the need for later costly cultural measures. Intensive forestry and costly forestry are not necessarily synonymous terms. High-order forestry in the hands of a skilled practitioner can be quite simple and inexpensive, yet highly efficient in attaining forestry objectives.

The more commonly encountered conditions in spruce-fir forests that call for remedial action are:

1. Regeneration failures.
2. Badly understocked stands.
3. Deteriorated growing stock.
4. Mounting losses from insects, disease, wind, and fire.
5. Low increment rate.

These five conditions occur in varying intensities and combinations throughout the spruce-fir region. Thus, all the standard practices that form the repertoire of the practicing forester, ranging from cutting methods to stand-improvement and protection measures, must be brought to bear on the problem if the overall goals are to be realized in a reasonable period.

This does not mean that each acre will require all remedial measures, but it does mean that on the tract as a whole all measures can be employed to good advantage. Execution of one measure tends to increase the effectiveness of the others. It is imperative, then, that the forester exercise discretion to assure that the corrective measures applied are silviculturally and economically appropriate for each site and stand condition.

It is impractical in this short paper to attempt to present all the variations in silvicultural practices demanded by the diversity of conditions existing in a territory as extensive as the one under discussion. The practices here recommended take the form of a broad framework that will help to establish broad principles, but flexible enough to permit choosing the method that will best fit local conditions.

Even so, basic cutting methods need not differ greatly between the western and eastern ends of the region despite the more difficult regeneration problems associated with midcontinental climates. True, silviculture will vary in detail, but only to the degree that coordination demands adjustments in keeping with the local complex. Because of harsher climatic conditions in the West, silvicultural measures must be undertaken there with greater precision and care to assure attainment of silvicultural goals.

Factors in Management

It goes almost without saying that the presence or absence of advance spruce-fir reproduction in the forest strongly influences the nature of the silvicultural measures to be practiced. Fortunately advance reproduction is abundant over most of the region. This is especially true of the so-called old-growth stands in the spruce-fir type group.

It is usually abundant also in the spruce-fir-hardwood group but is often inadequate or entirely lacking in the hardwood-spruce-fir group. Paucity of spruce-fir reproduction in this type group is usually due to its failure to compete successfully with hardwoods.

Second-growth stands not yet mature are also likely to be deficient in reproduction regardless of type group. The extremely dense canopy that characterizes young stands and the thick accumulation of needle litter on the forest floor tend to discourage the establishment of reproduction. Reliance for regenerating such stands must be placed on cutting methods especially designed to accomplish this.

Since advance reproduction is vital to continuance of lands in spruce-fir production particularly in those sites favorable to hardwoods, measures must be applied to assure its preservation and development. Fortunately, spruce-fir reproduction responds admirably to release. But to maintain its dominance over competing hardwoods it needs a height advantage that must increase as hardwood competition increases. Obviously such competition reaches its maximum in the hardwood-spruce-fir type group.

Spruce-fir management practices must take into account the silvical variations among the species that comprise the various spruce-fir types. In this respect the variations in tolerance among the various spruces and balsam fir is of special significance. Red spruce is the most tolerant of the group, followed by balsam fir, black spruce, and white spruce in that order. Thus red spruce enjoys a competitive advantage over balsam fir as well as white and black spruce when these species occur as associates.

However, balsam fir possesses certain compensating qualities. It seeds much more prolifically than the spruces. Its seedlings have a remarkable capacity for prompt and rapid root development and subsequent rapid height growth. These advantages are partly offset by the greater longevity of the spruces. Net results, however, are highly favorable to abundant balsam fir regeneration on most sites, thus making the problem of balsam fir encroachment difficult to overcome.

Despite the fact that balsam fir grows faster and regenerates more easily than spruce, it is questionable that balsam fir production will provide greater yields per acre over an indefinite period. The advantages of rapid growth and prompt restocking that balsam fir enjoys are largely offset by its lesser yield of cellulose; its susceptibility to numerous forest pests such as heart rots, the wooly aphid, and the budworm; and the losses it sustains from wind-breakage and sun-scald. These factors all add to the complexity and difficulties of spruce-fir management, which increase as balsam fir representation in the stand increases, and reach their maximum in the so called "balsam fir thickets."

One must recognize, however, that sites occur that are optimum for balsam fir only. On such sites production and continuance of balsam fir as predominant or sole species is a legitimate goal.

But by the same token, where spruce is the dominant tree in the climax it should be maintained to the extent of its original representation in the stand. Silviculture so directed will be most satisfactory in the long run. This means putting into effect a form of silviculture designed to reverse the trend of balsam fir encroachment to the stage where the original spruce-balsam fir ratio is regained.

Another important factor influencing management practices is danger from windthrow and wind-breakage. Although spruce and balsam fir are tolerant species naturally adapted to a selective system of cutting, a strong tendency to windthrow prevails because of their shallow root systems and the thin soil in which they commonly grow. High winds will often overthrow all trees on extensive areas. Where the trees grow in mixture with hardwoods, they receive support from their deeper-rooted associates, and this greatly reduces this danger. Balsam fir, being subject to weakness from heart rot, is particularly susceptible to wind-breakage.

Classifying the Forest Types

In applying the climax-forest principle to spruce-fir silviculture, the first requirement is to classify the forests into climax associations. Such a classification enables the forester to segregate forest types into classes biologically of the same value.

Biologically equivalent types, by and large, respond the same way to forestry measures. This is of practical significance to the forester. It permits him to delineate his properties into zones calling for uniform silvicultural treatment. Also it simplifies the problem of classifying sites for various levels of forestry practice commensurate with the potentialities of the site for growth and profitable returns.

Delineation of climax types is relatively simple where forests still occur in their natural state. Unfortunately extensive areas, because of repeated fires and other radical disturbances, now support a variety of temporary types. Even so, foresters versed in successional trends peculiar to the spruce-fir forest belt can interpret these conditions satisfactorily in terms of climax associations.

Such a classification has been attempted for the spruce-fir belt of eastern North America (Table 1). Absolute accuracy is not claimed

TABLE 1.—S.A.F. FOREST TYPES CLASSIFIED BY CLIMAX GROUPS AND MANAGEMENT OBJECTIVES

Forest type	S.A.F. type No.	Stage in succession	Ultimate climax group	Species to favor
				Primary
Red spruce	18	Climax		Red spruce
Red spruce-southern balsam fir	19	Climax		White spruce
Balsam fir	22	Climax		Black spruce
Black spruce	23	Climax		Balsam fir
Jack pine	1	Subclimax	Spruce-fir	*Secondary*
Tamarack	25	Subclimax		Paper birch
Aspen	4	Subclimax		Aspen
Pin cherry	5	Subclimax		Cedar
Paper birch	6	Subclimax		Tamarack
				Jack pine
				Primary
Red spruce-yellow birch	16	Climax		Red spruce
Red spruce (old field)	18	Subclimax		White spruce
Paper birch-red spruce-balsam fir	20	Subclimax		Balsam fir
White spruce (old field)	21	Subclimax		Yellow birch
White spruce-balsam fir-paper birch	21	Climax	Spruce-fir-hardwoods	Paper birch
Aspen	4	Subclimax		*Secondary*
Pin cherry	5	Subclimax		Aspen
Paper birch	6	Subclimax		Beech
Yellow birch	15	Subclimax		
				Primary
Red spruce-sugar maple-beech	17	Climax		Red spruce
Red spruce (old field)	18	Subclimax		Yellow birch
Aspen	4	Subclimax		Sugar maple
Pin cherry	5	Subclimax	Hardwoods-spruce-fir	*Secondary*
Paper birch	6	Subclimax		Balsam fir
Sugar maple-beech-yellow birch	12	Subclimax		Aspen
Yellow birch	15	Subclimax		Paper birch
				Beech

for this classification, but it is believed accurate enough to satisfy most practical needs.

Three broad climax groups are recognized: (1) spruce-fir, (2) spruce-fir-hardwoods, and (3) hardwoods-spruce-fir.

Within each group occurs a series of temporary and climax forest types, each of which is recognized as a legitimate component of its respective climax group. Of the 25 forest types listed, only 7 are considered to be in their climax stages. The remaining 18 may be assumed to represent transitional stages in a successional series which, if left undisturbed, would ultimately develop into one of the three climax group associations. All of the forest types bracketed under a given climax group are considered to be biological equivalents.

The species that characterize the original site have been selected as primary goals for management. But it does not follow that climax species should be considered the sole goal. Species associated with one or more of the successional stages leading to the climax may be equally legitimate goals. Under special conditions they may well become the primary goals.

Species considered to be the goals of management for each type group are shown in Table 1.

Characteristics of the Climax Groups

Each climax group possesses characteristics that make for easy or difficult management of spruce. Normally this difficulty increases with increase in soil fertility level. This is explained by the fact that deep, fertile, well-drained soils result in increased proportions of hardwoods.

But in regions with dry and continental climate, drought rather than increased soil fertility is the major factor favoring increased proportions of hardwoods. And hardwoods, particularly tolerant species, compete strenuously with spruce and fir for possession of the site. Thus the extent to which hardwoods are natural components of a site largely determines the management level required to assure satisfactory spruce-fir representation.

The hardwood-spruce-fir climax group, with its relatively fertile soils and consequent high representation of tolerant beech and sugar maple, is least susceptible of the climax groups to spruce-fir management. These hardwoods compete strenuously with spruce and balsam fir for possession of the land. To maintain spruce-fir production on these sites calls for the application of intensive forestry measures.

In the spruce-fir-hardwood climax groups, competition from hardwoods is less severe. The shallower, less fertile soils discourage production of the highly competitive beech and sugar maple. Instead the less competitive yellow birch, red maple, aspen, and paper birch take over. This climax group marks the transition zone between those easy and difficult to hold in spruce-fir production. Less intensive measures suffice to assure dominance to conifers in this type.

The spruce-fir climax group, with its thin or poorly drained soils, lends itself most readily to the management of spruce and balsam fir. Competition from hardwoods, if any, is wholly restricted

TABLE 2.—TENTATIVE ECOLOGIC SITE CLASSIFICATION FOR SPRUCE-FIR FOREST OF EASTERN NORTH AMERICA

Phytogeographic zones	Recognized forest types	Major type groups	Ground vegetation equivalents	Ease with which spruce-fir production can be maintained
Red spruce	Balsam fir (flat) Red spruce-balsam fir (flat) Red spruce (slope) Red spruce (flat)	Spruce-fir	*Hylocomium-Hypnum* *Cornus* *Oxalis-Hylocomium* (*Hylocomium-Hypnum*) (*Cornus-Maianthemum*)	Easy
	Paper birch-red spruce Balsam fir Red spruce-yellow birch	Spruce-fir-hardwoods	*Cornus Maianthemum* *Oxalis-cornus* *Oxalis-cornus*	Moderately difficult
	Red spruce-sugar maple-beech	Hardwoods-spruce-fir	*Viburnum-Oxalis*	Difficult
Black spruce	Black spruce-tamarack Black spruce (swamp) Black spruce-white cedar Black spruce-jack pine Black spruce-balsam fir Balsam fir	Spruce-fir	*Chamaedaphne-Ledum* *Kalmia-Ledum* *Sphagnum-Ledum* *Sphagnum-Carex* *Sphagnum-Cornus* *Sphagnum-Oxalis*	Easy
	Black spruce-paper birch Black spruce-aspen Black spruce alder	Spruce-fir hardwoods	*Oxalis-Coptis* *Hylocomium-Mitella* To be determined	Moderately difficult
	Aspen-paper birch black spruce	Hardwoods-spruce-fir	*Galium-Equisetum*	Difficult
White spruce	White spruce-black spruce Balsam fir White spruce-balsam fir	Spruce-fir	*Sphagnum* *Sphagnum-Oxalis* *Cornus-Linnea*	Easy
	White spruce-balsam fir-paper birch White spruce-balsam fir-aspen	Spruce-fir	*Rubus parviflorus* *Cornus Maianthemum*	Moderately difficult
	White spruce-balsam fir-yellow birch Paper birch-white spruce-balsam fir Sugar maple-white spruce-balsam fir Aspen-white spruce	Hardwoods-spruce-fir	*Aralia* To be determined *Aster-Corylus* (*Smilacina-Polygonatum*) (*Galium-Equisetum*)	Difficult

to light-foliaged species such as aspen and paper birch. Even so, serious problems of regeneration may arise when such sites are subjected to unwise cuttings that encourage invasion of alders and other rank growth, or expose the forest floor to higher temperatures and desiccating winds. But they offer no problem that cannot be solved through intelligent silvicultural treatment.

Site-Quality Classes

It is clear that the type of silviculture will vary among climax-association groups. The intensity of management practices in turn will vary in accordance with the productive capacity of the sites encountered. Thus, there is need for a breakdown of each climax association into site-quality classes.

Such a classification has great value to the practicing forester. It provides him with the needed index to timber yields. Further, it enables him to classify his properties into accessibility-quality-site zones for levels of forestry practice commensurate with the zones' potentialities for growth and profitable returns. Reasonably accurate identification of site quality can be attained through indicator plants, soils, forest cover, and other site manifestations.

An attempt has been made (Table 2) to show ground-vegetation types that characterize the major type groups. For each major group, ground-cover types are arranged on a scale of ascending soil fertility, thus providing a rough basis for classifying major type groups into site-quality classes.

Phytogeographic Zones

In recognition of the wide range in climatic conditions that prevail in an area as extensive as the spruce-fir forests, the region has been subdivided into silviculturally significant phytogeographic zones. The boundaries of these zones are determined by the species of spruce that characterizes each. On this basis the following three species zones are recognized: (1) red spruce, (2) black spruce, and (3) white spruce (Table 2).

Differences in stand composition and site factors, particularly moisture and temperature, are of sufficient magnitude between zones to influence the ease with which major silvicultural goals can be achieved.

In the southeast portion of the spruce-fir belt where red spruce is the characteristic tree, conifer regeneration is not an acute problem. Nor is it especially acute in the extensive black spruce types that characterize the flat terrain and broad shallow basins of the subarctic region.

But where white spruce supplants red spruce, often with admixtures of black spruce, as it does in the Lake States and the interior provinces of Canada, the problem of maintaining a satisfactory stocking of spruce is very difficult. Site differences and variations in tolerance and competitive capacity of associated species create problems that may necessitate silvicultural adjustments not only between zones but within the same zone.

Thus in dealing with the silvicultural problems of any specific broad climax group it is well to consider which phytogeographic province it falls in. In general, however, basic concepts can be applied to all zones with surety.

Cutting Systems

Main reliance for minimizing the occurrence of the stand deficiencies enumerated earlier should be through the employment of sound systems of cutting. If cutting methods are used that assure a complete cover of desirable reproduction, serious stand deficiencies can be avoided and thus the problem of growing full timber crops can be greatly simplified and production costs can be reduced.

Selection Cutting

Generally speaking, selection cutting promises to accomplish these goals most effectively. Thus all-aged management rates first priority; it is the preferred silvicultural system.

Spruce and balsam fir are both tolerant species well adapted to the selection system. The repeated light cuttings that characterize this system create favorable conditions for the establishment of abundant spruce-fir seedlings.

In the red spruce types, selection cutting definitely favors spruce regeneration at the expense of balsam fir largely because of the greater tolerance and longevity of red spruce. This does not hold true for the white and black spruce types containing balsam fir, since the latter outranks these two spruces in tolerance. However, the competitive advantage greater tolerance gives balsam fir can be largely cancelled by the pressure of frequent cuts of this species under selection management.

The selection system, because it maintains a generous crown cover, discourages the encroachment of hardwood and brush growth. Since accumulation of slash is negligible, it constitutes no deterrent to reproduction. On the moist, shaded forest floor the limited quantities of slash decompose rapidly, reducing fire risk to a minimum. Further, the system affords protection against windthrow. It assures maintenance of a thrifty residual growing stock capable of rapid volume increment and early future harvest cuts. And the short cutting cycles inherent to the system increase yields by reducing the heavy losses sustained from decay in short-lived balsam fir.

To attain maximum benefits from selection cutting, tree-marking should be undertaken on all cutting operations. Through marking, the forester exercises control over the cut both as to quantity and quality. It enables him to reserve healthy, thrifty growing stock so essential to rapid increment. Marking, skillfully done, anticipates mortality. The wood thus saved may even exceed the growth on the residual stand. Diameter-limit cutting, on the other hand, because of its rigidity, only partially accomplishes these objectives.

This does not mean that selection cutting is the only system for spruce-fir management. Economic pressure or unfavorable stand structure or stand condition may require some other system. Of course it does not follow that such cutting is undertaken for the purpose of creating even-aged stands. For a long time to come, spruce-fir silviculture must be based on a compromise.

Shelterwood Cutting

Where economic or other reasons make selection cutting impractical, shelterwood cutting can often be substituted with satisfactory results. Under this system one-third to one-half of the stand may be removed, opening it up uniformly to permit the establishment of reproduction under the shelter of the remaining trees. Ten to fifteen years later, when regeneration is complete, the remainder of the residual stand may be cut.

Scattered-Seed-Tree System

There is little place for the scattered-seed-tree system in the silviculture of spruce-fir stands. Because of the shallow-rooting habits of both spruce and fir there is every likelihood that the seed trees will be windthrown long before they have fulfilled their purpose.

Clear-Cutting

Some conditions occur in the spruce-fir region that call for clear-cutting or some modification of it. Overmature, even-aged stands of spruce and fir are cases in point. The absence or presence of advance reproduction in such stands determines the type of clear-cutting to apply.

Where reproduction of sufficient height and density is present, the entire area bearing such reproduction may be clear-cut. Where reproduction is scanty or absent, some system of strip-cutting should be employed. An effective and at the same time practical system is to cut alternate or progressive strips preferably from north to south and narrow enough (not to exceed 150 feet) to insure restocking from the adjoining uncut strips. As rapidly as the cut-over strips regenerate, the remaining uncut strips may be harvested.

Shelterwood and clear-cutting methods imply even-aged management, hence long-cycle cutting. This is in contrast to all-aged management and short-cycle cutting associated with the selection-cutting system that permit harvesting much of the volume normally lost through mortality under long-cycle cutting.

Adapting Cutting Systems to Stand Conditions

Effective silviculture hinges on proper adaptation of the cutting systems to varying stand conditions. Since each major type group presents its own peculiar set of problems, the type group in which the stand occurs must be borne in mind in the selection of the cutting system and the timing of its application.

Mature and Overmature Stands

The only choice of management for mature and overmature stands is clear-cutting. The danger of loss from windthrow and defect make this imperative.

The broken canopy that characterizes mature and overmature stands usually provides conditions essential for the establishment of advance reproduction. Thus advance reproduction is nearly everywhere present in such stands.

It is essential, however, that conifer reproduction be of sufficient height to compete successfully with invading hardwoods and other competing growth that follow clear-cutting. The intensity of this competition varies between type groups. In the spruce-fir group, reproduction should average between 6 inches and 1 foot in height; in the spruce-fir-hardwood group about 2 feet; and in the hardwood-spruce-fir between 4 and 5 feet to assure its ultimate dominance.

Perpetuation of spruce and fir will be greatly aided when profitable use can be made of the intermingling hardwoods. Utilization of the hardwood component is the real answer to successful spruce-fir management in the hardwood-spruce-fir type group.

If there is a deficiency of reproduction it is likely to occur in the hardwood-spruce-fir group. No known method of cutting can be counted on to remedy this situation. Clear-cutting, followed by planting and continued treatment for reduction of hardwoods by girdling or other measures, is probably the only way such areas can be maintained in spruce-fir production.

Immature Stands

Selection cutting is the preferred method of managing immature stands. It is best adapted to all-aged stands, but it can also be initiated in even-aged stands with the aim of converting them to selection forests. Because of the susceptibility of spruce-fir forests to wind damage there is a definite limit of intensity of cutting beyond which it is unsafe to proceed. The proportion or volume to remove should be governed by the character of the site and the composition, structure, density, and age of the stand — factors that strongly influence windfirmness.

The older age classes of immature stands should be cut more lightly (10 to 30 percent) than the young stands (20 to 50 percent); cuttings should be lighter in even-aged stands (20 to 30 percent); lighter on wet sites and steep slopes (10 to 20 percent) than on well-drained sites or rocky soils that provide good root anchorage (30 to 50 percent).

Normally wind damage is greater in pure conifer stands than in conifer-hardwood stands. The former should be cut lighter (10 to 40 percent) than the latter (30 to 50 percent).

A stand with high balsam fir representation should be cut more conservatively than one with a high red or white spruce component. Stands in which the hardwood component consists largely of intolerant species, such as aspen and paper birch, should be cut more lightly than those containing admixtures of tolerant hardwoods such as beech and sugar maple, which are known to be fairly windfirm.

Greatest danger from windfall is encountered in the spruce-fir type group; hence the cutting in this group should be on the conservative side. Balsam fir in this type group, with the exception of the black spruce type, is likely to be preponderant; and the bulk of the cut, where practical, should be taken in this species. In the other two type groups, cutting an equal or greater proportion of hardwoods should be undertaken to forestall encroachment of these species.

Stand Improvement Measures

Fortunately much of the spruce-fir area at the time of the last cutting supported advance conifer reproduction, which is developing into fairly satisfactory stands of pulpwood where adequately protected from fire. In the absence of advance reproduction, however, undesirable hardwoods have taken possession of the land.

Such lands are in dire need of rehabilitation. Even where reproduction is adequate, its presence is no assurance that a satisfactory crop will develop. Such stands, if left undisturbed, produce yields far below the capacity of the land. Stand-improvement measures are needed to relieve spruce-fir reproduction from serious hardwood competition; failing areas must be brought into production. Measures must be applied that will improve both the growth rate and quality of the incoming stand.

The development of residual stands, reproduction, and planted stock in the spruce region is often made difficult by the competing effects of unwanted trees. This competition assumes two distinct forms: (1) young hardwoods that spring up on cut-over areas and burns and through rapid height growth smother or overtop the slower-growing conifers; and (2) an overhead canopy of relict trees or an overstory of younger hardwoods. The crowns of such trees through dense shade and mechanical interference retard the growth of the desirable elements in the stand.

Weedings

The most practical way to prevent competing young hardwoods from choking out newly established conifers is to undertake weedings in which the undesirable species are killed or cut back. The time and frequency of weeding operations vary among the major type groups.

In the spruce-fir type group where weed species consist of light-foliaged intolerant species such as aspen and paper birch, softwood reproduction maintains itself fairly well. Early weedings are not required nor is there generally need for more than one weeding.

In the spruce-fir-hardwood type group where hardwoods are somewhat more aggressive, one weeding 8 years after logging will usually suffice to place softwoods in possession of the area.

In the hardwoods-spruce-fir type group, because of the extremely favorable conditions for hardwood growth, two or even three weedings spaced at 4- to 5-year intervals may be necessary to give ultimate dominance to the softwoods.

In all sites, however, the relative heights of the crop and weed trees must be considered. If the advance reproduction on the easily reproduced sites at the time of cutting averages 1 foot in height, it will often gain dominance without weeding. On the medium and difficulty reproduced sites the heights should average 2 and 4 feet respectively. As long as most of the conifers are putting on height growth averaging 6 inches or more per year there is no urgent need for weeding.

Girdling, Poisoning, and Felling

Several effective methods and variations have been developed to release understory conifers and giving them the opportunity for increased growth. The most commonly used are girdling, poisoning, and felling.

Discretion must be used in applying these measures. No money should be spent on destroying trees that do not suppress advance reproduction or whose crowns show evidence of deterioration. The measure should be used selectively, eliminating only trees of poor form and quality. When applied to younger, more thrifty hardwoods they should be limited to areas where the prospect for a profitable future market for the class of hardwoods in question is definitely remote.

Thinning

Thinning as an effective measure for increasing the yield and quality of spruce-fir stands deserves serious consideration, particularly on properties containing appreciable areas of even-aged second growth. The excessive competition that develops in such stands as they grow older necessitates thinning if a satisfactory growth rate is to be maintained.

Studies indicate that good results are obtained by thinnings that remove 20 to 25 percent of the stand at intervals of about 10 years. Seldom should the basal area of the stand be reduced below 100 square feet per acre—particularly when this involves removal of more than 35 percent of the stand. A safe residual basal-area range is from 100 to 150 square feet per acre.

Pruning

Pruning has as its objective the production of high-grade sawlogs or veneer stock at reasonable cost. Saw-timber production, or its integration with pulpwood production, already obtains in portions of the spruce-fir region. Pruning for quality production under such conditions appears fully justified.

When pruning is properly applied there need be little or no reduction in growth rate. Only straight-boled, vigorous trees, free of injury or disease, and whose position in the stand gives reasonable assurance of their development into crop trees, should be pruned.

As a rule pruning should be confined to trees not more than 4 or 5 inches d.b.h. Normally 150 fast-growing dominant or co-dominant trees per acre should be pruned. Rapid growth of pruned trees can be maintained through frequent thinnings aimed at freeing and encouraging the development of large crowns.

Planting

Cutting methods are aimed to achieve adequate restocking. Instances occur where regeneration fails to materialize. Sometimes fire, destructive logging, or other factors account for the absence of adequate reproduction. Where such areas occur on good growing sites and regeneration is unlikely in a reasonable period, planting appears fully justified.

Protection Measures

Logging Damage

Since preservation of advance reproduction is such an important factor in the maintenance of spruce and fir, damage to the incoming stand from logging operations must be kept to a minimum.

Measures should be instituted to prevent needless swamping of young trees and saplings, length and number of skid roads should be kept to a minimum, yarding should be substituted for stump-cutting wherever practical, and necessary steps should be taken to keep slash to a reasonable density. Individually and in the aggregate these factors are potent in reducing ultimate yields; they are often the chief factors responsible for conversion of spruce sites into shrub and alder growth or into pure hardwood stands.

Slash disposal methods should aim to reduce the density of the slash to a point where it is no longer a deterrent to reproduction. The amount of slash created through logging will vary with the volume of the cut and the extent to which spruce and fir are represented in the stand. Since the three major type groups vary widely in the latter respect no uniform policy of slash disposal can be applied. The three type groups provide a useful basis for prescribing slash-disposal methods.

In the spruce-fir type groups a satisfactory slash density can usually be achieved by burning 10 to 30 percent of the slash and scattering the remainder. On areas with extremely dense slash, burning only the densest slash and that on the most hazardous areas, as along roads and railroads, should have appeal to many owners. Such a method, supplemented by fire lanes and intensive patrolling, should provide adequate protection for such cut-over lands.

In the spruce-fir-hardwood type group where spruce-fir representation exceeds 50 percent, a satisfactory slash density can usually be achieved by reducing dense slash through scattering.

In the hardwood-spruce-fir type group no slash disposal measures are necessary.

Insects and Diseases

Because of the prevalence of destructive insects and disease in much of the spruce-fir territory, management techniques must be applied that promise to build up resistance to such pests. Some of the more troublesome of these are the spruce budworm, the eastern spruce bark beetle, the European spruce saw fly, the balsam wooly aphid, and numerous butt and heart rots. Fortunately selection-cutting methods designed to attain the normal objectives of increased growth are equally effective in building up resistance to these pests.

The repeated light cuts inherent to the selection-cutting system permit frequent removal of the highly susceptible, slow-growing, weakened, and decadent trees. But care must be exercised to retain vigorous stems in sufficient density and volume to preclude windfall and assure rapid increment. Stand resistance cannot be fully achieved in one cutting. It is a step-by-step process attained through repeated cuttings, each of which should further increase the resistance level of the stand.

Fire

Protection against fire is, of course, a prerequisite to successful timber growing. To attain effective fire protection calls for a well-trained protective organization, adequate improvements and equipment, together with well-thought-out plans for quick detection and prompt suppression.

Summary

To summarize briefly: Two questions epitomize the spruce-fir management problem: (1) How to restore spruce-fir lands that through mismanagement are now badly depleted and in a state of deterioration? and (2) How to manage existing stands at a profit and at the same time insure a level of production in keeping with the productive capacity of the land?

Attainment of these goals should be through the climax forest approach; for each climax type the composition and stand structure that characterize it should be used as silvicultural guides.

The key to the first problem—restoration of depleted and deteriorated forests — is stand-improvement measures. Foremost among these are weeding, girdling, and release cuttings designed to give spruce and balsam fir a dominant position in the final stand, supplemented where necessary by planting to maintain a high spruce-fir component and fully stocked stands.

The key to the second problem—maximum production and profitable management of existing stands—is skillful application of cutting methods that forestall the need for later costly cultural measures. Generally speaking, this goal can be most successfully attained through selection cutting. But other cutting methods may be essential first steps in the ultimate attainment of an all-aged forest.

Selection cutting assures adequate regeneration; it provides protection against windthrow; it is a deterrent to encroachment of hardwoods and brush growth; it achieves composition ratios that promote healthful, resistant stands. Moreover, it insures maintenance of thrifty growing stock capable of rapid volume increment and early harvest cuts. Such a cutting method, combined with protection measures against fire, forest pests, and excessive logging damage, should achieve timber crops in keeping with the full potential of the land.

Thirty Years of Natural Regeneration on a Douglas-Fir Cutover Area

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THE EARLY LIFE HISTORY of a Douglas-fir stand in the upper Wind River Valley in Washington is being studied to determine the progress of natural regeneration. The river bottom and lower slopes of the valley were clearcut in 1917, and the slash burned the following spring. As soon as the slash fire was out, a double line of sample plots was established across the valley from timber edge to timber edge to measure the rate of natural restocking.

The cross section of the valley represents a gentle northeast exposure, a flat river bottom, and a rather steep southwest exposure. The total distance from timber edge to timber edge is a little over a mile. The sample plots were examined annually and progress reports written. Results from 1919 through 1940 were published in 1943.[2] The present article summarizes the data through 1946 and shows the trend of restocking for various distances from the green timber edge over a 30-year period.

The northeast exposure was well stocked for 10 chains out from green timber the year after the slash fire (Table 1). By the end of 20 years this exposure was well stocked beyond the half-mile point. For the past 10 years the number of trees per acre has been declining near the timber edge. Here the stand is undergoing a natural thinning. Farther down the slope to the 48-chain point, where the stocking is poorer, the number of seedlings is still increasing. Heavy seed crops especially noticeable in 1918 and 1932 were followed by definite increases in number of seedlings.

Stocking of the river bottom and on the southwest exposure follows no such definite pattern and is unsatisfactory. Brush cover was heavy from the start. Some of the oldest trees on this understocked portion have started to produce seed, and now seedlings from this source are beginning to show up. The question now is: Will the sec-

[1]Pacific N.W. Forest and Range Exp. Sta., Forest Service, U. S. Dept. Agric.

[2]Isaac, Leo A. Reproductive habits of Douglas-fir. Charles Lathrop Pack Forestry Foundation. Washington, D. C. 1943.