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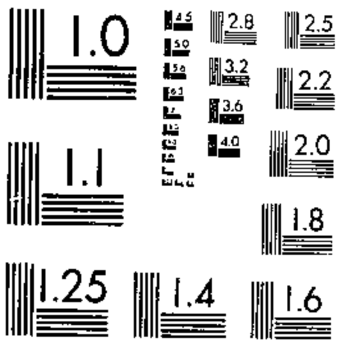


MICROCOPY RESOLUTION TEST CHART
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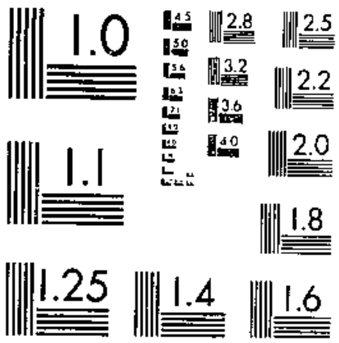


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# REPRODUCTION ON PULPWOOD LANDS IN THE NORTHEAST

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CONTENTS



## INTRODUCTION

Even a cursory study of the pulpwood situation will convince one of the need for keeping the potential pulpwood lands in this country in a continuously productive state. The prosperity and, indeed, the continuation of the pulp and paper industry demands a permanent domestic supply of pulpwood. Shortage of home-grown timber may be temporarily overcome by foreign importation, but owing to conditions in other countries this offers no dependable or permanent relief and evidently the industry must soon face the problem of raising its own pulpwood.

In the Northeast—New England and New York—the situation has already become serious, mainly for the reason that pulp and paper establishments have been concentrated here from the very beginning of the industry in North America. This concentration has been

[1] Maintained at Amherst, Mass., in cooperation with the Massachusetts Agricultural College.

logical and practically inevitable, owing to the favorable conditions in the region for the development and expansion of the pulp industry, such as large bodies of accessible spruce forests, an abundance of cheap power, low transportation costs, and nearness to markets.

However, neither cheap power and nearness to markets nor the industrial genius and push of the men behind the industry in the Northeast can maintain the industry here in the face of waning local supplies of raw material. The pulp and paper industry can no longer be regarded as regional. The price of pulpwood is governed by world-wide competition and the continuation of the industry in any particular region rests fundamentally on the possibilities of manufacturing paper pulp from domestic supplies more cheaply than it can be imported. Eventual curtailment of pulpwood will force many mills dependent on outside importation to close down. Paper and pulp concerns are awakening to the fact that the ultimate salvation of their industry lies in making their land produce the necessary raw material.

In the spruce region as a whole, conditions are favorable for the continuous production of pulpwood crops. Spruce stands reproduce themselves readily, growing conditions are good, and markets are excellent. There is only one prime requisite—that young growth be established on the land before the mature forest is cut off. For successful regeneration of spruce stands nearly total dependence must be placed on this advance growth. Wherever reproduction on cut-over lands is abundant, as it normally is, practically all of it is advance growth which was present in the original stand. Where reproduction is absent at the time of cutting, subsequent restocking progresses at an extremely slow pace or fails completely. When sufficient advance growth is present at the time of logging the opportunity for producing full pulpwood crops lies primarily in preserving and bringing to maturity trees already in existence at the time of cutting.

What measures are needful to insure good development of the more desirable species from this advance growth has never been broadly determined nor made widely known to forest owners. Studies of cut-over spruce and fir lands, both prior to and after clear cutting of pulpwood species came into general vogue, have been largely localized in nature, and the results of such studies have not been made generally available. To meet the need for better information, which might to advantage be widely disseminated, the Northeastern Forest Experiment Station in 1923 began to gather specific data on the actual conditions of extensive areas clear cut for pulpwood, such as would be representative of the entire spruce region.

The guiding purpose of this investigation was to find the answers to certain questions upon which must be based any satisfactory or stable policy for the management of lands for future pulpwood production. For example, what effect has the clear-cutting system, so commonly employed in spruce and fir stands to-day, on the growth and ultimate development of the future stand? What is the amount and character of the new growth coming in? Does it differ materially from the original stand? What will be the composition of the new crop of timber? What are the factors responsible for the successful establishment or failure of spruce and fir reproduction in the new stand? Will the rapidly growing hardwoods take possession of these areas to the exclusion of spruce and fir? What measures should be adopted to insure another crop of pulpwood following cutting, and what treatment is required to bring lands to full productivity?

To make clear the scope of the investigations along these lines, a brief description of the principal forest types considered will be helpful.

## THE SPRUCE FORESTS

The territory embraced by the spruce region covers practically the entire State of Maine, with the exception of a small section in the southeast, and extends westward over the northern half of New Hampshire and Vermont and the Adirondack Plateau region of New York. It follows down the Green Mountain range of Vermont, into the Berkshires of western Massachusetts. Five broad spruce types are ordinarily recognized in the spruce region: (1) Spruce-flat, (2) spruce-hardwoods, (3) spruce-slope, (4) spruce-swamp, and (5) old-field spruce. Nearly all so-called pure spruce stands have an admixture of hardwood species. Stands containing the highest percentage of spruce and fir are usually found in the old-field and spruce-slope types. A considerable admixture of hardwoods normally occurs in the other types (pl. 1, A), though spruce swamps and bogs often support pure conifer stands.

Spruce and fir are natural rivals, each struggling for possession of the same ground. In the virgin forest or on cut-over lands left undisturbed for a long period of time, spruce has no difficulty in maintaining its supremacy over its natural rival, since it is longer lived and has a greater capacity for enduring suppression.

### SPRUCE-FLAT TYPE

The spruce-flat type occurs on the better drained sites above the swamp areas and extends to the lower slopes, occupying the flats, low ridges, and knolls above the lakes and streams. The soil is moist and shallow and contains many bowlders. The forest floor is often covered with Hypnum mosses, with a thin mat of hardwood leaves on the knolls and ridges. The principal species in this type are red spruce (*Picea rubra*) and balsam fir (*Abies balsamea*), generally mixed with a few hardwoods, such as red maple (*Acer rubrum*), paper birch and yellow birch (*Betula papyrifera* and *B. lutea*), with a scattering of white spruce (*Picea glauca*), northern white pine (*Pinus strobus*), eastern hemlock (*Tsuga canadensis*), and northern white cedar (*Thuja occidentalis*) occurring as scattered individuals. The upper margin of this type is marked by the appearance of beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*). The spruce-flat type is of considerable importance commercially, being found extensively in the level regions of Maine, northern New Hampshire, Vermont, and New York. The timber is of much better quality than that found in the swamp type and the growth is more rapid.

### SPRUCE-HARDWOODS TYPE

The spruce-hardwoods type occupies the well-drained sites, preferring the deep, moist soils. It is usually encountered above the spruce-flat zone and below the upper-slope belt. Red spruce, found in mixture with balsam fir, yellow birch, beech, sugar maple, and occasionally northern white pine, red maple, and paper birch, is the chief species. Eastern hemlock is also commonly present. Red spruce reaches its best individual development in this type, as do also the associated hardwoods. It is also a type of wide commercial importance, being extensively represented through the spruce region of the Northeast.

For the purpose of discussion two subtypes will be recognized. The first is the yellow birch-spruce subtype, which usually borders the upper margins of the spruce flats or occurs on gentle slopes or benches within the spruce-hardwoods type, and has many characteristics of the spruce-flat type. Yellow birch, and to some extent red maple and paper birch, are the important hardwoods found in mixture with red spruce and balsam fir. This type is practically equivalent to what in Maine is termed the yellow-birch type.

The second subtype, the sugar maple-spruce, occurs on lower slopes and ridges and may be regarded as a borderland type between the spruce-hardwoods and northern hardwoods types. Sugar maple and beech are the principal hardwoods, and make up a considerable proportion of the stand. Red spruce, though generally well developed and of good quality, occurs much less frequently. These stands are usually associated with fairly deep, well-drained soils, often containing large quantities of rocks. This subtype forms a considerable proportion of the Adirondack region, and is also well represented in Vermont, New Hampshire, and Maine.

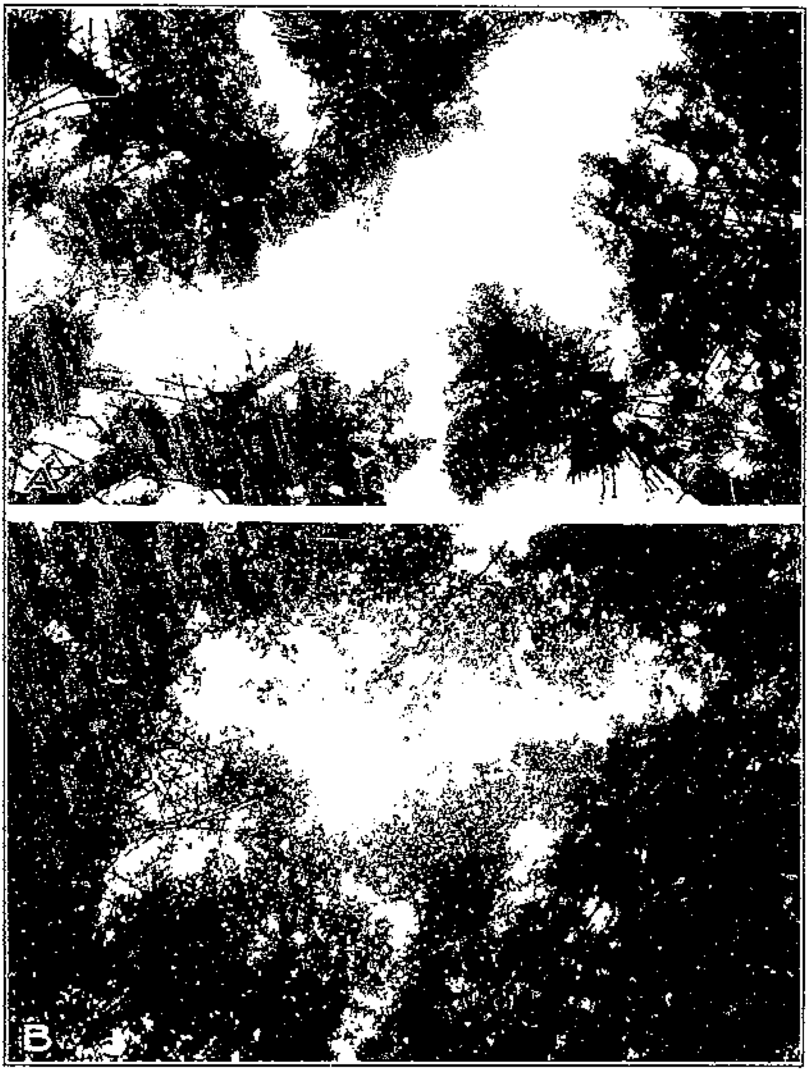
## SPRUCE-SLOPE TYPE

The spruce-slope type occupies the upper slopes, which are usually steep, rocky, and covered with a thin layer of soil. While spruce predominates in this type, balsam fir, yellow birch, and paper birch are commonly associated with it. The timber usually grows in thick stands and produces high yields. This type grades off into trees of poor quality at the upper limits, becoming more stunted as it approaches the timber line. The spruce-slope type is an important one in the mountainous sections of New York and New England.

## SPRUCE-SWAMP TYPE

The spruce-swamp type, of minor importance, occupies poorly drained areas near lakes and streams, occurring most abundantly in Maine and New York. The soil is usually peaty in character, has a high retentive capacity for water, and often supports a ground cover of Sphagnum moss of considerable depth. The most characteristic tree is the black spruce (*Picea mariana*), with balsam fir, tamarack (*Larix laricina*), northern white cedar, eastern hemlock, and northern white pine often present. Black ash (*Fraxinus nigra*), red maple, paper birch, and yellow birch are frequently represented. The growth in this type is generally slow but more rapid on its upper margin. Windfall is common, on account of the shallow root systems developed in the boggy soil.


A, A pulpwood stand in the spruce-hardwoods type, showing a characteristically large admixture of hardwoods; B, windfall on 1-year-old cutting logged for mature spruce and hardwoods. Spruce and fir are shallow rooted and on thin soils are subject to wind damage




CROWN CANOPY IN SPRUCE STANDS SHOWING THE OPENING THROUGH WHICH LIGHT REACHES THE FOREST FLOOR

A, Large conifer canopy; B, a mixture of hardwood and softwood crowns. In stands of either character sufficient light reaches the ground to encourage the establishment of abundant reproduction.

### OLD FIELD-SPRUCE TYPE

The old field-spruce type occurs scatteringly throughout the region but is confined principally to northern New England. It is restricted to lands once cleared for pasturage or agricultural crops. Owing to the high timber-productive capacity of these soils excellent growth and high yields are common. Pure stands of red spruce are frequent in this type, though balsam fir, white spruce, and occasionally tamarack and white pine appear in mixture. Pure red spruce stands are particularly characteristic of Vermont, whereas the mixed stands occur more frequently in Maine and New Hampshire. Here, in fact, white spruce often supplants red spruce to the extent of forming pure or nearly pure stands.

## METHODS OF STUDY

Approximately 420 temporary sample plots established throughout the spruce region of the Northeast, and so distributed as to represent a wide variety of type, site quality, composition of stand, and age of cut-over area, form the basis for the present study. Approximately 245 of these plots were taken in the spruce-flat type and 155 in the spruce-hardwoods type—the two types which supply the bulk of the pulpwood consumed by the industry. Sixteen plots were obtained in the spruce-slope type and only four in the old-field type. The data from these plots are supplemented by short-time observations on a series of permanent method-of-cutting plots established in the White Mountains, on which detailed studies of germination and survival of reproduction are being made. The temporary plots ranged from 0.1 of an acre to 1 acre in size, by far the greater number being one-eighth-acre plots. On most of the areas selected clear cutting of pulpwood species had been practiced; that is, all spruce and fir down to a diameter of 5 or 6 inches had been removed, while the hardwoods occurring in mixture were left uncut. This is a system of cutting commonly practiced throughout the Northeast. On transect strips, each containing 0.01 of an acre, all reproduction was recorded by species and height classes. Eight such strips were laid out to each acre of plot.

A complete record of all trees 1 inch and above in diameter was made on each plot, the 1-inch class comprising all trees 0.6 inch to 1.5 inches diameter at breast height, the 2-inch class 1.6 inches to 2.5 inches, and so on. Trees below the 1-inch class were regarded as reproduction and were recorded only on the transect strips. In order to obtain data on the character of material removed in the process of logging, stumps were measured, and recorded by species wherever this was discernible. In addition, approximately 500 red spruce and balsam fir seedlings were analyzed to determine the age and relative rate of growth and development of the two species under different growing conditions. Seedlings were cross-sectioned at intervals of 1 foot and the annual height growth determined, particular attention being paid to height growth following logging and to the relative capacity of spruce and fir to recover from suppression.

Height and crown widths distributed over a range of diameter and crown classes were measured on 10 per cent of the conifers and

5 per cent of the hardwoods. For each plot the type, location, absolute and relative elevations, aspect, stand, origin, and density were recorded, and notes were also made on the character of the soil, brush, and ground cover. Trees having well-developed crowns and located a few feet away from a stump furnished a clue to the cutting date, since these liberated trees usually show accelerated growth. The cutting date was also often determined by counting the annual rings on rapid-growing hardwoods which had sprung up in skid roads and skid trails the first growing season following logging.

Since but very few plots established on recently cut-over areas were available as a basis for stand tables, the plan followed was to reconstruct the stands on paper as they were immediately following cutting, due allowance being made for mortality during the period following cutting. Through the aid of diameter-growth tables, the present diameters of all trees now comprising the stand were reduced to their diameters at the time of cutting, and an average stand table for the newly cut-over areas was then compiled.

## RESULTS OF PAST AND PRESENT CUTTING METHODS

The original forests of the region covered extensive areas in unbroken masses, but varied from the more or less even-aged stands such as are encountered on old burns and blow-downs to the all-aged stands which are more typical of the region.

Then, as now, in the occasional vigorous even-aged stands characterized by a dense continuous overhead canopy, little sunlight struck the forest floor, and reproduction was likely to be scarce or sometimes entirely lacking. Seedlings seldom survived beyond the third or fourth year. In the older, more open stands, and in all-aged stands whose overhead canopy was less continuous (pl. 2), seed-bed conditions were favorable and the abundant seed resulted in plentiful natural reproduction.

Earlier lumbering operations encouraged the establishment of reproduction by removing here and there individuals or groups of the larger high-grade spruce and white pine, thus creating openings which were usually filled up at once by released conifer reproduction or by fast-growing hardwoods. In some instances the slower-growing spruce and fir had been suppressed for years under cover of the invading hardwoods, only to gain the ascendency eventually.

The early expansion of the pulp and paper industry made no radical change in this situation; but with the beginning of the twentieth century the consumption of paper increased enormously, bringing at once increased stumpage values and a greater severity of cutting. By 1913 most of the owners in the Northeast were cutting their pulpwood lands clean, only occasional spruce and fir trees over 5 inches in diameter being left. These trees, in most instances, were unable for many years to produce seed in any quantity. Areas which had supported nearly pure stands of spruce and fir were left practically treeless. Elsewhere the hardwoods, not being generally utilized, dominated the residual stand and produced yearly vast quantities of seed, resulting in a greatly increased representation in the following crop.

Even under these conditions, spruce and fir reproduction on cut-over spruce lands was normally plentiful. Conditions on uncut as well as on cut-over areas indicate that practically all of the pulpwood reproduction now found on cut-over areas was present in the stand prior to cutting and represents an accumulation extending over a period of several decades.

Table 3 summarizes for the spruce-flat, spruce-hardwoods, and spruce-slope types the average number of conifers and hardwoods left following logging, whereas Tables 1 and 2 show in detail by diameter classes the residual stand in the first two of these types. A glance at Table 3 shows that usually a considerable number of trees remained even on these so-called clear-cut areas. In the spruce-flat and spruce-slope types the bulk of these trees are spruce and fir. However, their average breast-high diameter does not exceed 2 inches in any of the types because of the degree to which these species are utilized. In the spruce-hardwoods type, the hardwoods greatly outnumber the conifers. Residual hardwoods in nearly all instances range from small trees to mature and overmature trees of large size.

In general, these hardwoods contain a considerable quantity of defect, which appears to be more marked in the cut-over stands than in the original forest. A possible explanation of this difference may be that through injuries received in logging the residual hardwood trees are more easily attacked by rot-producing fungi. How serious a factor this may be was demonstrated on a number of sample plots where, in a careful estimate of all standing merchantable hardwood trees, a total volume of 7,000 board feet of merchantable hardwoods per acre was found to contain only 2,400 board feet, or but 34 per cent, of sound material.

TABLE 1.—*Stand table by species and diameter classes, spruce-flat type, in number of trees per acre: Residual stand following cutting to small diameters for pulpwood species only*[1]

| Diameter class (inches) | Red spruce | Balsam fir | Yellow birch | Beech | Sugar maple | Red maple | Paper birch | Miscellaneous | Total spruce and fir | All merchantable hardwoods | All weed species |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 18.9 | 34.7 | 5.7 | 0.6 | 0.1 | 5.9 | 9.2 | 2.2 | 53.6 | 23.7 | 0.6 |
| 2 | 16.4 | 16.2 | 3.5 | .6 | | 2.1 | 2.1 | 1.8 | 32.0 | 10.1 | 1.3 |
| 3 | 10.4 | 10.0 | 3.3 | .5 | | 1.2 | 1.4 | 2.5 | 20.4 | 8.9 | .7 |
| 4 | 8.3 | 6.5 | 2.8 | .5 | | 1.0 | 1.0 | 1.8 | 14.8 | 7.1 | .7 |
| 5 | 5.5 | 4.5 | 2.4 | .2 | | 1.1 | 1.4 | 1.5 | 10.0 | 6.6 | .1 |
| 6 | 3.7 | 2.7 | 2.8 | .4 | | .9 | 1.0 | 1.2 | 6.4 | 6.3 | .1 |
| 7 | 3.8 | 2.0 | 2.6 | .4 | | .8 | 1.2 | .7 | 5.8 | 5.7 | .5 |
| 8 | 5.3 | 1.5 | 2.7 | .3 | | .7 | 1.0 | .7 | 6.8 | 5.4 | |
| 9 | 2.2 | .6 | 1.6 | .2 | | .8 | .8 | .6 | 2.8 | 4.0 | |
| 10 | 1.0 | .6 | 3.4 | .2 | | .5 | .7 | .8 | 1.6 | 5.6 | |
| 11 | .7 | .3 | 1.8 | .2 | .1 | .3 | .6 | .6 | 1.0 | 3.6 | |
| 12 | .2 | .1 | 1.2 | | | .3 | .5 | .8 | .3 | 2.8 | |
| 13 | .2 | .1 | 1.0 | | | .1 | .4 | .3 | .3 | 1.8 | |
| 14 | | | .9 | | | .2 | .3 | .3 | | 1.7 | |
| 15 | | | .5 | .1 | | .1 | .2 | .2 | | 1.1 | |
| 16 | | | .6 | | | | .1 | .2 | | .9 | |
| 17 | | | .5 | | | | .2 | | | .7 | |
| 18 | | | .2 | | | | | | | .2 | |
| 19 | | | .1 | | | | | | | .1 | |
| 20 | | | .1 | | | | | | | .1 | |
| 21 | | | .1 | | | | | | | .1 | |
| Total | 76.6 | 79.8 | 37.8 | 4.2 | .2 | 16.0 | 22.1 | 16.2 | 156.4 | 96.5 | 4.0 |
| Percentage | 29.8 | 31.1 | 14.7 | 1.6 | .1 | 6.2 | 8.6 | 6.3 | 60.9 | 37.5 | 1.6 |

[1] Basis, 226 plots. It will be noted that the number of plots forming the basis for Tables 1, 2, and 3 does not agree with the number used as a basis for the reproduction tables. This disagreement is due to the fact that the depth of the snow prevented the tallying of reproduction on a number of the plots established. In the spruce and hardwoods type additional reproduction plots were tallied subsequent to the compilation of the stand table.

TABLE 2.—*Stand table by species and diameter classes, spruce-hardwoods type, in number of trees per acre: Residual stand following cutting to small diameters for pulpwood species only*[1]

| Diameter class (inches) | Red spruce | Balsam fir | Yellow birch | Beech | Sugar maple | Red maple | Paper birch | Miscellaneous | Total spruce and fir | All merchantable hardwoods | All weed species |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.8 | 5.8 | 11.6 | 5.2 | 4.0 | 4.9 | 3.6 | 0.4 | 19.6 | 20.7 | 1.5 |
| 2 | 9.2 | 7.8 | 8.3 | 3.9 | 2.1 | 3.8 | 1.3 | .4 | 17.0 | 19.8 | 5.0 |
| 3 | 6.8 | 6.2 | 3.4 | 1.4 | .6 | .4 | .2 | .3 | 13.0 | 6.3 | 1.0 |
| 4 | 5.4 | 3.1 | 4.9 | 2.3 | 1.2 | 3.6 | .3 | .5 | 8.5 | 12.8 | .9 |
| 5 | 4.7 | 1.8 | 3.0 | 1.6 | .5 | .4 | .2 | | 6.5 | 5.7 | |
| 6 | 2.1 | 1.0 | 3.3 | 2.6 | .4 | .9 | .3 | .5 | 3.1 | 8.0 | .2 |
| 7 | 3.0 | .6 | 1.6 | 1.0 | .6 | .3 | .4 | .1 | 3.6 | 4.0 | |
| 8 | 1.4 | .1 | 3.3 | 1.8 | .3 | .8 | | | 1.5 | 6.2 | |
| 9 | .5 | .1 | 1.4 | 1.2 | | .3 | .4 | .1 | .6 | 3.4 | |
| 10 | .2 | | 2.3 | 1.8 | .4 | .8 | | .1 | .2 | 5.4 | |
| 11 | .2 | | 1.1 | 1.2 | | .1 | | | .2 | 2.4 | |
| 12 | .2 | | 2.4 | 1.2 | .4 | .5 | | | .2 | 4.5 | |
| 13 | | | .6 | .7 | .3 | | | | | 1.6 | |
| 14 | | | 1.2 | .7 | .6 | | | | | 2.5 | |
| 15 | | | .4 | .2 | .3 | | | | | .9 | |
| 16 | | | 1.0 | .6 | .3 | .3 | | .1 | | 2.3 | |
| 17 | | | .6 | .1 | | .3 | | | | 1.0 | |
| 18 | | | .8 | .1 | | | | | | .9 | |
| 19 | | | .1 | | | | | | | .1 | |
| 20 | | | .4 | | | | | | | .4 | |
| 22 | | | .3 | | | | | | | .3 | |
| Total | 47.5 | 26.5 | 52.0 | 27.6 | 12.0 | 17.4 | 6.7 | 2.5 | 74.0 | 118.2 | 9.5 |
| Percentage | 23.6 | 13.1 | 25.8 | 13.7 | 6.0 | 8.6 | 3.3 | 1.2 | 36.7 | 58.6 | 4.7 |

[1] Basis, 132 plots.

TABLE 3.—*Residual stand immediately following removal of spruce and fir for pulpwood in different forest types, in number of trees per acre 1 inch diameter at breast height and above*

| Forest type | Pulpwood species | | | Hardwoods and others | Weed species | All trees | Number of plots |
|---|---|---|---|---|---|---|---|
| | Spruce | Fir | Total | | | | |
| Spruce flat | 76.6 | 79.8 | 156.4 | 96.5 | 4.0 | 256.9 | 226 |
| Spruce and hardwoods | 47.5 | 26.5 | 74.0 | 118.2 | 9.5 | 201.7 | 132 |
| Spruce slope | 45.7 | 35.5 | 81.2 | 16.6 | 0 | 97.8 | 18 |

Cutting also leaves the residual trees subject to the drying influences of sun and wind, causing them to become stag headed and encouraging attacks from insects such as the sugar-maple borer (*Glycobius speciosus*) which attacks the sugar maple, and the bronze-birch borer (*Agrilus anxius*) which attacks both the paper and yellow birches. The paper and yellow birches are particularly susceptible to deterioration. Preliminary observations indicate that this deterioration increases directly in proportion to the amount of sunlight reaching the released trees.

As a rule, on the cut-over areas studied, all size classes subject to severe wind-throw had been removed. However, on extremely shallow soils spruce and fir trees even as small as 1 and 2 inches (diameter at breast height) were uprooted by the wind, and occasional large openings in the stand resulted in the wind-throw of some of the residual hardwoods, particularly yellow birch. Wind-throw in hardwoods, however, is of direct benefit to the young conifers.

Stands in which a selection method of cutting has been practiced often suffer severe losses from wind-throw. (Pl. 1, B.) In one such stand, in which 70 per cent of the original 13,000 board feet per acre had been removed, approximately 30 per cent of the residual stand of 3,800 board feet per acre was lost through wind-throw within 16 months of logging, including 40 per cent by volume of the residual hardwoods. This loss was further increased by subsequent windfall. Although this high loss—partly explained by the fact that the stand was unduly exposed—may be the result of a rather unusual set of conditions, it nevertheless helps to emphasize the consideration that must be given to wind-throw in the management of spruce stands.

## REPRODUCTION IN THE ORIGINAL STAND

As has been pointed out conditions in the original stand are normally favorable to the establishment of abundant conifer reproduction. Where considerable light reaches the forest floor, it is not uncommon to find a goodly scattering of spruce and fir seedlings hidden among the heavy growth of low herbaceous vegetation. (Pl. 3, A.) Old decayed logs and wind-thrown trees are frequently covered with dense masses of spruce and fir reproduction which in vigor and number exceed those growing on adjacent areas of equal size, indicating that these sites are most favorable to the germination and development of spruce and fir seedlings.

In the form of a reserve, these spruce and fir seedlings remain in suppression for long periods. If the period be not too long they will upon release assume their normal growth; but continued suppression is harmful to both species, especially to fir. (Pl. 3, B.) As will be shown subsequently, fir seedlings have the ability to take quick possession of the land but, lacking the stamina of spruce seedlings and requiring more light for their development as they grow older, are liable to die in large numbers before attaining any great height if release be too long deferred. At 3 to 4 feet they may develop suppressed, flattened crowns, insufficient for the demands of growth, greatly retarding development and lowering vitality, thus making the young trees particularly susceptible to disease. Wind-throw is also a factor in reducing the representation of fir.

Where beech and sugar maple form an important part of the stand, it is not unusual to find advance reproduction of these species on the forest floor in large numbers. In an uncut spruce-hardwood stand sugar maple, which formed a high percentage of the mature stand, constituted 86 per cent of the reproduction (Table 4), owing to its tolerance of shade. Beech formed only 5 per cent, while yellow birch, red spruce, and balsam fir were each represented to the extent of only 3 per cent. The birches and red maple are less tolerant and form a very small percentage of the advance reproduction, but following logging they come up abundantly in openings. Beech springs up in considerable numbers as root suckers, particularly from portions of roots barked in the process of log skidding.

TABLE 4.—*Reproduction per acre of various size classes in an uncut mature stand in the spruce-hardwoods type, containing a high percentage of sugar maple* [1]

| Size class | Pulpwood species | | | Sugar maple | Beech | Yellow birch | Total hardwoods | All species |
|---|---|---|---|---|---|---|---|---|
| | Red spruce | Balsam fir | Total | | | | | |
| 0 to 0.5 foot | 282 | 469 | 731 | [2] 4,694 | 118 | 270 | 5,082 | 5,813 |
| 0.6 to 1 foot | 14 | 24 | 38 | 4,207 | 361 | 155 | 4,813 | 4,851 |
| 1.1 to 2 feet | 62 | 1 | 63 | 1,737 | 85 | 42 | 1,864 | 1,927 |
| 2.1 to 3 feet | 23 | 3 | 26 | 1,143 | 53 | 30 | 1,226 | 1,252 |
| 3.1 to 4 feet | 19 | 1 | 20 | 557 | 32 | 20 | 609 | 629 |
| 4.1 feet, 1 inch diameter at breast height | 37 | -------- | 37 | 554 | 62 | 6 | 622 | 659 |
| Total | 417 | 498 | 915 | [2]12,952 | 711 | 523 | 14,216 | 15,131 |
| Per cent | 2.7 | 3.3 | 6.0 | 85.8 | 4.7 | 3.5 | 94.0 | 100 |

[1] Based on 72 chains of reproduction strips 6.6 feet wide.
[2] Including one red maple seedling.

## REPRODUCTION FOLLOWING CUTTING

Where advance reproduction is absent and reliance for seed trees for the new forest must be placed upon the few conifers under 5 or 6 inches in diameter, prospects for renewed pulpwood stands are slight. The remaining conifers, if of the suppressed class as is usually the case, will not for many years develop into effective seed-bearing trees. In the meantime hundreds of thousands of seedlings produced by the large residual hardwoods will take possession of the inadequately stocked areas. Changed seed-bed conditions and dense stands of hardwood sprouts, together with invading brush growth, discourage the establishment of spruce and fir following cutting. It is not surprising that, even on 20 and 30 year old cuttings, the spruce and fir reproduction that has come in since cutting is negligible. Such small quantities as do appear are for the most part of fir. Where seed-bed conditions are favorable the new seedlings may gain a foothold within the first year or two following cutting, but with each passing year conditions become less and less favorable for their establishment. No attempt will be made here to discuss all of the factors responsible for the complete or partial failure of new spruce and fir seedlings to establish themselves on cut-over lands where advance reproduction is absent. Not until more data have been obtained on seed supply, soil moisture, nutrients, light intensities, and other particulars affecting the establishment of these species can this question be fully answered.

## FACTORS AFFECTING THE QUANTITY OF ADVANCE REPRODUCTION

### FOREST TYPE

The quantity of spruce and fir reproduction on cut-over lands varies with forest type. A study of Tables 5 to 9 inclusive and Figures 1 to 4 showing the quantity and composition of reproduction clearly demonstrates this fact. It is of particular interest in this respect to compare the spruce-flat with the spruce-hardwoods type—

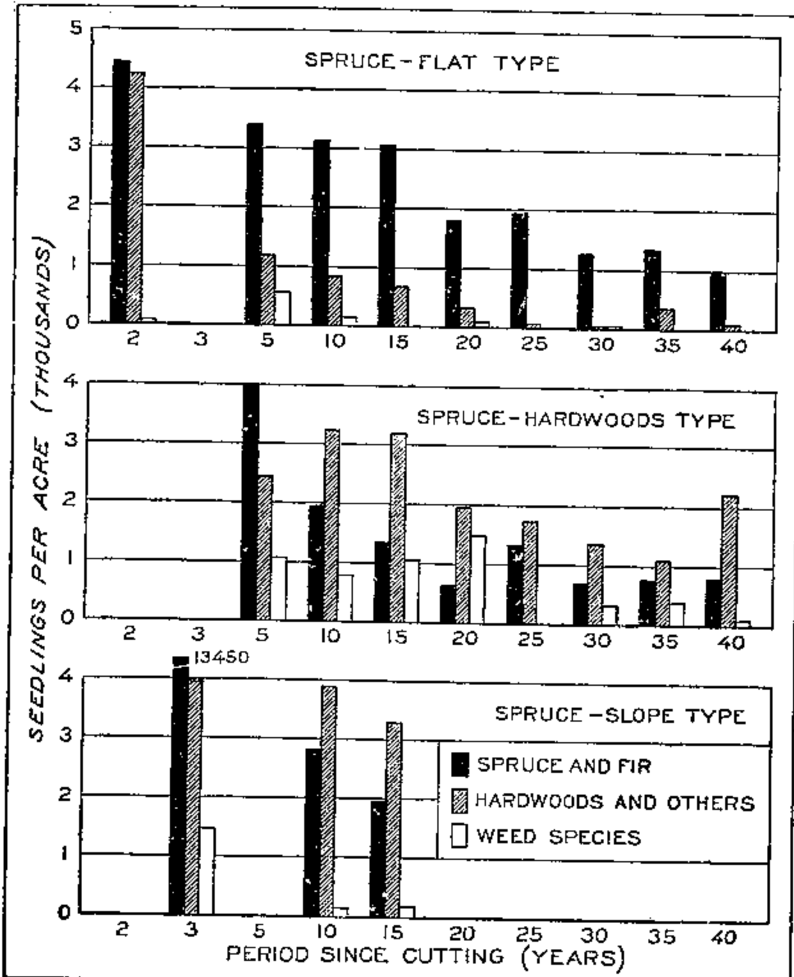



FIGURE 1.—Relation of composition and quantity of reproduction to age of cutting for various forest types. This includes only reproduction below 1 inch diameter at breast height

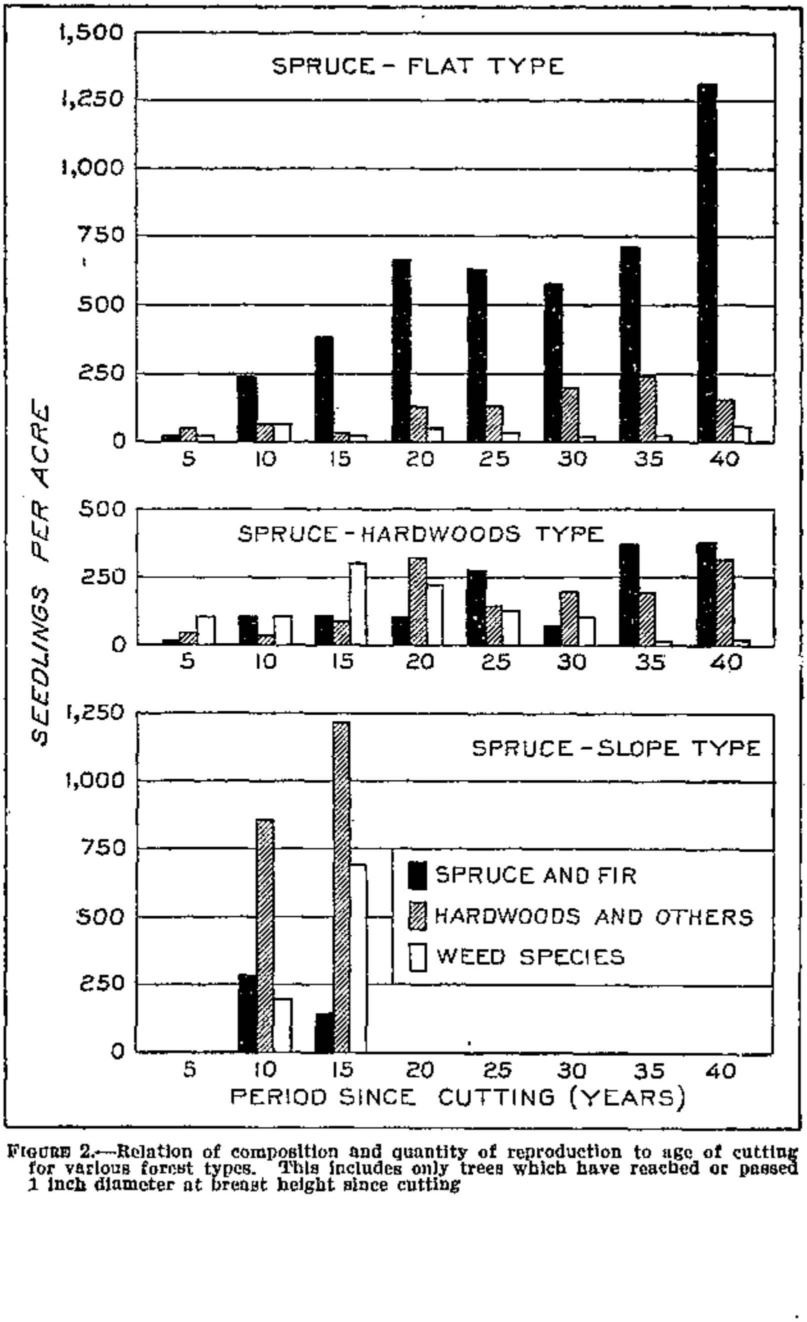



FIGURE 2.—Relation of composition and quantity of reproduction to age of cutting for various forest types. This includes only trees which have reached or passed 1 inch diameter at breast height since cutting

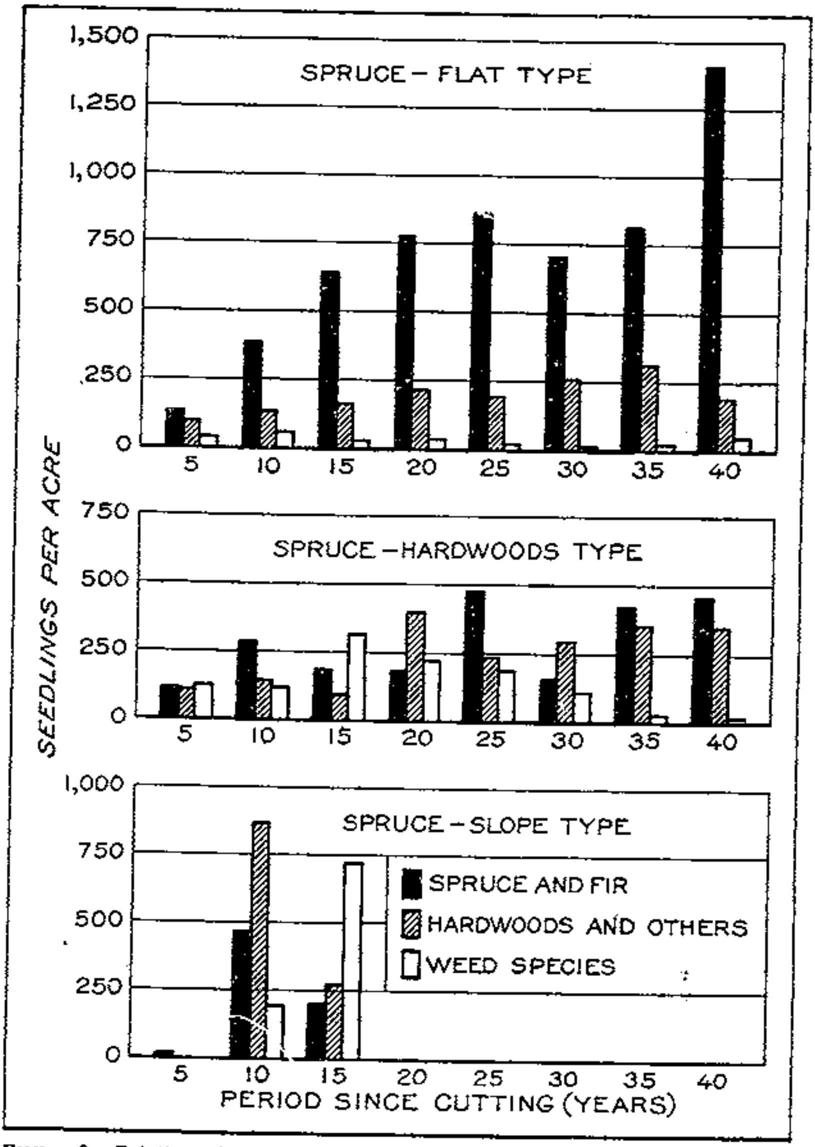



FIGURE 3.—Relation of composition and number of all trees 1 inch diameter at breast height and above (residual and new growth) to age of cutting for various forest types

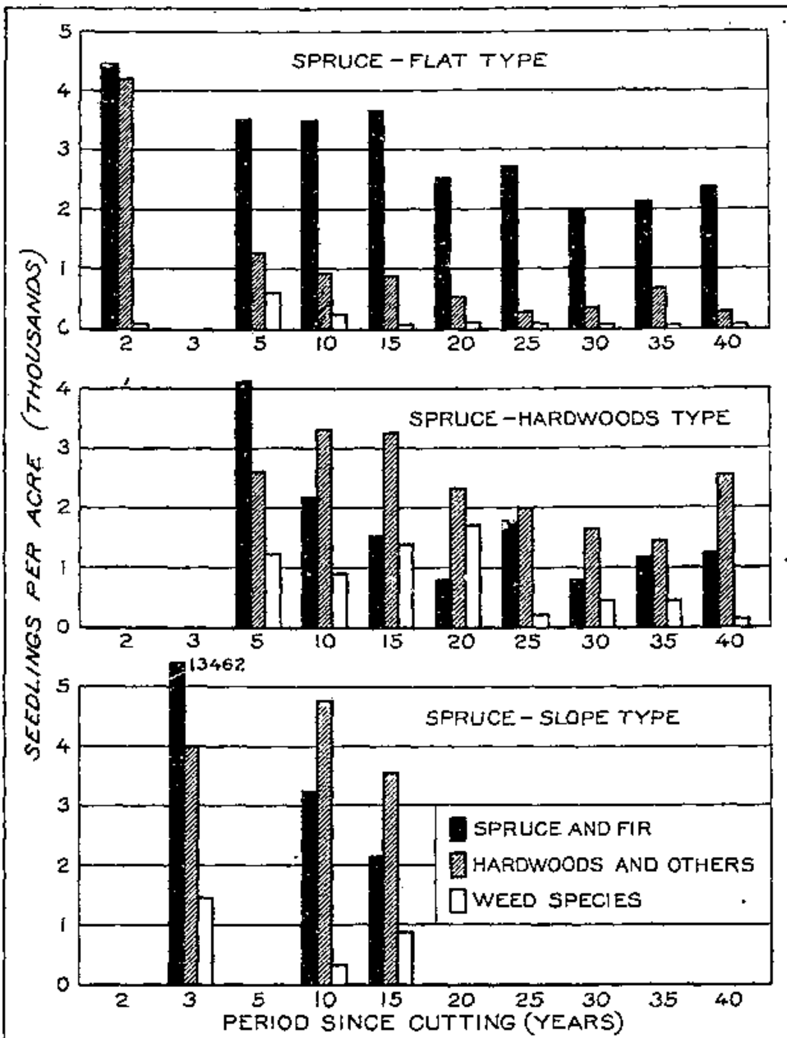



FIGURE 4.—Relation of composition and quantity of all stems (reproduction below 1 inch diameter at breast height plus all trees 1 inch diameter at breast height and above) to age of cutting for various forest types

the two types of greatest extent and importance in the spruce region. In both of these types data were gathered on cut-over areas up to 40 years old, making possible a direct comparison of the results, a discussion of which follows later. In the spruce-slope type only three ages of cut-over areas are represented, the maximum age being 15 years. In drawing comparisons, therefore, the limitations of the spruce-slope should be recognized.

Examination of Figure 1 and Table 5 indicates that certain facts hold true for all types studied, namely that the quantity of conifer reproduction below 1 inch diameter at breast height is greatest on the areas most recently cut over, decreasing progressively with increase in the period since cutting. This is concrete evidence that, as previously stated, the reproduction coming in after cutting exclusive of hardwoods is negligible.

TABLE 5.—*Relation of composition and quantity of reproduction smaller than 1 inch diameter at breast height to age of cut-over area for various forest types*

SPRUCE—FLAT TYPE

| Age (years) | Average stems of reproduction per acre | | | | | | | Proportion of spruce and fir | | Basis, plots |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spruce and fir | | Hardwoods and others | | Weed species | | Total | Spruce | Fir | |
| | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Per cent* | *Number* |
| 2 | 4,440 | 50.9 | 4,244 | 48.7 | 36 | 0.4 | 8,720 | 40.1 | 59.9 | 63 |
| 5 | 3,395 | 66.8 | 1,154 | 22.7 | 534 | 10.5 | 5,083 | 17.0 | 83.0 | 16 |
| 10 | 3,138 | 76.6 | 805 | 19.6 | 155 | 3.8 | 4,098 | 33.0 | 67.0 | 46 |
| 15 | 3,062 | 81.5 | 693 | 18.5 | 0 | 0 | 3,755 | 40.8 | 59.2 | 14 |
| 20 | 1,762 | 83.4 | 306 | 14.5 | 45 | 2.1 | 2,113 | 26.2 | 73.8 | 32 |
| 25 | 1,929 | 97.1 | 58 | 2.9 | 0 | 0 | 1,987 | 41.8 | 58.2 | 31 |
| 30 | 1,275 | 94.8 | 39 | 2.9 | 31 | 2.3 | 1,345 | 35.7 | 64.3 | 29 |
| 35 | 1,333 | 80.0 | 333 | 20.0 | 0 | 0 | 1,666 | 59.9 | 40.1 | 3 |
| 40 | 977 | 91.7 | 88 | 8.3 | 0 | 0 | 1,065 | 29.7 | 70.3 | 11 |

SPRUCE—HARDWOODS TYPE

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 3,004 | 52.9 | 2,472 | 32.7 | 1,090 | 14.4 | 7,556 | 65.0 | 35.0 | 17 |
| 10 | 1,926 | 32.6 | 3,214 | 54.4 | 771 | 13.0 | 5,011 | 74.1 | 25.9 | 53 |
| 15 | 1,325 | 23.7 | 3,180 | 56.8 | 1,090 | 19.5 | 5,595 | 36.2 | 63.8 | 20 |
| 20 | 580 | 14.5 | 1,930 | 48.2 | 1,490 | 37.3 | 4,000 | 63.7 | 36.3 | 10 |
| 25 | 1,328 | 43.5 | 1,722 | 56.5 | 0 | 0 | 3,050 | 78.2 | 21.8 | 12 |
| 30 | 638 | 27.8 | 1,357 | 59.1 | 302 | 13.1 | 2,297 | 51.6 | 48.4 | 24 |
| 35 | 711 | 32.8 | 1,058 | 48.8 | 398 | 18.4 | 2,167 | 72.4 | 27.6 | 6 |
| 40 | 750 | 24.8 | 2,200 | 72.6 | 80 | 2.6 | 3,030 | 64.0 | 36.0 | 10 |

SPRUCE—SLOPE TYPE

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 13,450 | 71.2 | 4,000 | 21.2 | 1,450 | 7.6 | 18,900 | 88.1 | 11.9 | 4 |
| 10 | 2,747 | 41.0 | 3,812 | 56.8 | 148 | 2.2 | 6,707 | 65.5 | 34.5 | 8 |
| 15 | 1,900 | 35.9 | 3,225 | 60.8 | 175 | 3.3 | 5,300 | 96.0 | 4.0 | 4 |

Tables 5 to 9 and Figures 1 to 4 also show that cut-over areas in the spruce-flat type have over twice the quantity of spruce and fir reproduction that cut-over areas in the spruce-hardwoods type have. Other conifers [2] and hardwoods, as well as weed species,[3] are present

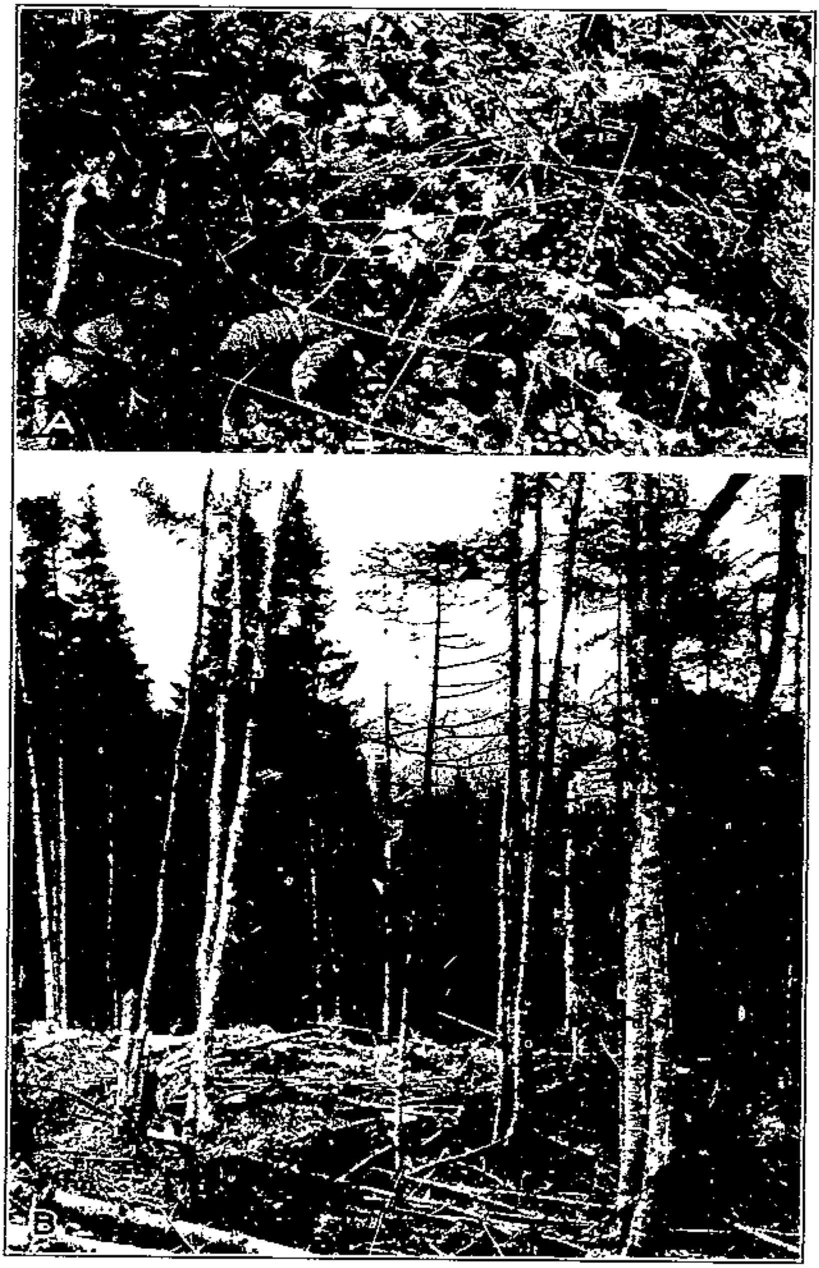
[2] Such as cedar, hemlock, and pine, which form a negligible part of the stand.
[3] Weed species, or unmerchantable hardwoods, seldom attaining a diameter of 8 inches at breast height consist of pin (fire) cherry (*Prunus pennsylvanica*), mountain ash (*Sorbus americana*), mountain maple (*Acer spicatum*), striped maple (moosewood), (*Acer pennsylvanicum*), and gray birch (*Betula populifolia*).

in considerably greater numbers in the spruce-hardwoods than in the spruce-flat type. In fact, the reproduction of hardwoods and others in this type outnumbers that on the spruce-flat by a ratio of over 2 to 1, while for the weed species the ratio is even greater. (Fig. 4.) The maximum quantity of spruce and fir reproduction to the acre encountered in the spruce-hardwoods type was spruce, 5,200; balsam fir, 7,800; and hardwoods, 13,400. In the spruce-flat type the maximum numbers were spruce, 16,125; balsam fir, 11,900; and hardwoods, 5,100. And in the spruce-slope type spruce, 20,400; balsam fir; 200; and hardwoods, 7,000. Occasional plots in all types were found to be devoid of all reproduction. The older cut-over areas contain relatively small numbers of seedlings, since most of the seedlings have, in the elapsed interval since cutting, outgrown the reproduction stage and can no longer be so classed.

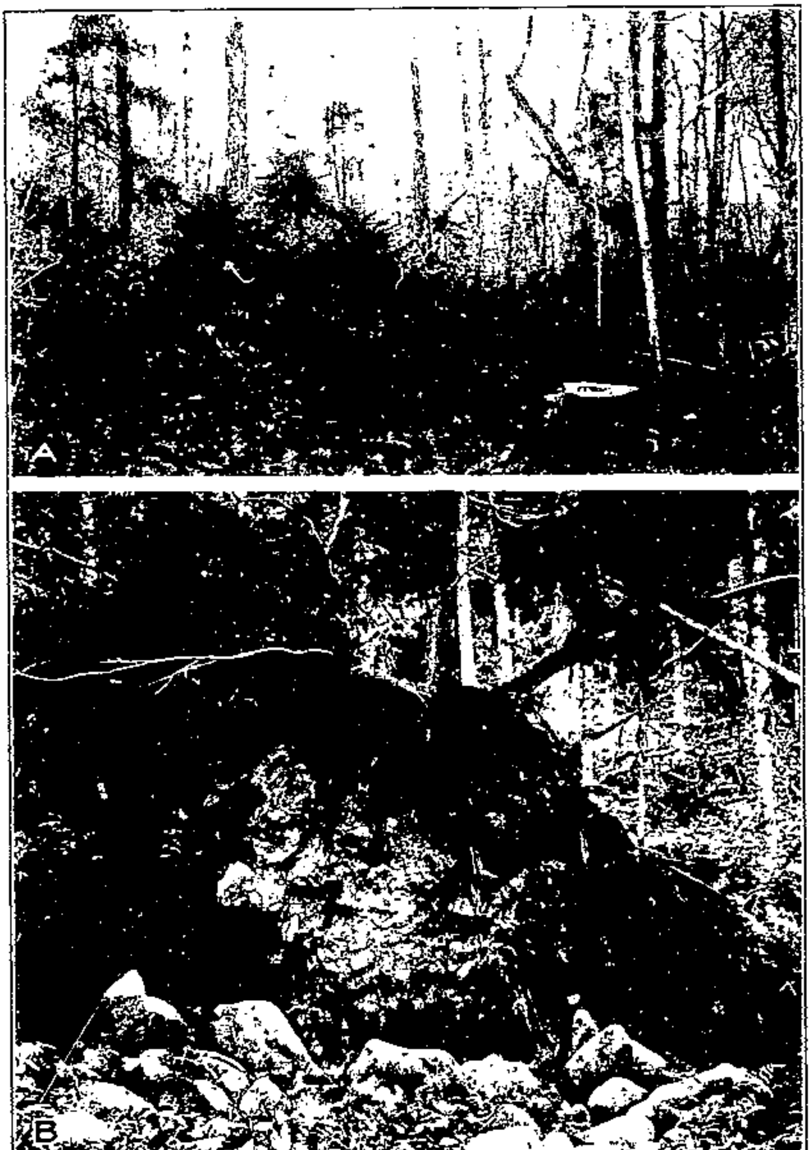
TABLE 6.—*Reproduction of various height classes in number of trees per acre in different age cuttings for various forest types*

| Age of cutting (years) | 0 to 0.5 ft. class | | 0.6 to 1.0 ft. class | | 1.1 to 2.0 ft. class | | 2.1 to 3.0 ft. class | | 3.1 to 4.0 ft. class | | 4.1 ft. to 1 in. diameter at breast height | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pulpwood | Others | Pulpwood | Others | Pulpwood | Others | Pulpwood | Others | Pulpwood | Others | Pulpwood | Others |
| SPRUCE-FLAT TYPE [1] | | | | | | | | | | | | |
| 5 | 409 | 174 | 1,150 | 136 | 744 | 92 | 672 | 378 | 393 | 517 | 187 | 248 |
| 10 | 37 | 0 | 681 | 111 | 528 | 86 | 732 | 151 | 038 | 210 | 068 | 279 |
| 15 | 452 | 21 | 906 | 164 | 614 | 92 | 414 | 100 | 271 | 81 | 406 | 28 |
| 20 | 121 | 0 | 205 | 40 | 228 | 24 | 359 | 15 | 236 | 21 | 393 | 30 |
| 25 | 170 | 0 | 403 | 9 | 393 | 0 | 331 | 6 | 232 | 3 | 270 | 12 |
| 30 | 75 | 0 | 347 | 28 | 152 | 6 | 337 | 29 | 146 | 19 | 247 | 0 |
| 35 | 229 | 0 | 499 | 100 | 166 | 0 | 433 | 100 | 90 | 0 | 90 | 0 |
| 40 | 120 | 0 | 430 | 50 | 150 | 20 | 100 | 10 | 60 | 0 | 80 | 0 |
| SPRUCE-HARDWOODS TYPE [2] | | | | | | | | | | | | |
| 5 | 417 | 11 | 1,640 | 1,256 | 850 | 532 | 424 | 315 | 458 | 526 | 192 | 900 |
| 10 | 77 | 208 | 344 | 1,172 | 309 | 665 | 442 | 625 | 295 | 460 | 477 | 853 |
| 15 | 65 | 10 | 625 | 815 | 305 | 635 | 170 | 915 | 145 | 725 | 115 | 1,170 |
| 20 | 80 | 50 | 210 | 1,120 | 160 | 570 | 90 | 300 | 80 | 200 | 20 | 1,020 |
| 25 | 0 | 91 | 540 | 1,031 | 291 | 90 | 223 | 32 | 182 | 124 | 257 | 150 |
| 30 | 67 | 0 | 220 | 963 | 117 | 250 | 133 | 205 | 59 | 87 | 33 | 132 |
| 35 | 16 | 0 | 149 | 298 | 166 | 531 | 166 | 264 | 140 | 330 | 98 | 0 |
| 40 | 30 | 20 | 360 | 2,020 | 190 | 180 | 70 | 50 | 60 | 10 | 40 | 0 |
| SPRUCE-SLOPE TYPE [3] | | | | | | | | | | | | |
| 3 | 2,050 | 0 | 750 | 7,500 | 2,000 | 650 | 1,100 | 2,250 | 200 | 1,500 | 0 | 300 |
| 10 | 0 | 12 | 362 | 212 | 424 | 49 | 500 | 112 | 675 | 349 | 687 | 3,228 |
| 15 | 0 | 0 | 800 | 125 | 475 | 175 | 300 | 50 | 225 | 200 | 100 | 2,850 |

[1] Basis, 182 plots. [2] Basis, 152 plots. [3] Basis, 16 plots.




A, Where the overhead canopy permits some direct light to strike the forest floor a wide variety of low vegetation covers the ground. Hidden among this growth are numerous spruce and fir seedlings; B, flat-topped balsam fir on 1-year-old cutting. The thin short crown is indicative of a long suppression period which has greatly restricted development of the tree. Spindly trees of this class often show the presence of heart rot and are easily windthrown




A, One-year-old cutting logged for spruce and fir only. Residual hardwoods, invading underbrush, and young hardwood growth interfere seriously with the development of small spruce and fir reproduction; B, overturned red spruce showing shallow root system and thin soil overlaying massive bowlders, large numbers of which often lie immediately beneath the surface soil and may be strewn promiscuously over the forest floor. Sites of this character are found on benches and flats and usually support stands with a high percentage of conifers. Opening up such stands is usually accomplished with danger from windfall

**Table 7.**—*Relation of composition and quantity of reproduction to age of cut-over area for various forest types, including only trees which have reached 1 inch diameter at breast height or larger since cutting*

| Age (years) | Average stems of reproduction per acre | | | | | | Total | Proportion of spruce and fir | | Basis, plots |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spruce and fir | | Hardwoods and others | | Weed species | | | Spruce | Fir | |
| | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Per cent* | *Number* |
| SPRUCE-FLAT TYPE | | | | | | | | | | |
| 5 | 5 | 6.3 | 32 | 53.3 | 23 | 38.4 | 60 | 0.0 | 100.0 | 16 |
| 10 | 234 | 65.0 | 61 | 16.9 | 65 | 18.1 | 360 | 13.5 | 86.5 | 46 |
| 15 | 377 | 88.7 | 26 | 6.1 | 22 | 5.2 | 425 | 10.0 | 90.0 | 14 |
| 20 | 646 | 79.8 | 122 | 15.1 | 41 | 5.1 | 809 | 13.6 | 86.4 | 32 |
| 25 | 620 | 82.2 | 111 | 14.7 | 23 | 3.1 | 754 | 38.9 | 61.1 | 31 |
| 30 | 566 | 73.5 | 187 | 24.3 | 17 | 2.2 | 770 | 34.5 | 65.5 | 29 |
| 35 | 688 | 73.3 | 235 | 25.0 | 16 | 1.7 | 939 | 28.4 | 71.6 | 3 |
| 40 | 1,314 | 86.5 | 147 | 9.7 | 58 | 3.8 | 1,519 | 6.6 | 93.4 | 11 |
| SPRUCE-HARDWOODS TYPE | | | | | | | | | | |
| 5 | 11 | 6.6 | 42 | 25.3 | 113 | 68.1 | 166 | 6.0 | 100.0 | 17 |
| 10 | 121 | 46.7 | 36 | 13.9 | 102 | 39.4 | 259 | 38.7 | 61.3 | 53 |
| 15 | 108 | 21.7 | 86 | 17.2 | 305 | 61.1 | 499 | 25.7 | 74.3 | 20 |
| 20 | 104 | 16.0 | 323 | 49.8 | 222 | 34.2 | 649 | 48.5 | 51.5 | 10 |
| 25 | 277 | 49.1 | 150 | 26.6 | 137 | 24.3 | 564 | 41.5 | 58.5 | 12 |
| 30 | 69 | 18.3 | 202 | 53.6 | 106 | 28.1 | 377 | 52.2 | 47.8 | 24 |
| 35 | 367 | 63.6 | 199 | 34.5 | 11 | 1.9 | 577 | 32.4 | 67.6 | 6 |
| 40 | 376 | 53.8 | 316 | 45.2 | 7 | 1.0 | 699 | 34.6 | 65.4 | 10 |
| SPRUCE-SLOPE TYPE | | | | | | | | | | |
| 3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0.0 | 4 |
| 10 | 276 | 20.9 | 852 | 64.7 | 190 | 14.4 | 1,318 | 34.6 | 65.4 | 8 |
| 15 | 138 | 6.7 | 1,220 | 59.5 | 692 | 33.8 | 2,050 | 66.7 | 33.3 | 4 |

**Table 8.**—*Relation of composition and quantity of all trees 1 inch diameter at breast height and above (residual and new growth) to age of cut-over area for various forest types*

| Age (years) | Average trees above 1 inch diameter at breast height per acre | | | | | | Total | Proportion of spruce and fir | | Basis plots |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spruce and fir | | Hardwoods and others | | Weed species | | | Spruce | Fir | |
| | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Per cent* | *Number* |
| SPRUCE-FLAT TYPE | | | | | | | | | | |
| 5 | 124 | 45.9 | 109 | 40.4 | 37 | 13.7 | 270 | 34.0 | 66.0 | 16 |
| 10 | 399 | 67.4 | 126 | 21.3 | 67 | 11.3 | 592 | 17.7 | 82.3 | 46 |
| 15 | 654 | 77.4 | 169 | 20.0 | 22 | 2.6 | 845 | 31.5 | 68.5 | 14 |
| 20 | 784 | 75.3 | 217 | 20.8 | 41 | 3.9 | 1,042 | 20.0 | 80.0 | 32 |
| 25 | 879 | 80.3 | 192 | 17.6 | 23 | 2.1 | 1,094 | 47.2 | 52.8 | 31 |
| 30 | 710 | 72.1 | 261 | 26.2 | 17 | 1.7 | 997 | 39.8 | 60.2 | 29 |
| 35 | 840 | 71.6 | 317 | 27.0 | 16 | 1.4 | 1,173 | 58.1 | 41.9 | 3 |
| 40 | 1,424 | 84.8 | 198 | 11.8 | 58 | 3.4 | 1,680 | 8.5 | 91.5 | 11 |
| SPRUCE-HARDWOODS TYPE | | | | | | | | | | |
| 5 | 112 | 33.6 | 108 | 32.4 | 113 | 34.0 | 333 | 57.1 | 42.9 | 17 |
| 10 | 270 | 51.4 | 136 | 25.9 | 119 | 22.7 | 525 | 42.4 | 57.6 | 53 |
| 15 | 178 | 30.9 | 93 | 16.1 | 306 | 53.0 | 577 | 39.6 | 60.4 | 20 |
| 20 | 175 | 22.3 | 386 | 49.3 | 222 | 28.4 | 783 | 53.9 | 46.1 | 10 |
| 25 | 481 | 53.0 | 243 | 26.8 | 183 | 20.2 | 907 | 40.9 | 59.1 | 12 |
| 30 | 155 | 28.1 | 281 | 50.9 | 116 | 21.0 | 552 | 73.1 | 26.9 | 24 |
| 35 | 422 | 52.6 | 356 | 44.4 | 24 | 3.0 | 802 | 39.8 | 60.2 | 6 |
| 40 | 467 | 55.7 | 347 | 41.3 | 25 | 3.0 | 839 | 37.7 | 62.3 | 10 |
| SPRUCE-SLOPE TYPE | | | | | | | | | | |
| 3 | 12 | 100.0 | 0 | 0.0 | 0 | 0.0 | 12 | 0.0 | 100.0 | 4 |
| 10 | 450 | 29.8 | 870 | 57.6 | 190 | 12.6 | 1,510 | 39.0 | 61.0 | 8 |
| 15 | 196 | 16.7 | 252 | 21.5 | 724 | 61.8 | 1,172 | 76.0 | 24.0 | 4 |

TABLE 9.—*Relation of composition and quantity of all stems (reproduction below 1-inch diameter at breast height plus all trees 1-inch diameter at breast height and above) to age of cut-over area for various forest types*

| Age (years) | Average stems per acre | | | | | | Total | Proportion of spruce and fir stems | | Basis, plots |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spruce and fir | | Hardwoods and others | | Weed species | | | Spruce | Fir | |
| | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Per cent* | *Number* |
| SPRUCE-FLAT TYPE | | | | | | | | | | |
| 2 [1] | 4,440 | 50.9 | 4,244 | 48.7 | 36 | 0.4 | 8,720 | 40.0 | 60.0 | 63 |
| 5 | 3,519 | 65.7 | 1,263 | 23.6 | 571 | 10.7 | 5,353 | 17.6 | 82.4 | 10 |
| 10 | 3,537 | 75.4 | 931 | 19.9 | 222 | 4.7 | 4,690 | 31.3 | 68.7 | 40 |
| 15 | 3,716 | 80.8 | 862 | 18.7 | 22 | .5 | 4,600 | 39.4 | 60.6 | 14 |
| 20 | 2,546 | 80.7 | 523 | 16.6 | 86 | 2.7 | 3,155 | 24.2 | 75.8 | 32 |
| 25 | 2,808 | 91.1 | 250 | 8.1 | 23 | .8 | 3,081 | 38.2 | 61.8 | 31 |
| 30 | 1,994 | 85.1 | 300 | 12.8 | 48 | 2.1 | 2,342 | 37.5 | 62.8 | 29 |
| 35 | 2,173 | 76.5 | 650 | 22.9 | 16 | .6 | 2,839 | 59.2 | 40.5 | 3 |
| 40 | 2,401 | 87.5 | 286 | 10.4 | 58 | 2.1 | 2,745 | 17.0 | 83.0 | 11 |
| SPRUCE-HARDWOODS TYPE | | | | | | | | | | |
| 5 | 4,106 | 52.0 | 2,580 | 32.7 | 1,203 | 15.3 | 7,889 | 64.8 | 35.2 | 17 |
| 10 | 2,196 | 34.1 | 3,350 | 52.1 | 890 | 13.8 | 6,436 | 70.0 | 30.0 | 53 |
| 15 | 1,503 | 24.4 | 3,273 | 53.0 | 1,396 | 22.6 | 6,172 | 30.6 | 69.4 | 20 |
| 20 | 755 | 15.8 | 2,316 | 48.4 | 1,712 | 35.8 | 4,783 | 61.3 | 38.7 | 10 |
| 25 | 1,809 | 45.7 | 1,065 | 40.7 | 183 | 4.6 | 3,057 | 68.3 | 31.7 | 12 |
| 30 | 793 | 27.8 | 1,638 | 57.5 | 418 | 14.7 | 2,849 | 55.7 | 44.3 | 24 |
| 35 | 1,133 | 38.2 | 1,414 | 47.6 | 422 | 14.2 | 2,969 | 60.3 | 39.7 | 6 |
| 40 | 1,217 | 31.5 | 2,547 | 65.8 | 105 | 2.7 | 3,869 | 53.9 | 46.1 | 10 |
| SPRUCE-SLOPE TYPE | | | | | | | | | | |
| 3 | 13,462 | 71.2 | 4,000 | 21.1 | 1,450 | 7.7 | 18,912 | 88.0 | 12.0 | 4 |
| 10 | 3,197 | 38.9 | 4,682 | 57.0 | 338 | 4.1 | 8,217 | 61.7 | 38.3 | 8 |
| 15 | 2,096 | 32.4 | 3,477 | 53.7 | 899 | 13.9 | 6,472 | 94.2 | 5.8 | 4 |

[1] Includes only reproduction below 1 inch diameter at breast height.

That excess of conifers in the spruce-flat over those in the spruce-hardwoods type is not restricted to small reproduction is indicated in Table 7 showing reproduction which has reached sapling size (1 inch and more diameter at breast height), since cutting, and again in Table 8 showing all stems, residual, and new growth above 1 inch diameter at breast height.

## STAND COMPOSITION

In attempting to determine which sites are especially adapted to the production of spruce and fir, it was observed that on areas where a large volume of these species had been present before cutting, spruce and fir reproduction was usually abundant. Table 10 shows the relation between the basal area of spruce and fir in the original stand and the present number of spruce and fir seedlings; Figure 5 graphically illustrates the same thing. For example, on plots containing only 20 square feet basal area of spruce and fir per acre, the curve shows an average of about 1,500 spruce and fir seedlings to the acre, whereas plots containing 140 square feet show an average of about 4,600 seedlings. Large numbers of hardwoods and weed species were usually found growing on the areas which had originally supported small volumes of spruce.

TABLE 10.—*Relation of composition and quantity of new and advance reproduction to the total basal area of spruce and fir in the original stand, 10-year-old cuttings in the spruce-hardwoods type*

| Basal area of spruce and fir (sq. ft.) | Average stems per acre of reproduction | | | | | | Total | Proportion of spruce and fir | | Basis, plots |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spruce and fir | | Hardwoods and others | | Weed species | | | Spruce | Fir | |
| | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Per cent* | *Number* |
| 11 to 20 | 1,510 | 22.4 | 4,786 | 70.9 | 452 | 6.7 | 6,748 | 52.6 | 47.4 | 4 |
| 21 to 30 | 1,975 | 34.3 | 3,336 | 57.9 | 452 | 7.8 | 5,763 | 50.4 | 49.6 | 8 |
| 31 to 40 | 1,660 | 31.9 | 3,086 | 59.4 | 452 | 8.7 | 5,198 | 41.9 | 58.1 | 8 |
| 41 to 50 | 1,990 | 39.2 | 2,636 | 51.9 | 452 | 8.9 | 5,078 | 46.5 | 53.5 | 10 |
| 51 to 60 | 3,150 | 48.2 | 2,836 | 43.4 | 552 | 8.4 | 6,538 | 38.2 | 61.8 | 6 |
| 61 to 70 | 2,710 | 43.0 | 2,436 | 38.7 | 1,152 | 18.3 | 6,298 | 55.2 | 44.8 | 8 |
| 71 to 80 | 1,620 | 30.5 | 2,936 | 55.3 | 752 | 14.2 | 5,308 | 53.4 | 46.6 | 3 |
| 81 to 90 | 2,320 | 26.3 | 4,336 | 49.2 | 2,152 | 24.5 | 8,808 | 70.0 | 30.0 | 2 |
| 91 to 100 | 4,700 | 53.8 | 3,386 | 38.7 | 652 | 7.5 | 8,738 | 88.3 | 11.7 | 1 |
| 101 to 110 | 1,760 | 35.2 | 2,186 | 43.7 | 1,052 | 21.1 | 4,998 | 28.7 | 71.3 | 2 |
| 111 to 120 | 6,410 | 54.1 | 4,586 | 38.7 | 852 | 7.2 | 11,848 | 74.2 | 25.8 | 2 |
| 141 to 150 | 4,150 | 52.8 | 2,856 | 36.3 | 852 | 10.8 | 7,858 | 35.1 | 64.9 | 1 |

The effect of the presence of hardwoods is illustrated in Tables 11 and 12 and Figures 6 and 7. Figure 6 shows that, where 70 per cent of the total basal area of the stand consists of hardwoods, approx-

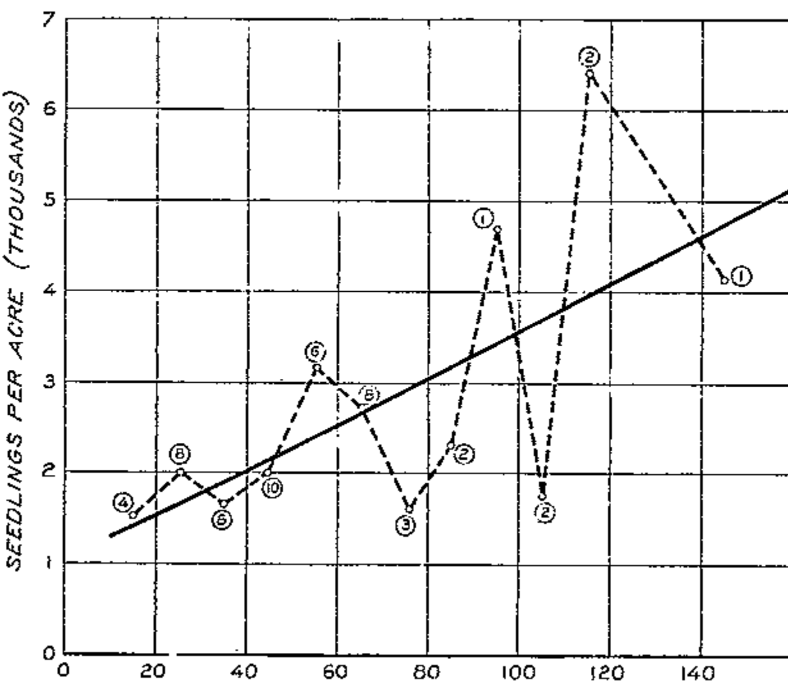



FIGURE 6.—Relationship of quantity of spruce and fir reproduction to quantity of spruce and fir in original stand

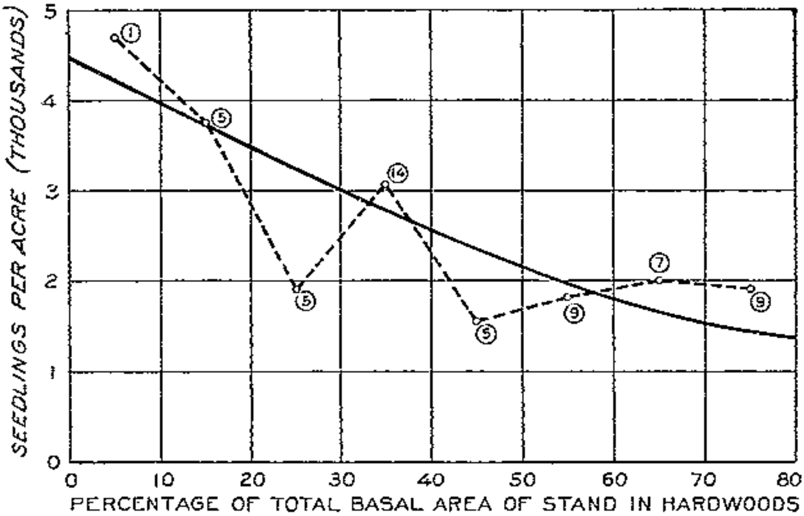



FIGURE 6.—Relationship of quantity of spruce and fir reproduction to hardwoods in original stand

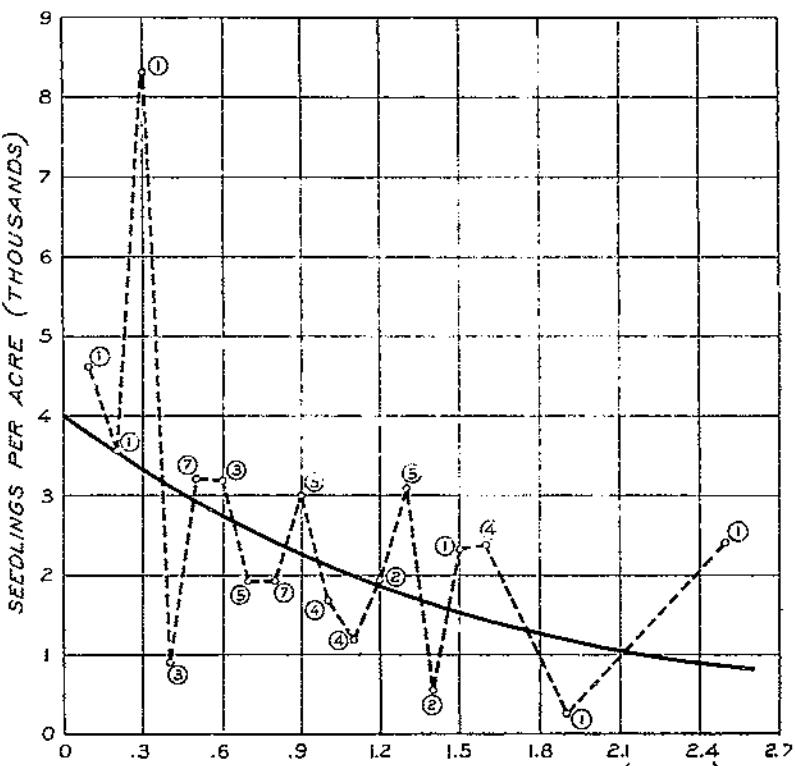



FIGURE 7.—Relationship of quantity of spruce and fir reproduction to crown area of hardwoods in original stand

imately 1,500 seedlings to the acre were tallied. On the other hand, where the hardwood representation was only 5 per cent, 4,200 were found. The tables show, too, that small volumes of spruce and fir usually indicate correspondingly large numbers of hardwoods.

TABLE 11.—*Relation of quantity of spruce and fir reproduction per acre to proportion of hardwoods in the original stand, as indicated by the percentage of total basal area of stand in hardwoods, 10-year-old cuttings in spruce-hardwoods type*

| Proportion of basal area in hardwoods (per cent) (acres) | Spruce and fir reproduction | Basis | | Proportion of basal area in hardwoods (per cent) (acres) | Spruce and fir reproduction | Basis | |
|---|---|---|---|---|---|---|---|
| | | Plots | Hardwood trees | | | Plots | Hardwood trees |
| | *Number* | *Number* | *Number* | | *Number* | *Number* | *Number* |
| 5 | 4,715 | 1 | 25 | 45 | 1,560 | 5 | 125 |
| 15 | 3,750 | 5 | 115 | 55 | 1,805 | 9 | 105 |
| 25 | 1,880 | 5 | 85 | 65 | 2,000 | 7 | 125 |
| 35 | 3,000 | 14 | 85 | 75 | 1,900 | 9 | 145 |

TABLE 12.—*Relation of quantity of spruce and fir reproduction per acre to proportion of hardwoods in original stand as indicated by crown area per acre of hardwoods, 10-year-old cuttings in spruce-hardwoods type*

| Crown area of hardwoods per acre (acres) | Spruce and fir reproduction | Basis | | Crown area of hardwoods per acre (acres) | Spruce and fir reproduction | Basis | |
|---|---|---|---|---|---|---|---|
| | | Plots | Hardwood trees | | | Plots | Hardwood trees |
| | *Number* | *Number* | *Number* | | *Number* | *Number* | *Number* |
| 0.1 | 4,610 | 1 | 35 | 1.0 | 1,040 | 4 | 95 |
| 0.2 | 3,570 | 1 | 85 | 1.1 | 1,160 | 4 | 85 |
| 0.3 | 8,315 | 1 | 105 | 1.2 | 1,930 | 2 | 145 |
| 0.4 | 920 | 3 | 135 | 1.3 | 3,010 | 5 | 125 |
| 0.5 | 3,220 | 7 | 85 | 1.4 | 560 | 2 | 165 |
| 0.6 | 3,180 | 3 | 55 | 1.5 | 2,290 | 1 | 115 |
| 0.7 | 1,020 | 5 | 85 | 1.6 | 2,370 | 4 | 155 |
| 0.8 | 1,010 | 7 | 105 | 1.9 | 220 | 1 | 175 |
| 0.9 | 3,000 | 3 | 85 | 2.5 | 2,400 | 1 | 205 |

Another expression of the extent to which hardwoods are present in the stand is the total crown area of hardwoods. According to Table 12 and Figure 7, an increase in the crown area per acre of hardwoods to as high as 2.5 acres involves a moderate decrease in the number of spruce and fir seedlings, even though comparatively large numbers of spruce and fir seedlings may be produced under a dense crown canopy. Under the densest crown area indicated in Table 12 were found 2,400 seedlings to the acre—an ample quantity to form a fully stocked stand of pulpwood if only no hardwoods were present to interfere with their development.

## LOGGING DAMAGE

The young growing stock destroyed in the process of logging was carefully recorded on a series of sample plots. The results are summarized in Table 13, and show that the average loss of seedling, conifers through logging amounts to 18 per cent, or more than 800 per acre, and that of hardwoods 22 per cent. Severe damage to spruce and fir occurs in the 2 to 5 foot height classes where 23 per cent of the young trees comprising these classes were destroyed, reducing the thrifty, fast-growing trees from 700 to 539 to the acre. Although abundant conifers were present in the residual stand, 86 per cent were in the 0.5 and 1 foot height classes.

TABLE 13.—*Percentage losses from logging in various size classes and stand left per acre*

| Height class (feet) | Loss through logging | | Trees per acre left after logging | | Height class (feet) | Loss through logging | | Trees per acre left after logging | |
|---|---|---|---|---|---|---|---|---|---|
| | Spruce and fir | Hardwoods | Spruce and fir | Hardwoods | | Spruce and fir | Hardwoods | Spruce and fir | Hardwoods |
| | *Per cent* | *Per cent* | *Number* | *Number* | | *Per cent* | *Per cent* | *Number* | *Number* |
| 0.5 | 15 | 22 | 2,318 | 4,012 | 4 | 26 | 28 | 94 | 20 |
| 1 | 24 | 16 | 866 | 755 | 5 | 27 | 0 | 60 | 21 |
| 2 | 21 | 38 | 257 | 119 | | | | | |
| 3 | 21 | 33 | 128 | 59 | Total | 18 | 22 | 3,723 | 5,886 |

The destruction of this young growing stock has one important result, that of increasing the length of the rotation, since a 5-foot spruce represents from 15 to 20 years of growth already contributed to the new stand. However, if one were assured of a fair percentage of ultimate survival in the 0.5 and 1 foot classes, the logging damage sustained by the larger size classes would not be such a serious matter. As it is, dense masses of underbrush and rapid-growing weed trees and other hardwoods frequently take possession of cut-over areas and only too often succeed in submerging vast quantities of spruce and fir seedlings. The destruction of the larger size classes is, therefore, equivalent to the destruction of the best prospects for attaining a predominance of spruce and fir in the stand. Thus, the presence or absence of advance reproduction in the larger height classes determines in many instances the success or failure of pulpwood species to form an integral part of the succeeding stand of timber.

## FACTORS AFFECTING THE COMPOSITION OF ADVANCE REPRODUCTION

### CUTTING IN THE VARIOUS SPRUCE TYPES

A study of the composition of spruce stands before and after cutting, of the representation of the various species comprising the reproduction, and particularly of the composition of the young growth and the progressive changes occurring on areas which have been cut over in different periods in the past, assists in predicting the character of the future stand, and also suggests the cultural treatment to be followed in producing stands of the desired species and stocking. The significance of these data will be discussed in detail for each type.

### SPRUCE-FLAT TYPE

Figure 8 indicates that logging operations make but little difference in the composition of the spruce-flat type, the residual stand of spruce and fir being reduced but 3.7 per cent, whereas hardwoods

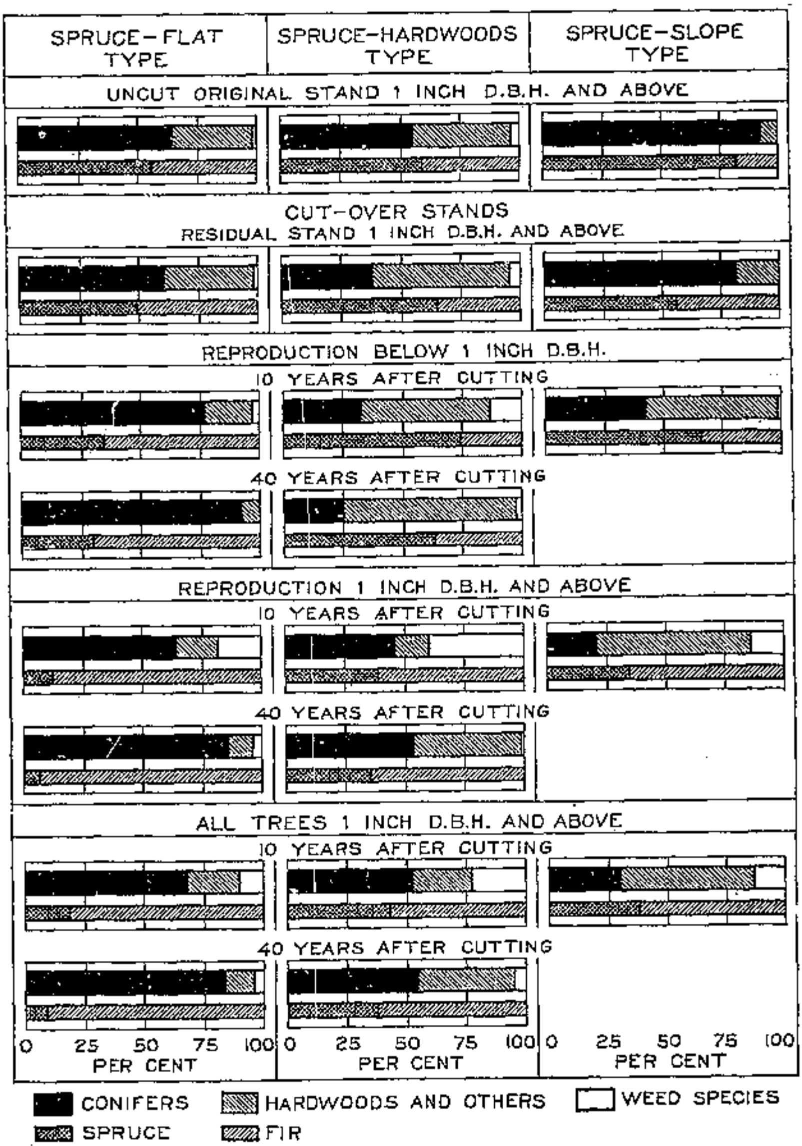



FIGURE 8.—Composition of all the component parts of stands for the spruce-flat, spruce-hardwoods, and upper spruce-slope type

and others were increased 3.3 per cent. Considering the general policy of removing only pulpwood species, the slight decrease in the representation of spruce and fir is surprising. It is perhaps explained by the fact that pine and hemlock, which occur commonly in the spruce-flat type, are removed along with the spruce and fir. As these species are intentionally included in this study under the classification of hardwoods and others, they tend to offset the decreased representation of spruce and fir. The relation between spruce and fir was more significantly changed, the predominance of spruce being reduced and fir increased so that the two approached close to parity, with fir 2 per cent in the lead.

It is encouraging to note the predominance of spruce and fir reproduction below 1-inch diameter at breast height over hardwoods in 10-year-old cut-over areas, and still more so in 40-year-old cut-over areas, outdistancing the larger diameters both in the residual and in the original stand. This tendency toward an increased representation of pulpwood species is maintained as the stand grows older; in the class of reproduction which has reached the sapling and pole stage since cutting, a lead in 10-year-old cut-over areas of 65 per cent and in 40-year-old cut-over areas of 86.5 per cent of all species is attained. The figures indicate that spruce and fir can successfully hold their position with the contemporary hardwood growth. In fact, the reduction in the representation of hardwoods from the relatively high percentage in 10-year-old cut-over areas to a comparatively low percentage in 40-year-old cut-over areas in all the component parts of the stand indicates that new hardwood growth experiences serious difficulty in competing with the pulpwood species in the spruce-flat type.

However, a decided change is noted in the relative proportion of spruce to fir. Whereas in the original stand spruce predominated over fir, in the young growth the situation is reversed. (Fig. 8.) Fir reproduction below 1 inch in the spruce-flat type has a distinct lead over spruce, its representation being well over 65 per cent. In the sapling and pole stands fir representation is even further increased, attaining a representation of over 80 per cent. This marked increase of fir in the sapling and pole stage is apparently due to the more rapid growth of fir in its early youth.

In the stand 1-inch diameter at breast height and above, in which the residual and advance growth are combined (fig. 8) spruce and fir attain 84.8 per cent in the 40-year-old cut-over areas, or a greater predominance by 20.2 per cent than in the original stand. The most radical change, however, is the great increase in the proportion of fir—largely at the expense of spruce and hardwoods—from 44.4 per cent in the original stand to 82.3 per cent in the 10-year-old cut-over areas and 91.5 per cent in the 40-year-old cut-over areas. It is inevitable that the next crop of timber will contain a greater proportion of fir than the original stand.

The conclusion is clear that the spruce-flat type is in a fair way to retain its original representation of spruce and fir, but that fir greatly increases at the expense of the more valuable spruce. The effect of the large residual hardwoods on the ultimate success of the young spruce and fir stand will be discussed later.

### SPRUCE-HARDWOODS TYPE

The smaller proportion of spruce and fir in the spruce-hardwoods type than in the spruce flat is well illustrated in Figure 8. This proportion varied widely on the areas studied, but the average representation of spruce and fir in the original stand was 54.8 per cent. In this representation the lead of spruce over fir was identical with that in the spruce-flat type, or 16.6 per cent. Cutting changed these proportions considerably, reducing spruce and fir to 36.7 per cent but at the same time giving spruce a still greater lead over fir, or 28.4 per cent. The susceptibility of fir to wind-throw and breakage in the spruce-hardwoods type is partly responsible for the relatively small representation of this species.

Tables 5, 7, and 8 make it clear that the future stand in the spruce-hardwood type will contain less spruce and fir than the original stand, the percentage of the pulpwood species being lower at each period after cutting with only two exceptions. Although spruce reproduction below 1 inch has a representation of 74.1 per cent and 64 per cent on 10 and 40 year old cut-over areas, respectively, (fig. 8), this representation is diminished in the sapling and pole stages to a point considerably below that in the original stand.

This usurping by fir of the dominant position previously held by the spruce is due probably not only to the slower growth of spruce, but also to the fact that as a result of its slower growth spruce is less able to compete with invading hardwoods and weed species, and is more likely to become submerged and to have its growth checked. The large representation of spruce, however, in young reproduction, coupled with the extreme tolerance of this species, holds promise of an ultimate increase in the new stand. Another factor tending to increase the proportion of spruce in the next crop is the relatively high representation of this species in the residual stand, where it has increased to 64.2 per cent of the pulpwood species, from 58.3 in the original stand. This increase is, of course, reflected in a higher percentage in the residual plus sapling and pole classes. Table 9 shows the effect of taking into account also reproduction below 1 inch diameter at breast height, where the representation of spruce, with the exception of the 15-year-old cut-over area, is well in the lead of fir. In view of the longevity and persistence of spruce, the prospects are favorable for maintaining its preponderance.

Reduction in the representation of conifers and to some extent of hardwoods is largely due to the heavy invasion of weed species, which constitute a more important factor in the spruce-hardwoods type than in the spruce flat. Figure 8 shows a remarkable increase from 3.1 per cent weed species in uncut spruce-hardwood stands to 39.4 per cent in sapling and pole stands in 10-year-old cut-over areas. The important part weed species play in the development of the new stand (Table 7) is illustrated even better on other recent cuttings. Cut-over areas average for the first three 5-year periods after cutting 56.3 per cent "weeds." The gradual decrease on the older cut-over areas indicates that "weeds" in time become less of a factor and with the closing in of the stand are gradually crowded out.

Owing to their undoubted prevalence in the spruce-hardwoods type, hardwoods here influence the young conifer stand much more strongly than they do in the spruce-flat type, and their presence constitutes an extremely disturbing element in the successful de-

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velopment of the advance reproduction. On areas formerly occupied by the conifers, spruce and fir are decreased in numbers solely through the encroachment of aggressive hardwoods.

As in the spruce-flat type, but to a somewhat less degree, the number of fir trees in the new stand increases at the expense of spruce.

## SPRUCE-SLOPE TYPE

Uncut stands in the spruce-slope type are almost entirely composed of spruce and fir. According to Figure 8 hardwoods are represented only to the extent of 7.8 per cent. Of the conifers present, 81.1 per cent consist of spruce. The method of logging practiced in this type leaves the ground bare of all trees except spruce and fir of very small size and an occasional hardwood. Removal of the larger trees does not materially change the stand's composition, although it does give an advantage to fir over spruce. The reproduction coming in after cutting, however, differs considerably, especially with respect to the proportion of hardwoods. Cutting in this type is usually followed by an abundant reproduction of hardwoods consisting largely of paper birch with yellow birch, pin (fire) cherry, and mountain maple. It is to be expected, therefore, that the representation of spruce and fir in the reproduction class, and especially later in the sapling and pole stage, should be considerably lower than that in the original stand. In young reproduction the representation is 41 per cent, but in the sapling and pole sizes it is only 21 per cent. Spruce and fir seedlings are suppressed by the density and rapid growth of the young hardwoods, and thus prevented from reaching sapling and pole size for a long period.

Since the maximum age represented in the data for this type is 15 years, it is not surprising that only a small number of spruce and fir appear in the sapling class. On the other hand, hardwoods and weed species, owing to their rapid growth, would nearly all have reached sapling and pole size within the 15-year period.

An average for conifers in the residual plus advance growth class of only 29.8 per cent on the surface appears alarming. But further study of 30 and 40 year old cut-over areas would undoubtedly reveal a much higher representation of spruce and fir. In the recent cuttings spruce and fir are still in the form of reproduction below 1 inch diameter at breast height.

In the reproduction classes of the pulpwood species alone, spruce comprises 65.5 per cent of the trees below 1 inch diameter at breast height, but only 34.6 per cent in the sapling and pole sizes, and 39 per cent in the residual plus advance growth. Slower development of the spruce again accounts for its low representation.

Although the relationships shown in Figure 8 do not present a very promising outlook for the future crop of spruce and fir, they do at least, when considered in the light of conditions on the ground, warrant some optimism with regard to the spruce-slope type in general. The suppressed spruce and fir, after a severe struggle, will push their way through the canopy of the contemporary stand of young hardwoods, and with competition from but few of the old residual hardwoods, will eventually assume control of the stand. However, here again, as in the other types, fir will have increased at the expense of spruce. Where clear cutting is employed on short rotation, as is usual in this type, the advantage is definitely in favor of the fir, and without question it will show a considerable increase in the next cut of pulpwood.

## SOILS

Throughout the spruce region the underlying structure consists of metamorphic and igneous rock of many varieties, chiefly of schists, gneisses, and granites. The soil is of glacial origin. The surface layers consist of glacial material of complex composition brought down in part as subglacial drift, but largely as englaciated material deposited in an irregular manner in layers of varying depths and in the form of moraines, eskers, and kames as the ice sheet gradually melted away. Each formation creates its own characteristic topography and distinctive soils. Soil type, therefore, is determined largely by the type of glacial formation.

That the character of the soil plays an important part in reproduction and stand composition is indicated by reproduction counts made in various spruce types exhibiting considerable difference in certain soil characteristics. By far the greatest number and proportion of conifers are ordinarily found on the shallow or poorly drained soils. Good drainage combined with soils of depth and fertility results in an increased proportion of hardwoods.

### THE SOIL PROFILE [4]

Soils of the spruce region have a distinctive profile in which the several layers, or horizons, are more or less well defined. This soil is known as the podsol. The podsol profile normally is divided into three main horizons. The upper or A horizon consists of a surface layer of partially decomposed forest litter overlying a black layer of thoroughly decomposed organic matter, under which occurs a layer of ashy gray mineral soil leached of practically all its organic matter and colloids. The second or B horizon consists of a dark coffee-brown soil grading from a very dark brown (nearly black) in the upper section to a reddish-yellow brown at the lower depths and having a relatively high content of organic matter and colloids. The third or C horizon consists of partially weathered parent material whose texture and mineral character depend on the parent rock material and the soil-forming processes which have acted upon it.[5]

This podsol profile is characteristic of a considerable portion of the spruce region. Gradations in this typical soil profile depend on the factors which control soil type. A significant fact brought out by the study is the rapidity with which soil types change within short distances as a result of slight changes in relief and drainage.

On the series of permanent sample plots previously mentioned, Morgan and Conrey recognized five distinct soil types. Drainage, as affected by glacial formation, played an important part in deter-

[4] Such preliminary studies of the soil profile as have been made were largely confined to soils on permanent sample plots established in the White Mountains. Analysis and description of these soils were first made in 1925 by G. Edgington and J. R. Adams, of the Bureau of Chemistry and Soils. In 1926 M. F. Morgan, of the Connecticut Agricultural Experiment Station, and G. W. Conrey, of the Ohio Agricultural Experiment Station, made a field examination of the different classes of soils encountered.

[5] For a more detailed description of the soil profile of the spruce region see Stickel (21) in Bibliography, p. 52.

mining the classification of these soils. In four of them all horizons are represented, the most highly developed ones occurring in well-drained soils. In the poorest-drained soil, the gray podsol layer is entirely lacking and the remaining horizons are much less pronounced in character.

### SOIL TYPES

Soil type No. 1 consists of a deep, well-drained fine sandy loam soil of a type which should be expected over a good portion of the White Mountain region. Granite bowlders occur throughout the profile.

Soil type No. 2 differs from type 1 probably in that the soil is derived from a schist rock where pyroxene minerals predominate. This soil is somewhat modified by seepage, and a higher development of this type occurs where better drainage conditions exist. Bowlders, chiefly of schist rock, occur throughout the profile.

Soil type No. 3 is typical in kame formations which are of common occurrence in the region. These formations are distinguished as small knolls composed chiefly of sand and gravel. Because of the loose gravelly character of the substratum, this soil type is subject to excessive drainage. No bowlders occur anywhere in the profile.

Soil type No. 4 is characteristic of benchlike formations such as occur above streams and lakes throughout Maine, northern New Hampshire and Vermont, and portions of the Adirondacks. This soil usually enjoys fairly good surface drainage, but underdrainage is slow. Many granitic bowlders occur throughout the profile, some of them protruding through the surface soil. Stands growing on such soils develop shallow root systems and are subject to wind-throw. (Pl. 4, B.)

Soil type No. 5 differs markedly in failing to show the pronounced profile which characterizes the others. It is poorly drained and is usually water-logged to within a foot or two of the surface. The surface soil is gray to black and somewhat mucky. No gray podsol layer is developed. Organic matter disappears at a depth of 10 to 14 inches; below this the soil is highly mottled gray and yellow, the grayish color predominating. The texture is a stony loam.

Soil types 1 and 3 are similar, the chief differences occurring in the lower horizons where the greater depth and looseness in type 3 permit freer and more rapid drainage. Type 2, though similar in many respects to types 1 and 3, is intermediate between them and type 4, having a fairly firm B horizon in contrast to the looseness and openness which characterize this horizon in soil types 1 and 3. In this respect it partakes somewhat of the features of type 4 where free underdrainage is less evident. Type 4 is markedly different from the first three types, especially in the C horizon, where the mottled compact nature of the soil is indicative of poor drainage. Soil type 5 differs from the other types principally in drainage and the degree to which the various soil horizons have been developed. In the region studied it was observed that the thickest layer of leached soil in the A horizon occurred in the better-drained soils. Good drainage apparently induces rapid decomposition of raw humus, and not only hastens the process of weathering but permits this weathering action to proceed to a considerable depth.

## SOIL TYPE AND FOREST TYPE

Hardwoods are more exacting in their soil requirements than spruce and fir. Development of hardwoods calls for well-drained, aerated soils of good depth that offer no serious obstacle to deep root penetration. Soil types 1 and 3, and to a less degree 2, meet these requirements. On such soils hardwoods establish themselves in large numbers, often to the exclusion of softwoods. This high representation of hardwoods is not due to the fact that the soil itself is inimical to the development of spruce and fir; on the contrary, spruce attains its best development on such soils once it succeeds in establishing itself. Rather is it owing to the keen competition set up by the hardwoods on these soils, where they are able to establish themselves quickly and to eliminate large numbers of the slower-growing and less aggressive conifers. Table 9 and Figure 4 show the relative abundance of softwoods and hardwoods in the spruce-hardwoods type. This forest type is largely the result of soil types 1, 2, and 3, and is therefore particularly favorable to the establishment of hardwood species.

Spruce flats are likely to have a high representation of soil type 4, a soil with poor underdrainage. Spruce and fir, possessing the ability to thrive in wet soils, have an advantage over the hardwoods—particularly over the more fastidious beech and sugar maple—and form the dominating element of the reproduction. The greater abundance of softwood reproduction in the spruce flat is clearly brought out in Table 9 and Figure 4. The hardwood reproduction in this type consists largely of birch and red maple, species not very exacting in their soil requirements, and tolerant of wet, poorly drained soils.

Beyond these very general conclusions, the soil problem is extremely complicated and one which has yet to be approached from many angles—not only those related to physical and chemical composition, but the biological aspects as well—before more exact deductions can be made. It is believed, however, that the soil investigations so far conducted, though preliminary in nature, warrant the conclusion that a definite relationship exists between the composition of reproduction and the physical character of the soil as affected by drainage, a fact which can be of considerable value to the forester in applying certain silvicultural measures in spruce stands.

## EXPOSURE

Variation in exposure, where accompanied by marked differences in physiographic and atmospheric conditions, frequently modifies the composition of the stand even to the extent of a change in forest type. In order to determine whether or not any dependable relationship exists between exposure and the composition of stands, data already gathered were classified and analyzed on the basis of exposure. (Table 14.) Data from the spruce-hardwoods type were selected for this purpose rather than those from the spruce-flat type because of the necessity for a sharp definition of topography and exposure. Spruce flats are likely to be level or rolling, whereas the spruce-hardwoods type more often occurs on the lower mountain slopes. Presumably the effect of exposure would be even more striking in the spruce-slope type, but the small quantity of data gathered in this type precluded a fair distribution of exposures.

TABLE 14.—*Relation of composition of reproduction to exposure, spruce-hardwoods type, on a basis of 132 plots*

| Exposure | Conifers | Hard-woods | Spruce | Fir | Exposure | Conifers | Hard-woods | Spruce | Fir |
|---|---|---|---|---|---|---|---|---|---|
| | *Per cent* | *Per cent* | *Per cent* | *Per cent* | | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| Northwest | 32 | 68 | 32 | 68 | South | 35 | 65 | 63 | 37 |
| North | 33 | 67 | 62 | 38 | Southwest | 52 | 48 | 82 | 18 |
| Northeast | 51 | 49 | 53 | 47 | West | 49 | 51 | 36 | 64 |
| East | 24 | 76 | 83 | 17 | Northwest | 32 | 68 | 32 | 68 |
| Southeast | 13 | 87 | 52 | 48 | Level | 41 | 59 | 62 | 38 |

The effect of exposure as indicated by Table 14 is indeterminate, and in some instances the results obtained are contradictory. Take, for example, the northerly and southerly aspects as separate units. The average representation of hardwoods for the north, northeast, and northwest exposures is 61.3 per cent as against 66.7 per cent for all southerly aspects. Yet the strictly northern exposure has a slightly higher representation of hardwoods than the southern. Similarly, if the north, northeast, and east exposures, and the south, southwest, and west are considered as two units, the conditions more or less parallel those existing on the northern and southern exposures; the average for hardwoods on the northeastern exposures is 64 per cent, and for the southwestern only 54.7 per cent. This might indicate a preference on the part of the hardwoods for the cool northeasterly exposures.

Of the conifer reproduction on the three northerly and three southerly exposures, the percentage of fir is considerably greater on northerly than on southerly exposures. This is more or less in accord with other evidence showing that fir prefers moist cool sites—it is more abundant in the moist spruce-flat type than in the higher and better drained spruce-hardwoods type. Fir on the northerly (northern, northwestern, and northeastern) exposures constitutes 51 per cent of the pulpwood species and only 34 per cent on the southerly (southern, southwestern, and southeastern) exposures; yet in comparison the representation of fir is lower on the northeasterly (northern, northeastern, and eastern) than on the southwesterly (southern, southwestern, and western), the percentages being 34 and 40 respectively. A comparison of eastern and western exposures also fails to bring to light any decided relationship between exposure and composition.

The rather contradictory results obtained lead to the conclusion that the spruce-hardwoods type is provided so abundantly with rainfall that exposure has no marked effect on the composition of the reproduction; or such must be the assumption until detailed studies of environmental factors have been made.

## SEED-BED CONDITIONS

Although advance reproduction is depended upon as the main resource in the renewal of the stand, it is not always sufficient in quantity to restock cut-over areas fully and must be supplemented by new crops of seedlings. It is essential, therefore, to learn what seed-bed conditions favor the establishment of desirable species.

#### THE CHERRY MOUNTAIN EXPERIMENT

It is generally recognized that seed-bed conditions play an important part in the germination and ultimate survival of reproduction and may to a large extent determine the composition of the succeeding crop of timber. In order to gain some information on this important question, 16 intensive reproduction plots were established on the Cherry Mountain permanent sample plots located in the White Mountain National Forest in the spruce-hardwoods type, and representing two distinct types of seed beds. On one set of plots all of the litter consisting of half-decomposed leaves, branches, rotted logs, moss, and herbaceous vegetation was removed, exposing the soil. The second set were left undisturbed. In this same year, and just previous to the cutting of the timber, an excellent crop of seed was borne by both spruce and fir. Tallies of all newly germinated seedlings were made at different periods, the results of which are recorded in Table 15.

TABLE 15.—*Relation of seed-bed condition to germination and survival of different species in 1925 crop of seedlings, in seedlings per mil-acre (1/1000 acre)*[1]

TREATED PLOTS (SOIL THOROUGHLY EXPOSED)

| Date of examination | Red spruce | Balsam fir | Yellow birch | Red maple | Pin cherry | Beech | Sugar maple | Conifers | | Hardwoods | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *P. ct.* | *No.* | *P. ct.* |
| June 11, 1925[2] | 2.7 | 25.3 | ... | ... | ... | ... | ... | 28.0 | 100.0 | ... | ... |
| Oct. 2, 1925 | 4.7 | 22.5 | 363.3 | 0.7 | 7.3 | 0.1 | 0 | 27.2 | 6.8 | 371.4 | 93.2 |
| June 1, 1926 | 1.4 | 8.0 | 32.0 | 0 | 2.6 | 0 | 0.2 | 9.4 | 21.3 | 34.8 | 78.7 |

UNTREATED PLOTS (GROUND COVER LEFT UNDISTURBED)

| Date of examination | Red spruce | Balsam fir | Yellow birch | Red maple | Pin cherry | Beech | Sugar maple | Conifers (No.) | Conifers (P. ct.) | Hardwoods (No.) | Hardwoods (P. ct.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| June 11, 1925[2] | 0 | 3.7 | ... | ... | ... | ... | ... | 3.7 | 100.0 | ... | ... |
| Oct. 2, 1925 | 1.7 | 4.7 | 84.5 | 1.0 | 1.3 | .1 | .1 | 6.4 | 6.0 | 87.0 | 93.1 |
| June 1, 1926 | .5 | 1.5 | 4.8 | .3 | .3 | 0 | .1 | 2.0 | 26.7 | 5.5 | 73.3 |

[1] 16 plots form the basis for this experiment.
[2] Hardwoods were just beginning to germinate.

The spring tally of 1925 on the exposed and undisturbed plots brought out some striking comparisons. On an acre basis, the exposed plots produced 2,700 spruce and 25,300 fir seedlings as against a total absence of spruce and 3,700 fir on the undisturbed plots. (Fig. 9.) Some hardwoods were just beginning to germinate, but the species could not be determined. The excess of seedlings on the exposed plots indicates that they represent seed-bed conditions favorable for germination of numerous seedlings. It is significant that no spruce germination had occurred on the undisturbed plots up to June 11.

The October tally, recording totals which on an acre basis would equal for exposed plots 4,700 spruce and 22,500 fir to the acre and for the undisturbed plots 1,700 spruce and 4,700 fir, gave evidence in approximate figures of (1) a 75 per cent increase of spruce and a 10 per cent loss of fir on the exposed plots; (2) the presence of 1,700 spruce on the undisturbed plots in contrast to a total absence of spruce in the June tally; (3) an increase of 25 per cent in the fir seedlings on the undisturbed plots; and (4) the germination of hardwoods in overwhelming numbers on both sets of plots, but with the exposed plots greatly in the lead.

A tally in the spring of 1926 indicated a tremendous winter mortality in all species. The spruce were reduced from 4,700 to 1,400 per acre, fir from 22,500 to 8,000, and hardwoods from 371,400 to 34,800 on the exposed plots, while on the undisturbed plots the spruce were reduced from 1,700 to 500 per acre, fir from 4,700 to 1,500, and hardwoods from 87,000 to 5,500. From the table it will be seen that the extremely heavy mortality in hardwoods during the first winter greatly increased the relative proportion of pulpwoods on both exposed and undisturbed plots.

A study of the data leads to the conclusion that spruce and fir germination is more profuse on exposed soils where litter and plant

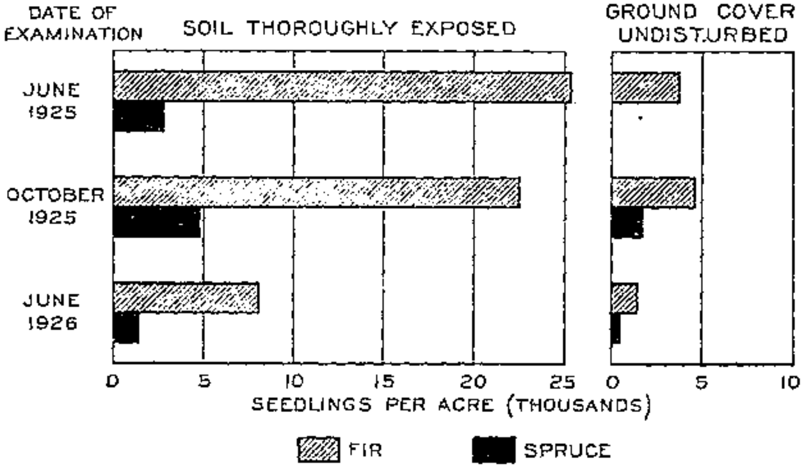
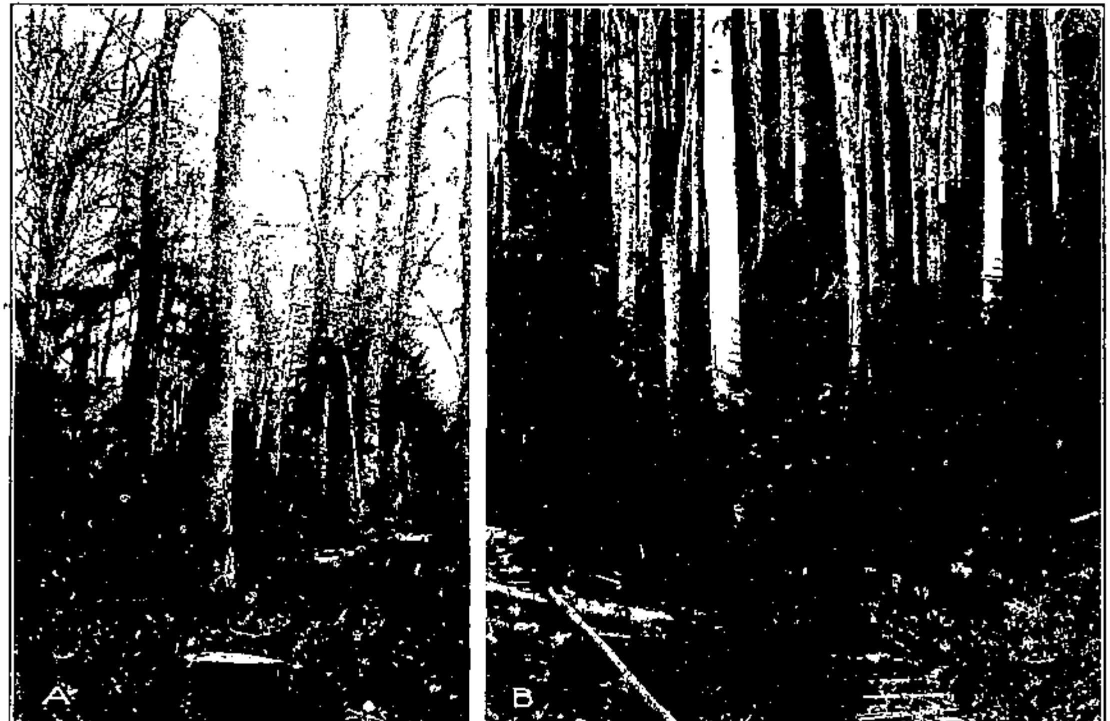



FIGURE 9.—Seedling survival in relation to seed-bed conditions

growth have been dragged away, as in skid trails and near log landings, than on undisturbed areas covered with hardwood leaf litter, matted needles, grasses, and other plant growth. An examination of the leaf litter on the undisturbed plots disclosed ungerminated seed lying between the dry layers of hardwood leaves. Leaf litter may thus tend to delay, even if it does not prevent, germination of seed. Germination of both spruce and fir also occurs earlier on exposed areas, and it appears that fir is able to take advantage of favorable conditions more quickly than is spruce. In the initial development of a new crop on cut-over areas of the spruce types, fir has a greater representation than in the original stand, because of its abundant germination and its ability to take immediate advantage of factors favoring growth and development.

## SEED-BED CONDITIONS BEFORE AND AFTER CUTTING

Examination of reproduction in the uncut stands throws additional light on the part played by seed-bed conditions in the estab-




A, The removal only of spruce and fir, a method of cutting commonly practiced in the Northeast, leaves the hardwoods the dominating element in the residual stand. One-year-old cutting in the spruce and hardwoods type

B, Good development of spruce under a stand of paper birch. Paper birch possess crowns characteristically open and permit normal development of the young under story of spruce and fir

A, Flat-topped leaderless red spruce sapling liberated through cutting. Trees of this character recover very slowly if at all, often requiring years to develop new terminals and resume normal growth

B, Red spruce seedling on 2-year-old cutting. Release from overhead shade is indicated by the rapid height growth during the 2-year period following logging. Seedlings between 3 and 5 feet in height put on the most rapid height growth following cutting lishment of spruce and fir seedlings. Whereas in cut-over stands spruce and fir seedlings find great difficulty in becoming established on old decayed windfalls, this appears to be one of the favorable sites in the old growth. The dense shade cast by mature spruce stands creates conditions inimical to the establishment of hardwood seedlings and at the same time preserves moisture in the forest floor. In view of these advantages and the great tolerance exhibited by both spruce and fir, it is not surprising that every type of seed bed, from mineral soil to deep humus and decayed wood of windfalls and logs, should be supplied with seedlings, regardless of the actual soil characteristics. If moisture, the controlling factor, is present in sufficient quantities, almost any type of seed bed encountered in the spruce forest answers the requirements for seedling germination and survival of conifers. Only where the canopy is extremely dense, or where the duff of half-decomposed needles and other vegetation has accumulated to a considerable depth, are spruce and fir seedlings prevented from getting a permanent foothold in the forest floor.

The opening up of the stand, however, greatly alters site conditions, for evaporation, rate of transpiration, and temperature are thereby greatly increased. On recently cut-over areas varying numbers of seedlings ranging from a few inches to a few feet in height, which in the old forest had succeeded in establishing themselves on decayed logs, were observed to have succumbed to the effects of sudden exposure. Decomposed humus, although it has a great retentive capacity for water, has also a high wilting coefficient; hence a proportionately small quantity of soil moisture is available to the seedlings it supports. Much of the mortality among the seedlings is due, probably, to their inability to get a proper amount of soil moisture and to lengthen their root systems quickly enough to keep pace with the rapidly subsiding moisture level following cutting. The percentage of forest floor covered with decayed logs, however, is comparatively small; hence the total number of seedlings lost through excessive exposure is relatively low.

It is evident from the above that a different type of seed bed from that ordinarily existing in the uncut forest must be present on cut-over lands if restocking of bare areas with new conifer seedlings is to be expected, and the indication is that desirable conditions are created through the removal of the mat of leaf litter and duff, placing the seed directly in contact with the bare soil. Thus the rootlets are permitted to penetrate immediately into the upper soil layers and to reach a permanent source of moisture without expending undue energy in pushing their way through dry and desiccating layers of matted leaves and other débris.

## FACTORS AFFECTING THE DEVELOPMENT OF THE NEW STAND

The presence of advance reproduction makes possible the early and rapid regeneration of the stand, as is evidenced by the normal development of young conifer stands on areas where there is no interference from competing growth. Regeneration of cut-over spruce lands with desirable species would be easy of accomplishment were it not for the keen competition offered by the residual stand of hardwoods and by the underbrush and young hardwood growth which often take possession of cut-over lands following logging. (Pl. 4, A.)

## COMPETING GROWTH

### WEEDS AND SHRUBS

Red raspberry (*Rubus idaeus*) is probably the most common type of undergrowth encountered on cut-over spruce lands, coming in most heavily on lands particularly suited to the growth of softwoods. Blueberry (*Vaccinium* sp.) and witch hobble (*Viburnum alnifolium*) also come up abundantly on cut-over areas, the former particularly on sandy soils and soils with peaty characteristics. Red raspberry appears to thrive best in moist situations enjoying an abundance of light. However, where the ground becomes too moist and boggy, it may give way to a growth of sedges and moss. The moist sites of the spruce-flat type appear to be the best for raspberry bushes. Where stands have been heavily cut and an abundance of sunlight strikes the forest floor, raspberry growth springs up in dense masses, often taking complete possession of log roads, skid trails, and log landings.

In some instances the common brake fern (*Pteridium latiusculum*) becomes established under the same conditions that favor the establishment of raspberry. Brake appears to be the more tolerant of shade, however, and where the two appear together the brake frequently shades out the raspberry. The density and extent of raspberry growth are strongly influenced by the openness or density of the canopy overhead. Where the canopy is unbroken raspberry is noticeably absent.

There are certain redeeming features connected with raspberry growth which are worthy of consideration. Undoubtedly, through its root system's complete occupation of the upper soil layer raspberry interferes seriously with the establishment of new seedlings, and at the same time suppresses so great a number of seedlings already established that much of the advance reproduction eventually dies. In this respect it may be considered as an aid in thinning out dense thickets of reproduction in the early youth of the stand, thus preventing, to a degree at least, the formation of overcrowded young stands of spruce and fir. Raspberry bushes seldom reach a height of over 4 or 5 feet. At this height the taller and more vigorous conifer seedlings, which have pushed their leaders through the tangled undergrowth, are released from severe competition, and thereafter put on rapid growth. Hardwoods are less able to withstand the severe crowding and shading by raspberry growth, witch hobble, and brake, and are severely hampered in their establishment by these factors. This is a distinct aid to the young conifers, for it is the hardwoods in the long run that act as the chief competitors of spruce and fir.

### WEED TREES AND YOUNG HARDWOODS

On the higher knolls in the spruce-flat type, particularly in the better drained spruce-hardwoods type where raspberry, brake, and blueberry bushes assume less importance, openings are frequently occupied by dense growths of mountain maple, striped maple, or pin cherry, in addition to a number of the merchantable hardwood species. Witch hobble is usually present, and in some instances is encountered in the spruce slope in mixture with pin cherry and paper or yellow birch.

On cut-over areas mountain and striped maple become unusually troublesome weed trees because of their tendency to produce fast-growing, wide-spreading clumps of sprouts after being cut down in swamping operations. Their sprouting capacity, their ability to grow under shade, and their power for early rapid growth as well as their general abundance all combine to hinder the development of the desirable species. On areas whose canopies have been little disturbed through cutting, beech and hard maple, being even more tolerant than striped and mountain maple, find little difficulty in becoming established. Where extensive clearings have been made pin cherry, paper birch, poplar, and to a less extent yellow birch, come in thickly. Prolific seeding and abundant germination account for the myriad hardwood stems that spring up on areas following logging. Rapid height growth then makes it possible for these stems to overtop the slower-growing spruce and fir, and thus early in life to attain a lead which they maintain for many years.

On log landings, skid trails, and roads particularly, where the taller reproduction has been cleared away or destroyed in the skidding and hauling operations, the dense masses of young hardwoods offer severe competition to spruce and fir reproduction. These cleared areas are dependent for restocking on small seedlings which may have escaped destruction and upon the subsequent germination of new seedlings. Hardly has the advance growth, however, had an opportunity to recover and attain an appreciable height when the weed hardwoods take possession of the open areas and through rapid height growth assume the role of oppressors.

### RESIDUAL STAND

A factor of far-reaching and lasting importance in its effect on the ultimate development of the young softwoods is the stand of large residual hardwoods left after logging. This menace is most pronounced in the spruce-hardwoods type where hardwoods occur most abundantly. (Pl. 5, A.) With the pulpwood species removed, the residual stand may vary from a few hardwood trees per acre to as high as 200, ranging from 1 inch to 25 or 30 inches diameter at breast height. (Table 12.) The young conifers, after fighting their way through a growth of underbrush must still contend for many years with this overstory before attaining a dominant position in the stand.

Age and composition of the residual stand have a distinct effect upon the development of the conifer reproduction following cutting since they control to a great extent the amount of light that reaches the forest floor. Considerable light penetrates the canopy where the residual hardwoods are overmature and have open crowns, permitting normal development of the understory of spruce and fir. In like manner the birches, particularly paper birch, with characteristically open crowns, give spruce and fir seedlings opportunity to develop normally, though with possibly less early height growth. (Pl. 5, B.) In young stands of birch where the canopy is considerably denser than in older stands, height growth is greatly retarded. Where beech and sugar maple occur in mixture with other hardwoods, the understory of young spruce and fir progresses very slowly, often coming to an almost complete standstill and developing short and very wide crowns, or in extreme cases even failing to maintain terminals and forming what are commonly termed umbrella tops. (Pl. 6, A.)

Where the stand consists of different species that make unlike demands upon the site, competition is greatly reduced. For example, where tolerant spruce and fir occur in mixture with the comparatively intolerant birches, pin cherry, and aspen, the demands with respect to light, moisture, and nutrients differ widely. This explains, in a measure at least, the fact that spruce and fir saplings are often found growing satisfactorily in abundance beneath such hardwoods as paper birch, aspen, pin cherry, and yellow birch.

Where spruce and fir grow in mixture with such hardwoods as beech and sugar maple, the demands of all with respect to external conditions, particularly light, are similar, and competition is most keen. Distinct layers of canopy are encountered, particularly in the spruce-hardwoods type. On one series of plots in this type, 25 young trees 3 to 6 feet in height—3 of which were fir and the remainder spruce—were found growing underneath the canopy of an 8-inch beech with a crown spread of 18 feet. The beech, in turn, was overtopped by a 16-inch yellow birch with a crown spread of 30 feet. The survival of spruce and fir beneath the 2-storied canopy formed by the beech and birch illustrates the capacity of these species to withstand extreme suppression. Eventually, unless the overhead canopy is removed, most of these young trees will stagnate and die. The sturdiest individuals that succeed in reaching into the intermediate story develop into flat-topped trees having little or no merchantable value, because of the mechanical interference offered by the limbs of the overtopping hardwoods.

It is in the spruce-hardwoods type that hardwoods exert their greatest influence over the new crop of pulpwood. Here spruce and fir become established only after the severest of struggles. In the spruce-flat type, owing to the shallow, often wet soils, beech and sugar maple, natural rivals of spruce and fir, are infrequent, and in the wetter sites even paper birch, the most common hardwood in mixture with spruce and fir, becomes scattering, or develops into small trees that succumb at an early age. Hence, with the diminishing importance of hardwoods as a factor affecting the development of the young conifer stand, and the general abundance of advance spruce and fir reproduction, little difficulty is experienced in the spruce-flat type in maintaining the pulpwood species.

The spruce-slope type with its steep slopes and rocky, shallow soil, presents conditions which are unfavorable to the establishment of many of the hardwood species common to the other types. Logging in this type leaves only a few scattering, crippled birches that die within a few years and the young stand of conifers thus meets with practically no competition from the residual stand. Although cutting is usually followed by dense growths of paper birch, pin cherry, and yellow birch, the conifers in time push their way through this growth and become the dominant element in the stand.

## EFFECT OF COMPETING HARDWOODS ON HEIGHT GROWTH OF SPRUCE SEEDLINGS

The extent to which hardwoods affect the height growth of red spruce seedlings is well illustrated by Figures 10 and 11. It will be seen from Figure 10 that seedlings growing beneath a heavy canopy of residual hardwoods fail to show, for as much as 12 years after cutting, any appreciable response in height growth as a result of the removal of the mature spruce and fir. The graph was drawn

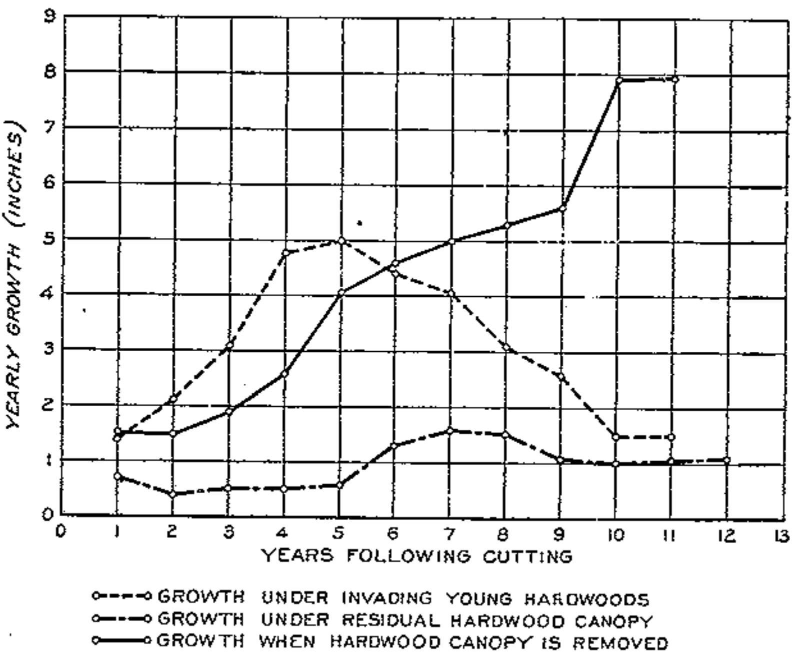



FIGURE 10.—Yearly height growth of red spruce following cutting under three different conditions of hardwood competition. Basis, 42 red spruce seedlings

from data taken on 12-year-old cut-over areas supporting a dense stand of residual hardwoods of which a high percentage was beech and sugar maple. A noticeable response, however, is shown for seedlings which were released from oppression through the removal of the hardwood canopy. Although the annual rate of growth of 1.5 inches during the first and second year following cutting shows practically no increase over that of seedlings growing in uncut stands, the third year witnesses an increase, as does each succeeding year, until a maximum of nearly 8 inches is attained in the tenth or eleventh year following cutting.

Where removal of both softwoods and hardwoods is followed by an invasion of young hardwoods, height growth of the released conifers will ultimately be retarded. For the first five years following logging the conifer seedlings make good growth, each successive year showing an increase over the previous one. But after the fifth year annual height growth begins to diminish, until by the tenth year it barely exceeds 1½ inches. At the time of examination this cutting was 11 years old and in addition to advance reproduction of spruce and fir supported an average of 700 hardwood stems above 1 inch diameter at breast height per acre, practically all of which had originated since the cutting, not to mention large numbers of additional hardwoods below this size. The main canopy of the hardwood growth was about 12 feet in height, indicating that the dominant young hardwoods had maintained an average annual growth of more

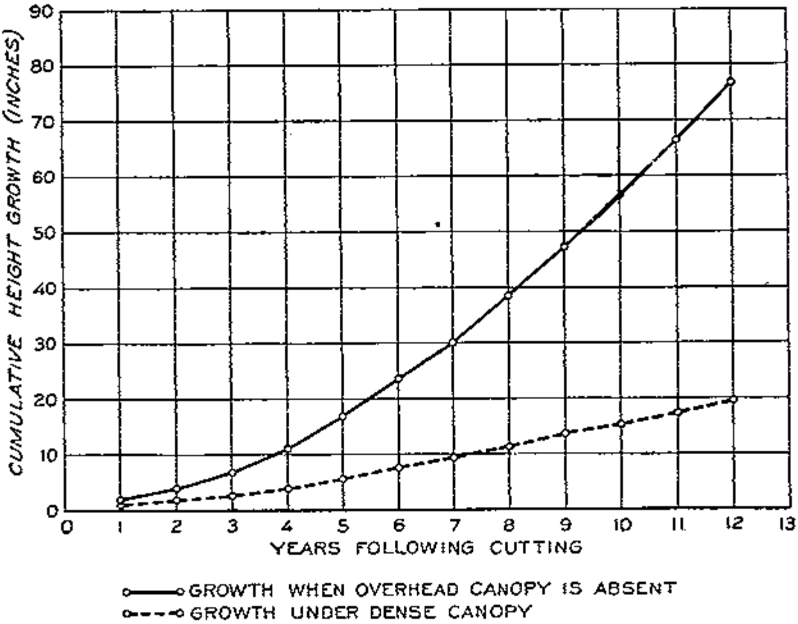



FIGURE 11.—Relative rates of growth of red spruce seedlings following cutting under open and dense canopies. Basis, 77 red spruce seedlings

than 1 foot. The spruce and fir seedlings, which at the time of cutting averaged 6 inches in height, were badly outstripped by their hardwood associates—the maximum height growth, attained in the fifth year, amounting to 5 inches. At the end of 11 years the total height growth put on by the 6-inch spruce was approximately 3 feet. Without question many of the spruce and fir will eventually break through the canopy formed by the new stand of hardwoods, but it will be many years before they gain supremacy.

Figure 11 compares the accumulated height growth of spruce seedlings under open and dense hardwood canopies for a period of 12 years following cutting. In the open the seedlings show a total height growth of more than 75 inches, as against barely 20 inches for those in the shade.

## RELATIVE RATES OF GROWTH OF RED SPRUCE AND BALSAM FIR SEEDLINGS

The relative rates of growth of red spruce and balsam fir seedlings following the removal of the mature stand can best be studied by consulting Table 16 and Figure 12. It will be noted that balsam fir, even the first year following cutting, puts on more height growth

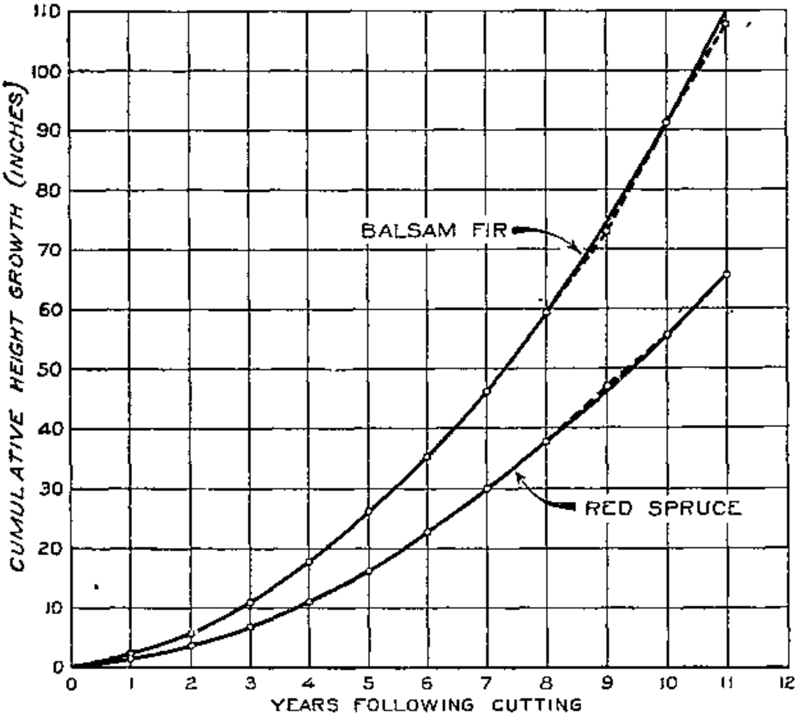



FIGURE 12.—Relative rates of growth of dominant red spruce and balsam fir seedlings following cutting. Spruce-hardwoods type. Basis, 62 red spruce and 30 balsam fir

than red spruce. Dominant seedlings were selected for analysis, although the small height growth put on by them the first year following cutting indicated that previous to cutting they had been somewhat suppressed. At the end of the eleventh year balsam fir had accumulated a 42-inch lead. This superior capacity for height growth in fir has already been cited as in a measure accounting for the high representation of fir in young sapling and pole stands found on cut-over areas.

**TABLE 16.**—*Relative rates of growth, by height classes, of dominant red spruce and balsam fir seedlings, formerly suppressed but released through cutting, spruce-hardwoods type*

RED SPRUCE

| Height class (feet) | Average height at time of cutting | Basis, seedlings | Current annual height growth since cutting | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | First year | Second year | Third year | Fourth year | Fifth year | Sixth year | Seventh year | Eighth year | Ninth year | Tenth year | Eleventh year | Total |
| | *Feet* | *No.* | *In.* | *In.* | *In.* | *In.* | *In.* | *In.* | *In.* | *In.* | *In.* | *In.* | *In.* | *In.* |
| 0 to 1 | 0.4 | 26 | 1.5 | 1.5 | 1.9 | 2.6 | 4.1 | 4.6 | 5.0 | 4.6 | 5.6 | 7.9 | 7.9 | 47.2 |
| 1.1 to 2 | 1.5 | 20 | 1.6 | 2.4 | 3.8 | 5.9 | 7.9 | 8.4 | 7.6 | 10.6 | 11.1 | 11.0 | 11.5 | 81.8 |
| 2.1 to 3 | 2.8 | 4 | 2.0 | 5.5 | 7.3 | 7.3 | 8.0 | 11.0 | 10.0 | 11.5 | 12.5 | 11.0 | 11.0 | 97.1 |
| 3.1 to 4 | 3.5 | 2 | 2.5 | 6.5 | 6.0 | 9.0 | 8.5 | 11.5 | 13.0 | 13.0 | 13.0 | 12.0 | 13.0 | 108.0 |
| 4.1 to 5 | 4.8 | 2 | 3.5 | 5.5 | 6.5 | 8.5 | 10.0 | 11.5 | 13.0 | 11.0 | 12.0 | 12.0 | 13.0 | 106.5 |
| 7.1 to 8 | 7.9 | 6 | .3 | .6 | 1.0 | 1.7 | 2.3 | 3.7 | 6.0 | 7.4 | 8.6 | 7.3 | 8.6 | 47.5 |
| 10.1 to 11 | 10.8 | 1 | 0 | 0 | 0 | .5 | 2.0 | 4.0 | 10.0 | 14.0 | 9.0 | 8.5 | 9.0 | 57.0 |
| 12.1 to 13 | 13.0 | 1 | 0 | 0 | .5 | 1.0 | 1.5 | 2.0 | 2.0 | 1.5 | 6.5 | 7.0 | 7.0 | 29.0 |
| Total or average | 2.2 | 62 | 1.5 | 2.2 | 3.0 | 4.2 | 5.7 | 6.5 | 6.8 | 7.8 | 8.0 | 9.3 | 9.7 | 65.3 |

BALSAM FIR

| Height class (feet) | Average height at time of cutting | Basis, seedlings | First year | Second year | Third year | Fourth year | Fifth year | Sixth year | Seventh year | Eighth year | Ninth year | Tenth year | Eleventh year | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 to 1 | 0.5 | 23 | 2.3 | 3.6 | 4.8 | 6.4 | 7.6 | 7.7 | 10.4 | 13.0 | 14.0 | 19.0 | 15.0 | 103.8 |
| 1.1 to 2 | 1.6 | 3 | 3.3 | 2.3 | 4.7 | 7.0 | 12.0 | 10.0 | 13.0 | 14.0 | 12.0 | 13.0 | 16.0 | 107.3 |
| 2.1 to 3 | 2.6 | 5 | 1.2 | 4.8 | 9.2 | 9.2 | 11.0 | 11.3 | 12.0 | 16.0 | 12.0 | 23.0 | 21.0 | 129.7 |
| 5.1 to 6 | 5.9 | 4 | 2.0 | 3.1 | 4.0 | 5.0 | 9.6 | 11.8 | 7.6 | 11.6 | 11.0 | 15.5 | 15.0 | 96.2 |
| 6.1 to 7 | 6.1 | 1 | 2.0 | 2.0 | 3.0 | 7.0 | 8.0 | 10.0 | 14.0 | 14.0 | 10.0 | 22.0 | 22.0 | 120.0 |
| Total or average | 1.6 | 36 | 2.2 | 3.6 | 5.3 | 6.7 | 8.6 | 9.1 | 10.6 | 13.2 | 13.1 | 18.8 | 16.1 | 107.3 |

For the 11 years following cutting, balsam fir put on an average height growth of 9.8 inches a year as against 5.9 inches for spruce. The maximum height growth in one year for all height classes of fir is 19 inches and for spruce 10 inches. Annual height growth in individual fir specimens was recorded as high as 23 inches, but this was unusual. Specimens of spruce seldom attain annual height growth of over 14 inches. In contrast with the rapid growth of spruce seedlings on cut-over areas is their slow growth under the heavy canopy of the mature stand. Figure 13 indicates that the average red spruce seedling developing in the mature stand attains a height of only 8 feet in 61 years, an average growth of approximately 1½ inches per year. It required 40 years to reach breast height. The general absence of fir seedlings in the higher-sized classes under a heavy canopy in the uncut stands, again indicating the less persistent character of the fir, makes it impractical to construct a curve showing age of fir seedlings at the various points above 4 feet in height. However, analyses of fir seedlings up to 3 and 4 feet in height, growing in mature stands, show approximately the same rate of height growth as spruce.

## EFFECT OF SIZE AND AGE OF SEEDLING ON HEIGHT GROWTH

A factor that must be given due weight in the management of spruce and fir stands, particularly in the spruce-hardwoods type, is the rate of growth that the seedlings and saplings of different sizes may be expected to attain following cutting, and their corresponding ability to meet competition. Even when spruce and fir reproduction is abundant, raspberry growth, witch hobble, weed species, and aggressive hardwoods compete strenuously for a position in the new stand, and it is therefore important that the advance reproduction be of sufficient height to maintain its ascendency over the incoming hardwoods and other competing growth.

An analysis of a large number of suppressed seedlings and saplings brought out great differences in their capacity for height growth following cutting. Only dominant individuals were selected for study. Figure 14 shows that small saplings, ranging between 2 and 5 feet in height at the time of cutting, put on the most rapid height growth thereafter. For example, small saplings 4 feet in height at the time of cutting reached a height of nearly 15.5 feet

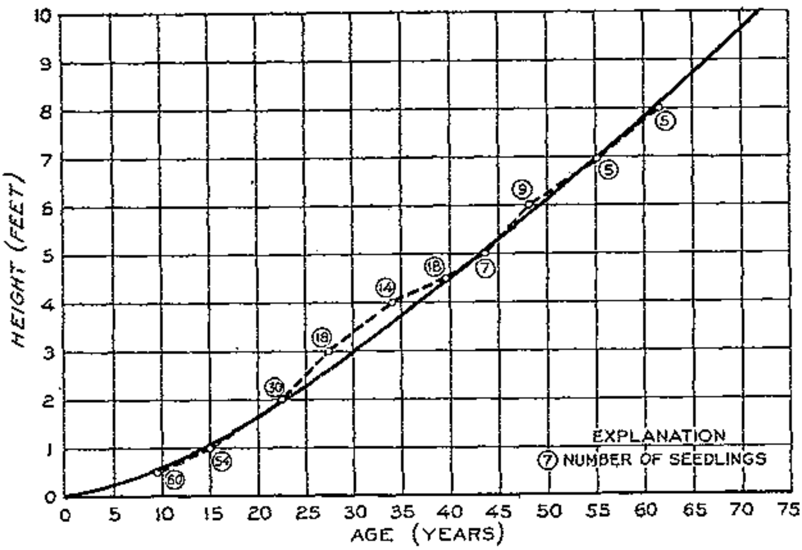



FIGURE 13.—Rate of growth of red spruce seedling growth under heavy canopy of mature stand (spruce-hardwoods type)

in a 13-year period, an increase of 11.5 feet. On the other hand, a 10-foot suppressed sapling in the same period of time increased only 5.5 feet in height. The yearly height-growth curves show that small saplings from 2 to 5 feet in height recover more promptly after cutting than do seedlings of any other height class. (Pl. 6, B.) Ten-foot saplings, for example, require a recovery period of five years before they show a truly accelerated growth. For extremely flat-topped trees where new terminals must be developed this period of suppression may be even longer. (Pl. 7, A.)

The figure also indicates that seedlings germinating in the year of cutting will attain breast height in approximately 14 to 15 years, if not interfered with by hardwoods or brush growth. The slow growth of spruce reproduction under the mature stand is also indicated, as well as the remarkable capacity it possesses for recovery after long periods of suppression. Even some specimens 10 and 15 feet tall

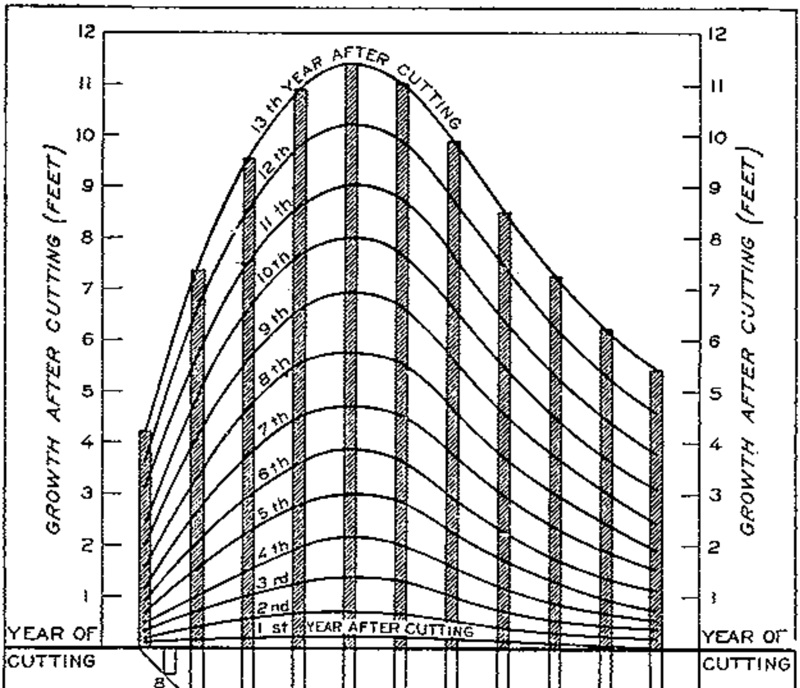



FIGURE 14.—Chart showing current annual and cumulative growth for 13 years following cutting for red spruce trees of various heights at time of cutting; and relationship of height to age. Seedlings and saplings suppressed at time of cutting and released through cutting. Original canopy dense. All trees now dominant. Basis, 62 red spruce

with a crown length of scarcely a foot and a width of 3 or 4 feet—the characteristic umbrella-topped trees with closely whorled branches and with no definite terminals—were observed to have developed new leaders following the removal of the overhead canopy, and to have begun developing normal crowns and putting on good height growth. In some instances trees were noted which had apparently undergone two suppression periods (as indicated by the closely whorled branches at two distinct points on the stem), each followed by recovery and rapid growth.

Figure 14 also illustrates the effect of age of spruce seedlings at the time of cutting on their age at various heights. For example, a seedling 14 years old and 1 foot tall when cutting occurred is shown to be over 22 years of age when it attained a height of 4.5 feet; whereas a seedling 30 years old and 3 feet tall at time of cutting is shown to be over 33 years of age by the time it reached breast height. This difference is due, of course, to the long period that the older seedling grew under the heavy canopy of the mature stand.

## SLASH DISPOSAL

In order to show the effect of slash on reproduction, observations of slash on cuttings of different ages were made. An intensive study of this phase of the problem through the establishment of permanent sample plots is now under way, but has not progressed to the point where comprehensive conclusions can be drawn.

### EXTENSIVE SURVEY OF SLASH CONDITIONS[6]

It was observed that the rate at which slash deteriorates varies greatly not only with species, but with the size of the material. Moisture, density, exposure to sunlight, and temperature as controlled by altitude and exposure, also affect, although less strikingly, the rate of decomposition. Pronounced differences in the state of decay of slash on cuttings of equal ages were noted. Softwood slash at elevations of 3,000 feet had reached less advanced stages of disintegration than on equal-aged cuttings located at 2,000 feet and lower. Sunlight and moisture were also noticeably responsible for the activity of rot-producing fungi. Generally speaking, beech, birch, and maple slash decomposed from two to three times as fast as that of spruce and fir.

#### HARDWOOD SLASH

Hardwood tops cut in late winter and early spring usually develop leaves of nearly normal size and in many instances remain green well into the summer season. Such tops, together with those cut during the summer, hardly represent a fire hazard until the approach of fall. In the course of the first year the smaller twigs and branches become brittle and show the first stages of fungous attack. But by the end of the third year new growth springing up on cut-over areas has taken possession of practically all the openings made by cutting, and during the growing season greatly reduces the fire hazard. In

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[6] Examination of slash on cut-over lands and formulation of the following discussion on slash deterioration thereon were made in cooperation with Perley Spaulding, U. S. Bureau of Plant Industry.

the spring and fall, however, the dry stems and leaves add to the fire danger. By this time, owing to the breaking-down action of three winters' snows, tops have flattened to a considerable degree and the branches and smaller limbs have rotted off and fallen to the ground. This process continues until by the seventh or eighth year the bulk of the hardwood slash has decomposed. Casehardened limbs and larger water-logged material may, however, persist for a considerably longer period; for example, on a 10-year-old cutting where yellow birch limbs 4 and 5 inches in diameter, lying near the ground and covered with decomposed slash, showed practically no signs of decay. Further examination of these limbs revealed the presence of considerable moisture and an unusually high temperature, a combination unsuited to fungous activity.

### SOFTWOOD SLASH

Softwood slash disintegrates at a much slower rate than does that of hardwood. An important fact is that the highly inflammable branches below 1 inch in diameter are often the last to decompose, since they dry out so quickly that conditions are extremely unfavorable for rot-producing fungi.

The first year after cutting is characterized by the drying out of needles and branches. Most of the spruce needles drop off by the end of the first season, but fir needles usually persist through the second season, some even remaining into the third. Fallen needles, together with leaves from broad-leaved trees, continue thereafter to collect near the bottom of slash piles, forming thick mats which may remain in an undecomposed state for a number of years. A slow but steady rotting in both sapwood and heartwood continues, so that ordinarily by the end of the eighth or ninth season, 2, 3, and 4 inch branches are fairly well rotted. Heavy winter snows assist in flattening piles and windrows of slash, tending to compact the entire mass, thus bending or crushing such advance reproduction as may be underneath. From the tenth year on, disintegration progresses fairly rapidly, the fire hazard being ordinarily reduced to normal by the twelfth year. However, on 12-year-old cut overs many of the thoroughly seasoned smaller branches in the topmost layer show no appreciable rot. (Pl. 8, A.) Even at the end of 20 years, main stems, though somewhat flattened and largely rotted, may still retain their original form, while in unlopped slash resinous branches often persist. It was noted that slash resulting from lopped tops disappears more quickly.

At the end of 12 years the heavy needle mat formed near the base has largely decomposed, but the slash pile does not yet represent favorable conditions for the germination of new seedlings. Occasional new spruce and fir seedlings were found germinating in slash piles in 18 and 20 year old cuttings. In most instances, however, they were found coming in on decayed logs sufficiently decomposed to form fairly deep layers of mold.

### AREA COVERED BY SLASH

Although it was observed that the percentage of area covered with slash is influenced by such factors as stand composition, number of trees, branchiness of timber, and degree of utilization, the controlling factors appear to be that of the volume of timber removed and the method of slash disposal. On special plots in the spruce-hardwoods type where different systems of cutting were employed, accurate records were kept of the quantity of timber removed, the quantity of slash resulting therefrom, and the area actually covered. Table 17 shows the relationship of system of cutting to area covered with

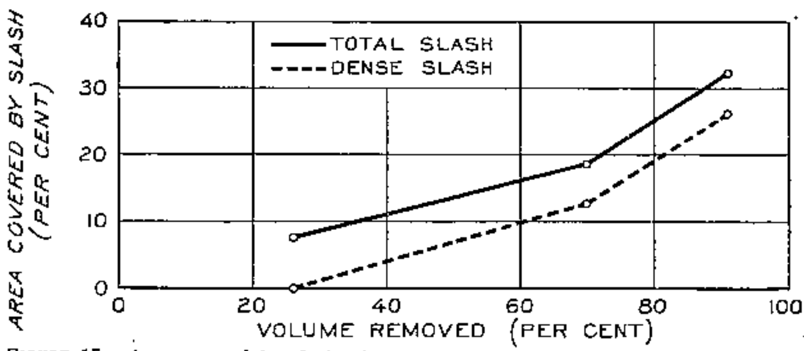



FIGURE 15.—Area covered by slash after piling and burning in relation to volume of stand removed. Spruce-hardwoods type

slash. On one-half the area slash was left undisturbed as it fell, while on the remaining half hardwood tops were lopped and the softwood slash piled and burned.

**TABLE 17.**—*Relation of volume of timber removed per acre by different methods of cutting to the percentage of area covered with slash*

| Method of cutting | Timber removed | | | | Portion of area covered with light and dense slash | | |
|---|---|---|---|---|---|---|---|
| | Spruce and fir | Hard-woods | Total | Merchant-able volume | Light to medium | Dense | Total |
| | *Board feet* | *Board feet* | *Board feet* | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| All merchantable species cut to low diameter | 11,250 | 3,980 | 15,230 | 91 | 6.0 | 26 | 32.0 |
| Selection cutting of all merchantable species | 4,080 | 5,120 | 9,200 | 70 | 6.5 | 12 | 18.5 |
| Conifers only, clear cut | 2,990 | 0 | 2,990 | 26 | 7.1 | 0 | 7.1 |

Figure 15 shows for the series of plots under discussion the relation of the percentage of volume removed to area covered with slash after piling and burning. The area most completely covered with slash, 32 per cent, had suffered the heaviest removal of timber, approximately 15,000 feet board measure per acre. Approximately 2 per cent of each plot was covered with slash for each thousand board feet of timber removed. On an adjacent experimental slash-disposal plot on which no slash was burned, approximately 57 per cent of the area was covered with slash. In this case for each 1,000 board feet of timber cut per acre, 8 per cent of the area was covered with slash.

Table 18 gives for the spruce-hardwoods type the percentage of the area studied that was covered with lopped hardwood and softwood slash, classified on the basis of slash density. The table shows that the removal of 8,750 board feet from the acre, fairly evenly divided between softwoods and hardwoods, resulted in covering 17 per cent of the area with conifer and 22 per cent with hardwood slash, or 4.5 per cent for each 1,000 feet of timber removed per acre. On the basis of the volume of wood removed, softwood slash covers only 67 per cent as much area as hardwood slash. Of the total of 39 per cent of the area slash-covered, 18 per cent of each acre is occupied by dense slash, 11 per cent by a moderate layer, and 10 per cent is lightly strewn. Although hardwood slash tends to occupy a greater surface area per unit of volume removed, 64 per cent of it falls in the class of medium and light slash as against 36 per cent that is classified as dense. This indicates a tendency of softwood slash to compact itself.

TABLE 18.—*Percentage of area covered with slash on area logged for merchantable hardwoods and softwoods, and percentage of slash of different densities; all slash lopped; spruce-hardwoods type*

| Slash | Timber removed per acre | Distridution of slash by type | Area covered with slash | | | | Distribution of slash by densities | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Dense | Medium | Light | Total | Dense | Medium | Light |
| | *Board feet* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| Conifer | 4,690 | 44 | 10 | 4 | 3 | 17 | 62 | 23 | 15 |
| Hardwood | 4,060 | 56 | 8 | 7 | 7 | 22 | 36 | 33 | 31 |
| Total or average | 8,750 | 100 | 18 | 11 | 10 | 39 | 46 | 28 | 26 |

In the spruce-flat type, on 58 transect strips run through pulpwood tracts on which but 4,200 feet per acre were removed, 29.2 per cent of the area was covered with slash, two-thirds of this of medium density and the remainder dense. In this instance, approximately 7 per cent of the area was covered for each 1,000 feet of timber removed. This high percentage of slash per thousand feet can be accounted for by the fact that the timber removed was of small size, averaging only 7.7 inches diameter at breast height, and also by the fact that considerable young growth of sapling and pole size was cut in swamping. In the spruce-slope type where pure stands of spruce and fir are common, extensive cut-over areas were encountered, which, with the exception of skid trails and haul roads, were entirely covered with slash. (Pl. 7, B.)

## EFFECT OF SLASH ON SEEDLING SURVIVAL

With the large quantity of advance reproduction present in spruce and fir stands, it is to be expected that much of it, particularly in the smaller size classes, should be covered by slash in the process of logging. Figure 16 shows that loss to spruce and fir from this source is particularly high in the one-half and 1 foot classes, averaging about 16.5 per cent, and diminishing steadily with increase in size to 8 per cent for the 5-foot class. It is impossible at present to state how permanent this loss will be. Where slash does not occur in dense masses and in windrows, a large part of the reproduction will survive, but there is no question that slash left after logging will reduce noticeably the amount of reproduction on cut-over areas.

In order to gain some knowledge of the degree to which slash suppresses and smothers advance reproduction, different densities of slash were applied to small quadrats in the spruce-flat type under uniform conditions of light, exposure, and soil. Check plots were also established on which no slash was placed. Since the experiment has been in progress for only two years the data presented are far from conclusive, but the trends are worthy of consideration.

Table 19 shows that over a period of two years the number of seedlings is considerably reduced as a result of being covered with slash, the dense slash completely exterminating all hardwoods. The average loss of red spruce and balsam fir combined on the heavy

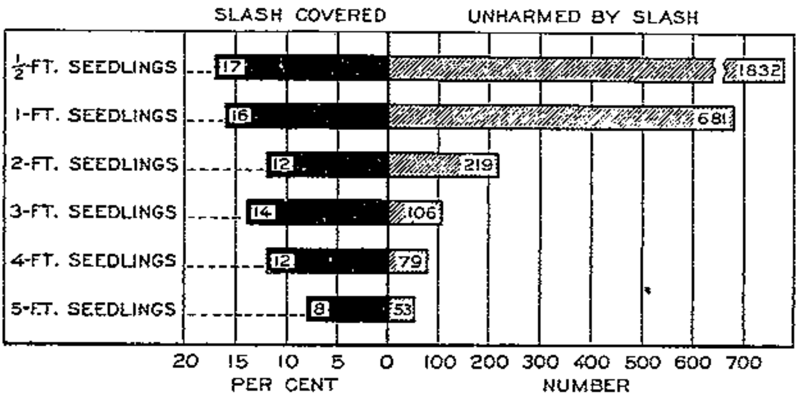



FIGURE 16.—Percentage of seedlings in various height classes covered by slash, and number left per acre. (Spruce-hardwoods type.)

slash areas is 47 per cent, under medium slash 27 per cent, under light slash 26 per cent, and on the check plot only 12 per cent. The aggressiveness of the fir is again indicated, in that lower mortality is recorded on all of the plots for this species than for the spruce. In general, the heaviest losses occurred in the smaller size classes.

TABLE 19.—*Number of seedlings of various species present just prior to application of slash (1923) and two years later (1925)*

SEEDLINGS UNDER HEAVY AND MEDIUM SLASH

| Species | Under heavy slash | | | Under medium slash | | |
|---|---|---|---|---|---|---|
| | 1923 | 1925 | Loss | 1923 | 1925 | Loss |
| | *Number* | *Number* | *Per cent* | *Number* | *Number* | *Per cent* |
| Red spruce | 21 | 10 | 52 | 13 | 6 | 54 |
| Balsam fir | 22 | 13 | 41 | 20 | 18 | 10 |
| Red maple | 7 | 0 | 100 | 0 | 3 | 0 |
| Yellow birch | 22 | 0 | 100 | 3 | 2 | 33 |

SEEDLINGS UNDER LIGHT SLASH AND NO SLASH

| Species | Under light slash | | | Under no slash | | |
|---|---|---|---|---|---|---|
| | 1923 | 1925 | Loss | 1923 | 1925 | Loss |
| | *Number* | *Number* | *Per cent* | *Number* | *Number* | *Per cent* |
| Red spruce | 6 | 2 | 67 | 14 | 12 | 14 |
| Balsam fir | 52 | 41 | 21 | 36 | 32 | 11 |
| Red maple | | | | 5 | 5 | 0 |
| Yellow birch | 29 | 2 | 93 | 9 | 8 | 11 |

Not enough data are on hand to indicate what effect slash burning has on the future composition of the stand. On plots established in an extensive 23-year-old cutting in the spruce-flat type, over which fire had run after spruce and fir, and also pine, had been removed, a tally of the young pole stand showed an average of 73 per cent spruce and 27 per cent fir. The high representation of spruce is most striking. It is impossible to state to what extent burning of slash was responsible for this, but the condition is so unusual as to warrant further investigation.

Observations in general on cut-over areas indicate that hardwood slash is less damaging to young growth than is that of softwood. The general open character of hardwood slash permits a certain number of seedlings to push their way through without undue interference. On some of the older areas it was not unusual to see seedlings making good progress through unlopped hardwood tops. Lopping hardwood tops compacts the slash and increases the chances of smothering. No great difference was noted in the rate of decay in lopped as against unlopped hardwood slash.

Softwood slash ordinarily forms so dense a cover and decays so slowly that it smothers out the advance reproduction very thoroughly. On cut-over areas from 8 to 12 years of age practically no advance reproduction succeeded in surviving the effects of a dense cover of softwood slash such as is represented by windrows and large piles. (Pl. 8, B.)

## SUMMARY


Because of increased stumpage values of spruce and fir, operators of pulpwood lands in the Northeast have recently adopted the practice of clear cutting their land. What effect this policy will have on future pulpwood production on these lands and what is necessary, in view of present conditions, to maintain desirable pulpwood stands in this region have been to some degree determined by an extensive survey of cut-over land of all ages throughout the spruce region of the Northeast.

Some of the outstanding facts brought out in the examination of a large number of temporary sample plots established on various-aged cut-over areas in the different forest types are as follows:

### ABUNDANCE OF REPRODUCTION

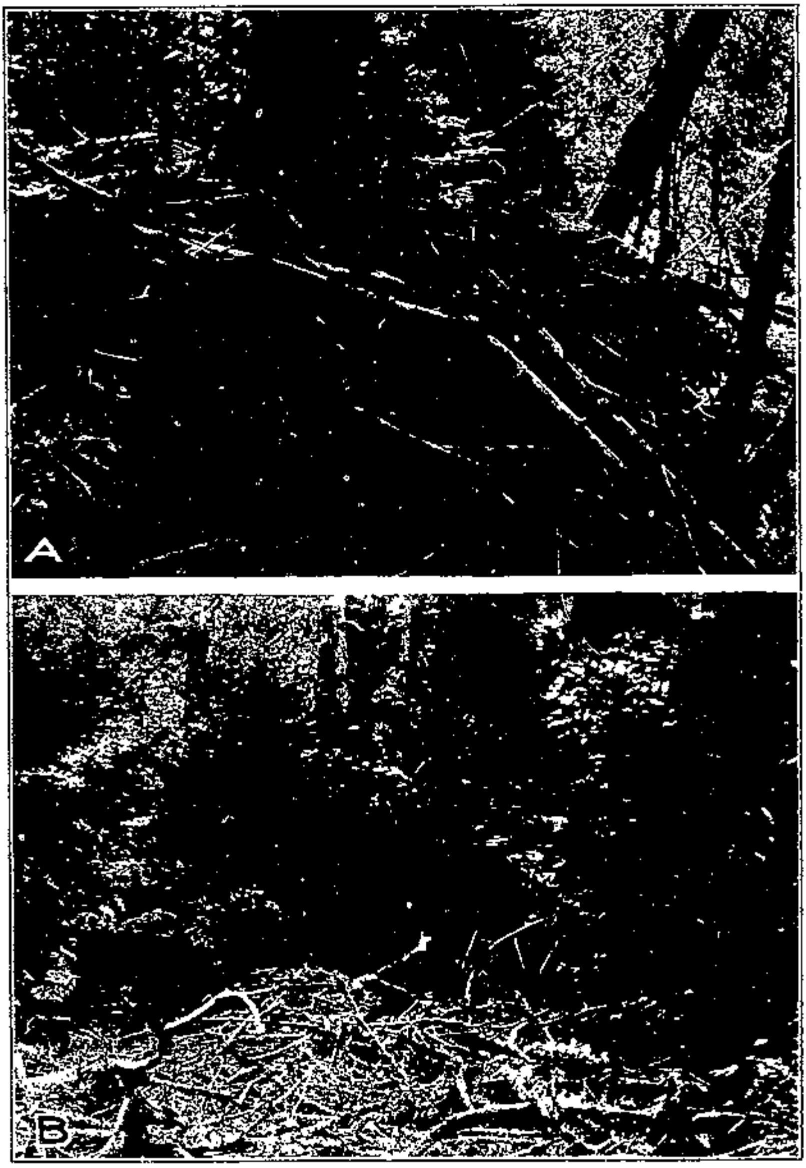
On most areas, regardless of the severity of the cutting, an abundance of spruce and fir reproduction was found, nearly all of which was advance growth present in the stand prior to cutting. Even in stands containing a large percentage of hardwoods, it is not unusual to find a satisfactory restocking of pulpwood reproduction. There is, however, a general lack of spruce and fir seedlings that have come up since cutting.

In quantity, the advance reproduction varies with forest type, the spruce-slope type having the most, spruce-flat next, and spruce-hardwoods the least; but in general, the largest quantities are found on areas which originally supported the largest volume of spruce and fir.

Abundance of seed, favorable seed-bed conditions, and the shade-enduring qualities possessed by both spruce and fir account for the


A, Twelve-year-old cutting. Formerly flat-topped spruce sapling released through removal of overhead canopy. Dense whorls of branches show point where height growth practically ceased while under cover of the mature stand

B, A recently cut-over area in spruce-slope type. With the exception of skid trails and haul roads practically the entire area is covered with slash. On steep slopes slash is a distinct aid in preventing excessive erosion




A, Conifer slash on 12-year-old cutting. The larger material in such slash usually rots first. The smaller branches lying near the surface of slash piles and exposed to the drying action of the wind and sun become thoroughly seasoned. This highly inflammable material even after a period of 12 years often shows little sign of decay; B, dense conifer slash crushes and kills advance reproduction growing beneath it and effectually prevents new reproduction from becoming established on areas occupied by it for a period of from 15 to 20 years. Note reproduction surrounding slash pile. Slash of this character should be burned to give seedlings an opportunity to utilize the land otherwise occupied by dense slash plentiful reproduction of these species in old-growth stands in all types. The spruce-flat type shows a tendency to produce large numbers of spruce and fir seedlings and a relatively small number of hardwoods and weed species; the spruce-hardwoods type, fewer seedlings of the pulpwood species and large numbers of hardwoods and weed species; and the spruce-slope type, great quantities of conifer seedlings, but at the same time numerous hardwoods and weed species.

The extent to which this advance reproduction is benefited by cutting is directly proportional to the severity of the cutting. Removal of the old stand changes site conditions, but exposure to added sunlight with accompanying changes in soil conditions results in damage to only a small percentage of the advance reproduction.

## HARDWOOD COMPETITION

Competitive hardwood growth is the most disturbing single factor operating to prevent the final establishment of spruce and fir. In spite of this, the spruce-flat and spruce-slope types are maintaining their original representation of conifers, but in the spruce-hardwoods type hardwoods are supplanting to a considerable extent both spruce and fir. In the spruce-flat type spruce and fir reproduction has much less difficulty in maintaining its position with the contemporary hardwood growth than in the spruce-hardwoods type. In the spruce-slope type conifer reproduction meets severe competition from young hardwoods, but with little overhead competition from residual hardwoods it will eventually dominate the stand.

Clear-cutting of spruce and fir prevents restocking of these species for many years following cutting; meanwhile, the large residual hardwoods are seeding abundantly, so that much additional hardwood growth is established. Promiscuous cutting of young growth in some instances may be chiefly responsible for the conversion of former mixed spruce and hardwood stands into pure hardwoods.

Where beech and sugar maple form an appreciable portion of the stand, any type of cutting, unless followed by special cultural treatment, results in the rapid encroachment of hardwoods on areas formerly occupied by spruce and fir. If yellow birch predominates and pulpwood reproduction is well advanced, the cutting out or girdling of hardwoods will greatly increase the reproduction of spruce and fir.

Openings made by cuttings are quickly invaded by a rank growth of brush, young hardwoods, and weed species, the amount and extent of brush being strongly influenced by the density or openness of the canopy overhead, particularly in the case of raspberry. Generally speaking, cut overs are completely clothed by these invaders by the end of the third year.

## SPRUCE VERSUS FIR IN NEW STANDS

Clear-cutting has the effect of changing the composition of the new stand, and of increasing fir at the expense of the more valuable spruce. But, since these stands are normally stocked with advance reproduction and the relative representation of spruce and fir in the future stand is already largely determined, it is questionable whether any scheme of cutting will have any material effect on the relative abundance of spruce and fir in the next crop of pulpwood.

## SEED-BED CONDITIONS

On old-growth stands, where competition from brush growth is less severe, all types of seed beds, regardless of actual soil characteristics, appear to be suitable for spruce and fir reproduction, providing sufficient moisture is present. On cut-over areas, spruce and fir germination is more profuse on exposed soils where litter and plant growth have been dragged away and rootlets can penetrate immediately to a permanent source of moisture, than on undisturbed areas covered with hardwood leaf litter, matted needles, grasses, and other plant growth. On exposed plots an average per acre of 4,700 spruce and 22,500 fir have been found, as against 1,700 spruce and 4,700 fir for the undisturbed plots. Hardwood leaf litter occasionally prevents germination of seed.

## SEEDLING DEVELOPMENT

Moderately suppressed spruce and fir reproduction responds vigorously in height growth following the removal of the overhead canopy through cutting, fir responding more rapidly than spruce. Seedlings ranging between 2 and 5 feet put on the most rapid height growth.

Seedlings germinated at the time of cutting have the advantage over all competitive growth and reach breast height in about 15 years; seedlings growing under the heavy canopy of a mature stand require approximately 40 years.

On upper spruce slopes young spruce and fir seedlings compete very successfully with invading young hardwoods for a period of five years after cutting, after which annual height growth shows diminution due to the rapidity with which young hardwoods begin to overtop spruce and fir.

## IMPORTANCE OF SOIL CONDITIONS

Character of soil, which is largely the result of drainage as determined by glacial formation, plays an important part in stand composition. Preponderance of hardwoods and small representation of spruce and fir in deep, well-drained, aerated soils is not due to the fact that these soils are inimical to the development of conifers, but to the fact that they are particularly suited to the hardwoods. On the other hand, the preponderance of spruce and fir in the spruce-flat type may be attributed to the ability of these species to thrive in soils not particularly suited to the hardwoods.

Soil types in spruce stands change rapidly within comparatively short distances, even slight variations in topography and drainage resulting in a change of soil type.

## SLASH DISPOSAL

The rate at which slash decomposes varies greatly with respect to species as well as to size of the material. Beech, birch, and maple slash decomposes from two to three times as fast as that of spruce and fir. By the end of the seventh or eighth year, practically all hardwood slash on cut-over areas has disappeared; but it may take 20 years for conifer slash to decompose completely. Abnormal fire hazard disappears at the end of the third or fourth year in hardwood-slash areas, whereas softwood slash constitutes an abnormal hazard for 8 to 12 years. The larger softwood slash rots first. Even after 10 or 12 years branches less than 1 inch in diameter may show but little sign of decay.

The quantity and density of slash vary with the species and volume of timber removed per unit of area.

Dense softwood slash, even when unlopped, not only crushes and kills the advance reproduction beneath it but effectually prevents the establishment of new reproduction on all areas occupied by it for a period of 15 to 20 years. Hardwood slash rarely hinders reproduction seriously for more than 5 or 6 years. Lopping hardwood tops compacts the slash on relatively small areas and increases the chances for smothering seedlings.

Dense conifer slash should be burned (preferably in the winter as logging progresses), but similar disposal of hardwood slash is rarely warranted.

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