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AN ECOLOGICAL APPROACH TO TOLERANT HARDWOOD SILVICULTURE

by
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Project H. 84

by

J. M. Jarvis[1]

INTRODUCTION

Partly because of the nature of the stands and partly because of cutting practices, the tolerant hardwoods (sugar maple, yellow birch, and beech[2]) of Ontario and Quebec form "silvicultural slums". With proper silvicultural management, however, these hardwood areas could become the most productive forests in eastern Canada.

In the early nineteen hundreds, logging in the tolerant hardwoods was restricted to the more accessible areas. The problem of moving the heavy logs overland or of floating them to mills led many loggers to the conclusion that operations in the tolerant hardwoods were unprofitable. Accordingly, interest in their silviculture was almost non-existent. With the development of better transportation facilities, new logging methods, and modern manufacturing technique, the tolerant hardwoods have become much more important.

The demand created by the Second World War for veneer and plywood products, and the building boom which followed, have greatly stimulated the hardwood industry. In 1952, primary production of all hardwoods including aspen, poplar, and white birch amounted to some 936,000,000 cubic feet, an increase of 39 per cent over the immediate pre-war level.

In 1952, the total amount of tolerant hardwood lumber manufactured in Canada amounted to 400,000,000 board feet, of which about 340,000,000 board feet were sawn in Ontario and Quebec. Also, in that year, approximately 85,000,000 board feet (log measure) of tolerant hardwoods were used in making veneer and plywood in these two provinces. The increasing value of the hardwoods in the export trade is shown by the export value of veneers and plywoods—19 million dollars in 1953, as compared to 1·6 million dollars in 1939. Yellow birch ranks first in volume produced, sugar maple second, and basswood third. Other species such as red maple, elm, beech, oak, ash, and black cherry make up the remainder.

Most of the tolerant hardwood stands are all-aged associations in which sugar maple and yellow birch are the predominant species. The maple is usually so defective that operators have little interest in it; their cut consists mostly of yellow birch. This leaves a residual stand of defective maple which is suitable only for such products as dissolving pulp, firewood, and charcoal. The demand for maple products of this kind is small; consequently, little of the defective material is utilized.

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[1] Research Forester, Ontario Research Unit, Forestry Branch, Ottawa.

[2] A list of species showing the scientific name, common name, and abbreviation of the common name, is given in Appendix I. A glossary of terms used in a special sense is given in Appendix IV.

The areas of uncut timber are limited and these are being used rapidly. Therefore, it is urgent that practical silvicultural methods be developed for treating the hardwood stands in order to ensure future crops of good quality trees.

In 1950 and 1951 the Forestry Branch conducted surveys throughout the northern range of the maple-birch-beech types in Ontario and Quebec to obtain information on the condition of the tolerant hardwoods and their proper silvicultural management. This report summarizes the results of the study, relates the findings to the ecology of the various tolerant hardwood associations and offers suggestions for the silvicultural management of these forests.

THE SURVEYS

The surveys were confined entirely to the tolerant hardwood cover types[3]. They were largely of an observational nature with sampling reduced to a minimum and done only to supplement the observations. By adopting this approach it was possible to cover a large part of the tolerant hardwood region and examine many different conditions. In all, more than 70 areas were studied and in 19 of them the reproduction and main stands were sampled. The locations of the 19 areas are shown in Figure 1.

As yellow birch is the most sought-after tolerant hardwood species, special emphasis was given to it throughout the studies. Therefore, the surveys were confined to the Laurentian (L.4a), Algonquin—Pontiac (L.4b), Middle Ottawa (L.4c), Georgian Bay (L.4d), and Algoma (L.10) Forest Sections [4] of the Great Lakes—St. Lawrence Forest Region where yellow birch occurs most abundantly. The location of these forest sections is also shown in Figure 1.

Observations

In each area studied the observations included:

(a) A study of the occurrence of the various types in relation to landform, topographic position and site.

(b) A detailed examination of representative stands and cut-over areas to determine the effects of; (i) site on the quality of the trees, (ii) site and competition on the vigor, quality and abundance of the different species in the reproduction, and (iii) logging of various intensities on the residual trees and the reproduction.

(c) The determination of the most suitable seed-beds for the establishment of each species.

Sampling

The sampling of the reproduction was by line plots located at 4-chain intervals along lines spaced 10 chains apart. The plots were circular, 1/250 acre in size, and were sub-divided into four quadrants, which are referred to hereunder as 'quadrats' because of the general acceptance of this term in connection with regeneration surveys. Records taken on each quadrat consisted of:

(a) A tally of the five largest stems of each species below 3·6 inches in diameter at breast height. Sound and defective stems were recorded separately. Where first-year seedlings were tallied, they were also separated.

(b) A tally of all trees over 3·6 inches in diameter at breast height by species and 1-inch classes. Sound and defective trees were separated.

[3] For the purpose of this study the tolerant hardwood cover types are defined as those in which natural succession is always towards the formation of stands of sugar maple, beech, and yellow birch, either pure or in combination with one another.

[4] Revisions of Halliday's Forest Classification for Canada (7) to be published in the near future.

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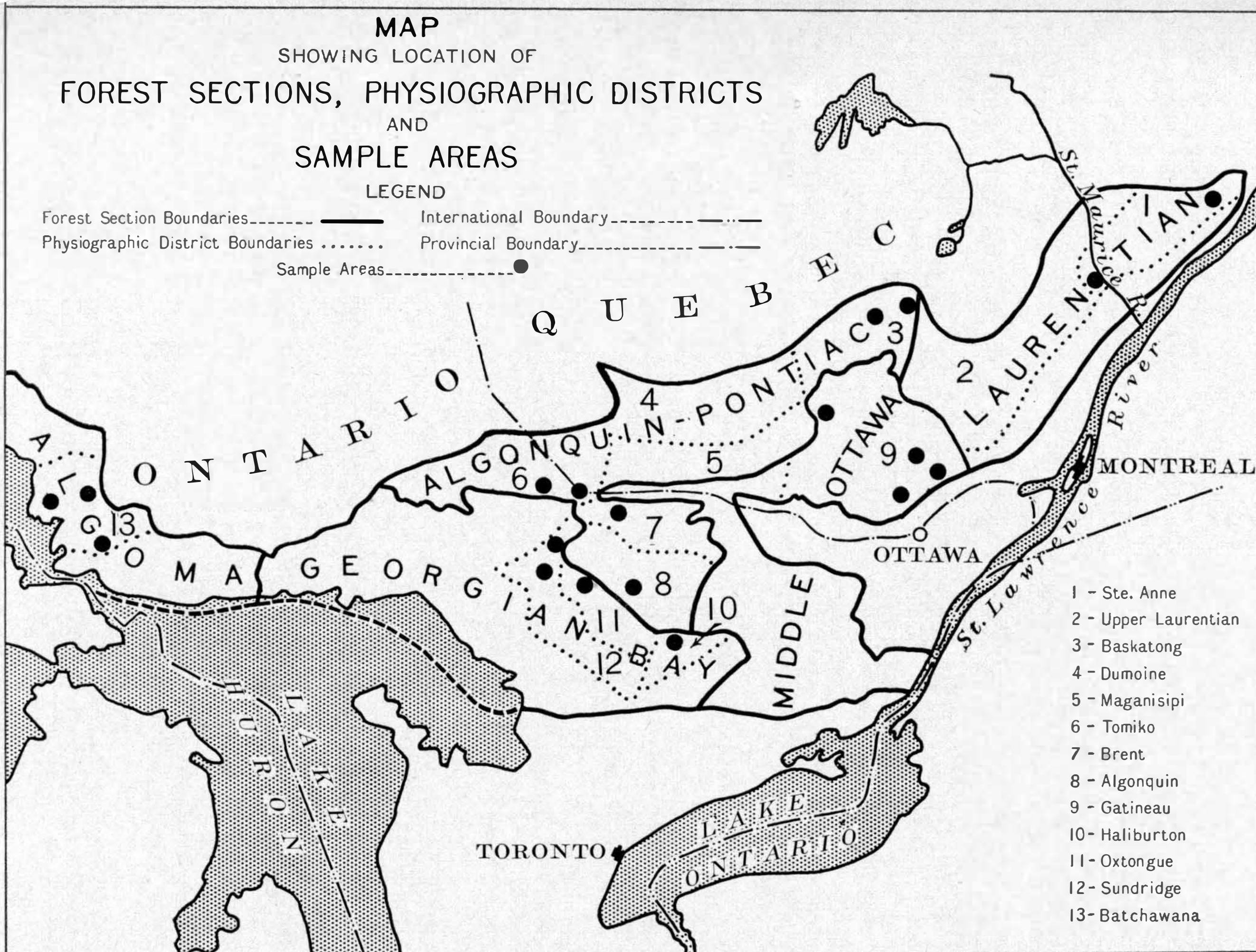

Figure 1

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The forest in the Ste. Anne District is similar in many respects to that of the upper Laurentian District. However, the rougher terrain and abrupt changes in elevation of the Ste. Anne District result in much greater diversity of associations. The higher elevations support softwood types, typical of the Boreal Region; the lower elevations favour hardwood types characteristic of the Great Lakes—St. Lawrence Region. In between, different transitions may be found and the composition of each is influenced by local climatic and drainage conditions.

Algonquin—Pontiac Forest Section (L.4b): The Algonquin—Pontiac Forest Section extends west from the Laurentian Section almost to Sudbury and south into the Algonquin Highlands. The forest cover of this section is somewhat similar to that of the Laurentian Forest Section. However, the proportion of mixedwoods is smaller and the yellow birch content of the tolerant hardwood stands is less, especially in the southern part. Black spruce, a common species in the Boreal Region, is found frequently on upland sites in the most northern areas.

Six districts, the Baskatong, Dumoine, Tomiko, Maganisipi, Brent, and Algonquin, occur in this Forest Section and in each the tolerant hardwoods are represented.

The Baskatong District, which lies north of Mont Laurier in Quebec, is chiefly lowland with elevations ranging from 700 to 1,000 feet above sea-level. However, in the southern and eastern parts upland areas occur frequently. (Mt. Sir Wilfrid reaches an elevation of 2,570 feet.) Lacustrine flats, deltaic flats, and broad swamps occupy extensive areas between the till-capped hills of granite, granite-gneiss, and altered sediments high in iron-bearing minerals. Drumlins are frequent in the southern portions.

The Dumoine District, immediately west of the Baskatong District, is upland in which elevations range from 1,000 to 1,500 feet above sea-level. The terrain is gently to moderately rolling and the bedrock hills of granite, granite-gneiss and altered sediments high in ferro-magnesium minerals, are covered with dumped and moulded till. Rock-cored drumlins and small esker trains are also present.

Many species are absent from the Baskatong and Dumoine Districts because the climate is cool and moist, and the winter temperatures are sometimes extremely low. Sugar maple is restricted almost entirely to the warm, dry and fresh, upper slopes and it reaches the northern limits of its range within these districts. Yellow birch is abundant on all sites and on all slopes, but the greatest concentrations are on the middle and lower slopes where it often constitutes almost 100 per cent of the volume of the stands. White birch and red maple are the only other hardwoods to be found in abundance. Softwoods are present in large numbers, especially where the overhead canopy of hardwoods is open. Balsam fir is found on all sites, white spruce on fresh sites, white cedar on moist sites, and black spruce on dry and moist sites.

The tolerant hardwood stands in the Baskatong and Dumoine Districts are similar in species composition and relationship of associations to topographic position. However, in the Baskatong District, till soils are limited whereas in the Dumoine District they are extensive. As a result hardwoods are much more abundant in the latter district.

The Tomiko District, north of Lake Nipissing in Ontario, is from 800 to 1,200 feet above sea-level and may be regarded as midland. It is gently rolling, and very shallow washed till covers the granite, granite-gneiss and mica-schist bedrock hills. Swamps and fluvial flats are numerous.

The Maganisipi District, east of the Tomiko District and north of the Ottawa River, is also midland, from 800 to 1,200 feet above sea-level. It differs from the Tomiko District in that the terrain is strongly rolling and broken. Many of the valleys are terraced and drumlins and eskers occur in the southern part.

The cool climate, with almost normal precipitation[6], of the Tomiko and Maganisipi Districts is somewhat favourable to many tolerant hardwood species. Here sugar maple is more vigorous and is found more frequently on the lower and middle slopes than it is in similar situations in either the Dumoine or Baskatong Districts. Beech is present, but not in sufficient numbers to be an important associate. Yellow birch is abundant; however it does not constitute as great a proportion of the stands, particularly on the dry and fresh upper and middle slopes, as it does in the Baskatong and Dumoine Districts. Red oak, ironwood, and elm may be found in some stands but their occurrence is not general throughout the districts. Balsam fir, white cedar, white spruce, and black spruce are often present but usually they are suppressed by the more vigorous hardwoods. White pine used to be abundant on ridges and upper slopes but most of it has been cut. Hemlock is common on shallow ridges and upper slopes.

The tolerant hardwood stands are frequent throughout the Maganisipi District on the deep moderately abundant upland till soils. They are less common in the Tomiko District because of the extensive broad fluvial flats and swamps which favour the softwoods.

The Brent District, east of North Bay and south of the Ottawa River, is upland, varying from 1,000 to 1,500 feet above sea-level. Shallow dumped till covers the moderately rolling bedrock granite hills, which are separated by broad fluvial valley trains. Morainic mounds of materials, which appear to have been dumped in water, occur locally.

The Algonquin District immediately south of the Brent District is also upland, from 1,200 to 1,700 feet above sea-level. As in the Brent District, shallow dumped till covers the moderately-rolling bedrock hills of granite and granite-gneiss. However, in this district the fluvial materials between the hills occur only as narrow deposits.

The climate is moderately favourable to the tolerant hardwoods in the Algonquin and Brent Districts but the cold winters and late spring frosts restrict some species. Sugar maple is abundant on all slopes but is most aggressive on warm, dry and fresh sites. Yellow birch forms a smaller portion of the stands here than in the districts mentioned previously. It is found occasionally on all sites but it is most common on cooler moist sites of middle and lower slopes. Beech and ironwood occur mostly on the upper slopes; they are most aggressive on warmer, dry and fresh sites. Red maple, elm, black cherry, basswood, ash, and white birch may be found infrequently on all slopes. The softwoods are white pine, white spruce, balsam fir, hemlock, and white cedar; balsam fir is the most aggressive softwood species but it cannot compete successfully with the hardwoods.

The tolerant hardwoods are more abundant in the Algonquin District than in the Brent District because of the higher proportion of till soils in the former. Much of the Brent District is overlain with sandy moraines, terraces, and outwash plains, which are not suited to the growing of hardwoods.

[6] In Brown's "Tentative division of the forest sections within the Great Lakes—St. Lawrence Forest Region on a physiographic basis" (5), the North Bay District was selected as the regional standard. This district has a mean annual precipitation of 22" with an average of 10" for June, July and August.

Middle Ottawa Forest Section (L.4c): The Ottawa River bisects this section which extends north into Quebec and south into Ontario. The forest is of a mixed nature and is characterized by upland hardwoods, pine ridges, hardwood and mixedwood swamps, and pine flats.

Several districts make up the Section but tolerant hardwoods are abundant only in the Gatineau District. This area varies from lowland to midland with elevations from 500 to 1,200 feet above sea-level. The relief is strongly rolling and broken; shallow till soil covers the bedrock hills of granite, granite-gneiss, crystalline limestone, and ferro-magnesium altered rocks. Lacustrine materials are present in the valleys, and in the southern part of the district, shallow, washed till covers many of the lower slopes. Drumlins occur frequently in the northern part.

The somewhat dry climate and the varied topography of the Gatineau District favour many hardwood species. Sugar maple is dominant throughout and occurs on all slopes and on all sites. Yellow birch is concentrated on the moister sites. Although present throughout the district, it is most common in the north. In the south, yellow birch has poor form and does not produce good sawlogs. Butternut sometimes occurs in openings and reaches its northern limit in the district. Red oak prefers warm, dry and fresh upper slopes and is most abundant in the southern part of the district. (Here, red oak together with red and white pine often occupy the ridge tops completely.) Other species found in the tolerant hardwood stands include beech, ironwood, white and black ash, red maple, basswood, hemlock, balsam fir, white cedar, and white spruce.

Georgian Bay Forest Section (L. 4d): This section borders the north and east shores of Georgian Bay. The forest is characterized by extensive areas of lowland mixedwoods. Admixtures of white birch and aspen, which have come in after fire and cutting, are also common.

There are nine districts in the Forest Section but only three (Haliburton, Sundridge, and Oxtongue) have extensive areas of tolerant hardwoods.

The Haliburton District, south of the Algonquin Highlands, is upland and elevations range from 1,000 to 1,400 feet above sea-level. Till soils cover the strongly rolling bedrock hills of granite, granite-gneiss, and crystalline limestone. Rock-cored drumlins occur occasionally, and fluvial terraces are found in the narrow valleys between the hills.

The Oxtongue District, west of the Algonquin Highlands, is upland, and varies in elevation from 1,000 to 1,500 feet above sea-level. It is moderately to strongly rolling, and till soils cover the bedrock hills of granite, granite-gneiss, and biotite schists. Terraced flats are present in the narrow valleys.

The Sundridge District, south of Lake Nipissing, is midland, with elevations from 800 to 1,200 feet above sea-level. Washed till covers the moderately to strongly rolling bedrock hills of granite, granite-gneiss, and biotite schists. Washed drumlins and fluvial-lacustrine flats are abundant.

The warm moist climate prevailing in the Oxtongue, Sundridge, and Haliburton Districts is favourable to many of the tolerant hardwoods; basswood, red oak, ironwood, and ash are more numerous here than they are in any of the districts previously described. Sugar maple and beech dominate the dry and fresh sites regardless of topographic position. Yellow birch is farily common on cool, moist, middle and lower slopes but it is often found as a scattered tree on other sites. Because of low elevations and extensive fluvial-lacustrine flats, the hardwood areas are not as extensive in the Sundridge District as in the other two. In the Haliburton, Oxtongue, and southern part of the Sundridge Districts, white pine and red oak often replace maple and beech on the ridge tops. In the vicinity of South River, Dorset, and Haliburton, red spruce is present in many of the stands.

Algoma Forest Section (L. 10): The Algoma Forest Section lies along the east shore of Lake Superior and the north shore of Lake Huron. It is distinctive because of its ridge tops and north-facing slopes which are covered with tolerant hardwoods, its south-facing slopes dominated by hardwoods mixed with pine and cedar, and its flats and valleys which support softwood and mixedwood stands containing white spruce and balsam fir.

Three districts may be recognized within the Section but only the Batchawana District, north of Sault Ste. Marie, has many tolerant hardwood stands.

The terrain of the Batchawana District varies from lowland to upland with elevations ranging from 600 to 2,000 feet above sea-level. The relief is rough, almost trap-like with long, gentle north slopes and short, steep south slopes. The till-capped bedrock hills of granite, granite-gneiss, basic igneous and altered sedimentary rocks are aligned in an east-west direction. Deep valleys between the hills contain glacio-fluvial deposits; these are almost alluvial in places. Near Lake Superior, lacustrine and deltaic flats occur in the low broad valleys, and washed till and terrace materials may be found on the lower slopes of the hills.

The abundance of rich till soils favours tolerant hardwoods but the cool wet climate restricts the number of species. Sugar maple occurs on all slopes which support hardwoods, but it is most abundant on warm, dry and fresh sites. Yellow birch is also present on all slopes, but unlike maple it is more abundant on cool moist sites. Ironwood may be found on warm, dry and fresh upper slopes, and red maple and elm on the cool, moist, middle and lower slopes. Red oak occurs occasionally in the western part of the district; beech is absent. White spruce, balsam fir and white cedar are usually present but hemlock is scarce. White pine is also found in the hardwood stands but its occurrence is sporadic and it is mostly restricted to upper south slopes.

The species occurrence in the various districts is illustrated in Figure 2 which shows the relative abundance of the species by forest sections, districts and physiographic sites, and in Table 2 which shows the major tree associations and where these associations are found.

ECOLOGY AND REPRODUCTION

The tolerant hardwood forests of the Great Lakes—St. Lawrence Forest Region, referred to as "hemlock—white pine—northern hardwoods" (4) and "northern hardwoods" (6), are characteristically climatic climax aggregations; that is, they will continue to reproduce themselves as long as the climate remains unchanged. The individual associations comprising the forest are, in a sense, physiographic or edaphic climaxes; each one is able to occupy a particular habitat only as long as the minimum requirements for each species in the association are satisfied. Most of the species are tolerant of shade (3), but there is a gradation in this respect from the very tolerant sugar maple and beech through the tolerant basswood, the moderately tolerant yellow birch, to the less tolerant red oak. All of the trees are long-lived, reasonably windfirm because of widespreading root systems, and produce enormous quantities of seed. Despite these broad similarities the species differ considerably in their ability to reproduce themselves. The silvical characteristics which influence regeneration include such factors as: (a) size and inherent characteristics of the seed, (b) seed dissemination, (c) ability of seeds to germinate on various seed-beds, (d) the capacity of seedlings to survive and develop under diverse conditions, and (e) sprouting ability. These characteristics are discussed below for each of the several species.

TABLE 2—COMMON TOLERANT HARDWOOD ASSOCIATIONS BY DISTRICTS AND TOPOGRAPHIC POSITION

Districts

Topographic Position	Upper Laurentian	Ste. Anne	Baskatong Dumoine	Tomiko Maganisipi	Brent Algonquin	Gatineau	Sundridge Oxtongue Haliburton	Batchawana
Shallow till-capped ridges	sM-Be-yB	sM-Be-yB	sM-yB(bFwSwP)*	sM-yB	sM sM-Be-He(wP) sM-Be-I	sM-Be-He(wP) sM-Be-I(Ba-rO-wP)	sM-Be-He(wP)	sM
Upper till slopes	sM-Be-yB	sM sM-Be sM-Be-yB	sM-yB(bF-wS-wP)	sM sM-yB	sM sM-Be sM-Be-He(wP) sM-Be-I	sM sM-Be sM-Be-He(wP) sM-Be-I(Ba-rO-wP)	sM sM-Be sM-Be-He(wP)	sM
Middle till slopes	sM-yB-He sM-yB(wS-bF)	sM sM-Be sM-Be-yB	yB(bF-wS-wP)	sM-yB sM-yB-He	sM sM-Be sM-yB sM-yB-He(wP)	sM sM-Be sM-Be-yB(Ba) sM-yB	sM sM-Be sM-Be-yB(Ba) sM-yB sM-yB-He	sM-yB
Lower till slopes	sM-yB(wS-bF) yB(wS-bF)	sM-Be-yB yB(wS-bF)	yB(bF-wS-wP)	sM-yB	sM sM-yB sM-yB-He(wP) yB(bAs-E-rM)	sM sM-Be sM-Be-yB(Ba) sM-yB yB(bAs-E-rM) yB-sM(wS-bF)	sM sM-Be sM-Be-yB(Ba) sM-yB sM-yB-He yB(bAs-E-rM)	sM-yB
Sand terraces	yB(wS-bF)	yB(wS-bF)	yB(bF-wS-wP)	yB(wS-bF)	sM-yB(wS-bF)			

* Minor species are shown in brackets; see Appendix I for the species names.

Sugar Maple

Sugar maple is the dominant species in both the main stands and in the reproduction on all sites supporting tolerant hardwood associations in all but the most northerly of the areas investigated. In most stands it is usually so aggressive that it can increase its numbers at the expense of all other species.

Sugar maple is an exceptionally tolerant tree; it is long-lived and attains ages of between 200 and 300 years (8). It has moderately shallow roots and requires a fresh, rich loam for best development; it does not occur on poorly drained sites (10). Most trees bear unisexual and bisexual flowers which appear with the leaves in the spring (1). The fruit consists of a pair of reddish-brown terminally-winged samaras; it matures in the autumn, and is dispersed by the wind soon after maturity. Heavy seed crops occur every 3 to 7 years (2). Sugar maple usually reproduces by seed but it has the ability to sprout, especially the younger trees.

The dominant position maintained by sugar maple can be attributed to its great tolerance of shade at all ages, the frequency of good seed years, and the vigour inherent in the seed. The cotyledons have sufficient strength to force their way through several layers on leaf litter on germination, and thus have no trouble establishing themselves on the seed-beds which are most common in the tolerant hardwood stands. The exceptional tolerance of the seedlings enables them to survive for several years under dense shade and consequently there is always advance growth present to compete for any opening which may occur in the canopy. Sugar maple's ability to sprout from stumps is a phenomenon which is most advantageous for the propagation of the species when conditions are unfavourable for seedling growth.

Sugar maple reproduction was abundant in all of the areas examined, but the greatest concentrations were on dry sites (Table 3, *also* Appendix II). As the sites became moister there was a small but constant decrease in abundance and frequency of occurrence. Generally all sizes from small cotyledons to large advance growth were present in each stand; the number of stems in various size-classes depended on the amount of light which filtered through the overhead canopy. If the canopy of the main stand was dense, most of the reproduction was small; if the canopy was somewhat open, much of the reproduction was large.

TABLE 3—PER CENT STOCKING TO SUGAR MAPLE

(All Areas)

Site	Number of Plots	Sound Stems	Defective Stems	All Stems
		%	%	%
Dry	1,368	1	93	94
Fresh	2,590	4	89	93
Moist	340	5	74	79

Sugar maple reproduction is extremely vigorous on all physiographic sites in the Gatineau, Oxtongue, Sundridge, Haliburton, Brent, and Algonquin Districts. On dry and fresh sites the maple seedlings are usually so aggressive that they limit the occurrence and retard the development of the reproduction of other species.

In the Ste. Anne, Upper Laurentian, Tomiko, Maganisipi, and Batchawana Districts, sugar maple reproduction occurs profusely on almost all slopes and sites but it is aggressive only on the dry and fresh sites of the upper and middle south slopes, upper north slopes and ridge tops. On the lower slopes competition from sugar maple is seldom the limiting factor in the occurrence of other species.

Sugar maple reproduction in the Baskatong and Dumoine Districts is confined to the dry and fresh, upper and middle south slopes and ridge tops. But, even in these locations where the climate is warmer than normal, sugar maple seedlings are not usually vigorous.

Yellow Birch

Yellow birch is somewhat intolerant of shade and will not survive if it fails to achieve a dominant position early in life. However, it is more tolerant in its soil and moisture requirements than sugar maple, and consequently it is capable of growing well on almost all physiographic sites.

Yellow birch is long-lived, reaching maturity at an age of about 150 years (8). It has a shallow, wide-spreading root system and grows well on a variety of soils and moisture conditions (8, 10). The flowers are unisexual, borne in catkins, and both male and female flowers are found on the same tree (1). The fruit matures in the autumn and consists of a stout cone bearing many tiny two-winged nuts. These nuts are dispersed during the autumn and winter and may be carried long distances by the wind. Heavy seed crops occur every 2 or 3 years (2) with lighter crops in the intervening years. So far as is known, birch does not produce suckers. Only rarely does it reproduce by sprouts.

Although yellow birch produces enormous quantities of seed, the cotyledons are unable to establish themselves successfully on the continuous mats of hardwood leaf-litter which are always present under tolerant hardwood stands. In undisturbed stands, yellow birch reproduction occurs mostly on rotten logs, and around the edges of boulders and rock outcrops where leaf-litter is absent. In cut-over areas, yellow birch seedlings and saplings are also found on skid trails, haulroads, and other areas where the leaf-litter has been disturbed or where the ground has been scarified. Since yellow birch seedlings are found only on areas where the leaf-litter is either absent or has been disturbed, it is evident that the structure of the leaf-litter is a limiting factor in the establishment of the seedlings.

For the first 2 or 3 years birch seedlings are quite tolerant of shade, but height growth is so slow under dense shade that the young seedlings are unable to keep up with the maple and they are eventually crowded out. Also, because of this slow growth the birch seedlings are susceptible to smothering when the leaves drop from the main canopy in the autumn. Height growth is more rapid in more open areas and consequently the danger of smothering is considerably less. However, unless the advance sugar maple has been destroyed, it will eventually close in over the birch seedlings and shade them so much that they die.

Yellow birch reproduction was not nearly as abundant as sugar maple in any of the areas examined (Table 4, *also* Appendix II). In general, yellow birch

TABLE 4—PER CENT STOCKING TO YELLOW BIRCH

(All Areas)

Site	Number of Plots	Sound Stems	Defective Stems	All Stems
		%	%	%
Dry	1,368	4	1	5
Fresh	2,590	6	3	9
Moist	340	16	7	23

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stocking increases as moisture conditions become wetter; this is attributed to the less vigorous competition from sugar maple on the wetter areas. Also, yellow birch reproduction is most abundant in northern districts, where sugar maple is least aggressive; conversely, it is least abundant in the southern districts where sugar maple is most aggressive.

Beech

Beech has a broad moisture tolerance and will grow well on various kinds of soil. However, it is much more sensitive to extremes of cold than either sugar maple or birch. This species may be considered as reaching its northern limits in the Upper Laurentian, Ste. Anne, Tomiko, and Maganisipi Districts. It occurs occasionally in the Baskatong and Dumoine Districts, but only on the most favourable sites. It is absent from the Batchawana District.

Beech is a tolerant, long-lived tree frequently reaching ages of between 300 and 400 years (8). It has a shallow root system and will grow on a variety of soil and moisture conditions (8, 10). The flowers are unisexual and both sexes are found on the same tree (1). The fruit is a three-cornered nut which matures in the autumn. Owing to the weight of the seed, dissemination is limited to relatively short distances. Seed crops occur every 2 to 3 years (2). Beech produces stump sprouts and root suckers readily, but these seldom grow to appreciable size.

Beech is considered to be a climax species, yet it is seldom found in pure stands even on the most favourable sites. The seed germinates well on most seed-beds. The seedlings are tolerant of shade for some years but they do not persist nearly as long as those of sugar maple. Eventually most of the seedlings become suppressed, and unless they obtain some release from shade they die.

In those districts where beech occurs the quantity of its reproduction varies considerably. This is illustrated by Table 5 which shows stocking figures for stands with similar histories in the Tomiko–Algonquin and Gatineau–Oxtongue Districts. (Figures for all the districts which were sampled are given in Appendix II.) In the southerly districts (Brent, Algonquin, Sundridge, Oxtongue, Haliburton, and Gatineau), beech reproduction is present on all physiographic sites, but it is most abundant and vigorous on the warm, dry and fresh, slopes and ridges. In the Upper Laurentian, Ste. Anne, and southern parts of the Tomiko and Maganisipi Districts, beech reproduction is generally restricted to the dry and fresh upper south slopes but even in these warm locations the seedlings are not extremely vigorous.

TABLE 5—PER CENT STOCKING TO BEECH

Site	Number of Plots	Sound Stems	Defective Stems	All Stems
		%	%	%
(a) Tomiko and Algonquin Districts (stands cut lightly 1947–48).				
Dry	52	0	11	11
Fresh	104	0	2	2
Moist	not sampled			
(b) Gatineau and Oxtongue Districts (stands cut lightly 1947–48).				
Dry	772	4	37	41
Fresh	724	2	25	27
Moist	84	1	10	11

Red Maple

Red maple occurs in all the areas studied (*see* Appendix II), but it is usually most abundant where sugar maple is least aggressive. On the dry sites (especially in the Haliburton, Oxtongue, Sundridge, Brent, Algonquin, and Gatineau Districts) red maple seldom develops beyond a high shrub. Growth is better on the fresh sites and the tree reaches its optimum development on moist telluric slopes.

This species reaches maturity at about 80 years of age (8). It is shallow-rooted and grows well on a variety of soil and moisture conditions (8, 10). Red maple is tolerant of shade but does not approach sugar maple in this respect. The flowers are polygamous and appear before the leaves. The fruit, consisting of terminally winged samaras, matures in the spring and soon falls to the ground (1). Good seed crops occur almost every year and the seed will germinate on almost any seed-bed. Some seeds germinate soon after dispersal; others do not germinate until the following year. Seedlings can tolerate a wide range of soil, moisture, and climatic conditions. Red maple sprouts readily, especially from young stumps. Competition from the more shade-tolerant species, usually sugar maple, is the primary factor limiting the abundance of red maple.

Basswood

Basswood occurs mostly in the more southern districts of the Great Lakes—St. Lawrence Forest Region (the Haliburton, Oxtongue, Sundridge, Brent, Algonquin, Gatineau, and southern parts of the Upper Laurentian and Ste. Anne Districts). Locally, this species is fairly numerous but it is never the main tree.

It is a fast-growing long-lived tree, reaching maturity when it is between 90 and 140 years of age (8). It is moderately tolerant of shade, especially in its youth, but it is not nearly as tolerant as sugar maple. The species has a deep root system and grows best on fresh to moist deep loamy soils (8, 10). The flowers are bisexual and form when the leaves are almost full-grown (1). The fruit is a nut-like berry about one-third of an inch in diameter; it matures about October and is dispersed during the autumn and winter. Good seed crops occur nearly every year (2). Although this species produces large quantities of seed it is generally recognized that most of the seed is dormant. It is maintained by some investigators (13) that dormancy is primarily caused by the impermeable seed coats which cover the embryo.

Although reproduction of this species is generaly scarce, it is found on all sites and consists mostly of sprouts from older trees and stumps. A high percentage of these sprouts are sound and appear capable of developing into good trees. Basswood seedlings are not common and they are found only in the more open areas. Most basswood seedlings are healthy and vigorous.

Other Species

Limited amounts of other species are found on the tolerant hardwood areas. These species vary in kind and quantity from district to district but they are always most common where competition from sugar maple is least. Their occurrence is largely a matter of choice.

RECOMMENDED SILVICULTURAL PRACTICES

The silvicultural management of the tolerant hardwoods will not be easy. The forest is heterogeneous and the terrain it occupies is diverse. Any silvicultural practices which are undertaken will require a high degree of skill if they are to be successful. They must be flexible and adaptable to many conditions of site and cover, and they must be based on a good understanding of the land and the silvicultural characteristics of the species.

Sugar maple is the problem species in the tolerant hardwood forest. It is very aggressive and, except at the northern limit of its range, it can take over most of the hardwood sites from any of its associates. Despite its widespread occurrence there are relatively few areas where sugar maple is capable of developing into trees suitable for sawlogs and veneer stock. Many of the areas now producing mediocre maple cordwood could grow good softwood and hardwood timber of other species. Unfortunately these trees are less tolerant of shade than maple and they cannot compete successfully without help. Other areas which could be growing good maple will do so only if cultural treatments are undertaken to remove the older defective trees and free the young growth from overhead competition.

The species that could be profitably encouraged by silvicultural measures are shown in Table 6, by sites and districts. Those districts recommended for growing sugar maple and yellow birch, the most important species, are shown in Figure 3. For some of the tolerant hardwood sites no preferred species are indicated in the table. On these areas, shrub competition, topography, and local climate are such that tree species do not develop well and little return could be realized from an investment in silviculture. It will be noted that softwoods are suggested as associates for many of the sites where conditions are suitable for their development and where competition from sugar maple could be controlled most easily. In addition to the recommendations made in Table 6, it might be feasible to introduce red spruce, by planting, in the Batchawana District. This district has a cool, moist climate and red spruce should grow well on the fresh and moist sites.

Sugar Maple

For best development this species requires a rich, well-drained loam and the sites within those districts recommended for maple (Table 6 *and* Figure 3) which best meet its requirements are summarized in Table 7. These sites occupy a relatively small area in comparison to the whole area studied. However, the potential yield of maple sawlogs on these areas is so great that they cannot be overlooked.

Favourable conditions for maple in the Haliburton, Oxtongue, Sundridge, Batchawana, and parts of the Gatineau Districts are related to the occurrence of biotite-schists, crystalline limestone, and other altered sedimentary rocks which enrich the soil. In the Brent and Algonquin Districts the soils are somewhat less fertile. However, in many areas they have weathered into good-quality loams with a high organic content which will produce good sugar maple.

Generally the other districts are unsuitable for the practice of maple silviculture. In the Tomiko and Maganisipi Districts the proportion of well-drained sites is small and the climate is somewhat unfavourable. In the remaining districts the high iron content of the soil is the major influencing factor. Iron oxidizes and coats the soil particles, hindering base exchange (14). This causes a nutrient deficiency which contributes towards the poor development and poor quality of the sugar maple.

Even in those areas where sound sugar maple can be grown, the present stands are in poor condition. A defective sugar maple, typical of the majority of trees in the main stands, is shown in Figure 4. Much of the defect in maple is caused by decay fungi (12) which enter the host through broken branches, cracks, logging scars, and other injuries such as those caused by whipping and falling branches.

Sugar maple seedlings and saplings have a thin brittle bark and are very susceptible to mechanical injury. Also most of them are under dense canopies

TABLE 6—RECOMMENDED TREE SPECIES FOR THE VARIOUS TOLERANT HARDWOOD SITES BY DISTRICTS

(Species listed below will give best yield of quality timber with least expenditure.)

Districts

Physiographic Site	Upper Laurentian	Ste. Anne	Baskatong Dumoine	Tomiko Maganisipi	Brent Algonquin	Gatineau	Sundridge Oxtongue Haliburton	Batchawana
Ridges—								
dry				wS, wP	wP	wP		wP
fresh			bS, wS	wS, wP	wP	wP	sM, wP, He	sM, wP, wS
moist	yB, rS	yB, rS	bS, wS	bS, wP	wP, He	rS, wS, wP	sM, Ba, wP, He	yB, sM
Upper Slopes—								
dry			wS	yB, wS, wP	He, wS	wP	sM, wP, He	sM, wP, wS
fresh	yB, rS	yB, rS	yB, wS	yB, wS, wP	sM, He, wS	sM, rO, rS, wP	sM, He	yB, sM, wS
moist	yB, rS	yB, rS	yB, wS	yB	sM, yB, Ba, wS, He	sM, Ba	yB, sM, Ba, He	yB, wS
Middle Slopes—								
dry	yB	yB	yB	yB, wS, wP	wP	yB, sM, rO	sM, wP, He	yB, sM, wS
fresh	yB, rS, wS	yB, rS, wS, rM	yB	yB	sM, wP	sM	yB, sM, rM	yB, sM
moist	yB, rS, wS	yB, rS, wS, rM	wS	yB	sM, yB, Ba, wP, He,wS	sM, yB, rM, Ba	yB,sM,rM,Ba,He	yB, wS
Lower Slopes—								
dry	yB	yB	yB	yB	sM, wP, He	yB, sM, rS	yB, sM, wP, He	yB, sM
fresh	yB, rS, wS	yB,rS,wS,rM	wS,bS	yB	sM,yB,wP,wS	yB, sM	yB, sM, rM	yB, wS
moist	yB, rS, wS	yB,rS,wS,rM	wS, bS	yB, wS	yB, ws, He	yB,sM,Ba,rM	yB,sM,rM,Ba,He	yB, wS

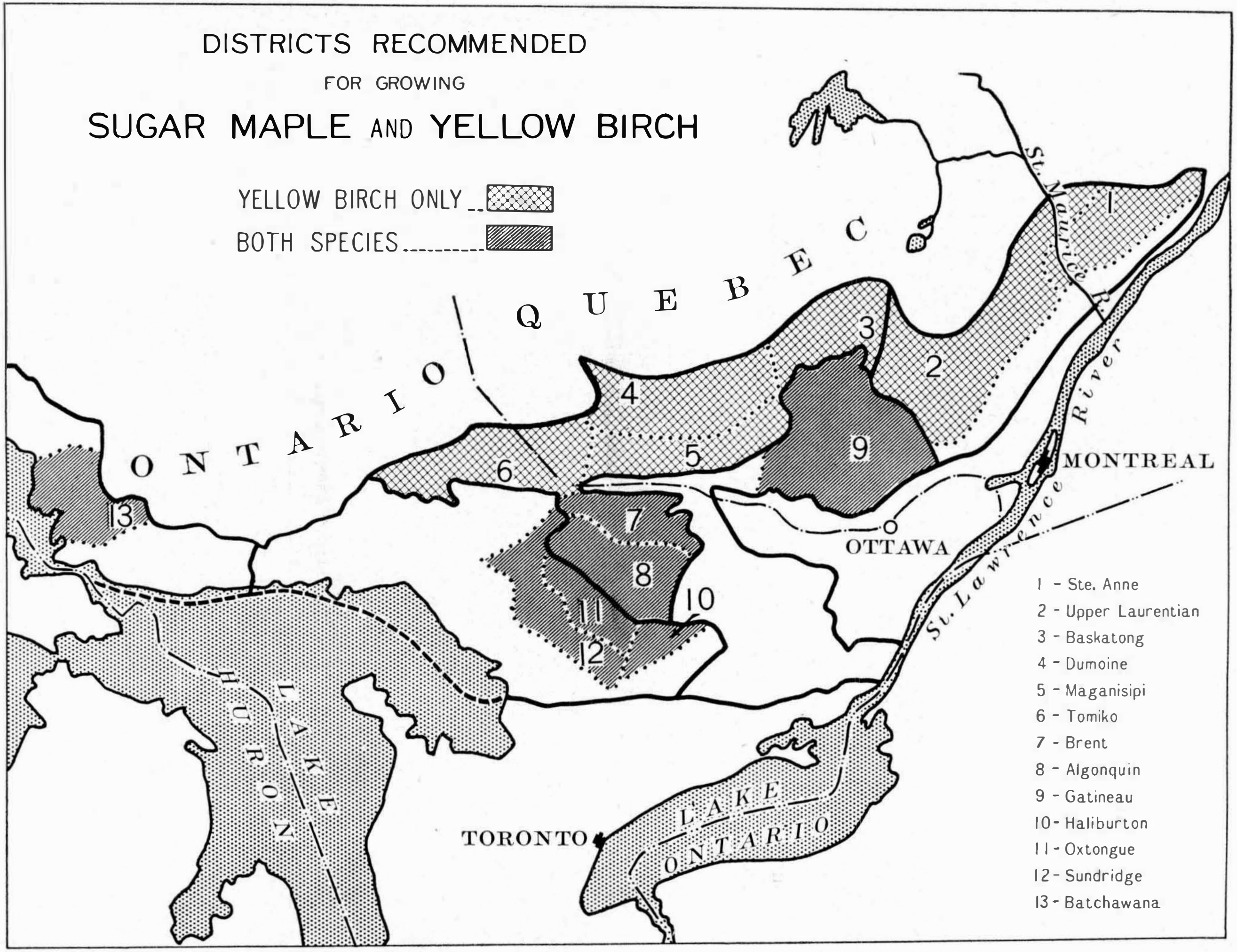
DISTRICTS RECOMMENDED
FOR GROWING
SUGAR MAPLE AND YELLOW BIRCH
YELLOW BIRCH ONLY
BOTH SPECIES
QUEBEC
ONTARIO
St. Maurice R.
River
MONTREAL
OTTAWA
St. Lawrence
TORONTO
LAKE HURON
LAKE ONTARIO
1 - Ste. Anne
2 - Upper Laurentian
3 - Baskatong
4 - Dumoine
5 - Maganisipi
6 - Tomiko
7 - Brent
8 - Algonquin
9 - Gatineau
10 - Haliburton
11 - Oxtongue
12 - Sundridge
13 - Batchawana
FORESTRY BRANCH 1954

Figure 3

TABLE 7—SITES BY DISTRICTS MOST SUITABLE FOR PRODUCTION OF SUGAR MAPLE SAW TIMBER

Brent Algonquin	Gatineau	Sundridge Oxtongue Haliburton	Batchawana
Upper slopes — fresh — moist	Upper slopes — fresh — moist	All sites and slopes except dry ridges	Ridges — fresh — moist
Middle Slopes — fresh — moist	Middle slopes — dry — fresh — moist		Upper slopes — dry — fresh
Lower slopes — dry — fresh	Lower slopes — dry — fresh — moist		Middle slopes — dry — fresh
			Lower slopes — dry

and growth is slow. Because of this slow growth, wounds do not heal quickly and the young trees become infected with fungi. A typical unhealed wound on a young sugar maple is shown in Figure 5. A branch was broken off and the sapling was unable to form a callus over the stub. The decay organisms were able to penetrate the main stem and cause rot. This condition is illustrated by Figure 6 which shows the characteristic spread of rot from dead branch stubs.

Since most stands containing sugar maple are all-aged associations and most of the volume is defective, any improvement measures must favour the sound, elite seedlings and saplings.

Such measures will include:

(*a*) The removal of old overmature and defective trees by felling, girdling, or some other method. This should be done over a period of years so that a good stand of saplings will be built up, and the individual stems will not suffer from sudden exposure. A typical sapling stand resulting from the girdling of the larger trees is shown in Figure 7. It will be noted that the saplings have straight stems; they have pruned themselves and the branch stubs have healed over.

The removal of large unmerchantable trees by felling does considerable damage to the young growth; therefore, if sound saplings are present, the larger trees should be removed by girdling or poisoning. Such trees break up gradually and cause less damage.

(*b*) After a stand of good saplings has been formed, frequent thinnings will be necessary to prevent the young trees from injuring one another, and to improve the form and increase the diameter growth-rate of the best stems. A thinned sapling stand is shown in Figure 8. The favoured stems are not always the largest, as emphasis is placed on soundness and good form.

In most areas sugar maple should grow to between 30 and 40 feet in height in 50 years. At that time, it should be evident which trees are going to form the next crop. The second-growth stand shown in Figure 9 illustrates this point. The trees in the foreground are 35 years old and the one with the axe stuck in it should be removed. It has a bad frost crack and will never develop into a good sawlog tree.

FIGURE 4. Defective sugar maple, Algonquin District. Note fungus fruiting body on the trunk.

FIGURE 5. Wound in a young sugar maple sapling. A branch was broken off and the stub did not heal over.

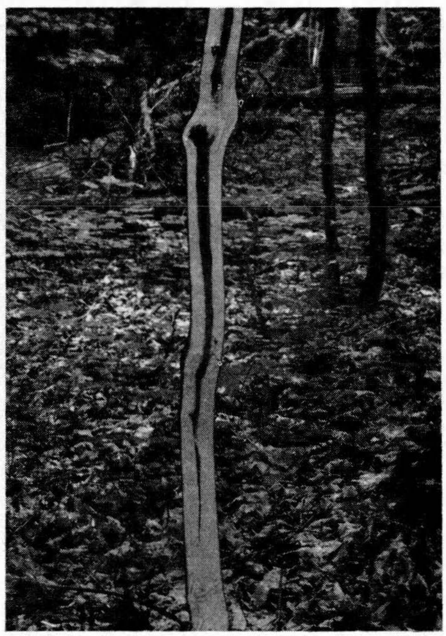

FIGURE 6. Characteristic spread of rot from a wound in a young sugar maple—in this example a dead branch stub.

Yellow Birch

Yellow birch will grow well on a wide range of conditions and it can be managed successfully in all of the districts studied (Table 6 *and* Figure 3). This species will reproduce well on all sites with the exception of those on the driest ridges where exposure and insolation are extreme. The major requirements for establishing birch are: (*a*) the provision of suitable seed-beds on which the seed can germinate, and (*b*) the provision of sufficient light for the successful development of the seedlings.

In the more southern districts competition from sugar maple is severe. Therefore, on areas where good sugar maple can be grown, it would be easier to encourage it than to encourage birch. As can be seen in Table 6, yellow birch has been recommended for only a limited number of sites in those districts where it is possible to grow good sugar maple.

Farther north, especially in the Baskatong and Dumoine Districts, competition from sugar maple has less effect on the establishment of birch seedlings than it has farther south. However, in these northern districts the restocking of an area to yellow birch can be retarded for several years by balsam fir advance growth and mountain maple if steps are not taken to discourage them at the time of the cut.

Light partial logging does not favour the regeneration of yellow birch, as the disturbance is not sufficient to create enough seed-beds suitable for the establishment of the seedlings. Also, the removal of only a few trees per acre does not destroy enough of the advance growth, nor does it provide sufficient openings in the canopy to allow the birch seedlings to compete with other species, especially sugar maple. The beneficial effect of scarification on the establishment of yellow birch seedlings is illustrated in Figure 10. Seedlings are abundant wherever the ground has been scarified; there are none where the ground has not been scarified. The adverse effect of advance growth on the development of birch seedlings may be seen in Figure 11. The seedling shown is less than 12 inches high; it has little chance of survival because of suppression by the beech and sugar maple advance growth on either side of it.

Heavy cutting is favourable to birch regeneration because felling and skidding a large number of trees results in more and larger seed-beds. Also it destroys much of the sugar maple advance growth. It is not the intention, however, to recommend heavy cutting as the answer to the problem of growing yellow birch because most second-growth stands resulting from such cutting methods are inferior in quality.

In establishing yellow birch a system of partial cutting leaving seed trees will give best results. This is in general agreement with Eyre and Zillgitt (6), and Linteau (11). Depending upon circumstances, the mature timber can be removed in patches or by single tree selection. Because of the all-aged structure of the hardwood forests, and the dense crowns of the trees, the main canopy should be reduced to about 40 per cent closure in order to create the best light conditions, at ground level, for the establishment and development of birch seedlings. This is a greater canopy reduction than that prescribed by Linteau (11). In addition it will be necessary to make seed-beds. This can be done with a bulldozer or similar implement either before or after the logging, but preferably after the leaves have fallen. Such machines, in addition to making seed-beds, root out and destroy much of the sugar maple advance growth, thereby reducing competition. Typical seed-beds made by a bulldozer are shown in Figure 12. If a large part of the advance growth is not destroyed by the scarification, it will be necessary to make release cleanings within a few years to free the young birch. The results of a careful thinning are seen in Figure 13, which shows a

FIGURE 7. Sapling stand resulting from the girdling of the defective and over-mature trees.

FIGURE 8. Thinning in a sapling stand to favour the best stems.

40-year-old stand of maple and birch on a fresh, lower slope in the Gatineau District. The area had been cut heavily and then the saplings were thinned frequently to favour the birch and better maple.

Beech

Light cutting favours restocking to beech, as there is usually advance growth ready to compete for any openings created by logging. Heavy cutting and clear cutting are less favourable, since beech advance growth is seldom able to survive the shock of suddenly being exposed to overhead light. Also the seedlings which become established after a heavy cut do not develop under the intense insolation in the open area.

Almost every beech has some defect, and loggers have little interest in the timber. In Ontario and Quebec beech is ranked among the poorest of lumber-producing trees. Until markets capable of utilizing low-grade material are developed, it should be considered a weed species. It could be eliminated with relative ease by girdling or poisoning the older trees to remove the seed source, then cutting out the younger trees during thinning operations. Beech sprouts readily, but there is no danger of it propagating itself from either the stumps or the girdled trees as the sprouts usually lack vigour. Also, since the seed is heavy, there is little danger of it coming in from distant areas.

Red Maple

Red maple occurs throughout the Great Lakes—St. Lawrence Forest Region. This species will grow under various conditions, but because of competition from sugar maple it seldom produces good timber. Restocking to red maple is usually better after heavy cutting or clear cutting than it is after selective cutting; the removal of much or all of the overhead canopy creates light conditions favourable for the development of the advance growth, sprouts, and seedlings. Red maple is recommended as an associate for yellow birch, especially on the moister sites, in the districts where the climate is not too cold.

Basswood

Basswood is mostly confined to the more southern districts in the Great Lakes—St. Lawrence Forest Region. This tree is often numerous in some stands but it is never the main tree. Like red maple it sends up many stump sprouts and consequently it is able to persist indefinitely from a single seedling establishment.

Basswood produces large quantities of seed but most of it has a tendency to be dormant because of the impermeable seed casts covering the embryo. Therefore, it would appear that heavy cutting would increase the amount of basswood regeneration because opening the canopy would hasten decomposition of the litter and the basswood seed coats, thereby releasing the embryos while they are still viable.

DISCUSSION

Any treatment designed to favour the regeneration of the less tolerant species should: (i) provide sufficient light through openings in the main canopy; (ii) assure an ample supply of seed; (iii) provide suitable seed-beds, especially for those species which have difficulty in becoming established on leaf-litter; and (iv) allow for release cuttings to maintain the saplings after they have become established. For those species which are sensitive to extreme temperatures, all treatments should be confined to locations where good air drainage prevails at night so that any risk of late spring frosts is minimized.

FIGURE 9. Second-growth maple stand. Trees in the foreground are 35 years old. Tree at the right should be removed as it has a bad frost crack.

FIGURE 10. Two-month-old yellow birch seedlings on scarified soil. Note the absence of seedlings on the unscarified portion, upper left.

It is realized that the foregoing are generalizations. They are based, however, on many observations and the preliminary results of several experiments.

The Forestry Branch has been working in the tolerant hardwoods since the early 1930's. The first studies consisted mainly of small cutting experiments in co-operation with industry to determine the effects of various intensities of cutting on reproduction and on stand development. The results from these experiments have been encouraging enough to stimulate interest on the part of several companies.

Following the Second World War, research in the tolerant hardwoods has increased considerably and work has been going forward in two broad fields: (i) ecological observations and fact-finding surveys—the results of which form the basis of this report; and (ii) applied research aimed at developing practical silvicultural methods for managing the tolerant hardwoods. Future work will involve: (i) the continuation of the ecological observations and the applied studies; and (ii) fundamental research to solve some of the many problems which have arisen in the work already undertaken.

The applied research, which is presently being undertaken in co-operation with industry, consists of two series of cutting experiments; the first designed to test the hypothesis that the removal of defective and other unmerchantable stems will result in significant improvements in the yield of merchantable timber from tolerant hardwood stands; and the second to test the hypothesis that a greatly improved stocking of yellow birch can be obtained on maple—beech—birch sites by partial logging and preparation of suitable seed-beds.

Results are not yet available from the first experiments, as it will be some time before the full effects of the release (and future cleanings) will be realized. However, preliminary observations indicate that the growth-rate of the released saplings has increased considerably and that many of the young stems will develop into high-quality trees. The results from the initial studies in the second series have been much better than were expected and show that preparation of seed-beds by scarifying with a bulldozer has greatly increased the stocking to yellow birch. On areas where the shade from the main canopy was only about 40 per cent, seedling development is much better than where the canopy was dense.

The recommendation has been made that softwoods should be grown on some of the sites now occupied by tolerant hardwoods. No attempt is made here to discuss possible methods for converting the hardwood stands to mixedwoods as this is beyond the scope of this publication.

SUMMARY

This report summarizes the findings of a survey of the tolerant hardwood stands in the Northern Part of the Great Lakes—St. Lawrence Forest Region in Ontario and Quebec. The forest sections of the Region are divided into physiographic districts and those in which the tolerant hardwoods are most common are described. The ecological characteristics of the hardwoods in each district are discussed and recommendations are made for their silvicultural management.

The survey was carried out in 1951 and in 1952. It was mostly of an observational nature and sampling was reduced to a minimum. As yellow birch is presently the most sought-after tolerant hardwood species, emphasis was placed on determining the conditions most favourable for its maintenance in the stands.

In all but the most northern areas, sugar maple is the dominant species in the main stands and in the reproduction. In most areas this species is so aggressive that it can increase its numbers at the expense of the other species. Most

FIGURE 11. Two-year-old birch seedlings shaded by sugar maple and beech advance growth.

FIGURE 12. Seed-bed made by a bulldozer powered by a D-6 Caterpillar tractor.

of the trees and the reproduction are defective. The proportion of sound stems is higher on moister sites than it is on drier sites.

Although sugar maple is found throughout southern Ontario and Quebec, there are relatively few locations where it is capable of developing into trees suitable for sawlogs and veneer. Many areas now producing only mediocre cordwood could produce good quality softwoods and other hardwoods. Some areas are capable of growing good sugar maple but the present stands are highly defective. Cultural treatments to relieve the young growth from overhead shade and to protect the elite saplings from mechanical injury must be undertaken if high-quality maple stands are to be obtained.

Yellow birch is found in the main stands in all areas investigated but only under certain circumstances does it restock the cut-over areas in adequate numbers. The scarcity of yellow birch reproduction is attributed to the lack of suitable seed-beds and to the inability of the seedlings to compete with advance growth of other species, especially sugar maple. Yellow birch regeneration is most vigorous on those sites and in those districts where sugar maple is least aggressive. Yellow birch seedlings are tolerant of shade for the first two or three years of their life but height growth is poor under dense shade. The seedlings cannot compete successfully; most of them are either smothered by falling leaves or crowded out by the more tolerant species. Height growth is much better in the open areas and the seedlings are able to compete more favourably.

To establish yellow birch in quantity on hardwood sites it will be necessary to use a system of partial cutting which provides for an adequate seed supply and reduces the canopy to approximately 40 per cent crown closure. In addition, seed-beds will have to be prepared and much of the sugar maple advance growth destroyed. In the event that the birch seedlings become crowded, provision will have to be made for release cuttings to free the best stems.

Beech is more sensitive to extreme cold temperatures than either sugar maple or birch and it reaches its northern limit farther south than they do. In the more southern areas this species is confined mostly to upper slopes and ridges. Reproduction is most abundant on dry and fresh sites and like maple it is very defective.

Beech contains so many defects that operators have no interest in it. In Ontario and Quebec it is ranked among the poorest of lumber-producing trees. Unless markets are developed which will use low-quality wood, every effort should be made to eliminate beech from the tolerant hardwood stands.

Basswood is an important associate species in the more southern districts. It is quite prominent in some stands but is never the dominant tree. This tree reproduces mostly by stump sprouts and consequently is able to persist indefinitely from a single seedling establishment.

Basswood produces large quantities of seed but most of them are dormant because of the impermeable seed coats covering the embryo. It is believed that heavy cutting would increase the amount of basswood regeneration because opening up the canopy would hasten the decomposition of the seed coats and release the embryo while it is still viable.

The other associate species such as red maple, red oak, white ash, black ash, butternut, black cherry, and ironwood are generally scattered and confined to certain physiographic sites. The limited occurrence of these species can be attributed to one or more of the following: (i) factors affecting the production and dissemination of the seed; (ii) the ability or lack of ability of the seed to germinate on various seed-beds; (iii) factors affecting the survival and development of the seedlings; and (iv) inherent characteristics of the seed, and the ability to sprout. Any cutting methods designed to favour one of these species will have to take into consideration its silvical characteristics and provide the necessary conditions under which it can compete favourably.

FIGURE 13. Forty-year-old stand of sugar maple and yellow birch, Gatineau District. The area had been cut heavily and the sapling stand was thinned frequently to favour the birch and the better maple.

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APPENDIX I

List of Species Showing Common Name, Scientific Name and Abbreviation

Common Name	Scientific Name	Abbreviation
Ash, black	*Fraxinus nigra* Marsh	bAs
Ash, white	*Fraxinus americana* L.	wAs
Aspen	*Populus tremuloides* Michx	tA
Beech	*Fagus grandifolia* Ehrh	Be
Birch, yellow	*Betula lutea* Michx	yB
Birch, white	*Betula papyrifera* Marsh	wB
Butternut	*Juglans cinerea* L.	Bu
Fir, balsam	*Abies balsamea* (L.) Mill	bF
Basswood	*Tilia americana* L.	Ba
Cedar, white	*Thuja occidentalis* L.	eC
Cherry, black	*Prunus serotina* Ehrh	bCh
Elm	*Ulmus americana* L.	wE
Hemlock	*Tsuga canadensis* (L.) Carr	eH
Ironwood	*Ostrya virginiana* (Mill.) K. Koch	I
Maple, sugar	*Acer saccharum* Marsh	sM
Maple, red	*Acer rubrum* L.	rM
Maple, mountain	*Acer spicatum* Lam	moM
Oak, red	*Quercus rubra* L.	rO
Pine, red	*Pinus resinosa* Ait	rP
Pine, white	*Pinus strobus* L.	wP
Spruce, black	*Picea mariana* (Mill.) BSP	bS
Spruce, red	*Picea rubens* Sarg	rS
Spruce, white	*Picea glauca* (Moench) Voss	wS

APPENDIX II

Reproduction Summaries

NOTE:—Figures in the following tables include all stems below sawlog size, i.e. 12 inches d.b.h.

TABLE I

Percentage of quadrats stocked, stands lightly cut, 1947-48, Tomiko and Algonquin Districts

Site	Number of Plots	sM		rM		Be		yB		rO		I		wE		bF		eH	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	52	2	94	2	17	0	11	25	0	2	0	8	10	0	0	13	10	T	0
Fresh	104	2	98	0	1	0	2	23	4	2	1	1	6	0	1	1	1	1	0

S = Sound D = Defective T = less than one per cent stocked.

TABLE 2

Numbers of stems per acre, stands lightly cut, 1947-48, Tomiko and Algonquin Districts.

Site	Number of Plots	sM		rM		Be		yB		rO		I		wE		bF		eH	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	52	19	4,246	38	346	0	134	227	0	19	0	96	115	0	0	134	134	19	0
Fresh	104	19	4,664	0	19	0	52	736	142	23	8	8	75	0	47	8	8	8	0

S = Sound D = Defective

TABLE 3

Percentage of quadrats stocked, stands lightly cut, 1944-45, Batchawana District.

Site	Number of Plots	sM		rM		yB		I		bF		wS		eH		eC		wP	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	28	0	93	7	32	7	4	7	0	7	7	4	0	0	0	0	0	0	0
Fresh	176	1	87	T	19	7	T	T	T	7	3	1	1	1	0	T	0	T	0
Moist	52	3	83	2	42	35	3	0	0	6	6	4	0	0	0	4	0	0	0

S=Sound D=Defective T=Less than one per cent stocked.

TABLE 4

Numbers of stems per acre, stands lightly cut, 1944-45, Batchawana District.

Site	Number of Plots	sM		rM		yB		I		bF		wS		eH		eC		wP	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	28	0	2,998	31	843	0	31	0	218	0	0	0	0	0	0	0	0	0	0
Fresh	176	0	3,545	0	511	73	0	3	8	49	69	10	0	5	0	0	0	0	0
Moist	52	41	2,852	20	767	394	62	0	0	82	42	41	0	0	0	2	0	0	0

S=Sound D=Defective

TABLE 5

Percentage of quadrats stocked, stands heavily cut, 1933–35, Ste. Anne District.

Site	Number of Plots	sM		rM		Be		yB		wB		bF		rS	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D
Fresh	128	5	63	1	6	5	29	6	14	0	0	2	6	0	0
Moist	32	6	41	3	28	6	41	3	28	3	0	0	0	6	3

S = Sound D = Defective

TABLE 6

Numbers of stems per acre, stands heavily cut 1933–35, Ste. Anne District

Site	Number of Plots	sM		rM		Be		yB		wB		bF		rS	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D
Fresh	128	144	1,048	15	182	51	510	70	201	0	0	41	39	0	0
Moist	32	94	561	62	748	186	436	31	437	0	0	0	0	62	31

S = Sound D = Defective

TABLE 7

Percentage of quadrats stocked, stands lightly cut, 1947-48, Gatineau and Oxtongue Districts.

Site	Number of Plots	sM		rM		Be		yB		wB		rO		I		Ba		As*		wE		bF		wP		s**		eH		eC	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry.............	772	2	91	1	10	4	37	2	2	T	0	2	8	8	15	3	2	1	1	T	T	11	12	0	T	1	1	T	T	1	T
Fresh............	724	4	88	2	5	2	25	7	3	2	1	1	1	5	12	3	T	2	2	1	T	14	5	T	0	1	T	1	T	0	0
Moist............	84	3	81	2	T	1	10	12	7	2	0			1	4	2	0	9	0	4	T	9	6	0	0	1	0	5	2	0	0

*White ash on dry and fresh sites, black and white ash on moist sites.
**Red spruce Oxtongue District, white spruce Gatineau district.
S=Sound D=Defective T=less than one per cent stocked.

TABLE 8

Numbers of stems per acre, stands lightly cut, 1947-48, Gatineau and Oxtongue Districts.

Site	Number of Plots	sM		rM		Be		yB		wB		rO		I		Ba		As*		wE		bF		wP		s**		eH		eC	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry.............	772	63	3,594	28	192	44	761	22	17	0	0	18	123	90	336	31	36	11	6	4	17	123	215	0	0	12	6	0	0	34	1
Fresh............	724	104	3,448	22	123	54	465	115	59	27	7	9	12	67	175	19	7	28	13	3	6	162	80	0	0	21	4	0	0	0	0
Moist............	84	55	3,169	0	10	0	98	66	174	56	9	0	0	9	30	19	0	139	0	38	19	160	61	0	0	0	0	41	20	0	0

*White ash on dry and fresh sites, black and white ash on moist sites.
**Red spruce Oxtongue District, white spruce Gatineau District.
S=Sound D=Defective

TABLE 9

Percentage of quadrats stocked, stands lightly cut, 1939–40, Gatineau District.

Site	Number of Plots	sM		rM		Be		yB		wB		rO		I		Ba		wAs		wE		bCh		bF		eH		eC	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	304	0	98	T	1	0	28	2	0	0	0	2	0	9	T	1	0	T	0	6	0	2	0	6	0	1	T	T	T
Fresh	570	T	94	0	T	0	20	3	T	T	T	0	T	6	1	T	0			1	T	T	0	3	T	8	T	T	0
Moist	12	0	58	0	0	8	8	8	0							8	0			0	0			8	8	8	0	0	8

S=Sound D=Defective T=less than one per cent stocking.

TABLE 10

Numbers of stems per acre, stands lightly cut, 1939–40, Gatineau District.

Site	Number of Plots	sM		rM		Be		yB		wB		rO		I		Ba		wAs		wE		bSh		bF		eH		eC	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	304	0	2,940	10	13	0	1,042	0	0	0	0	23	0	23	13	0	0	0	0	10	0	0	0	117	0	19	6	2	0
Fresh	570	0	2,817	0	10	0	269	24	7	26	26	0	0	119	42	0	0			13	0	0	0	89	10	39	0	2	0
Moist	12	0	664	0	0	0	83	83	0	0	0	0	0	0	0	416	0			0	0	0	0	83	83	83	0	0	83

S=Sound D=Defective

TABLE 11

Percentage of quadrats stocked, stands heavily cut, 1926-27, Gatineau District.

Site	Number of Plots	sM		rM		Be		yB		I		Ba		As*		wE		bF		s**		eH	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry................................	112	3	97	0	3	0	36	3	0	0	0	0	0	0	0	0	0	T	2	0	2	T	T
Fresh..............................	568	11	84	T	T	1	22	3	T	1	0	2	T	0	T	1	T	T	2	T	0	T	T
Moist..............................	92	11	63	0	0	0	3	7	2	0	0	T	0	3	0	5	0	0	0	0	0	0	0

S=Sound D=Defective T=less than one per cent stocking.
*As=white ash on fresh sites, black and white ash on moist sites.
**s=red and white spruce.

TABLE 12

Numbers of stems per acre, stands heavily cut, 1926-27, Gatineau District.

Site	Number of Plots	sM		rM		Be		yB		I		Ba		As*		wE		bF		s**		eH	
		S	D	S	D	S	D	S	D	S	S	S	D	S	D	S	D	S	D	S	D	S	D
Dry................................	112	0	1,792	0	26	0	228	27	0	0	0	0	0	0	0	0	0	0	27	0	17	0	18
Fresh..............................	568	103	1,426	1	1	9	177	35	11	12	0	31	6	0	0	19	13	8	24	6	0	2	8
Moist..............................	92	57	1,074	0	0	0	28	51	23	0	0	9	0	41	0	50	0	0	0	0	0	0	0

S=Sound D=Defective
*As=white ash on fresh sites, black and white ash on moist sites.
**s=red and white spruce.

TABLE 13

Percentage of quadrats stocked, areas clear cut, 1919-20, Sundridge District.

Site	Number of Plots	sM		yB		Be		rM		Ba		I		wE		wB		bCh		eH		bF		wS	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	100	0	95	14	0	0	3	0	10	0	1	5	5	0	0	0	1	6	4	2	0	8	4	0	0
Fresh	320	0	96	6	3	0	T	0	8	0	T	3	5	T	1	0	0	5	3	T	0	3	2	T	0
Moist	68	0	93	24	9	0	0	1	12	1	1	0	6	1	1	0	0	1	1	0	0	7	1	1	0

S=Sound D=Defective T=less than one per cent stocked.

TABLE 14

Numbers of stems per acre, areas clear cut, 1919-20, Sundridge District.

Site	Number of Plots	sM		yB		Be		rM		Ba		I		wE		wB		bCh		eH		bF		wS	
		S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Dry	100	0	3,940	30	0	0	20	0	220	0	10	100	40	0	0	0	0	30	70	0	0	10	10	0	0
Fresh	320	0	3,300	28	31	0	6	0	195	0	0	33	39	21	3	0	0	15	31	0	0	30	11	0	0
Moist	68	0	2,240	143	58	0	0	43	185	0	0	0	92	14	71	0	0	0	31	0	0	85	14	0	0

S=Sound D=Defective

APPENDIX III

Climatic Summary

Climatic conditions are quite different in various parts of the Great Lakes—St. Lawrence Forest Region. The mean annual temperature ranges from 34° to 42°F., and the length of the growing season from 100 to 200 days; the most extreme annual average temperatures are 94° and −38°F.

The mean annual precipitation varies from 25 to 45 inches with an average total for the three summer months (June, July, and August) of 10 inches; total annual snowfall varies from 45 to 175 inches.

Generally the temperatures are warmer in the south than in the north and the precipitation is greater in the east than in the west.

The following table summarizes the values of the various climatic features within those districts studied.

CLIMATIC SUMMARY

	Laurentian Section	Algonquin-Pontiac Section		Middle Ottawa Section	Georgian Bay Section	Algoma Section
—	Upper Laurentian Ste. Anne Districts	Baskatong Dumoine Districts	Tomiko Maganisipi Brent Algonquin Districts	Gatineau District	Sundridge Oxtongue Haliburton Districts	Batchawana District
Mean annual temperature	38°	38°	38°	40°	41°	36°
July normal	64°	65°	64°	66°	66°	63°
January normal	10°	9°	11°	10°	14°	8°
Annual average extreme high	93°	93°	91°	93°	93°	89°
Annual average extreme low	−36°	−36°	−36°	−33°	−30°	−30°
Beginning of growing season	April 27	April 27	April 27	April 27	April 23	May 3
End of growing season	Oct. 14	Oct. 14	Oct. 14	Oct. 17	Oct. 18	Oct. 13
Last spring frost	June 10	June 10	June 10	May 24	May 25	June 5
First autumn frost	Sept. 10	Sept. 10	Sept. 10	Sept. 24	Sept. 20	Sept. 17
Mean annual precipitation	40″	35″	32″	29″	36″	37″
June and July average precipitation	12″	10″	9″	8″	10″	9″
Snowfall	90″	91″	83″	79″	95″	127 ″
Moisture surplus	20″	14″	12″	8″	15″	17″
Moisture deficiency	0·0″	0·0″	0·5″	2·0″	0·5″	0·0″
Average number of rainy days June, July, and August	40	40	35	30	34	43

APPENDIX IV

Glossary of Terms

1. *Cotyledons*...................... The seedlings which had germinated during the current year.
2. *Cutting, clear*.................. All trees of merchantable sizes felled.
3. *Cutting, heavy*.................. Fifty or more trees per acre felled.
4. *Cutting, light*.................. Two or three trees per acre felled.
5. *Growth, advance*................. All stems below 3·6 inches in diameter at breast height which had been established prior to the date of logging.
6. *Growth, defective, small*........... All stems below 3·6 inches in diameter at breast height which had poor form, badly broken branches, open or poorly healed wounds, cankers, and rots.
7. *Midland*........................ Upland areas in which elevations rarely exceed 1,200 feet above sea-level.
8. *Regeneration*.................... All stems which have become established after logging.
9. *Seedlings*........................ All stems below 0·5 inch in diameter at breast height which had become established after the date of logging.
10. *Site*........................... The complex of physical and biological factors for an area which determine what forest or other vegetation it may carry. (Bri. Comm. For. Term. 1953.)
11. *Site, dry*....................... A mid-drainage position in any catena (on any material) in a range from very dry (i.e. shallow rock ridge tops) to very wet (i.e. swamps). Lack of available moisture for part of the growing season.
12. *Site, fresh*...................... A mid-drainage position in any catena (on any material) in a range from very dry (i.e. shallow rock ridge tops) to very wet (i.e. swamps). Adequate moisture for optimum growth of mesophytic plants throughout the growing season.
13. *Site, moist*...................... A mid-drainage position in any catena (on any material) in a range from very dry (i.e. shallow rock ridge tops) to very wet (i.e. swamps). Excess moisture for part of the growing season.
14. *Site, cool*....................... Middle and lower slopes not exposed to direct insolation and somewhat protected from drying winds; good air drainage at night.
15. *Site warm*..................... Shallow ridges and upper slopes exposed to insolation and somewhat protected from drying winds; good air drainage at night.
16. *Trees, defective*.................. All trees which can not be expected to yield a merchantable sawlog, according to present utilization standards, either now or in the future.

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