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SITE-TYPES, GROWTH AND YIELD at the Lake Edward Forest Experimental Area Quebec

by
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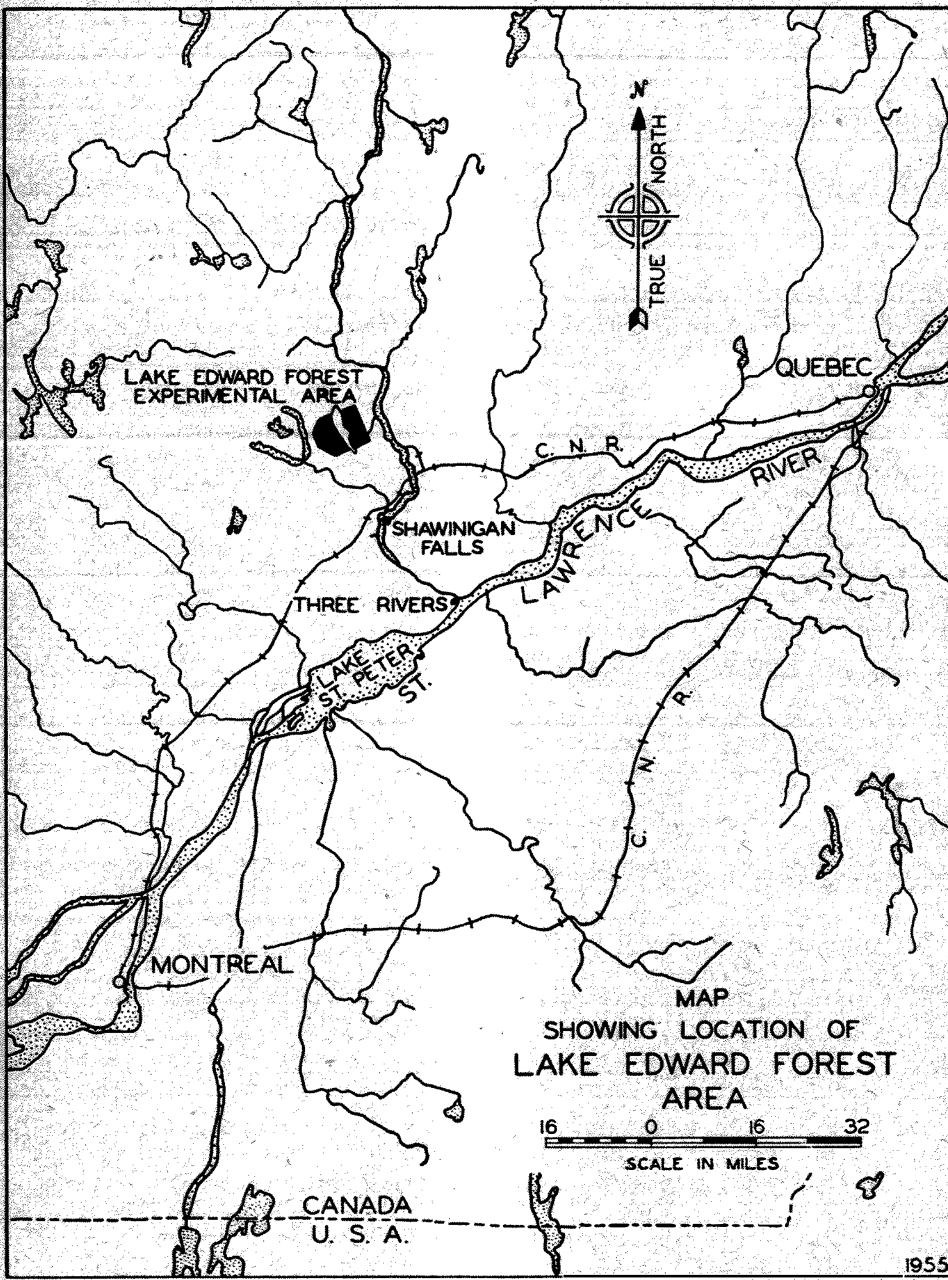
LAKE EDWARD FOREST EXPERIMENTAL AREA
TRUE NORTH
N
QUEBEC
C. N. R.
SHAWINIGAN FALLS
THREE RIVERS
LAWRENCE RIVER
LAKE ST. PETER
ST.
C. N. R.
MONTREAL
MAP
SHOWING LOCATION OF
LAKE EDWARD FOREST
AREA
16 0 16 32
SCALE IN MILES
CANADA
U. S. A.
1955

FOREWORD

The Canadian pulp and paper industry entered upon a period of great expansion after the first World War, with the result that ever increasing demands were placed upon the forest. The prospective depletion of the rich forests close to the mills, combined with apparently slow growth and regeneration after logging, aroused concern for the future supplies of pulpwood.

As a result, various conservation measures were taken by governments and private industry, one of which was the establishment of the Lake Edward Experimental Area in 1918 by the Commission of Conservation in co-operation with the Laurentide Pulp and Paper Company. This typical pulpwood forest had been cut-over in 1910. The next cut appeared remote and by no means assured; but, as this report shows, more softwood was apparently standing in the forest 40 years later than ever before, and cutting actually started again in 1950.

The history of this area since the date of its establishment as an experimental area is perhaps more complete than for any other comparable forest tract in Eastern Canada. From studies made in the area in 1936 and later, a practical system of site classification was developed and used for the first time in forest surveys.

Credit for the continuity and success of this project is due to the Consolidated Paper Corporation, for preserving the area intact and for carrying out the present cutting experiment to the recommendations of the Forestry Branch.

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SITE-TYPES, GROWTH AND YIELD at the Lake Edward Forest Experimental Area Laviolette County, Quebec

INTRODUCTION

The Lake Edward Experimental Area was established in 1918, 15 miles northwest of Grand'Mere, Quebec, on the limits of the Laurentide Pulp and Paper Company, later succee ed by the Consolidated Paper Corporation. Comprising five square miles on both sides of Lake Edward, the area is typical of the spruce—balsam—yellow birch forest found in the eastern part of the Great Lakes-St. Lawrence forest region. The objects were to study the regeneration and growth of softwood in this mixedwood forest following a pulpwood cut in 1910; and from the finding to develop suitable silvicultural practices in order to promote sustained-yield forest management.

Among the first experiments were cutting and girdling hardwoods to release softwoods, thinnings in young growth, and seed-bed treatment. However, other problems, especially those relating to competition, suppression, and site differences, drew attention later to the need for much more extensive information on the forest types before any silvicultural measures could be formulated.

The first line-plot survey made in 1925 yielded extensive data on the stands, growing stock, and results of the last logging operation; the second and third surveys of 1936 and 1946 added site relationships along with the growth data. At the time of the 1946 remeasurement, the forest was clearly ready for cutting again. A partial cut was begun in 1950 and it has continued each year since then.

Reports covering site- ype identification and correlations of site with diameter growth, written by Sisam (7) and Heimburger (4), were published in 1938 and 1941; the growth study by the line-plot surveys of 1925 and 1936 was reported upon by the present writer (6) in 1941.

The findings for the first cutting cycle 1910-1950 are now summarized and brought up-to-date.

THE FOREST AREA

The Lake Edward Fore t Ex erimental Area lies to the east and west of Lake Edward, Laviolette County, Quebec. The area is situated at latitude 46° 45′ N and longitude 72° 56′ W, and is about 900 feet above sea-level; it lies near the southeast edge of the Laurentian Plateau, a peneplain composed of Laurentian (Precambrian) gn iss with a few intrusions of granite and anorthosite, and heavily glaciated in a south-southeast direction. A description of the geology and physiography of the area has been given by Heimburger (4) to which reference may be made for further details.

The forest is composed of tolerant hardwoods—yellow birch *(Betula lutea* Michx. f.), sugar maple *(Acer saccharum* Marsh.) and beech (*Fagus grandifolia* Ehrh.), and softwoods—balsam fir *(Abies balsamea* (L.) Mill.), and red spruce *(Picea rubens* Sarg.). Red maple *(Acer rubrum* L.) and white birch *(Betula papyrifera* Marsh. and var. *cordifolia* (Regel) Fern.) are also quite common. White pine *(Pinus strobus L.)* occurs scattered on the ridges and around the lakes. Black spruce *(Picea mariana* BSP.) and white cedar *(Thuja occidentalis* L.)

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grow in swamps and on the rocky moss-covered lake shores. Larch *(Larix laricina* (Du Roi) Koch) is found in some of the more open swamps. Hemlock *(Tsuga canadensis* (L.) Carr.) occurs widely scattered in association with hardwoods, and black ash *(Fraxinus nigra* Marsh.) is found in the small swamps and on stream banks in the upland types. White spruce *(Picea glauca* (Moench) Voss) is found scattered, chiefly on alluvial soil. Aspen *(Populus tremuloides* Michx.) occurs on some burned-over areas nearby. The area is situated close to the northern boundaries of the natural range of hemlock and beech.

The forest was cut over at least twice, about 1890 and 1910. During the earlier cutting for sawlogs, only the large white pine and spruce were removed from the more accessible localities. In the later cutting for pulpwood, to diameter limits of 10 inches for spruce and 7 inches for balsam fir, many patches of timber were left, including considerably more balsam than might have been taken by the 7-inch limit.

Site-Types

Few aspects of forest research have received more attention than site classification. Since the end of the last century site-type studies have been made in most European countries, notably Russia and Finland, and in North America. Although primarily intended to classify the forest for more intensive management, these studies also try to explain why certain conditions exist, and to identify similar sites for the extension of knowledge beyond the borders of a particular locality.

Certain natural associations depending upon cover-type, climate, and physiography, well known to many observers, have provided the starting point for most systems of site classification. The chief problem then has been to find the simplest way to identify and classify them. In Canada, Halliday's (2) broad classification of the whole country into forest regions and forest sections is generally accepted as the basic climatic classification, and site-types may then be identified within each of the so-called forest regions, or sections.

The use of plant indicators first awakened general i terest through its chief proponent, Cajander (1), who described his objectives as follows:

> The object of classifying localities into quality classes is to combine into one and the same class all those localities the capacity of which for growing forest is the same or approximately the same, and to separate into different classes those in which the yield capacity differs more markedly.

Cajander identified his sites by plant associations, more or less independently of the forest cover. The system was widely applied in Europe, with considerable but not unqualified success. More recently, following Russian experience, the tendency has been to include forest cover and physiographic features and to rely less upon vegetation alone. As it is practically impossible to dissociate tree cover from ground vegetation, this trend might be accepted as a modification of the original concept rather than as a departure from it.

Heimburger (3), through exhaustive field studies on physiography and soil, found adequate supporting data for the hypothesis that ground vegetation characterizes biologically equivalent sites in the Adirondack region.

Similar forest conditions at Lake Edward allowed correlation between the most important types common to both localities. Consequently these site-types have replaced the more conventional cover-types based upon tree volumes, and now form the basis of classification for all aspects of the growth study.

More recently Westveld (8) has correlated cover-type, land form and ground vegetation with climax types and their successional stages in the forests of the Northeast, with much the same conclusions as at Lake Edward. He also emphasized the need for site classification by natural units in management of mixedwood forests.

On the Lake Edward area, the following site-types were recognized in ascending order of quality: Kalmia-Ledum and Sphagnum-Oxalis (swamp types not studied in detail); Cornus; Oxalis-Cornus; Viburnum-Oxalis; and Viburnum.

Kalmia-Ledum and Sphagnum-Oxalis

Swamp types are of little importance in this locality and only the best of each supports a merchantable stand of timber. The former (Kalmia-Ledum) is black spruce swamp of muskeg type; the latter (Sphagnum-Oxalis) is a richer type containing some hardwood with balsam fir, spruce, and cedar. Generally, the ground is covered with dense alders and sphagnum moss.

Cornus (Softwood)

The Cornus or "spruce ledge" type is generally found on steep hillsides and cliffs, on borders of swamps, streams, and lakes, and occasionally on swampy draws. Bunchberry *(Cornus canadensis)* predominates among herbaceous plants, and there are also mosses, lichens, and blueberry. Mountain maple *(Acer spicatum)*, abundant on richer sites, is rare.

In the main stand, the principal species is red spruce, followed by balsam fir, and then by cedar or white birch; hardwoods, among which white birch predominates, amount to less than 20 per cent by volume.

Oxalis-Cornus (Soft — Hardwood)

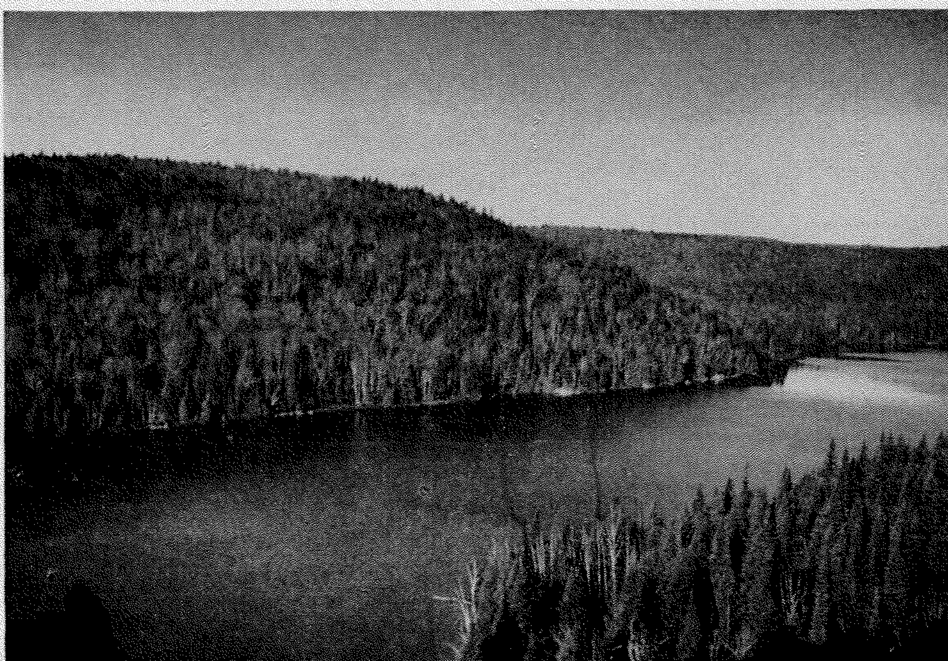
The Oxalis-Cornus type is easily identified by a profusion of wood sorrel *(Oxalis montana)*, with bunchberry to a greater or lesser extent, depending upon whether the site is poorer or richer than the average. Mountain maple is also present, often very dense; striped maple *(Acer pensylvanicum)* generally occurs on the richer varieties only. The ground is level to moderately sloping, fairly well drained, and moist. This site occupies 62 per cent of the area, usually the lower slopes.

The composition of the main stand varies from 75 per cent softwood to 75 per cent hardwood, some of the variation being due to past cuttings for conifers only. On the average, conifers are in the majority (60 per cent) and the proportion is increasing. This is the optimum site for balsam fir, all things considered. Balsam fir has a greater volume than spruce in the main stand, and it is far more abundant than in any other type. Yellow birch amounts to 30 per cent of the total volume of the stand, but its percentage of defect is very high. Sugar maple and beech—particularly the latter—are found only on the border-line sites of the Oxalis-Cornus type, approaching the Viburnum-Oxalis type, and when in quantity are consistent indicators of the Viburnum-Oxalis and Viburnum ty es.

Viburnum Oxalis (Hard — Softwood)

The Viburnum-Oxalis type is usually found on the upper slopes, where the forest cover is about 75 per cent hardwood. Indicator species are not frequent because of the thick leaf litter; witch-hobble *(Viburnum alnifolium)* may be represented by a few scattered plants or, rarely, there may be a considerable amount; wood sorrel (Oxalis) is also scattered. Mountain maple is present; striped maple is common, sometimes even more plentiful than mountain maple.

Hardwoods are usually of better quality than on other sites, including sugar maple and beech. Sugar maple is abundant and the seedlings seem to replace underbrush, particularly under shade. There is more red spruce than balsam fir. This type is favourable for the growth of conifers, but it is still more so for hardwoods; hence in the ensuing competition conifers are less successful than they are in the Oxalis-Cornus type.



The southwest part of the lake shore showing a part of the Viburnum-Oxalis type (hard-softwood) where softwoods are not very numerous.

Viburnum (Hardwood)

Found on hill-tops capped with shallow unmodified glacial till, this type is almost pure hardwood. It is characterized by moderate to thick undergrowth of witch-hobble, striped maple, and, less frequently, mountain maple. Wood sorrel is rarely if ever present. Yellow birch, beech and sugar maple are the main tree species. Specimens of red spruce persist here and there; balsam fir is negligible in quantity and usually defective.

Type Distribution and Analysis

The distribution of site-types was determined by proportional representation of the plots tallied in 1936. The Viburnum type and the swamp types were disregarded entirely in 1925, but otherwise the proportions determined by the two surveys are very similar for both periods. The swamp types, Sphagnum-Oxalis and Kalmia-Ledum, and the hardwood Viburnum type are not considered in subsequent analyses because of their infrequency and low economic value. Distribution of site-types with the corresponding cover-type is as follows:

TABLE 1

Distribution of Site-Types

Site Type	Abbreviation	Cover-type	No. of Plots 1936	Per cent of Total Area
Cornus....................	CoT	Softwood	34	10
Oxalis-Cornus..............	O-CoT	Soft-hardwood	214	62
Viburnum-Oxalis............	Vi-OT	Hard-softwood	68	20
Viburnum.................	ViT	Hardwood	7	2
Swamps...................	K-LT, S-OT		20	6
			343	100

The site and cover-types correspond closely if two mixedwood subtypes are recognized, probably because the forest has largely attained its climax.

Cover-types alone based on tree volume may be appropriate for describing existing stands but they are too easily altered by cutting or accidents of nature, even if only temporarily. The Lake Edward site-types could also be named by the characteristic tree species if so desired, provided the same natural conditions were kept in mind: red spruce (Cornus), spruce—balsam—yellow birch (Oxalis-Cornus), spruce—yellow birch—maple (Viburnum Oxalis), and maple-beech (Viburnum). They are closely correlated with land forms.

Laboratory analyses of soil samples by Heimburger (4) included determination of acidity, inoculation tests, examination of texture and basic mineral content, calcium determination, and degree of incorporation of humus into mineral soil. Good cor elation was shown between the type of humus layer and site-types. Poorer site-types generally have a more acid humus layer. There is a close correlation between site-types and different degrees of nitrification, and slightly higher l me contents were found in samples from richer sites.

Heimburger (4) states:

> The Cornus type has generally the deepest humus layers and "A" horizons. The main difference between the types seems to be in the thickness of the "B" horizons. In the Cornus and the Viburnum types this is very often limited by the shallow layer of mineral soil resting directly on bed-rock. In the Oxalis-Cornus and the Viburnum-Oxalis types the mineral soil usually is of sufficient depth for the full development of the soil profile. The Oxalis-Cornus type as a rule has a shallower soil than the Viburnum-Oxalis type.
>
> ...The content of organic matter, as expressed by loss upon ignition, decreases in the humus layer as the sites become relatively richer. On the other hand, the "A" horizons show an increase of incorporated organic matter in the richer sites...
>
> Differences in dr inage and in mineral soil fertility are probably much more important in determining the quality of site in this area, in view of the moist climate, than soil texture ... (R.N. 66)

In commenting upon the indicator value of the main plants, Heimburger (4) continues:

> All the main species of the ground vegetation can be subdivided into four groups, namely, (1) indicators of poorer, softwood-producing sites; (2) those occurring mainly on medium rich sites; (3) indicators of rich, hardwood sites; and (4) species occurring with about equal abundance and degree of cover on all the sites and therefore poor indicators of site within the material sampled. (R.N. 66)

These species are shown in Appendix I, along with the abundance and sociability of the major components of the vegetation on the various sites. The original graph was revised from a consideration of Heimburger's note and from ground observations to conform with present practice.

Height-Diameter Relationships

The average height-age of dominant trees in any one locality or stand is generally accepted as a direct measure of site quality; however, the height-age relationship is not believed to be valid when suppression occurs in early life, as is commonly the case on the richer sites.

Nevertheless, site quality is generally accepted as being the limiting factor in height growth. The height-diameter curves for red spruce, shown in Figure I, consistently follow the site relationship and this is believed to hold true in climax or near climax forest.

Therefore it is suggested that height-diameter, and not height-age, expresses best the site relationship for red spruce in this mixedwood type of forest. The relationship happens to hold true for balsam fir also, but is less reliable since balsam fir is shorter lived. Fewer large trees on the poorer sites account for closing off the curves sooner on the Cornus and Oxalis-Cornus types. Yellow birch is also shown.

Application

The present writer was able to test the validity of this concept of site-types in the forest survey of 1936, and to complete the growth study for the area after the final plot remeasurement in 1946. The types were not difficult to recognize or map in the regular manner on cruise lines, once they had been described and explained in the field by Heimburger in the course of two or three days. At first, the plant indicator species were relied upon almost entirely for type identification. As time went on, the types and their peculiarities emerged more definitely, particularly after compilation, and Losee (5) has shown that site-types in climax forests can be mapped from aerial photographs. Immature varieties and temporary fire types with the successional trends in vegetation following disturbances have yet to be studied, however.

FOREST SURVEYS

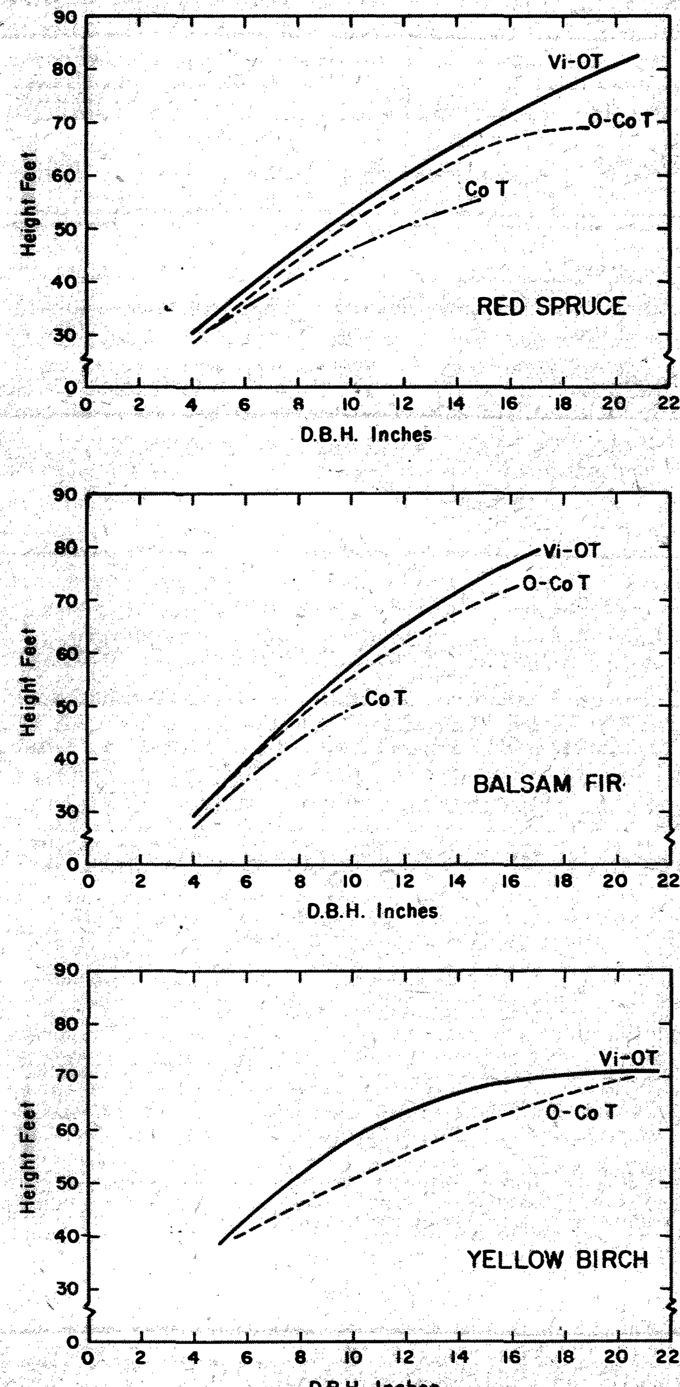
When experimental work was begun at Lake Edward in 1918, permanent sample plots were established, varying in size from one-quarter to several acres. On these were conducted girdling, thinning, release cutting, and seed-bed treatments. Control plots were established in untreated forest, and other plots set up purely to record the growth and yield. At the same time, a strip survey, primarily for measuring reproduction, was made over the whole area. Unfortunately, the very general results from this survey were difficult to compare with the later permanent line-plot survey.

At that time, also, the lack of empirical and fundamental information was a handicap in planning what experimental work to do, and finally, curtailment of sample plot work between 1931 and 1936 lead to revision of the whole policy concerning Lake Edward. Silvicultural treatment was clearly less needed than originally thought and the result of some short-term experiments had been obscured. Fortunately, about this time site-types were ready for use and site-type and growth studies finally converged in 1936. Every development since then has served to strengthen the association at Lake Edward.

The first intensive line-plot survey, begun in 1924 and finished in 1926, is considered for comparative purposes to have been made in the year 1925; the second was made in 1936, and the third in 1946. Although an attempt was made to work back from the 1925 survey by means of mortality and increment borings to estimate the residual growing stock after cutting, the results are not

Figure I

INFLUENCE OF SITE IN THE HEIGHT-DIAMETER RELATIONSHIP



very accurate. Consequently, the record is not complete between the time of cutting (1910-1912) and 1925, nor is it possible to determine exactly how much was on the ground immediately before and after the cut. The stump tally on the line-plots in 1936 is the only estimate of the volume taken off in previous cutting operations.

In the line-plot survey of 1925, fifth-acre plots were established at 10-chain intervals and the lines were blazed. Squared posts with numbered tags attached marked the corners of each plot. All living trees on the plot 4 inches d.b.h. and up, together with those which had died within the last ten years, were tallied in inch-classes. Saplings (1 to 3 inches) on a subplot 0.5 by 1.0 chain, and seedlings on a square-rod subplot, were tallied. Plots were not laid out in the hardwood type nor in unmerchantable swamp types. Single increment borings were taken on spruce, balsam fir, and cedar. Altogether, 321 plots were thus laid out.

A resurvey of the area was completed in 1936. Lines were spaced as before at intervals of 10 chains, but the plots were arranged in a grid over the area. Although the survey covers the same ground, the plots are not identical with those originally laid out; and they are one square chain instead of two square chains in area. Lines were run with a box compass and were not blazed. The distinct association of tree species noted after compilation of the 1936 survey data enabled reclassification of the 1925 plots into the same system simply by inspection of the main stand and reproduction tally sheets and by comparing the two maps.

All living trees of 0.6 inch d.b.h. and upwards on the plot were tallied in one-inch classes; those which had died in the last ten years were tallied separately. Stumps of trees cut in previous logging operations were measured and tallied in two classes, as having been cut in 1890 or in 1910. Seedlings on a square-rod subplot in each plot were counted by species in three classes, namely: less than 0.5 foot, 0.5 foot to 3.0 feet, and 3.0 feet upwards in height. Increment borings were taken on dominant and co-dominant spruce, balsam fir, and white and yellow birch. Two opposite borings were taken on each tree, to a total of 1,900; radial growth in the last ten years was recorded, also total age on one or two trees per plot. A few heights were measured on each plot, the total number amounting to about 800. Notes on ground cover, history, and soil were taken.

Plots were moved slightly backward or forward if they fell across a clearly defined type line, or partly in swamp or lake, but such cases were infrequent. Plots we classified in the field according to site-type. Cruise lines were mapped to show topography, site-type division, and location. Altogether 343 line-plots were established. (See centrepiece map.)

The line-plots established in 1936 were remeasured in 1946, all but one being found without difficulty. (A new plot was laid out in the spot where the original was supposed to be.) Increment borings and heights were taken in the same manner. New increment curves and volume tables were prepared, but as the latter showed only small differences, the original 1936 tables were used in computing the 1946 as well as the revised 1925 stock tables.

The total volume of trees 4 inches d.b.h. and up was compiled for each plot in 1936 and in 1946. From statistical analysis of plot volumes, it was concluded that the surveys are accurate within acceptable limits.

RESULTS

Cutting naturally affects the age-class, structure, and species composition of the growing stock; therefore a brief reference to past operations may help to explain the growth and yield figures which follow. Pine was the first species cut, then the largest spruce, and these operations, spread over many years throughout the whole area, were completed in 1902. According to stump tallies, 17 trees per acre were removed. The pulpwood cutting to regulation diameter li its (spruce 10″, balsam 7″), beginning about 1910 and ending in 1912, removed an average (over the whole area) of 13 trees per acre but actually only covered about half the area. The extent to which each site-type was subjected to cutting is in these proportions: 80 per cent of the Cornus type, 52 per cent of the Oxalis-Cornus, and 15 per cent of the Viburnum-Oxalis. Generally speaking, the Cornus type now comprises more younger aged and fully stocked stands; the Oxalis-Cornus type is moderately stocked and all aged; and the Viburnum-Oxalis type is under-stocked with softwoods.

The last cutting has resulted in a patchwork of young and old growth, and in what appears to be a considerable increase of balsam fir. The pine has been re oved permanently, and as the spruce will not likely be allowed to grow again to its maximum size, the way has been opened for a larger proportion of balsam fir in the future. By 1936 the average softwood volume of the Oxalis-Cornus type plots cut-over in 1910 was slightly higher than the uncut. Of course these probably had a higher volume in the first place; and the trees are still much smaller even though more numerous. Nevertheless the cut-over forest seems to have recovered remarkably well in the 30 years following.

Some stands were still immature in 1936, particul rly where balsam fir had passed through a thicket stage; other stands, missed by the loggers, contain only a few large trees. Consequently, considerable variation is found in the proportions of softwoods to hardwoods and in stand structure, which the average figures in the stand and stock tables do not adequately reflect.

The degree of stability attained in 1936, as mortality dropped and rapid growth was resumed, was interrupted again later when the older balsam fir trees began to break off and uproot. Spruce on the other hand was not affected and continued to grow with increasing vigour. It is doubtful however whether the forest as a whole could ever develop fully as long as the hardwoods, comprising nearly half the total volume, were not being cut. Fortunately this is now being corrected.

Growing Stock

Stand and stock tables were prepared for all species in all site-types from the line-plot tallies in 1925, 1936 and 1946, and the tables for 1925 and 1946 are given in Appendix II. Sum aries from these tables show by stages what has happened since the cu ting in 1910 and they provide the basic data for the growth study. The volumes are shown in Table 2 and graphically in Figures 2 and 3.

From Table 2 and Figures 2 and 3 it will be seen that spruce and balsam increased from 736 to 1,484 cubic feet per acre between 1925 and 1946; that is, they have doubled in volume in 21 years. At the same time, hardwoods have increased by only 20 per cent and their total volume is now considerably less than the total volume of pru e and balsam. Softwoods on the whole therefore have made out very well in competition with hardwoods, in spite of the unpromising beginning reported by earlier observers.

Spru e is gaining steadily on balsam fir and by 1946 the average volumes (for the three types) were very nearly equal. Balsam fir held its own in the Oxalis-Cornus type until 1936; then mounting mortality took effect as trees reached maturity and left spruce to progress even more rapidly. By 1946 the volumes were: spruce 730 cubic feet per acre, and balsam 922 cubic feet per acre. Spruce is far ahead in the other two types.

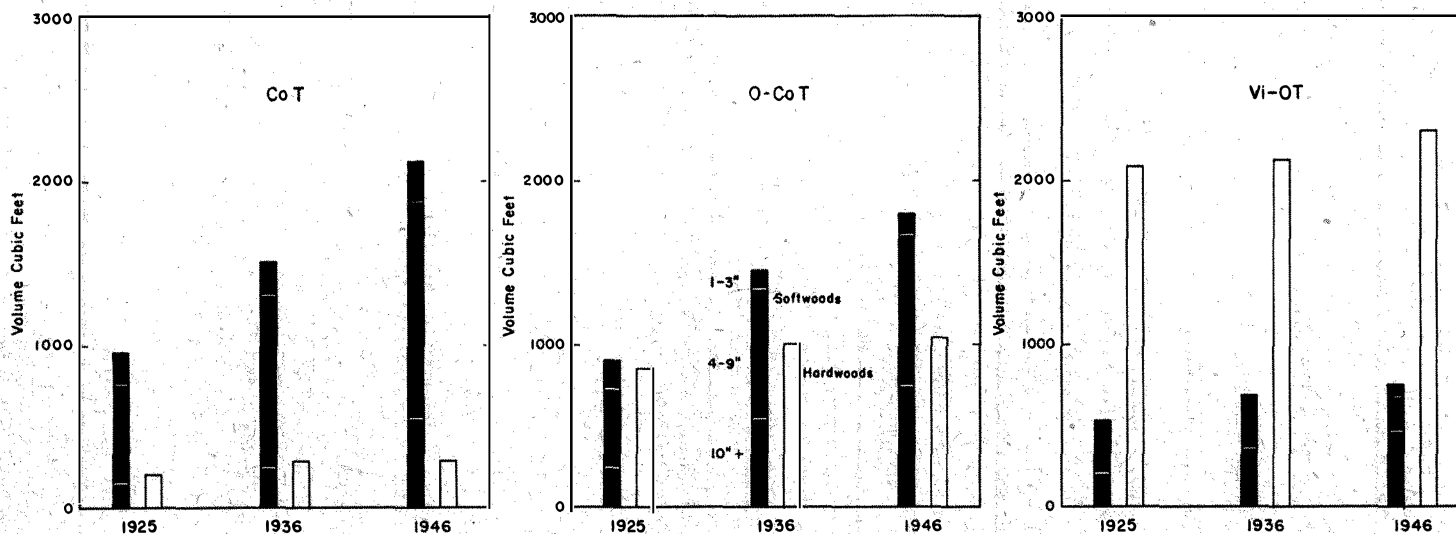
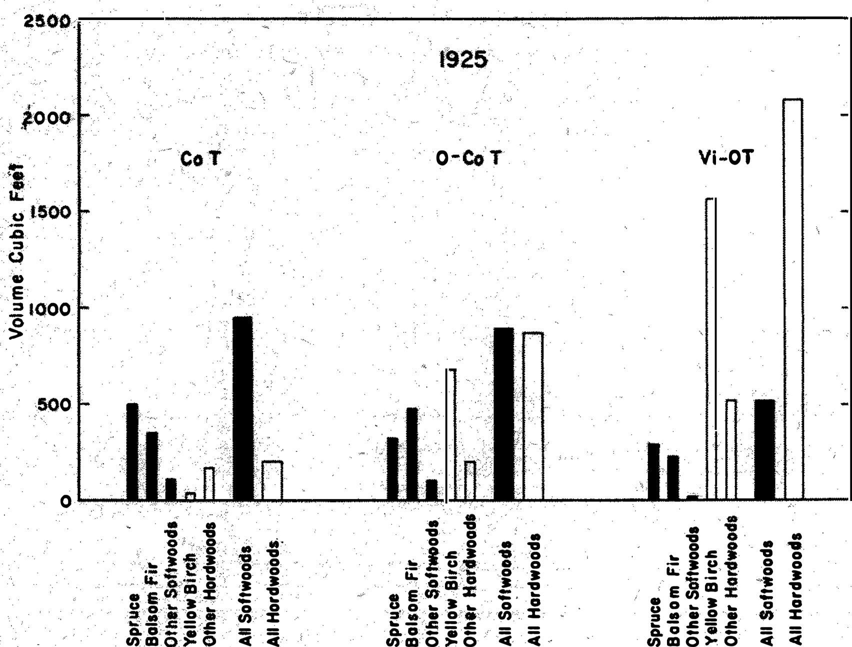


Figure 2

TOTAL VOLUMES PER ACRE

Figure 3

TOTAL VOLUMES PER ACRE BY SPECIES



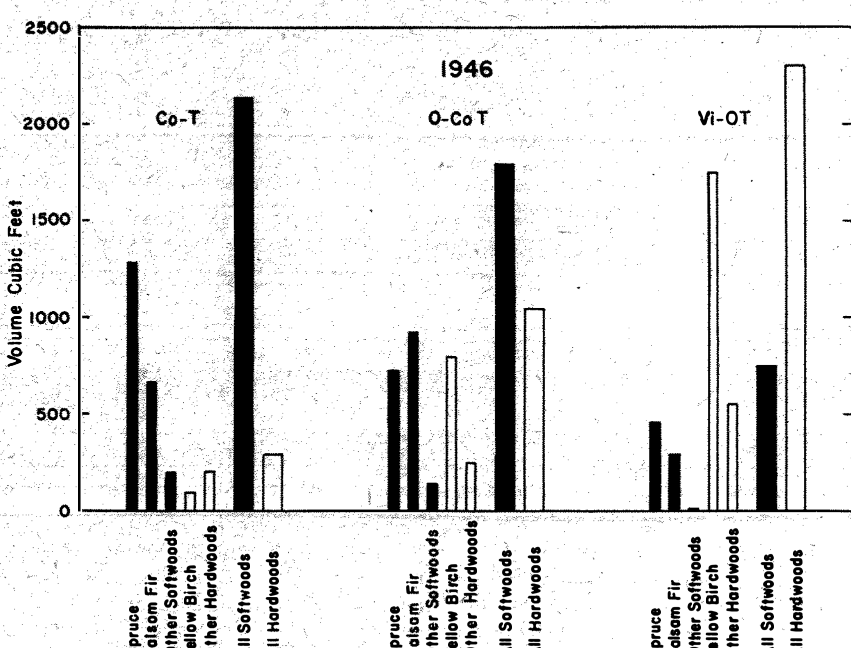


TABLE 2

Summary of Stock Tables

Cubic Feet per Acre, 1" d.b.h. and up

1925

Species	CoT	O-CoT	Vi-OT	Average
Spruce	498	321	286	332
Balsam	348	472	221	404
Total	846	793	507	736
Other Softwoods	108	96	15	80
All Softwoods	954	889	522	816
Yellow Birch	37	674	1,566	798
Other Hardwoods	167	195	515	262
All Hardwoods	204	870	2,081	1,060
All Species	1,158	1,759	2,603	1,876
1936				
Spruce	882	550	346	541
Balsam	470	773	302	637
Total	1,352	1,323	648	1,178
Other Softwoods	154	131	24	110
All Softwoods	1,506	1,454	672	1,288
Yellow Birch	110	757	1,615	872
Other Hardwoods	184	246	511	296
All Hardwoods	294	1,003	2,126	1,168
All Species	1,800	2,457	2,798	2,456
1946				
Spruce	1,279	730	460	730
Balsam	657	922	284	754
Total	1,936	1,652	744	1,484
Other Softwoods	187	135	4	112
All Softwoods	2,123	1,787	748	1,596
Yellow Birch	89	792	1,749	923
Other Hardwoods	201	249	557	310
All Hardwoods	290	1,041	2,306	1,233
All Species	2,413	2,828	3,054	2,829

Productivity expressed in total wood volume is consistent with respect to the site classes but the inherent difference in growth rate between softwoods and hardwoods could temporarily derange this relationship in less mature stands.

Conversely, the largest volumes of spruce and balsam are found in the Cornus type (the poorest) and they decline in the Oxalis-Cornus and Viburnum-Oxalis types as the site improves. This is directly the result of competition from hardwoods. Individually these trees show better form and height with site improvement; that is, the best tree specimens are found in the Viburnum-Oxalis type, but the largest volumes are found in the Cornus type.

The large volume in the Cornus type is perhaps more remarkable considering that the heaviest cutting took place there. On the other hand, the Viburnum-Oxalis type has never recovered from the cutting in 1890 and very little was cut in the second operation in 1910.

Numbers of Trees

The numbers of trees (4 inches d.b.h. and up), shown for each species in the stand and stock tables, are summarized in Table 3. The numbers of saplings, one inch to 3 inches, are shown later with the reproduction.

The numbers of trees, both softwood and hardwood, continued to increase after 1925 in all types, but the increase was very small in the Viburnum-Oxalis type. Poor sites usually have larger numbers of trees than rich sites. This was true in 1925 and in 1946. The number of spruce and balsam trees (4 inches and up) more than doubled between 1925 and 1946 in the Cornus type; they increased moderately in the Oxalis-Cornus but remained almost stationary in the Viburnum-Oxalis type. The average for the three types increased from 141 to 241 per acre. Spruce continued to gain on balsam fir in all types, in numbers of trees as in volume, and it now leads in all but the Oxalis-Cornus type. In this, balsam fir trees are more numerous.

TABLE 3

Summary of Stand Tables

Number of Trees per Acre, 4" and up

1925

Species	CoT	O-CoT	Vi-OT	Average
Spruce	106	55	38	57
Balsam	89	96	44	84
Total	195	151	82	141
Other Softwoods	17	11	2	10
Total Softwoods	212	162	84	151
Yellow Birch	5	38	68	41
Other Hardwoods	26	28	44	31
Total Hardwoods	31	66	112	72
All Species	243	228	196	223

1946

Species	CoT	O-CoT	Vi-OT	Average
Spruce	263	104	44	108
Balsam	156	159	40	133
Total	419	263	84	241
Other Softwoods	43	18	—	17
Total Softwoods	462	281	84	258
Yellow Birch	8	41	64	42
Other Hardwoods	42	48	55	49
Total Hardwoods	50	89	119	91
All Species	512	370	203	349

Stand Structure

The structure or profile of a forest stand refers here to the total volumes by inch diameter classes. It is useful for comparing one stand with another, for showing to what degree the stand has developed towards its climax and in which diameter classes one can expect the most growth in the near future. Each fully developed type usually has its own peculiar pattern when plotted in a profile. This pattern is a bell-shaped curve for the Cornus and Oxalis-Cornus types (the former being higher but considerably narrower than the latter). The pattern is asymmetrical for the Viburnum-Oxalis type, with the peak towards the upper end of the diameter range. Data obtained from the stock tables were plotted and are shown in Figure 4 for each of the site-types, and for spruce and balsam together.

Poor site, resulting in short trees, reduces the volume of all species in the Cornus type. An abundance of balsam fir combined with shorter life span lowers the proportion of large sized trees in the Oxalis-Cornus type. Severe competition in the Viburnum-Oxalis type further reduces the number of softwood trees. Once the softwoods have gained freedom from suppression, however, they grow rapidly and reach great height; the culmination point in the Vi-O type profile is seen to be far to the right of centre. Most of these trees are spruce, because only an occasional balsam survives in the larger diameters.

Little is known about the original stands before the 1910 cutting. It is doubtful whether the total volume of wood was ever much greater than at present. The Cornus type probably contains more and the Viburnum-Oxalis type less softwood now, but on the whole the main difference is thought to be in the smaller average size but larger number of trees.

The virgin forest of the Ouareau River observation area, 60 miles to the west in the Mont Tremblant region, is the only known standard with which a comparison might be made, and the same site-type relationships were found there too. This suggests that the Lake Edward types are not far from their climax forms, in spite of the cutting which took place less than 40 years before.

The percentages of volumes by broad groups for 1925 and 1946 (Table 4) are also good indices of stand structure.

TABLE 4

Stand Structure, all Softwoods

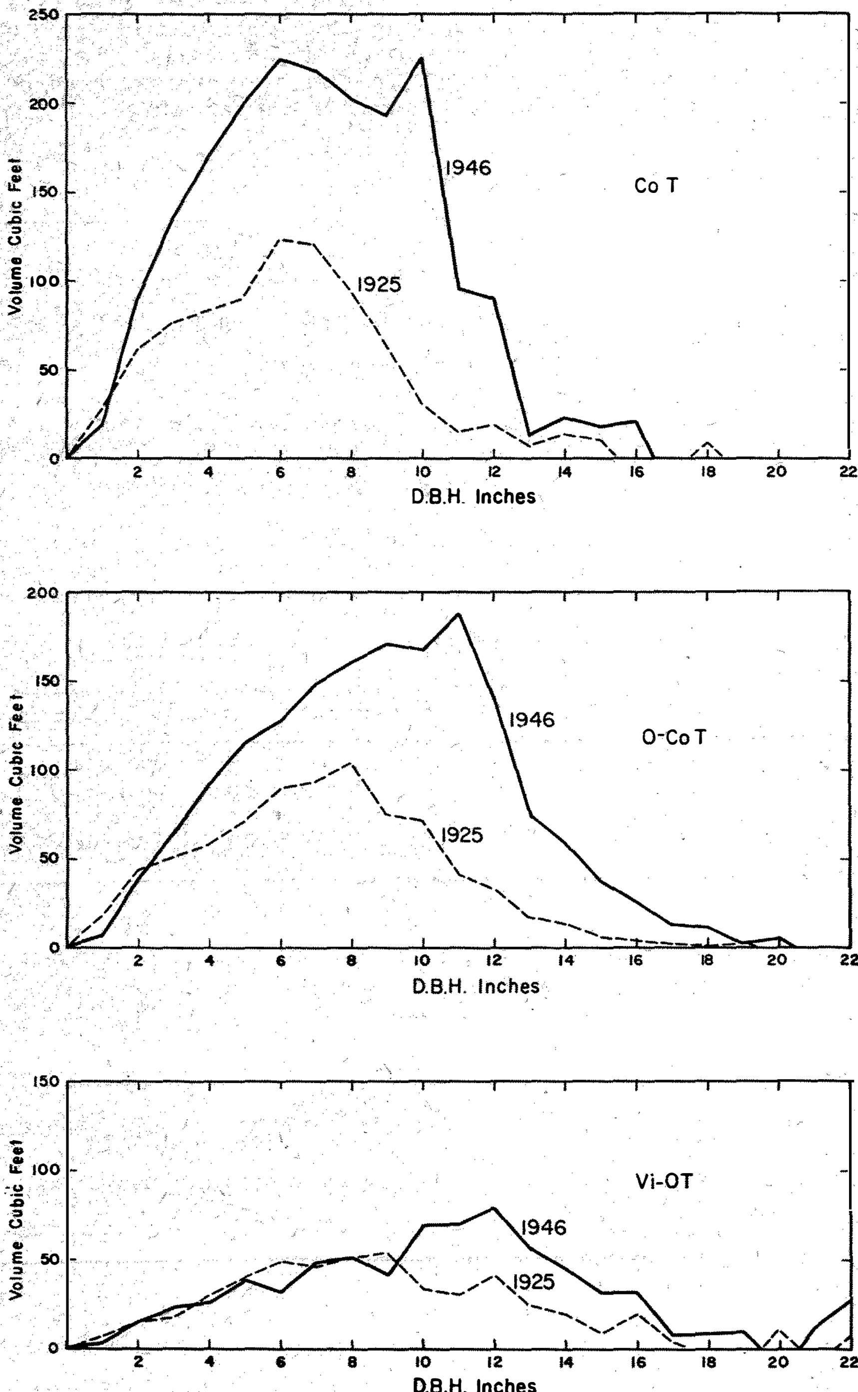
Percentage of Total Volumes of Softwoods

Year	D.B.H.	CoT	O-CoT	Vi-OT
1925	1–3 4–9 10″+	19% 65 16	14% 58 28	8% 52 40
Total	—	100%	100%	100%
Total Cubic Feet	—	954	889	522
1946	1–3 4–9 10″+	12% 62 26	6% 48 46	6% 32 62
Total		100%	100%	100%
Total Cubic Feet		2,123	1,786	748

Figure 4

STOCK PROFILES - TOTAL VOLUME PER ACRE BY D.B.H. CLASSES

(Spruce and Balsam Fir only)



These percentages show close relationships with the site-types. For example in 1946 only 26 per cent of the softwoods in the Co type were over 10 inches d.b.h., compared to 46 per cent in the O-Co and 62 per cent in the Vi-O type. The greatest proportional increase in large trees (10 inches and up) between 1925 and 1946 took place in the Vi-O type, from 40 per cent to 62 per cent. Competition with hardwoods is evidently no longer a factor among these large trees, and they can profit to the full capacity of this rich site.

Table 5 shows the percentages of each species by site-types, and the changes which have occurred between 1925 and 1946.

TABLE 5

Species Composition

Percentage of Total Volume

1925

Species	CoT	O-CoT	Vi-OT	Average
Spruce	43	18	11	19
Balsam	30	27	8	23
Total	73	45	19	42
Other Softwoods	9	5	1	5
All Softwoods	82	50	20	47
Yellow Birch	3	39	60	40
Other Hardwoods	15	11	20	13
A l Hardwoods	18	50	80	53
A l Species	100	100	100	100

1946

Species	CoT	O-CoT	Vi-OT	Average
Spruce	53	26	15	26
Balsam	27	33	10	27
Total	80	59	25	53
Other Softwoods	8	5	—	4
All Softwoods	88	64	25	57
Yellow Birch	4	28	58	32
Other Hardwoods	8	8	17	11
All Hardwoods	12	36	75	43
All Species	100	100	100	100

Spruce is gaining steadily on balsam, on the average only one per cent behind in 1946; and softwoods having gained 10 per cent at the expense of hardwoods since 1925, now constitute 57 per cent of the total volume of all species. Hardwoods lost 14 per cent in the O-Co type. Competition is apt to be keen in this type; therefore the loss is significant. The percentages in this type are now 64 to 36, instead of 50 in 1925.

Mortality

The annual mortality for each of the three periods is shown in Table 6. The heavy mortality between 1915 and 1925, amounting to 33·6 cubic feet of spruce and balsam per acre, or 4·6 per cent of the 1925 volume, consisted largely of mature balsam fir left over from the 1910 cut. Had the diameter limits (spruce 10 inches, balsam 7 inches) been strictly adherred to, and had the whole area been cut-over in 1910 instead of barely over half, most of what later died would probably have been cut before being blown down. The average dropped to 8·8 cubic feet in 1925-36, and rose again to 12·8 cubic feet in 1936-46.

TABLE 6
ANNUAL MORTALITY
Total Cubic Feet per Acre

Species	CoT	O-CoT	Vi-OT	Average
1915 — 25				
Spruce	15·0	11·5	9·6	11·4
Balsam	21·1	24·5	14·9	22·2
Total	36·1	36·0	24·5	33·6
Other Softwoods	3·8	6·0	·9	4·7
All Softwoods	39·9	42·0	25·4	38·3
Yellow Birch	2·4	7·0	19·7	9·3
Other Hardwoods	5·5	5·8	4·7	5·4
All Hardwoods	7·9	12·8	24·4	14·7
All Species	47·8	54·8	49·8	53·0
1925 — 36				
Spruce	4·3	2·0	2·7	2·4
Balsam	3·1	6·7	7·2	6·4
Total	7·4	8·7	9·9	8·8
Other Softwoods	5·3	3·0	1·5	2·9
All Softwoods	12·7	11·7	11·4	11·7
Yellow Birch	—	4·0	11·0	5·1
Other Hardwoods	2·1	5·0	6·5	5·0
All Hardwoods	2·1	9·0	17·5	10·1
All Species	14·8	20·7	28·9	21·8
1936 — 46				
Spruce	2·6	1·6	·4	1·5
Balsam	5·1	13·0	9·6	11·3
Total	7·7	14·6	10·0	12·8
Other Softwoods	1·0	2·0	1·3	1·7
All Softwoods	8·7	16·6	11·3	14·5
Yellow Birch	5·1	7·0	9·5	7·3
Other Hardwoods	1·5	4·0	4·6	3·9
All Hardwoods	6·6	11·0	14·1	11·2
All Species	15·3	27·6	25·4	25·7

39-13-EL—4

Spruce mortality is a fairly constant function of the volume regardless of type and it decreased steadily after 1925 to a negligible amount in 1946, that is, from an annual average of 3·4 per cent to 0·2 per cent of the present volume. Balsam fir on the other hand varies much more with site and age. After a general decrease in all types after 1925 from the excessive mortality immediately following the cut, the annual rate began to increase again from one per cent in 1936 to 1·5 per cent in 1946. Also in this same period it varied from 0·8 per cent in the Co type to 3·4 per cent in the Vi-O type.

Spruce therefore continues to grow steadily and to occupy an ever-increasing proportion of the stand, whereas balsam fir is declining, although still growing well. Spruce deteriorates slowly with age, is windfirm, rot resistant, and may survive for many years even though towering over the younger forest. Balsam fir, on the contrary, dies suddenly when it reaches a certain age or size and, being susceptible to butt rot and windthrow, suffers seriously from changes in the canopy after cutting or other disturbance.

Yellow birch mortality, in spite of the dieback, is practically negligible; a rate of less than one per cent annually since 1925. Most of the tree tops have been affected but fortunately without subsequent mortality.

It should be noted that the total of all spruce and balsam mortality between 1910 and 1950, (calculated at the nearest periodic rate for the years not covered, 1910 to 1915 and 1946 to 1950) is 1,174 cubic feet per acre. The total growing stock in 1946, with the addition of four years' growth from 1946 to 1950, is 1,606 cubic feet. The mortality therefore during the cycle 1910 to 1950 amounts to over 70 per cent of the final volume. Had it been practical to cut frequently and thus forestall this mortality, the final yield could have been increased by approximately that much.

Rate of Growth

Rate of growth is admittedly one of the most important factors in forest regulation because it governs the rate at which cutting can be safely carried on. Growth data at present are scarce and while management plans are based upon the best information available, the long-term growth rate is still uncertain. Moreover, provision is generally made for adjustment in the rate of cutting at regular intervals, usually 10 years, and growth can be estimated quite accurately for that length of time. Precedents from which growth could be observed following the usual cutting methods in effect since about 1925, simply do not exist beyond these 25 or 30 years.

In overmature forest, growth and mortality being more or less in balance, no general increase in growth rate can take place until the overmature trees are cut. However, as young growth increases in area, and as the reserve of mature timber diminishes, the rate at which timber can be cut without depleting the forest must eventually be balanced against the rate of growth in the young stands which have regenerated since logging (or fire).

Growth figures are also needed for forest management policy. The many and varied opinions regarding the possibilities of increasing yields, expanding forest industries, restoring marginal farm land to forest and so on, are evidence of the necessity for more specific and accurate information. Until more is known about the forest, and short cuts are by no means ruled out, the slow patient way of measuring and remeasuring plots is the surest way of providing the growth data required. The Lake Edward data based upon such plots, and extending over a period of 40 years, are indeed suitable. The one condition however is that these findings be understood to apply to growth after partial, not clear cutting.

Growth data presented here are based upon the growing stock volumes obtained from the line-plot surveys and are applicable to three periods, as follows: 1910 to 1925, determined by means of increment borings and mortality estimates from the 1925 survey; 1925 to 1936, from independent line-plot surveys; 1936 to 1950, from remeasurement of identical plots in 1946. Extrapolation from the nearest existing date filled in the gaps, 1910 to 1915, and 1946 to 1950.

It might be explained that the periodic increment refers here to the 10 to 15-year periods only, and "average increment" to the whole cutting cycle, in this case the 40 years between cuts.

The net periodic increment varies so much that it should not be isolated entirely from the average, or it might easily exaggerate a condition in the forest which is only temporary.

The periodic net annual increment is given in Table 7 for each species, in each type, for the three periods and a combined total for the last two periods, 1925-46. Growth per cent by Pressler's formula is shown in Table 8, and the average annual increment 1910 to 1950 in Table 9. These figures are illustrated in Figures 5 and 6.

TABLE 7

Periodic Net Annual Increment

Total Volume Cu. Ft. per Acre, 1" d.b.h. and up

1915-25*

Species	CoT	O-CoT	Vi-OT	Average
Spruce	0·6	−2·1	−1·9	−1·7
Balsam	−6·4	−6·8	−7·5	−6·9
Total	−5·8	−8·9	−9·4	−8·6
Other Softwoods	−1·3	−4·1	−0·6	−3·0
All Softwoods	−7·1	−13·0	−10·0	−11·6
Yellow Birch	−1·3	5·4	10·2	5·7
Other Hardwoods	0·6	−0·2	7·9	1·6
All Hardwoods	−0·7	5·2	18·1	7·3
All Species	−7·8	−7·8	8·1	−4·3

* Figures were determined from increment borings and are not as reliable as those from the line-plot data, 1925 on.

1925-36

Species	CoT	O-CoT	Vi-OT	Average
Spruce	34·9	20·8	5·4	19·0
Balsam	11·0	27·4	7·4	21·3
Total	45·9	48·2	12·8	40·3
Other Softwoods	4·3	3·1	0·8	2·7
All Softwoods	50·2	51·3	13·6	43·0
Yellow Birch	6·6	7·5	4·4	6·7
Other Hardwoods	1·6	4·5	−0·4	3·1
All Hardwoods	8·2	12·0	4·0	9·8
All Species	58·4	63·3	17·6	52·8

1936-46

Species	CoT	O-CoT	Vi-OT	Average
Spruce	39·7	18·0	11·4	18·9
Balsam	18·7	14·9	−1·8	11·7
Total	58·4	32·9	9·6	30·6
Other Softwoods	3·3	0·4	−2·0	·2
All Softwoods	61·7	33·3	7·6	30·8
Yellow Birch	−2·1	3·5	13·4	5·0
Other Hardwoods	1·7	0·3	4·6	1·4
All Hardwoods	−0·4	3·8	18·0	6·4
All Species	61·3	37·1	25·6	37·2

1925-46

Species	CoT	O-CoT	Vi-OT	Average
Spruce	37·2	19·5	8·2	19·0
Balsam	14·7	21·4	3·0	16·7
Total	51·9	40·9	11·2	35·7
Other Softwoods	3·8	1·8	−0·5	1·5
All Softwoods	55·7	42·7	10·7	37·2
Yellow Birch	2·5	5·6	8·7	5·9
Other Hardwoods	1·7	2·5	2·3	2·4
All Hardwoods	4·2	8·1	11·0	8·3
All Species	59·9	50·8	21·7	45·5

TABLE 8
Growth Per Cent (Pressler)

Period 1925-36

Species	CoT	O-CoT	Vi-OT	Average
Spruce	5·1	4·8	1·7	4·3
Balsam	2·7	4·4	2·8	4·1
S. and B	4·2	4·6	2·2	4·2

Period 1936-46

Species	CoT	O-CoT	Vi-OT	Average
Spruce	3·7	2·8	2·8	3·0
Balsam	3·3	1·8	·6	1·7
S. and B	3·5	2·2	1·4	2·3

Interval 1925-46

Species	CoT	O-CoT	Vi-OT	Average
Spruce	4·2	3·7	2·2	3·6
Balsam	2·9	3·1	1·2	2·9
S. and B	3·7	3·3	1·8	3·2

TABLE 9

Average Annual Increment, Cycle 1910-1950

Spruce and Balsam Only

Site-type	Area	Increment (cu. ft.)
Cornus	10	30·9
Oxalis-Cornus	62	21·4
Virburnum-Oxalis	20	3·4
Weighted average	92%	18·5

N.B. 8% of area is swamp or pure hardwood type (Vi-T 2%) and therefore omitted.

In the first period (1915-25), spruce and balsam decreased at the rate of 8·6 cubic feet per acre; in the second period they increased at the rate of 40·3 cubic feet, and in the third period, at the rate of 30·6 cubic feet per acre. By extending the rates for the first and third periods to cover the gaps between the time of cutting and periods actually covered by the growth study, the average annual increment for these species for the 40-year cycle (1910-1950) is 18·5 cubic feet.

This average figure is disappointingly low, but there might be extenuating circumstances. For instance, the large net loss (1910 to 1925) which appreciably reduces the average would not have occurred had balsam fir been utilized then as now.

A great improvement took place after 1925 when mortality was reduced to a minimum. Between then and 1946 spruce and balsam grew at an average rate of 35·7 cubic feet per acre, in spite of the fact that hardwoods, having never been cut, were competing under conditions still more favourable to them.

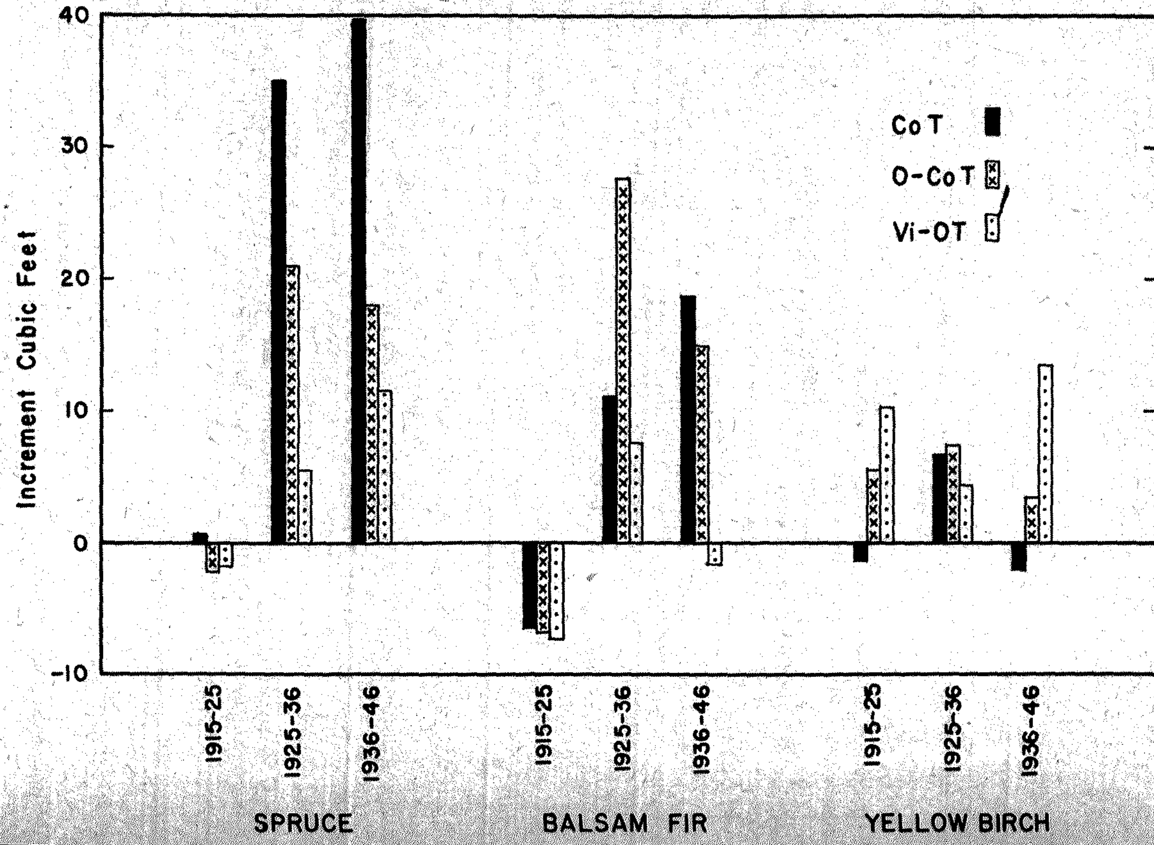
The decline in net growth from 40·3 cubic feet in the second p riod (1925-36) to 30·6 cubic feet in the third (1936-46), or from 4·2 per cent to 2·3 per cent, is a warning that the rising mortality calls for immediate cutting to utilize these dying trees. Hardwood growth dropped also from 9·8 to 6·4 cubic feet; consequently the culmination point had probably been reached and some decline could be expected as the forest approached maturity.

Contrary to the trend in other types, the rates of growth for spruce and balsam in the Cornus type increased after 1936, from 45·9 to 58·4 cubic feet, probably because of the younger age of the stands. The highest growth rate is found in this, the poorest type, both in actual increment and percent. This apparent anomaly is mainly due to greater suppression on richer sites, whereas competition from hardwoods is not a serious factor in the Cornus type.

Conversely the hardwood growth rate increases as the site becomes richer but the average of 8·3 c bic feet between 1925 and 1946 is less than a quarter the corresponding rate for softwoods. In the Viburnum-Oxalis type alone, the growth rate of hardwoods is slightly greater than that of softwoods, 11·0 to 10·7 cubic feet, but elsewhere it is considerably less. Even in the Oxalis-Cornus type, which is very favourable for yellow birch, the growth rate for hardwoods is less than one-fifth that of softwoods. This might increase considerably if the overmature trees were to be removed. However, the growth rate is so much slower in the hardwood species in their present condition that the net growth for "all species" declines in passing from the Cornus through to the Viburnum-Oxalis type.

Figure 5

PERIODIC NET ANNUAL INCREMENT BY SPECIES AND SITE TYPES



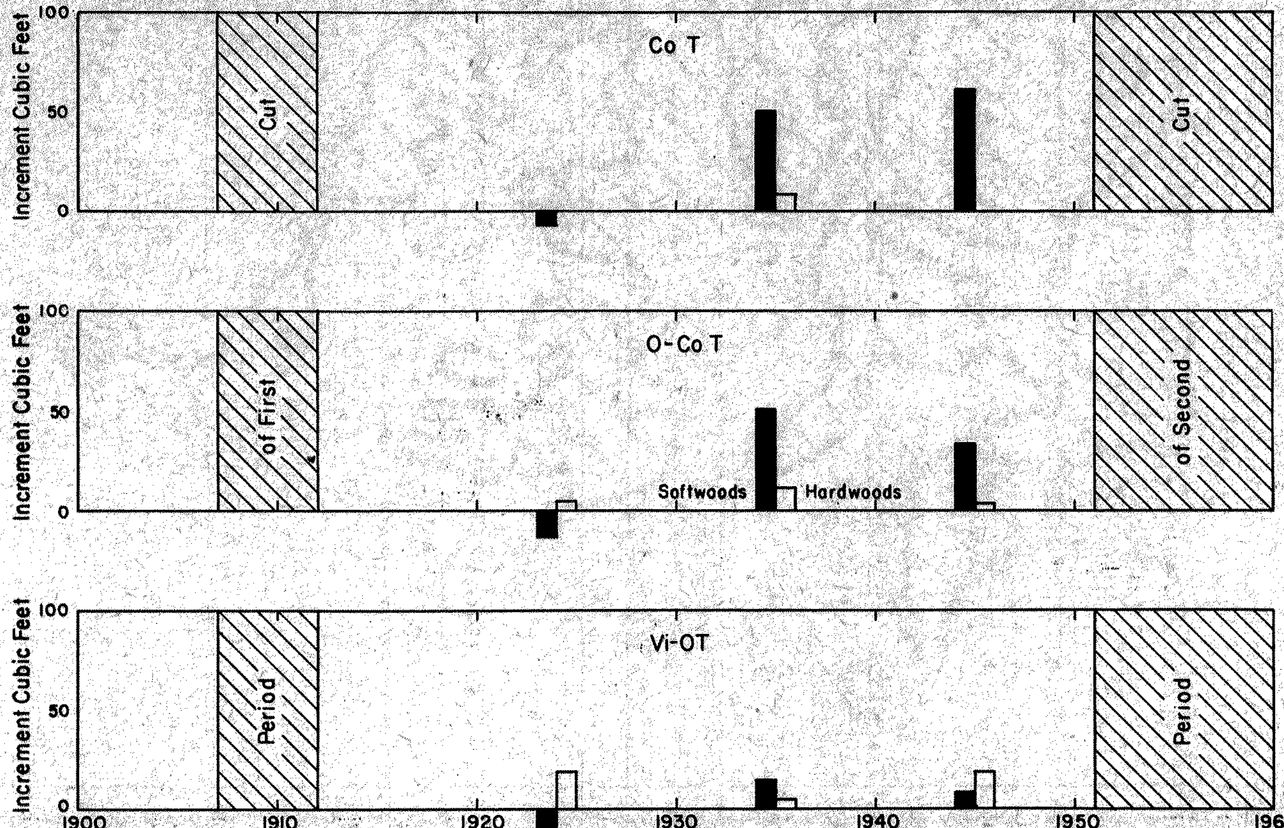
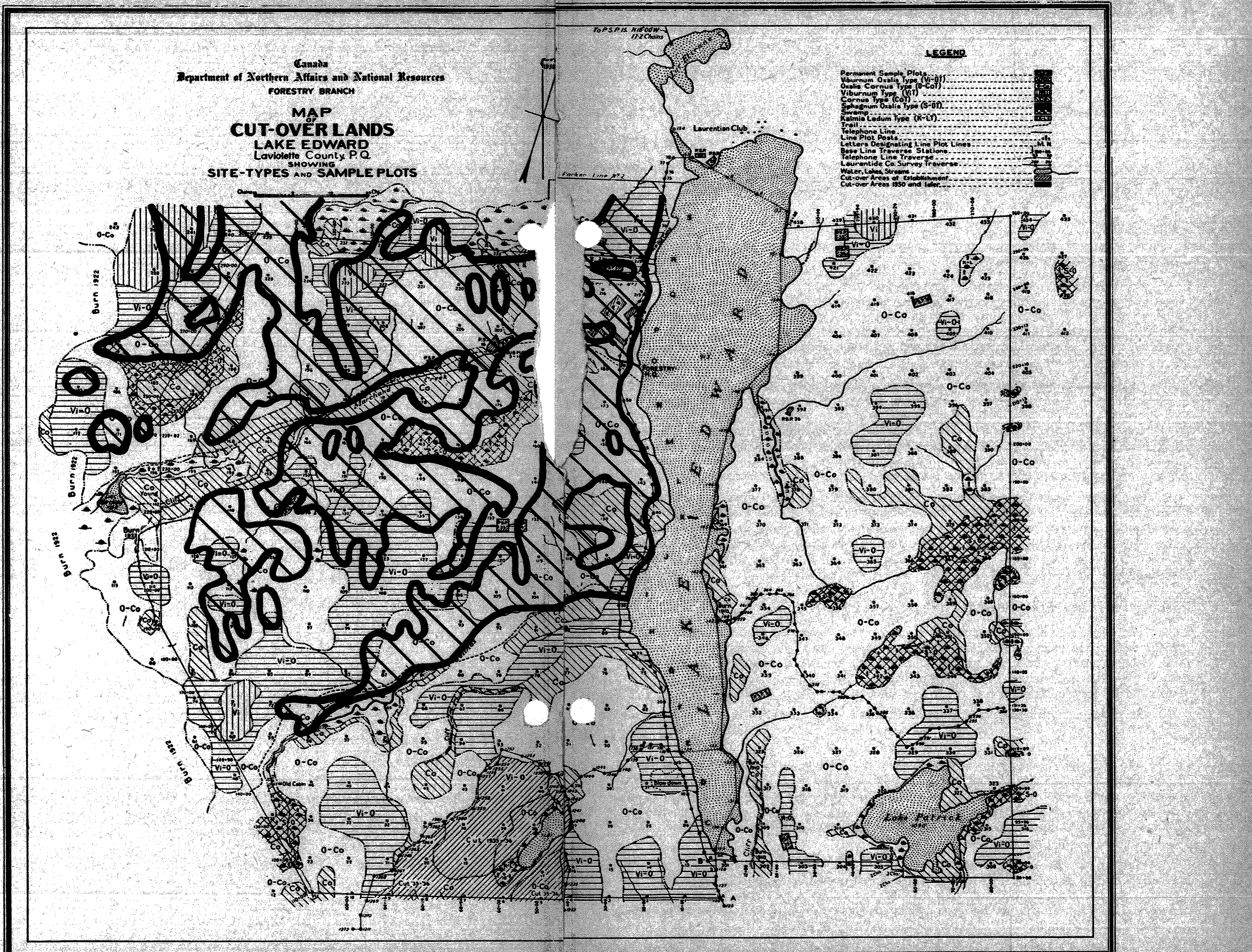


Figure 6

PERIODIC NET ANNUAL INCREMENT OF SPRUCE AND BALSAM FIR
in
RELATION TO THE CYCLE BETWEEN CUTTING OPERATIONS


Canada
Department of Northern Affairs and National Resources
FORESTRY BRANCH
MAP of CUT-OVER LANDS
LAKE EDWARD
Laviolette County, P.Q.
SHOWING
SITE-TYPES AND SAMPLE PLOTS
LEGEND
Permanent Sample Plots
Viburnum Oxalis Type (Vi-OT)
Oxalis Cornus Type (O-CoT)
Viburnum Type (ViT)
Cornus Type (CoT)
Sphagnum Oxalis Type (S-OT)
Swamp
Kalmia Ledum Type (K-LT)
Trail
Telephone Line
Line Plot Posts
Letters Designating Line Plot Lines
Base Line Traverse Stations
Telephone Line Traverse
Laurentide Co. Survey Traverse
Water, Lakes, Streams
Cut-over Areas at Establishment
Cut-over Areas 1950 and later
Laurentian Club
Parker Line No. 2
Burn 1922
Lake Patrick
Cut 1935-36
Vi-O
O-Co
Co

Although balsam fir is usually a faster growing tree than spruce, its volume increment between 1925 and 1946 was less than that of spruce, 16·7 cubic feet compared to 19·0 cubic feet; and in the first period after cutting the net loss in spruce was only a quarter that of balsam fir. Whereas spruce thrives in all types, balsam fir shows a marked preference for the Oxalis-Cornus type, but even there, spruce net increment finally exceeded balsam fir, 18·0 cubic feet to 14·9 cubic feet, (1936–46).

This relationship is even more pronounced in the growth per cent figures (Table 9). The average rate for all types between 1925 and 1946 is spruce 3·6 per cent, balsam fir 2·9 per cent. Yellow birch, in comparison, is less than one per cent.

Gross Annual Increment

The periodic gross annual increment, obtained from mortality and net increment added together, shows the total wood grown within the period. It therefore gives a clearer indication of the capacities of the sites than the net increment, because it minimizes the fluctuations due to mortality. However, one drawback is the difficulty in obtaining accurate estimates of the mortality.

The results, given in Table 10, show much the same relationships (between site-types) as the net increment. There is a definite progression in growth rate after 1925 in the Cornus type, and the period 1925-36 was, on the average, the most productive for all species. The maximum rate for spruce and balsam together was found to be 66·1 cubic feet per acre in the Cornus type, 1936-46, followed by 56·9 cubic feet in the Oxalis-Cornus type, 1925-36. Balsam fir gross increment is larger than spruce in the latter type only, but the percentage difference is becoming smaller as time goes on.

Excessive mortality in balsam fir in the Oxalis-Cornus type is evidently not the only reason for the fall in growth rate after 1936. Competition with hardwoods and the mature age of the balsam fir must also have slowed down the growth during the last period. The higher rate could likely have been maintained and the increment raised to the same level as before through intensive silviculture.

Diameter – Age Relationship

The total age at breast height of one or two trees per plot was recorded in 1936 while increment borings were being taken, and the ages were averaged for each diameter class for spruce and balsam fir in all types. The age data were plotted and curves drawn which appear in Figure 7; and the values for selected diameter classes read from the curves, are given in Table 11.

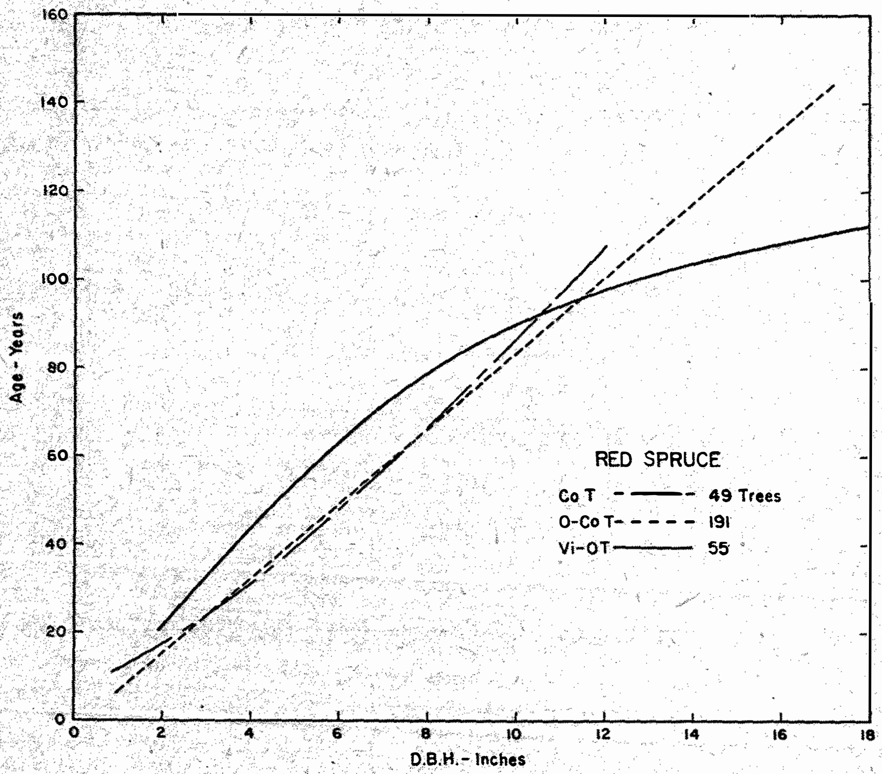
As expected, the ages are quite irregular owing to periods of suppression. However, a fairly clear trend may be seen in the curves for both spruce and balsam which is dependent upon the site-type and hardwood competition.

The Cornus type curves for both spruce and balsam rise gradually at first then more sharply, thus showing no signs of early competition but a longer time to reach a given size owing to the poorer site; the Viburnum-Oxalis type curves on the other hand, rise sharply at first (hardwood suppression) then flatten off as diameter growth picks up in the upper diameter classes (richer sites and competition overcome).

Balsam fir attained diameters from 1 to 7 inches ten years earlier in the Oxalis-Cornus type than in the Cornus or Viburnum-Oxalis types. Individually, balsam fir trees may grow faster in diameter than spruce. From these measurements, the average 8 inch d.b.h. balsam fir tree was observed to be about 60

Figure 7

AVERAGE AGE AT BREAST HEIGHT BY SITE TYPES



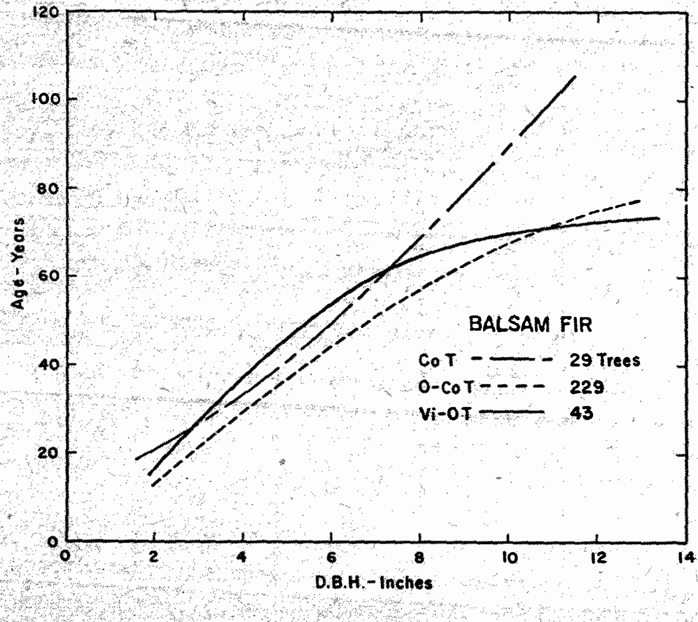


TABLE 10

Periodic Gross Annual Increment*

Total Volume in Cubic Feet per Acre

1915-25

	CoT	O-CoT	Vi-OT	Average
Spruce	15·6	9·4	7·7	9·7
Balsam	14·7	17·7	7·4	15·3
Total	30·3	27·1	15·1	25·0
Y. Birch	1·1	12·4	29·9	15·0
All Hardwoods	7·2	18·0	42·5	22·0

1925-36

	CoT	O-CoT	Vi-OT	Average
Spruce	39·2	22·8	8·1	21·4
Balsam	14·1	34·1	14·6	27·7
Total	53·3	56·9	22·7	49·1
Y. Birch	6·6	11·5	15·4	11·8
All Hardwoods	10·3	21·0	21·5	19·9

1936-46

	CoT	O-CoT	Vi-OT	Average
Spruce	42·3	19·6	11·8	20·4
Balsam	23·8	27·9	7·8	23·0
Total	66·1	47·5	19·6	43·4
Y. Birch	3·0	10·5	22·9	12·3
All Hardwoods	6·2	14·8	32·1	17·6

* Obtained by addition of mortality to net annual increment.

TABLE 11

Average Age at Breast Height of Trees of Selected Diameters

Diameter	2″	6″	10″	14″	18″
Red Spruce					
CoT	18	48	87		
O-CoT	15	49	83	117	151
Vi-OT	22	63	90	104	112
Balsam Fir					
CoT	16	53	70		
O-CoT	13	44	67		
Vi-OT	21	50	89		

years old, spruce 70 years; at 10 inches balsam fir is more than 70 years, spruce is nearly 90. Stands of balsam fir, however, do not necessarily grow faster than spruce. Besides, Westveld (8) questions the ultimate value of faster growth rate in balsam fir because the yield is offset by smaller cellulose content, pest depredations, butt rot and wind breakage. Certain sites however, found to be optimum for this species, can be very productive, such as the Oxalis-Cornus type at Lake Edward.

Defect

Butt rot is very extensive in balsam fir and a relationship with site suggests that competition is a factor. If this is the case some improvement could be obtained through thinnings and frequent cutting to eliminate those periods of stagnation which evidently leave the trees more susceptible. Butt rot in balsam fir is also said to be associated with lime content in the soil. More lime was found in soil samples from Lake Edward than in the Adirondacks (3), and the lime content is greater in the soils of richer sites (4), which is another possible reason for the high incidence.

Attempts to estimate the occurrence of rot and defect were made at the time of plot measurement in 1936 and 1946. One method was to sound the spruce and balsam trees for butt rot by tapping with an axe; another method was to note those trees with serious visual defect. The results of both methods tried concurrently in 1946 are nearly the same, the average volumes of all the trees so tallied being 129 and 150 cubic feet per acre respectively. Many of these trees would of course still be utilized except for a short length of butt. About half, or an average of 75 cubic feet per acre, should cover the loss in volume from this source.

The same relationships were found in 1946 as in the previous period. Butt rot increases as the site improves and the percentage of occurrence is twice as great in balsam fir as in spruce. An increase was noted in the Co and O-Co types after 1936, particularly in balsam fir, which emphasized the necessity for cutting as soon as possible.

Reproduction

Seedling counts at present do not contribute very much to the growth study because the forest is mature, uneven-aged and obviously quite well stocked. With early cutting in prospect there seemed to be little advantage in changing to the stocked quadrat, or present standard method, until at least the first remeasurement after cutting. A similar seedling count was made therefore in 1946 of all species less than 0·6 inch d.b.h. on a rod square (16½ feet) sub-plot, which gives an average number per acre without regard to distribution.

The number of saplings one to three inches taken from the stand tables for the years 1925 and 1946 are given in Table 13.

Seedling mortality and replacement goes on in cycles until a break occurs in the overhead canopy; then advance growth of red spruce, sugar maple and yellow birch develops rapidly. Afterwards, however, or if the openings are very large, balsam fir, white birch and pin cherry seed in and may become numerous on the poorer sites. Mountain maple and striped maple come in densely on the richer sites under similar conditions.

TABLE 12

Reproduction Summary

Number of Seedlings per Acre, 1936

Species	CoT	O-CoT	Vi-OT
Spruce	352	344	350
Balsam	342	1,275	849
Total	694	1,619	1,199
Other Softwoods	107	67	2
All Softwoods	801	1,686	1,201
White Birch	42	11	4
Yellow Birch	—	8	63
Red Maple	24	11	75
Sugar Maple	—	15	657
Others	—	11	19
Total	66	56	818
All Species	867	1,742	2,019

1946

Species	CoT	O-CoT	Vi-OT
Spruce	272	321	245
Balsam	2,260	2,276	510
Total	2,532	2,597	755
Other Softwoods	113	102	2
All Softwoods	2,645	2,699	757
White Birch	28	25	2
Yellow Birch	—	62	158
Red Maple	19	137	261
Sugar Maple	—	65	1,341
Others	—	13	44
Total	47	302	1,806
All Species	2,692	3,001	2,563

Results of the seedlings counts are consistent with the site-types. The most important difference between 1946 and 1936 is the very large increase in the numbers of balsam fir seedlings in the Cornus and Oxalis-Cornus types. A corresponding decrease of balsam fir in the Viburnum-Oxalis type is more than made up for by sugar maple; and the totals of "all species" are considerably more than those of 1936, which is to be expected considering the more advanced state of deterioration of the main stand.

Spruce seedlings alone survive throughout all three types in about the same numbers, 250 to 320 per acre, while balsam fir varies from 500 to 2,300. Shrubs and hardwoods suppress coniferous seedlings particularly in the Vi-O type, and balsam fir may do likewise for a while in the Co type, but neither entirely prevent spruce regeneration.

Spruce shows more tenacity after the seedling sta e. The variation in the numbers of spruce saplings, one to three inches d.b.h., among site-typ s is somewhat larger than it is for seedlings but the numbers in 1946 compare fairly well with balsam fir, an average of 173 spruce to 251 balsam fir. That is, spruce

TABLE 13

Number of Saplings per Acre, 1"-3" d.b.h.

1925

	CoT	O-CoT	Vi-OT	Average
Spruce	419	247	132	240
Balsam	534	370	103	330
Total	953	617	235	570
Other Softwoods	83	67	10	56
All Softwoods	1,036	684	245	626
Yellow Birch	10	39	46	37
Other Hardwoods	156	90	67	92
All Hardwoods	166	129	113	129
All Species	1,202	813	358	755

1946

	CoT	O-CoT	Vi-OT	Average
Spruce	364	155	136	173
Balsam	618	258	46	251
Total	982	413	182	424
Other Softwoods	81	32	—	30
All Softwoods	1,063	445	182	454
Yellow Birch	6	17	18	16
Other Hardwoods	90	53	99	67
All Hardwoods	96	70	117	83
All Species	1,159	515	299	537

comprises 41 per cent of the saplings, compared to only 15 per cent of the seedlings. Thus balsam fir loses its early advantage as time goes on provided the forest retains its natural state.

No yellow birch or sugar maple were tallied in the Cornus type in 1936 or in 1946. These species enter the O-Co type with about 60 per acre; yellow birch increases to 150 and sugar maple to 1,300 per acre in the Vi-O type. The seedlings are therefore very good indicators of site and a very useful supplement to the ground vegetation in site identification.

Cutting Operations 1950

The last survey, made in 1946, clearly showed that the forest was ready to cut. Rate of growth was still high; but much of the balsam fir had reached maturity, and an unduly large quantity had blown down, or broken off as a result of butt rot. Many spruce had reached a very large size and were ready for harvesting. Furthermore, the budworm was present on the balsam fir—fortunately with little further damage. The birch was affected by die-back, though this too had apparently been arrested. Obviously it was time to start cutting to avoid wasting a large quantity of valuable timber by neglect.

Accordingly, arrangements were made with the Consolidated Paper Corporation to start a cutting experiment in accord with silvicultural principles, and of immediate practical value. Although it was against Corporation policy to sell softwood stumpage, and even though the area would not have been reached in the regular cutting program for at least another 20 years, a partial cut in softwoods and hardwoods was agreed upon. The results of the survey used in planning the cutting experiment showed that if one-third of the volume of softwoods were removed, the rate of growth was high enough to restore it in 25 or 30 years. In other words, what was cut now would be restored in the time it would take to reach the area as originally planned.

The cutting system was to cut heavily in balsam fir and favour the thrifty spru e. All hardwoods suitable for the market were to be cut too. In 1950-51, the first year of operation, control was established by diameter limits at the stump of 14 inches for spruce and 10 inches for balsam. Examination the following summer showed too much spruce being cut and not nough balsam fir, so the limits were changed to 16 inches and 8 inches respectively, which also gave a larger cut. The average volume above the 14- and 10-inch limits was estimated at 550 cubic feet per acre; above the 16- and 8-inch limits, 577 cubic feet. The diameter limit for yellow birch was also set at 16 inches; other hardwoods could be cut without restriction.

The average of the first three years o erations gave a cut of approximately 770 cubic feet (converted to total volume from scaling returns) of spruce and balsam per acre—equal to about 90 per cent of the volume increment between 1925 and 1950. This compares with 492 and 277 cubic feet (merchantable volume) removed in 1890 and 1910 respectively, the total being 769 cubic feet. The discrepancy between the estimate and the actual cut is believed to be due to the additional amount cut in roads and landings; also to the fact that the best part of the area has been cut. The yield will undoubtedly fall off as operations extend to the east shore of the lake where the timber volumes are somewhat lower than average.

However, the cutting is spread more uniformly over the area instead of in patches as before. Therefore recovery and growth should be better and without the heavy mortality from overmature trees. It seems reasonable to expect that the volume now being cut will be replaced during the next 25 years. In the meantime, each year's cut is being checked, the area mapped, and the line-plots within the area tallied.

Table 14 shows the volume in each type.

TABLE 14

Estimated Volume before Cutting, 1950

Total Cubic Feet per Acre

	CoT	O-CoT	Vi-OT	Average for area
Spruce and Fir	2,170	1,785	783	1,601
Other Softwoods	200	137	—	113
All Softwoods	2,370	1,922	783	1,714
Yellow Birch	81	806	1,803	966
Other Hardwoods	208	250	575	313
All Hardwoods	289	1,056	2,378	1,279
All Species	2,659	2,978	3,161	2,993

N.B.—These figures are derived from the 1946 survey adjusted for 4 years' additional growth at the same rate as in the period 1936-46.

The choice of diameter limits had to be made according to the requirements of the most widespread type, the Oxalis-Cornus (62 per cent of the area). Had it been practical to differentiate, balsam fir would have been cut without restriction in the Cornus and Viburnum-Oxalis types, spruce would have been cut to a 12-inch diameter in the Cornus type and not at all in the Viburnum-Oxalis, unless tree marking had been possible. However, the present diameter limits are not too far removed from what is considered to be sound silvicultural practice.

The volume of spruce and balsam estimated to be available for cutting under the limits in force is as follows:

TABLE 15

Volume above Diameter Limit, 1950

Total cu. ft. per acre, Spruce 16", Balsam 8"

Type	Species	Cu. ft. per acre
CoT (Softwood)	Spruce	38·7
	Balsam	298·6
Total		337·3
O-CoT (Soft-Hardwood)	Spruce	79·8
	Balsam	647·7
Total		727·5
Vi-OT (Hard-Softwood)	Spruce	131·5
	Balsam	224·1
Total		355·6

N.B.—Stump diameters used in practice are equivalent to 14" and 7" d.b.h.

Brief mention of this cutting operation is in order now; a report will follow when it is finished and when all the plots have been remeasured.

DISCUSSION

Each of the periods into which the cutting cycle has been divided shows very definite characteristics: a decrement in this first owing to heavy mortality; very rapid growth in the second after the thrifty young trees were released; and a sharp falling-off in the third as balsam fir reached maturity and began to die. Two principal facts emerge from the data which portray these trends: that cutting in 1950 was some 10 years overdue, therefore a cycle of 30 years would have been better than 40; and that spruce and balsam regenerate after that method of cutting on all but the richest sites in spite of hardwood competition.

At first, it appears anomalous that the growth of spruce and balsam slows down as the site improves, both in volume and in per cent. Actually it must be owing solely to competition with hardwoods because the best tree specimens are still found on the richest sites. Naturally these sites invite a larger number and variety of competitors, and possession is the result of conflict from the very earliest stages in regeneration. Also the net periodic growth rate of spruce and balsam, reaching a maximum of 58 cubic feet per acre per annum in one type, can exaggerate the impression of growth unless evaluated with the average increment for all types for the whole cycle, in this case only 18·5 cubic feet.

A giant yellow birch in the Viburnum-Oxalis type, 42 inches in diameter and 80 feet in height.

The net periodic rate is definitely short term. Therefore greater weight attaches to the average if a large area is involved, and for a longer time.

As a result of the different reactions of the site-types to disturbance, certain recommendations for cutting are possible which, it is believed, will tip the balance in favour of the most desirable species—spruce, balsam and yellow birch.

The Cornus type, as previously described, is mostly red spruce, frequently with thick balsam fir reproduction which often develops rather poorly. There is some white birch but practically no tolerant hardwoods, and in spite of being the poorest in absolute site quality, it produces the highest yields of softwood. As little danger of invasion by tolerant hardwoods or shrubs exists, balsam fir could be clear-cut and spruce could be safely cut to somewhat lower diameter limits than at present, perhaps 10 inches or 12 inches, instead of 16 inches. However, some shade must be retained to prevent white birch and cherry from filling in large openings.

The Oxalis-Cornus type, occupying undulating ground and moderate slopes, supports good growth of spruce, fir and yellow birch and on the whole is more inclined to favour softwoods. Balsam fir finds optimum conditions, and yellow birch also attains large size with good form. This type offers far the best possibilities for intensive silviculture; conversely, unrestricted logging may do it the most harm. As competition is keen between various types of vegetation, including softwoods and hardwoods, changes can be effect d by proper measures. For instance, if too large openings were made the forest would degenerate into shrubs, cherry and some white birch, and these would be interspersed with patches of decadent yellow birch providing shade but also suppressing other younger and more valuable trees underneath. Cover is necessary for spruce and yellow birch regeneration. Spruce should be cut sparingly and allowed to reach a fairly large size, both for growth and for seed production, and there should be definitely two rotations of balsam fir to one of spruce. The richest varieties of the type are more inclined to hardwoods, the poorer to softwoods.

The Viburnum-Oxalis type is definitely more favourable for hardwoods and only red spruce competes successfully with the yellow birch, maple and beech. Sugar maple appears numerically strong in this type and its heavy regeneration and dense leaf-litter probably hinder the establishment of other species. On the other hand, when the spruce and the occasional balsam do break through this competition, they may produce the finest and tallest specimens found in any type; growth is more rapid, and ability to recover from long periods of suppression is more marked. Thrifty young spruce should be preserved because they continue to grow with undiminished vigour up to at least 25 inches and to ages exceeding 300 years. Scarification of the ground is thought to be desirable to obtain reproduction of spruce and yellow birch but autumn logging might achieve, to some extent, the same result. Balsam fir could be clear-cut because of its short life and inability to withstand prolonged suppression.

The relationships between spruce and balsam are brought out clearly by the site-types. The intimate association of these speci s in the forest and the relative usefulness of their wood products, whether as pulpwood or lumber, tend to lessen the importance of making the distinction. In the boreal forest, smaller trees, slower growth, absence of red spruce and of hardwood competition somewhat obscure the advantages of spruce, but failure to appreciate them in the tolerant hardwood zone will give poor results. Spruce is the most stable spe ies, which is a point worth noting when cutting is being planned.

On the other hand balsam fir deteriorates through successive blow-down and insect attacks, especially when deprived of support from other species. After widespread clear-cutting or too low diameter limits, and especially when spruce and balsam ar cut to the same limit, balsam fir will become numerous.

Stump of red spruce cut in 1950, measuring 25 inches in diameter, 90 feet in height, and 250 years of age, in the Viburnum-Oxalis type. At 170 years of age, it was only 10 inches in diameter.

When balsam fir is at or near maturity, spruce is approaching its period of best growth. From the age data collected, it would seem that the rotation age for balsam should be not less than 60 years, nor less than 120 for spruce.

Also, being more resistant to decay, insect attack, and blow-down, spruce maintains a reasonably fast rate of growth up to a very great age. For example, a red spruce stump 25 inches in diameter, 90 feet high, and 250 years of age, seen in the Viburnum-Oxalis type, had most of its diameter growth added after the age of 170 years. Up to that time it had grown under suppression to only 12 inches in diameter. This is not exceptional.

Balsam fir may produce higher yields than spruce if cut frequently enough to save the mortality. Balsam fir growing stock in the Oxalis-Cornus type at Lake Edward is still greater than spruce but the margin had shrunk considerably by 1946. In the other types, spruce considerably increased it lead, so that the average for the three types became nearly the same for both species. There is little doubt that spruce volume would exceed balsam fir in a very few years even in the Oxalis-Cornus type if the forest remained free from cutting or other major disturbance. Westveld's conclusions (8) are much the same for similar situations in the Northeast.

The future appears decidedly more favourable for softwoods than for hardwoods except in the Viburnum-Oxalis type, because they grow faster and invade hardwood sites to a greater extent. The future of yellow birch is som what obscured on account of poor reproduction and possibly competition from sugar maple seedlings. Although softwood growth rate is falling off because of increasing mortality in balsam fir, hardwood suppression is known now to be less formidable than formerly expected, and with hardwood cutting in progress the effects will likely be reduced in the future. Net growth may be slow for the first 10 years, then it could pick up sharply and perhaps exceed anything in the past.

Shading is evidently necessary to secure reproduction of spruce and ye low birch. Conifers will eventually reproduce in the Cornus type regardless of what happens, but reproduction is hastened if weed species can be kept out. Still heavier growth of shrubs, cherry, white birch and red maple can be foreseen in the Oxalis-Cornus type after clear cutting; and even under favourable conditions balsam fir will be much more numerous than spruce, sometimes in thickets. Shade and preservation of seed trees are particularly important in the Viburnum-Oxalis type and the ground needs scarification or some sort of treatment to bring in yellow birch. Every type and every aspe t underlines the fact that adequate forest cover should be maintained at all times.

To what extent has the study solved the problems set forth at the time of establishment of the experimental area? Naturally not entirely, but two questions at least may be answered.

Howe wrote in 1918:*

> We want to increase the production of spruce, the most valuable species at present on this cut-over land, or at least we would like to restore it to its former position in the forest. How can this be done?

Spruce regeneration is much slower than balsam fir after cutting, but the conditions after the 1910 logging, bad as they seemed at the time, were actually beneficial in the long run. Evidently therefore spruce restoration is assured if enough shade is left for the reproduction, and if the smaller though merchantable spruce trees up to 10 or 12 inches in diameter are left standing.

Again, Wright in 1921 asks:*

> When may we expect another crop on cut over lands, and what factors influence the length of time required to get it?

* Quoted from correspondence.

After cutting to the regulation diameter limits (spruce 10 inches, balsam 7 inches), a return cut was obtained on 70 per cent of the area within 40 years and cutting could have started some ten years sooner. The factors deciding the interval between cuts are, in the long run, economic, but greater yield and better quality are incentives for frequent light cuts on the right sites. Short cutting cycles become more practical as the market for wood improves and as roads are extended into the forest.

Finally, while the immediate objective was to obtain information on regeneration after cutting, it was hoped that the results could ultimately influence a change-over from "extractive" to "reproductive" forestry far beyond the borders of the experimental area. The way is now open to apply these findings more widely.

CONCLUSIONS

Observations in the field, and study of the data taken in the three line-plot surveys extending over a period of nearly 40 years, lead to the following conclusions:

1. Ground cover indicator species proved effective in differentiating site-types. The correlations found in the 1936 survey with respect to volume, increment, regeneration, species distribution, height growth, and defect were fully supported by the additional data of 1946. The development of the forest in each site-type is now sufficiently well known to influence the choice of cutting method.
2. Spruce and balsam have regenerated well enough in the 40 years since the first pulpwood cutting (diameter limits, 10 inches and 7 inches respectively) to produce a larger growing stock than ever before. A second cut using higher diameter limits began in 1950. Heavy mortality is not likely to be repeated following the present cut as most of the balsam fir is being taken out. Yet, even though some loss should occur, the shading so provided during those early critical years would suppress shrubs and thus assist the new stand to become established.
3. The growth rate for spruce and balsam was, on the average, four times that of hardwoods during the period for which data are complete (1925-46). Hardwoods would likely be stimulated in the Viburnum-Oxalis type, where their growth rate equals that of softwoods, if hardwood cutting were carried out at the same time. This type covers 20 per cent of the area and is one type (of the three main ones) where hardwoods predominate in volume.
4. To obtain maximum yields, cutting should take place at least every 30 years, not 40 years as at present; and there should be two rotations of balsam fir to one of spruce. Balsam fir should be cut at 60 to 80 years of age, and spruce at 120 to 160 years, with variations according to site.
5. Spruce is steadily increasing, with a rising growth rate and diminishing mortality, whereas mature balsam fir is breaking up rapidly.
6. The hardwood forest is deteriorating slowly. The great age to which yellow birch and maple can attain results in a persistent population of defective trees of little or no commercial value. Silvicultural measures would speed their removal to advantage. Logging unfortunately removes only the best, though it does leave a considerable amount of crown cover, whose openings should provide opportunity for advance growth to develop. There is still a field for girdling if fuelwood cutting is uneconomical.

7. Reproduction of spruce, balsam fir, yellow birch and maple is satisfactory under the overhead canopy, especially when it thins out naturally. Hardwoods outnumber spruce and balsam only on the hardwood sites. Competition on most of the area is between desirable species and the underbrush, rather than between conifers and hardwoods.
8. The potential growth rate of the forest is high enough to warrant more intensive silviculture, and this possibility has been greatly extended by the recent increase in value of hardwoods.

SUMMARY

The Lake Edward Experimental Area, five square miles in area, was established in 1918. It is situated some 15 miles northwest of Grand'Mere, Quebec and six miles west of the St. Maurice River, on the limits of the former Laurentide Pulp and Paper Company, now part of the Consolidated Paper Corporation. It is in the Great Lakes—St. Lawrence forest region and is typical of the southern forest which supplies a great deal of pulpwood in addition to most of the sawlogs and hardwood cut in the province. The purpose of establishment was to study growth after cutting for pulpwood.

Spruce and pine sawlogs were cut about 1890, and pulpwood about 1910 and 1912. Though balsam fir has always been used for pulpwood, the mills would not at first accept more than 25 per cent of it in total pulpwood offered. Much merchantable wood, therefore, above the regulation diameter limits then in force (spruce 10 inches, balsam fir 7 inches) was left uncut.

A considerable amount of experimental work was done between 1918 and 1928: girdling hardwoods to release conifers, seed-bed treatment, thinnings, and release cuttings. The effects of treatment were followed through the establishment and remeasurement of some 50 permanent sample plots.

It was most urgent to discover how long it would take for spruce and balsam to regenerate after cutting, and whether silvicultural treatment was required to restore those species to their former place in the stand. The prospects appeared very unpromising for a return cut within a reasonable time because hardwoods and underbrush, undisturbed by cutting, threatened to choke out the softwoods.

Accordingly, a growth study was begun in 1924. Two years later some 300 fifth-acre plots had been laid out. For various reasons these were replaced in 1936 with a grid of tenth-acre plots. These were remeasured in 1946, and will continue to be used in the future.

The site-type classification was introduced in 1936; all the data taken before and after that date were worked up on the basis of the three types covering more than 90 per cent of the area: Cornus (softwood) 19 per cent, Oxalis-Cornus (soft-hardwood) 62 per cent, and Viburnum-Oxalis (hard-softwood) 20 per cent. These site-types divide off the hardwood sites from those which are more favourable to conifers. The correlations among these types are dealt with by Sisam (7) and Ray (6).

From a period of slow growth and heavy mortality between 1910 and 1925, the forest entered upon a period of very rapid growth which continued until 1946. Exact figures for the residual volume of the stand in 1910 are not available; but in 1925, the volume of spruce and balsam, averaged for the three types, was 736 cubic feet per acre (1 inch and up, total volumes). The volume increased to 1,178 cubic feet in 1936, and to 1,484 cubic feet in 1946, or twice what it was in 1925. Corresponding increase in volume of all hardwoods has only been from 1,060 cubic feet in 1925 to 1,233 cubic feet in 1946.

Heavy mortality was recorded in spruce and balsam between 1910 and 1925 (34 cubic feet annually), and very little mortality between 1925 and 1936 (8·8 cubic feet), but it began to show up again in 1946 (13 cubic feet). Mortality in spruce dwindled to 2 cubic feet between 1925 and 1926; in balsam fir it dropped to 6 cubic feet between 1925 and 1936, but increased to 11 cubic feet between 1936 and 1946. Consequently, the proportion of spruce is increasing considerably in relation to balsam fir. Yellow birch has been affected by dieback, so far with very little mortality—only 7 cubic feet per acre between 1936 and 1946.

The net annual increment of spruce and balsam for the period 1915-25 (estimated by increment borings corrected for mortality) was negative, with a loss of 11·6 cubic feet per acre; for 1925-46 net increment was 35·7 cubic feet per acre annually. By averaging these figures for the whole cycle between cuts, namely 1910 and 1950, the average net annual increment for spruce and balsam is 18·5 cubic feet. This applies to 92 per cent of the area, the remainder being pure hardwood (two per cent) and unmerchantable swamp. The net annual increment for hardwoods is only 8·0 cubic feet, or less than one-half the amount for spruce and balsam in the same period. Mortality between 1910-1950 amounted to 70 per cent of the final yield in 1946.

This early work has now served its purposes. Hardwoods, it was learned, are no match for red spruce and balsam fir except on the richest sites, which comprise not more than one quarter of the area. Even there, red spruce will often regenerate and overcome suppression. The forest was ready for the next cut 30 years after the first pulpwood cutting, although actually cutting began 10 years later, and this recovery combined with the recent hardwood operations has altered the picture completely.

More intricate problems of economics and silviculture to stimulate regeneration and growth of the most valuable species are now involved. To solve them requires a background of data built up over a long term by regular measurement and frequent observation.

The findings apply specifically to the Lake Edward area where they are being tested in the form of experimental cutting, but they are not without significance elsewhere in the same forest region, as the same types occur throughout the Algonquin-Laurentides Section L-4A.

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APPENDIX I

Indicator Value of the Vegetation

INDICATOR VALUE OF THE VEGETATION

Heimburger stated as follows:

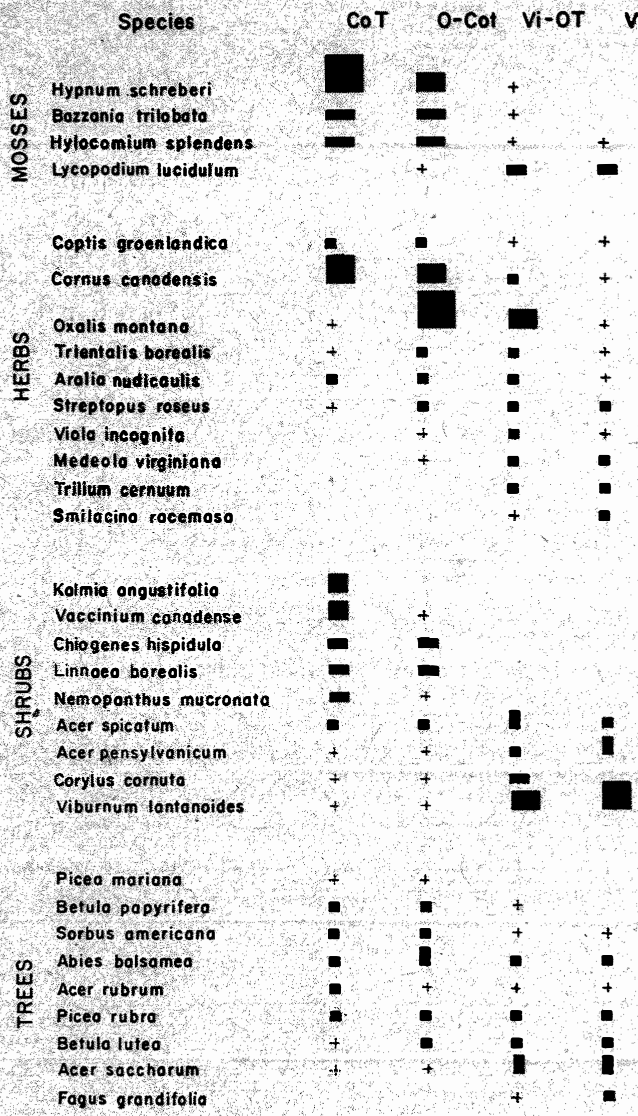
> The occurrence and degree of cover of the main plants of the ground vegetation is represented graphically in Fig. 1. The plants are in each group arranged according to their increasing demands upon the quality of site, much in the same manner as in the former study (Heimburger, 1934). As the vegetation was analysed by means of the Raunkiaer ring on all the sa ple areas comprising the present study, the data are more directly comparable an in former work. Because the material obtained so far is much too inadequate for a regional representation of the site require ents of the main plants, their order in the graph cannot be taken as final. The main trends, however, stand out clearly, and are almost identical with those of the western type series of the Adirondacks. All the main species of the ground vegetation can be subdivided into four groups, namely, (1) indicators of poorer, softwood-producing sites, (2) those occurring mainly on medium rich sites, (3) indicators of rich, hardwood sites, and (4) species occurring with about equal abundance and degree of cover on all the sites, and therefore poor indicators of s te within the material sampled. [Table 16]

Heimburger's estimates of cover were transformed by Dr. Andre Linteau into total estimate, which is a comprehensive rating of cover and abundance by Braun-Blanquet (1932). This was accomplished by consideration of Heimburger's figures and of personal observations of this character of the main plants at Lake Edward. The accompanying chart (Figure 8) includes the sociability of the same plants. By this is meant the grouping of the plants "whether the species stand close together in mass formation and thus cover the ground in patches or are wholly isolated and stand scattered among each other in motley mixture".

The consideration of both total estimate and sociability enables one to imagine more clearly how the various site-types appear in the field and constitutes a good check for one who has to apply the technique.

Figure 8

TOTAL ESTIMATE AND SOCIABILITY OF THE MAIN PLANTS
in
THE SITE-TYPES AT LAKE EDWARD



Total Estimate (Vertical Scale)		Sociability (Horizontal Scale)	
+	Sparse	1	Growing singly
1	Plentiful	2	Grouped or in tufts
2	Very numerous	3	In groups or small patches
3	Covering 1/4 to 1/2 area	4	In small colonies, extensive patches or forming carpet
4	Covering 1/2 to 3/4 area	5	In great crowds or pure populations
5	Covering more than 3/4 area		

TABLE 16

Indicator Value of Single Species

Indicators of poor sites	Indicators of medium rich sites	Indicators of rich sites	Poor indicators of site
Mosses and Hepatics			
Bazzania tribolata			
Hyloconium splendens			
Hypnum schreberi			Brachythecium spp.
Pteridophytes			
		Lycopodium lucidulum	Thelypteris spinulosa
Herbs			
Coptis groenlandica	Aralia nudicaulis	Medeola virginiana	Aster acuminatus
Cornus canadensis	Oxalis montana	Smilacina racemosa	Clintonia borealis
	Trientalis borealis	Streptopus roseus	Goodyera repens
		Trillium cernuum	Maianthemum canadense
		Viola incognita	Monotropa uniflora
			Rubus pubescens
			Trillium undulatum
Dwarf-shrubs			
Chiogenes hispidula	Linnaea borealis		Taxus canadensis
Kalmia angustifolia			
Vaccinium canadense			
Shrubs			
Nemopanthus mucronata		Corylus cornuta	Acer spicatum
		Viburnum lantanoides	Lonicera canadensis
Tree seedlings			
Betula papyrifera	Betula lutea	Acer pensylvanicum	Abies balsamea
Picea mariana		Acer saccharum	Acer rubrum
			Picea rubra
Sorbus americana		Fagus grandifolia	Thuja occidentalis

APPENDIX II

Stand and Stock Tables

Lake Edward Forest Experimental Area — 1925 and 1946

TABLE 17

LAKE EDWARD EXPERIMENTAL AREA — 1925

STAND AND STOCK TABLE, PER ACRE

CORNUS TYPE

BASIS: 35 plots (1/5 acre)

D.B.H. Class	Spruce	Balsam	Spruce & Balsam	Cedar	Other Softwoods	Total Softwoods	White Birch	Yellow Birch	Maple	Other Hardwoods	Total Hardwoods
					Number of Trees						
1	232·[illegible]	336·0	568·0	49·7		617·7	68·3	3·4		4·1	75·8
2	120·0	141·0	261·0	25·5		286·5	53·8	4·8	2·5		61·1
3	07·0	57·3	124·3	7·6		131·9	26·9	2·1	1·0		30·0
1–3	419·0	534·3	953·3	82·8		1,036·1	149·0	10·3	3·5	4·1	166·9
4	32·8	33·0	65·8	4·3	·2	70·3	9·7	2·1	·5		12·3
5	21·2	20·8	42·0	2·2	·2	44·4	5·9	·9			6·8
6	21·0	15·2	36·2	1·7		37·9	2·8	·5			3·3
7	13·1	10·9	24·0	3·3		27·3	2·6	·2	·2	·2	3·2
8	8·4	5·2	13·6	1·6		15·2	·3		·3		·6
9	4·8	2·2	7·0	·7		7·7	·5	·7			1·2
4–9	101·3	87·3	188·6	13·8	·4	202·8	21·8	4·4	1·0	·2	27·4
10	1·9[illegible]	·69	2·5[illegible]	1·21		3·80	·69	·17			·86
11	·52	·52	1·04	·34		1·38	·52				·52
12	·86	·17	1·[illegible]3	·52		1·55	·52				·52
13	·34		·34	·34		·68	·52				·52
14	·52		·52	·34		·86	·52	·52			1·04
15	·34		·34	·17		·51	·34				·34
16				·17		·17					
17							·17				·17
18	·17		·17			·17					
19											
10+	4·7	1·4	6·0	3·1		9·1	3·3	·7			4·0
Total	525	623	1,148	100	—	1,248	174	15	5	4	198
					Total Volume in Cubic Feet						
1–3	84·4	81·6	166·0	12·9		178·9	30·1	3·6	1·4	·2	35·3
4–9	328·6	247·2	575·8	41·7		618·1	57·2	16·3	4·0	·9	78·4
10+	84·6	19·6	104·2	52·5		156·7	72·7	17·5			90·2
Total	497·6	348·4	846·0	107·1	·6	953·7	160·0	37·4	5·4	1·1	203·9

TABLE 18

LAKE EDWARD EXPERIMENTAL AREA — 1925
STAND AND STOCK TABLE, PER ACRE
OXALIS-CORNUS TYPE

BASIS: 216 plots (1/5 acre)

D.B.H. Class	Spruce	Balsam	Spruce & Balsam	Cedar	Other Softwoods	Total Softwoods	White Birch	Yellow Birch	Maple	Other Hardwoods	Total Hardwoods
					Number of Trees						
1	139·0	218·0	357·0	43·7		400·7	39·5	15·0	9·0	·9	64·4
2	74·9	104·0	178·9	15·6		194·5	20·1	14·7	8·3	·3	43·4
3	33·5	48·2	81·7	7·1		88·8	9·5	9·1	3·2		21·8
1–3	247·4	370·2	617·6	66·4		684·0	69·1	38·8	20·5	1·2	129·6
4	15·8	28·8	44·6	2·6	·2	47·4	5·7	5·7	2·2	·2	13·7
5	10·6	20·6	31·2	1·8	·2	33·2	3·8	4·5	1·3	·1	9·7
6	8·7	16·1	24·8	1·3		26·1	3·1	3·6	1·2	·2	8·1
7	6·0	11·6	17·6	·9		18·5	1·7	3·4	·9	·0	6·0
8	6·1	8·0	14·1	·7	·1	14·9	1·4	2·8	·4	·0	4·6
9	3·1	4·5	7·6	·7		8·3	1·2	2·6	·3		4·1
4–9	50·3	89·6	139·9	8·0	·5	148·4	16·9	22·6	6·3	·5	46·2
10	2·34	3·12	5·46	·68		6·14	·88	2·24	·18	·04	3·34
11	1·13	1·41	2·54	·45		2·99	·72	1·56	·09	·04	2·41
12	·75	·86	1·61	·45		2·06	·95	2·12	·14	·02	3·23
13	·50	·20	·70	·41		1·11	·68	1·36	·09	·02	2·15
14	·25	·18	·43	·39	·07	·92	·48	1·61	·04		2·13
15	·16	·02	·18	·39		·57	·14	1·27	·02		1·43
16	·07	·02	·09	·09		·18	·02	1·20	·02		1·24
17		·04	·04	·09		·13	·07	·84			·91
18		·02	·02	·09		·11	·02	·72			·74
19	·04		·04	·04		·08	·07	·54			·61
20				·04		·04	·02	·36		·02	·40
21								·43			·43
22								·41			·41
23				·02		·02		·24			·24
24								·18			·18
25								·09			·09
26								·09			·09
27								·07			·07
28								·02			·02
30								·04			·04
33								·02			·02
10 +	5·3	5·9	11·2	3·1	·1	14·3	4·0	15·4	·6	·1	20·1
Total	303	466	769	77	·6	847	90	77	27	2	196
					Total Volume in Cubic Feet						
1–3	48·2	64·2	112·4	10·0	·1	122·5	11·5	13·9	4·0		29·4
4–9	179·8	310·0	489·8	23·1	1·3	514·2	58·1	108·0	20·7	1·6	188·4
10 +	92·7	98·3	191·0	56·5	4·4	251·9	85·1	551·9	11·6	4·1	652·7
Total	320·7	472·5	793·2	89·6	5·8	888·6	154·7	673·8	36·3	5·7	870·5

TABLE 19

LAKE EDWARD EXPERIMENTAL AREA — 1925
STAND AND STOCK TABLE, PER ACRE
VIBURNUM-OXALIS TYPE

BASIS: 70 plots (1/5 acre)

D.B.H. Class	Spruce	Balsam	Spruce & Balsam	Cedar	Other Softwoods	Total Softwoods	White Birch	Yellow Birch	Maple	Other Hardwoods	Total Hardwoods
Number of Trees											
1	81·6	62·2	143·8	8·0	·3	152·1	3·1	14·1	32·0	2·5	51·7
2	35·1	29·6	64·7	2·2		66·9	2·5	18·5	14·8	1·2	37·0
3	15·4	11·7	27·1	·3		27·4	1·2	13·5	8·3	1·5	24·5
1–3	132·1	103·5	235·6	10·5	·3	246·4	6·8	46·1	55·1	5·2	113·2
4	10·3	12·5	22·8	·4		23·2	1·5	7·6	5·4	1·4	15·9
5	6·5	10·7	17·2	·5		17·7	1·3	6·1	3·5	1·3	12·2
6	5·8	7·4	13·2			13·2	·9	6·1	3·1	2·2	12·3
7	3·2	5·4	8·6	·2		8·8	·6	5·9	2·8	1·1	10·4
8	3·2	3·5	6·7	·2	·1	7·0	·2	5·4	2·0	·8	8·4
9	3·0	2·3	5·3			5·3	·5	5·0	1·5	·8	7·8
4–9	32·0	41·8	73·8	1·3	·1	75·2	5·0	36·1	18·3	7·6	67·0
10	1·85	·77	2·62			2·62	·23	3·77	1·46	1·16	6·62
11	1·23	·54	1·77			1·77	·08	3·23	·85	·23	4·39
12	1·62	·38	2·00	·08		2·08	·23	2·84	1·38	·62	5·07
13	·54	·38	·92	·23		1·15	·08	3·[illegible]0	1·00	·38	4·46
14	·54	·08	·62			·62	·08	3·00	1·08	·23	4·39
15	·23		·23			·23	·15	2·08	·85	·08	3·16
16	·38	·08	·46	·08		·54	·15	2·00	·69	·23	3·07
17		·08	·08			·08		2·16	·62	·08	2·86
18				·08		·08		2·38	·23	·08	2·69
19							·08	1·62	·23		1·93
20	·15		·15			·15		1·69	·08	·08	1·8[illegible]
21								·92	·23		1·15
22		·08	·08			·08		·69	·15		·84
23								·23	·08		·31
24								·69			·69
25								·54			·54
26								·31			·31
28								·15			·15
29								·15			·15
31								·15			·15
32								·08			·08
10+	6·5	2·4	8·9	·5		9·4	1·1	31·7	8·9	3·2	44·9
Total	171	148	318	12		331	13	114	82	16	225
Total Volume in Cubic Feet											
1–3	22·5	17·0	39·5	1·1		40·6	1·3	18·1	9·6	1·6	30·6
4–9	121·0	148·2	269·2	3·2	·5	272·9	17·1	199·2	69·1	38·6	324·0
10+	142·7	55·6	198·3	10·3		208·6	27·7	1,349·2	269·2	80·3	1,726·4
Total	286·2	220·8	507·0	14·6	·5	522·1	46·1	1,566·5	347·9	120·5	2,081·0

TABLE 20

LAKE EDWARD EXPERIMENTAL AREA — 1946
STAND AND STOCK TABLE, PER ACRE
CORNUS TYPE

BASIS: 34 plots (1/10 acre)

D.B.H. Class	Spruce	Balsam	Spruce & Balsam	Cedar	Other Softwoods	Total Softwoods	White Birch	Yellow Birch	Maple	Total Hardwoods
Number of Trees										
1	113·0	264·0	377·0	28·5		405·5	25·0	·9		25·9
2	148·0	236·0	384·0	33·8	·3	418·1	35·0	2·1	2·4	39·5
3	103·0	118·0	221·0	17·6	1·5	240·1	23·5	3·2	3·5	30·2
1–3	364·0	618·[illegible]	982·0	79·9	1·8	1,063·7	83·5	6·2	5·9	95·6
4	74·1	60·3	134·4	15·9	·6	150·9	14·1	·9	2·9	17·9
5	60·3	31·8	92·1	6·5	·9	99·5	9·7	1·8	1·2	12·7
6	41·2	24·4	65·6	4·7	1·5	71·8	3·5	·9		4·4
7	27·1	16·5	43·6	2·6	·3	46·5	3·2	·6	·9	4·7
8	18·2	1[illegible]·9	29·1	2·9	·3	32·3	2·5	1·2		3·7
9	15·6	5·6	21·2	2·6		23·8	·6	·9		1·5
4–9	236·5	149·5	386·0	35·2	3·6	424·8	33·6	6·3	5·0	44·9
10	14·10	5·00	19·10	1·76		20·86	1·47	·88	·29	2·64
11	4·71	1·76	6·47	1·47		7·94	·88			·88
12	5·00		5·00	·29		5·29		·29		·29
13	·59		·59			·59	·29	·29		·58
14	·88		·88			·88	·29	·29		·58
15	·59		·59			·59	·59			·59
16	·59		·59	·29		·88				
18					·29	·29				
21								·29		·29
10 +	26·5	6·8	33·2	3·8	·3	37·3	3·5	2·0	·3	5·8
Total	627	774	1,401	119	6	1,526	121	14	11	146
Total Volume in Cubic Feet										
1–3	108·5	134·7	243·2	19·6	1·1	263·9	22·4	1·1	2·6	26·1
4–9	772·3	434·1	1,206·4	91·4	12·1	1,309·9	94·6	32·5	10·8	137·9
10 +	398·0	88·4	486·4	47·3	15·3	549·0	67·2	55·4	3·8	126·4
Total	1,278·8	657·2	1,936·0	158·3	28·5	2,122·8	184·2	89·0	17·2	290·4

TABLE 21

LAKE EDWARD EXPERIMENTAL AREA — 1946
STAND AND STOCK TABLE, PER ACRE
OXALIS-CORNUS TYPE

BASIS: 214 plots (1/10 acre)

D.B.H. Class	Spruce	Balsam	Spruce & Balsam	Cedar	Other Softwoods	Total Softwoods	White Birch	Yellow Birch	Maple	Other Hardwoods	Total Hardwoods
					Number of Trees						
1	53·2	96·0	149·2	10·5		159·7	8·9	2·6	1·6	·8	13·9
2	59·8	101·0	160·8	14·3	—	175·1	16·6	7·0	4·3	1·1	29·0
3	41·7	61·3	103·0	8·3	·1	111·4	12·5	7·9	5·7	·6	26·7
1–3	154·7	258·3	413·0	33·1	·1	446·2	38·0	17·5	11·6	2·5	69·6
4	28·1	43·5	71·6	5·4		77·0	10·3	5·9	5·7	·6	22·5
5	19·1	31·9	51·0	2·9		53·9	6·6	5·3	3·5	·3	15·7
6	13·2	22·4	35·6	1·3		36·9	3·2	3·8	2·3	·3	9·6
7	10·0	18·0	28·0	1·3	·1	29·4	2·6	2·6	1·8	—	7·0
8	8·1	13·6	21·7	1·3	·1	23·1	1·4	2·4	1·0	·1	4·9
9	6·8	10·4	17·2	·7	·2	18·1	1·6	2·9	·7	·1	5·3
4–9	85·3	139·8	225·1	12·9	·4	238·4	25·7	22·9	15·0	1·4	65·0
10	5·12	7·81	12·93	·42	·09	13·44	·84	3·02	·39	·14	4·39
11	5·58	5·86	11·44	·98		12·42	·93	1·86	·32	·09	3·20
12	3·62	3·25	6·87	·74	·14	7·75	·79	1·86	·18	·05	2·88
13	1·67	1·35	3·02	·37	·09	3·48	·37	2·14	·09		2·60
14	1·26	·70	1·96	·74		2·70	·33	2·04			2·37
15	·88	·19	1·07	·32	·05	1·44	·09	1·48		·05	1·62
16	·59	·09	·68	·05	·05	·78	·09	1·16	·05		1·30
17	·18	·09	·27	·14		·41	·09	·93			1·02
18	·18	·05	·23	·05		·28	·05	1·11	·05		1·21
19	·05		·05	·05		·10	·05	·84		·05	·94
20	·09		·09	·09		·18		·56			·56
21								·42			·42
22					·05	·05		·65			·65
23				·09		·09		·28			·28
24								·14			·14
25								·05			·05
26								·19			·19
30								·05			·05
35								·05			·05
10 +	19·2	19·3	38·5	4·0	·4	43·1	3·6	18·8	1·1	·4	23·9
Total	259	417	676	50	·9	728	67	59	28	4	158
					Total Volume in Cubic Feet						
1–3	45·3	65·4	110·7	8·7		119·4	11·4	9·4	4·3	·5	25·6
4–9	301·6	513·2	814·8	33·4	2·9	851·1	80·1	106·9	46·4	4·3	237·7
10 +	383·6	343·7	727·3	75·4	13·4	816·1	74·1	675·3	19·8	8·4	777·6
Total	730·5	922·3	1,652·8	117·5	16·3	1,786·6	165·6	791·6	70·5	13·2	1,040·9

TABLE 22

LAKE EDWARD EXPERIMENTAL AREA — 1946
STAND AND STOCK TABLE, PER ACRE
VIBURNUM-OXALIS TYPE

BASIS: 68 plots (1/10 acre)

D.B.H. Class	Spruce	Balsam	Spruce & Balsam	Other Softwoods	Total Softwoods	White Birch	Yellow Birch	Maple	Other Hardwoods	Total Hardwoods
Number of Trees										
1	59·9	18·7	78·6	·4	79·0	1·3	4·4	49·9	4·5	60·1
2	52·3	15·5	67·8	·1	67·9	·4	7·1	26·7	2·2	36·4
3	23·5	11·7	35·2		35·2	1·2	6·2	11·3	2·4	21·1
1–3	135·7	45·9	181·6	·5	182·1	2·9	17·7	87·9	9·1	117·6
4	12·2	7·2	19·4	·3	19·7	2·2	7·5	8·2	2·5	20·4
5	7·2	9·4	16·6	·3	16·9	·6	6·5	5·3	1·2	13·6
6	4·3	4·7	9·0	·1	9·1	1·2	3·4	5·0	1·5	11·1
7	4·0	5·0	9·0		9·0	·6	3·8	3·2	1·8	9·4
8	2·8	4·0	6·8		6·8	·3	4·1	2·6	·9	7·9
9	1·8	2·4	4·2		4·2	·3	3·2	2·2	1·0	6·7
4–9	32·3	32·7	65·0	·7	65·7	5·2	28·5	26·5	8·9	69·1
10	2·50	2·64	5·14		5·14		4·41	2·50	·29	7·20
11	2·65	1·47	4·12		4·12	·15	3·08	1·77	·59	5·59
12	1·77	1·91	3·68		3·68	·29	3·82	1·18	·88	6·17
13	1·47	·74	2·21		2·21		3·23	1·32	·59	5·14
14	1·32	·15	1·47	·15	1·62		2·94	·44	·15	3·53
15	·88		·88		·88	·15	2·94	·29	·15	3·53
16	·44	·29	·73		·73		2·06	1·18	·29	3·53
17	·15		·15		·15	·15	2·94	·59		3·68
18	·15		·15		·15		1·76	·29	·15	2·20
19	·15		·15		·15		1·03	·29		1·32
20							1·76	·15		1·91
21	·15		·15		·15		1·47			1·47
22	·29		·29		·29		1·32	·15		1·47
23							·59			·59
24	·15		·15		·15		1·62			1·62
25							·44			·44
26							·29			·29
28							·15	·15		·30
29							·29			·29
32							·15			·15
10+	12·1	7·2	19·3	·2	19·5	·7	36·3	10·3	3·1	50·4
Total	180	86	266	1	267	9	82	125	21	237
Total Volume in Cubic Feet										
1–3	30·7	11·6	42·3	—	42·3	·8	7·7	14·7	2·6	25·8
4–9	108·3	129·9	238·2	1·6	239·8	16·6	143·4	97·7	43·6	301·3
10+	320·6	142·5	463·1	3·0	466·1	19·2	1,598·4	280·2	81·1	1,978·9
Total	459·6	284·0	743·6	4·6	748·2	36·6	1,749·5	392·6	127·3	2,306·0