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Survey of the effect of forest drainage operations: (1) Forest productivity and ecological characteristics in the Saint-Anaclet and Cabano peatlands

Richard Zarnovican

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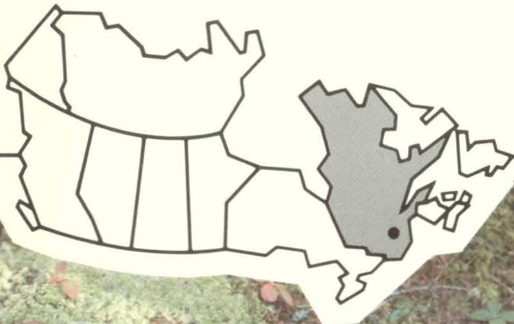

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SURVEY OF THE EFFECT OF FOREST DRAINAGE OPERATIONS: (1) FOREST PRODUCTIVITY AND ECOLOGICAL CHARACTERISTICS IN THE SAINT-ANACLET AND CABANO PEATLANDS

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ABSTRACT

This report presents the findings of a research project, whose main objective was to analyze growth and yield conditions in the peatlands in Saint-Anaclet and Cabano for the purpose of establishing experimental plots to assess the effects of drainage on the growth and development of forest stands. We only selected the spruce-mosses and spruce-litter types because of the extensive areas covered by those forest types, the homogeneous structure of the stands involved, and the volume of the wood obtained from them.

This choice was based on the fact that distribution of stems in rectangular plots measuring 20 by 15 m were normal, that these are even-aged stands of 50 and 80 years, that height growth in black spruce was comparable with growth in site classes II and IV of Vézina and Linteau yield tables, and that the annual increment in volume was 3.4 m^3/ha/year in the spruce-litter type and 1.4 m^3/ha/year in the spruce-mosses type. These results were comparable to those criteria used in Finland: the annual yield of the stand should be 1.5 m^3/ha/year and more if the peatland will be drained.

RÉSUMÉ

Le présent rapport présente les résultats de travaux dont l'objectif principal était d'analyser les conditions de croissance et de rendement des essences forestières dans les tourbières de Saint-Anaclet et de Cabano en vue d'y établir des parcelles expérimentales pour étudier l'effet du drainage sur la croissance et le développement des peuplements forestiers. Seules la pessière à mousses et la pessière à litière ont été retenues et ce, en tenant compte de l'importance spatiale de ces types forestiers, de l'homogénéité de leur structure et de la valeur du bois des essences.

Ces deux types de pessières ont été choisis en raison du fait que la distribution des tiges dans les parcelles rectangulaires de 20 par 15 m était normale, que ces peuplements étaient équiennes, entre 50 et 80 ans, que la croissance en hauteur de l'épinette noire était comparable à celle des pessières de classe II et IV des tables de Vézina et Linteau et que le rendement annuel en volume était de 3,4 m^3/ha/an pour la pessière à litière et de 1,4 m^3/ha/an pour la pessière à mousse. Ces résultats se comparent aux critères utilisés en Finlande qui donnent un rendement en volume annuel de 1,5 m^3/ha/an ou plus pour qu'une tourbière soit drainée.

INTRODUCTION

South of the 50th parallel, peatlands account for 6.3 percent of the total forested area of Quebec (Bolghari 1985). While exploitation of the forests growing on these peatlands is potentially feasible, it is not always commercially viable if the stands are left in their natural state. The low productivity of these stands is largely the result of a lack of oxygen and poor soil drainage. These factors inhibit the normal growth and development of several species. Root systems develop at the surface, in the first 10 to 20 cm of the soil (Strong and La Roi 1983). The trees are deprived of nutrients (Tilton 1978) and grow slowly (Boggie 1977). Furthermore, they are predisposed to uprooting by wind action (Armstrong et al. 1976).

The drainage of forested peatlands has been suggested and has been used as the conceptual framework for numerous studies directly or indirectly related to wood production both in Europe (Heikurainen 1964; Boggie 1972, 1977; Adams et al. 1972; Savill 1976; Coutts 1982; Kollist and Valk 1982; Valk 1982; Raid 1983; Braekke 1983) and in Canada (Payandeh 1973, 1982; Stanek 1977; Lieffers and Rothwell 1986, 1987).

In recent decades, the practice of draining peatlands has become widespread, especially in Finland and the Soviet Union (Kollist 1982; Seppälä 1986). The object of this practice is to improve soil aeration conditions and thereby stimulate tree growth (Heikurainen 1964; Löhmus 1983). Drainage does indeed result in an improvement in the site index, an increase in cover, and larger merchantable volumes of timber (Kollist 1982; Sobik 1982; Chindyaev 1986). In Scotch pine (*Pinus sylvestris* L.) growing on good, well-drained sites, radial growth appears to reflect the cumulative effect of the previous year's temperature and precipitation (Joensuu 1984). Because of the high cost of drainage, however, it is crucial to assess a number of site aspects including: the type of peatland involved, the condition of the stand, its composition, its ability to respond to treatment, its current productivity, and so forth. In considering these points, the drainage of ombrotrophic bogs, for example, could be avoided (Vasander 1982; Seppälä 1986).

In Canada and in Quebec, data on the production of timber from drained peatlands are scarce (Trottier 1986; Hillman 1987). Studies on black spruce, for example, have reported improved site index values and enhanced wood yields (Hillman 1987). Other studies, however (Payandeh 1982), have found that drainage had only a modest effect on wood yields in black spruce (*Picea mariana* [Mill.] BSP).

Working hypotheses

A lowered groundwater table might induce root systems to develop to greater depth (Boggie 1972). Alteration of the productivity and/or the composition of the grass cover might reduce the rate of accumulation of organic matter and reactivate decomposition and mineralization processes. Under these conditions, with the return of nutrients in active circulation that would be associated with more vigorous exploitation of the various soil horizons, root development and growth might be stimulated as might the productivity of the aerial parts of the trees concerned. However, there are no grounds for assuming that drainage would actually have these effects. A different scenario, less positive but just as realistic, may equally well be considered:

(1) Drainage might stimulate more vigorous plagiotropic root development (Savill 1976). Depending on the density of the stand concerned, the probability of competition would be correspondently greater.

(2) Reactivation of an effective decomposition and mineralization process might take many years considering the very short periods of potential activity due to the climate of Quebec.

(3) The ground might thaw more slowly with a lower groundwater table. As the thermal conductivity of the environment would thereby be reduced (Lieffers and Rothwell 1986), the connection with point 2 is obvious.

These few brief considerations show the complexity of the issue and demonstrate the need for in-depth studies before profitable exploitation of these forest areas can reasonably be undertaken. The peatlands of Saint-Anaclet and Cabano were drained in 1986 and the technical data dealing with the drainage operations are available from the Rimouski office of Forestry Canada.

Object of the study

The initial objective was to determine homogeneous spatial units on the basis of the structure and composition of forest stands. Volume yields and height growth rates for the main species were estimated to select the most productive forest types. A subsequent objective of the study is the establishment of permanent plots from which ecological and mensurational data on the selected forest types will be collected over a five-year period. The data will be used to assess the effects of lowering the groundwater table on the growth and composition of the forest, aspects that are influenced by the drainage system.

General considerations

Location

The Saint-Anaclet peatland is located near Rimouski, at a latitude of 48°30' north and a longitude of 68°20' west. The altitude varies between 25 and 30 m and the drained part covers an area of 183 hectares comprising 17 private lots.

The Cabano peatland is located at a latitude of 47°40' north and a longitude of 68°15' west; its altitude is approximately 235 m. The drained area of the site covers approximately 73 ha and comprises 11 private lots.

Climate

The two peatlands are strikingly similar with regard to their respective macroclimates. The **Atlas climatique du Québec** (Climate Atlas of Quebec), published by the Meteorology Service of Canada, states that mean precipitation is 1000 mm yearly of which 300 mm falls in the form of snow. The mean annual temperature is approximately 2.5°C and the mean annual length of the growing season ranges from 160 to 170 days. The Saint-Anaclet peatland, however, is part of the St. Lawrence littoral strip and is thus affected by the proximity of the sea. As a result, it is characterized by a smaller annual temperature range, milder winters, a later spring, and cooler summers. As for the Cabano site, it has a shorter mean frost-free season than the Saint-Anaclet site. In both areas, the climate is temperate continental, but it is slightly cooler in the Cabano peatland.

Geomorphology

Both sites are covered with an organic deposit of variable thickness resulting from the gradual filling of glacial depressions with peat. The peat consists of layers of macroresidues with a very high proportion of woody debris and is largely water-saturated. The matrix is dark brown with an amorphous structure. At Saint-Anaclet, the organic deposit, ranging in thickness from less than 50 cm to over 2 m, lies on a deposit of marine clay or a deposit of gravelly and sandy beaches. In the Cabano peatland, the organic deposit is nonexistent in some places and up to more than 2 m thick in others. Nearly half the total surface area of the site, however, is covered by an organic deposit that is less than 50 cm thick. Underlaying the organic deposit are either silty clay loams of glaciolacustrine origine or fluvioglacial loams or sands.

Vegetation

The forest type found in both peatlands may be classified in the phytogeographic category designated "balsam fir with yellow birch forest of the Lac Matapédia and Gaspé Peninsula ecological region" by Thibault and Hotte (1987). The peatlands in question, however, consist of edaphic coniferous stands that are conditioned by the excessive water content of the soil.

History

Settlement of the Saint-Anaclet region began in the early nineteenth century. Pressure on the forest began with wholesale clearing of the best farmland and agriculture practiced for family self-sufficiency. Efforts to secure additional sources of income for the families of the area led to more efficient organization of tree-harvesting and timber-production activities: the first sawmills were established in this region before the 1850s. At the experimental site, the forest was affected by the construction of the Intercolonial Railway early in the 1870s and to an even greater extent by the fire of 1901. The date of that fire is confirmed by the presence of charcoal in the soil profiles and coincides with the age of the forest. In addition, the presence of earthworms indicates that some areas of the site which are now wooded were formerly used as agricultural land.

With regard to the Cabano site, according to Mr. Carron of Cabano, the area's stands of black spruce and white spruce were cut for sawlogs during the winter of 1927 by the Guérette Company of Rivière-Bleue. Some idea of the size of the trees involved may be obtained from Mr. Carron's assertion that four 16-foot logs could be cut from a single tree and that the company produced 1000 board feet of lumber from 13 logs. Mr. Carron also informed us that in 1935 there was a forest fire that ravaged not only the broadleaved forest of the district but also the forest covering our experimental site. This information was confirmed by the presence of charcoal in the soil.

MATERIALS AND METHODS

During the summer of 1987, a floristic and mensurational survey was carried out by means of systematic sampling in 40 m^2 circular plots. In all, 91 such plots were established at Saint-Anaclet, and forty were established at Cabano. The object of the survey was to assess the homogeneity of the forest types and identify their characteristic one- or two-species stands. The principal ecological data were gathered and the necessary sampling operations were carried out in the stands at the end of the summer.

For the mensurational survey, a stem count was taken in each of the plots according to 2-cm diameter at breast height (dbh) classes. The findings of the survey were used to calculate the basal areas of the various species. The segment method (Godron, M. 1971. Essai sur une approche probabiliste de l'écologie des végétaux. Unpublished thesis, Université de Montpellier, (France)) was adopted for the floristic survey of low-growing strata. A 50-cm segment was used and the frequency of occurrence of each of the various species was observed. For analyses, weighted frequency profiles (Daget and Godron 1982) were used to identify the characteristic species of the various forest types.

In this way, 29 plots of black spruce forest (13 of cedar forest, 5 of tamarack forest, and 4 of poplar forest) were identified and delimited in the Saint-Anaclet peatland. At Cabano, we marked out 12 plots of cedar forest, 9 of tamarack forest, and 9 of black spruce forest. In these plots (47 in the Saint-Anaclet peatland and 23 in the Cabano peatland), the radial increments of all merchantable stems (491 in the Saint-Anaclet region and 262 in the Cabano region) were systematically measured on cores extracted with a Pressler increment borer. The data so obtained, the annual volume increment was determined by the difference-of-tariffs method. In order to compare yields, the multiple-comparison variance analysis test was used. Lastly, to complete the mensurational survey, stem analysis of dominant trees with no visible defects was performed. Eighty-one stems were analyzed in all, including 63 in the Saint-Anaclet region (TL 12, BS 38, EWC 8, WB 2, JP 1, BF 2) and 18 in the Cabano region (TL 9, BS 6, EWC 1, BF 2). The methodology described in an article by Zarnovican (1985) was used for stem analysis.

The root systems of two black spruce, two eastern cedars (*Thuja occidentalis* L.), one tamarack (*Larix laricina* [Du Roi] K. Koch), and one balsam fir (*Abies balsamea* [L.] Mill.) were dug up by hand and partially cut. The roots were numbered, and the spatial orientation in a specific plane was determined. Root depth, diameter at the root collar, at midlength, and at the point of severing were noted, as were distances of the second- and third-order roots from the tap root. Diameter measurements were orthogonally duplicated. Supporting and transport roots were qualitatively classified, depending on whether they were flattened or rounded. The position of each root in a vertical, horizontal, or oblique plane was also noted. Lastly, the field work was supplemented with soil survey operations (16 at Saint-Anaclet and 15 at Cabano) and sampling of the organic horizons. We followed the Canadian Soil Survey methodology both for gathering data in the field and for laboratory analysis. Samples were analyzed at the Laurentian Forestry Centre's (LFC) soils laboratory. The two peatlands tracts were compared with respect to fertility by means of the multiple-comparison variance analysis test.

RESULTS AND DISCUSSION

On the basis of a strong correlation between the fertility of the wooded peatlands, the forest types, and the composition of the lower strata (Veijalainen 1984; Schneider 1985. Classement des pessières et mélèzins sur sol organique du Québec pour le drainage forestier. Unpublished report, Fédération des producteurs de bois du Québec, Longueuil.; Grandtner 1985), we selected forest type as a unit of comparison for ecological and mensurational characteristics. It should be emphasized that forest type is defined in terms of composition of the canopy and composition of the lower strata.

Ecology of the forest types occurring in the Saint-Anaclet peatland

From 47 canopy composition identification operations, four forest types were established: spruce forest (25 cases), cedar forest (15 cases), poplar forest (3 cases), and tamarack forest with cedar (4 cases).

Spruce forest

Spruce forests are coniferous, single-storied forests dominated by black spruce with tamarack, balsam fir, and cedar occurring sporadically. On the basis of the floristic composition of the ground cover, which is strongly influenced by the density of the stand, the 25 spruce stands considered may be divided into three main groups:

Spruce-mosses

Spruce-mosses type is coniferous forest of moderate density. Mean values for height, dbh, and basal area are 11.2 m, 9.5 cm, and 19 dm^2, respectively (Table 1).

Here the low-growing strata are reduced to nothing but the moss cover, consisting primarily of *Pleurozium schreberi* although *Ptilium crista-castrensis* and *Decranum polysetum* are also found. *Cornus canadensis*, *Sphagnum russovi*, and *Nemopanthus mucronata* occur sporadically.

Spruce-mosses type is characterized by a typic or fibric mesisol. The fibric layer (15 to 25 cm) of the uppermost horizon consists of mosses on the surface and an underlying layer of Sphagnum with a well-preserved fibrous structure. At the time of the survey, the fibric layer was dry or damp. It is distinguished from the mesic layer by a regular, clearly defined boundary which ordinarily consists of traces of charcoal. The intermediate horizon is usually made up of mesic layers. This horizon is over 50 cm thick, and it displays an amorphous structure. It consists of woody macroresidues and sometimes Carex and Sphagnum residues as well. At the time of the survey, this layer was water-saturated, and the groundwater table was more than 80 cm down. The trees were superficially rooted with tier formations present in their root structures, presumably because of the rapid growth of Sphagnum and

Table 1. Forest measurement characteristics of forest types occurring in the Saint-Anaclet peatland

Forest type	Number of plots*	Dbh (cm)	Height (m)	Number of stems	Basal area (dm^2)
Spruce-litter	4	9.4	11.7	28	18.3
Spruce-mosses	17	9.5	11.2	27	19.0
Spruce-ericaceous	4	5.8	8.0	42	10.7
Cedar	15	15.5	13.3	23	33.1
Tamarack-cedar	4	16.5	18.8	15	31.4
Poplar	3	14.2	16.8	20	30.0

Figures indicate mean values. *Area of plot: 40 m^2

other mosses. The nutrient supply available to this grouping (Table 2) appears to be midway between those characteristic of the spruce-litter and spruce-ericaceous types.

Spruce-litter

Spruce-litter type is a dense forest with a canopy of black spruce and tamarack and an understory of cedar. The closed canopy prevents light from reaching the understory and thereby inhibits the establishment and growth of low-growing synusial species. *Clintonia borealis* and *Coptis groenlandica* occur very sporadically. The mean dbh of trees in stands of this type is 9.4 cm and their mean height is 11.7 m. Lastly, the mean number of stems per plot is 28, with a mean basal area of 18.3 dm^2 (Table 1).

The soil of this forest type is very similar of that of spruce-mosses type. The difference consists in the appearance of a fibric surface layer made up of needles, twigs, and leaves. This layer was very dry, even dusty, at the time of the survey. Mean root depth was 17 cm (Table 2), and the groundwater table was at a depth of more than 80 cm at the time of the survey. Data on the nutrient supply available to the root layer (Table 2) indicate that the soil is acid, being weakly saturated with bases. The soil in spruce-litter forests, however, seems to be richer in nutrients than that of either spruce-mosses or the spruce-ericaceous type.

Spruce-ericaceous

This forest type may be described as a heath on which black spruce grow. The tree cover is dense, with an average of 42 stems per plot, but the individual specimens are small in diameter. The mean dbh for this type of stand is 5.8 cm, the mean height 8 m, and the basal area 10.7 dm^2 (Table 1). The ground cover is characterized by the abundant, constant presence of *Vaccinium angustifolium*, *Kalmia angustifolia*, and *Ledum groenlandicum*.

The soil is a typic or fibric mesisol characterized by the presence of a fibric layer 20 to 30 cm thick. This layer, which is wet without being water-saturated, is very slightly decomposed and consists of Sphagnum mosses and ericaceous dwarf shrubs. This also confirms the C_{humic}/C_{fulvic} ratio (equal to 1.08 with a very heavy ericaceous dwarf shrub root density). The fibric layer is clearly distinguished from the mesic layer by the presence of charcoals at its lower boundary. The mesic layer, which is more than 40 cm thick, consists mainly of woody macroresidues. It is characterized by an amorphous structure containing fragments of tree trunks, and it is generally water-saturated. At the time of the survey, the depth of the water table was more than 80 cm. The tree species that grow in spruce forests with ericaceous dwarf shrubs are shallow-rooted, with root systems extending to a maximum depth of 15 cm, and the nutrient supply available to it (Table 2) appears to be poorer than that available to any other forest type in the Saint-Anaclet peatland.

Cedar forest

Cedar forest type is a coniferous forest, frequently occurring in pure stands; they are sometimes associated with tamarack, balsam fir, white birch, and black spruce. Stand density is highly variable, ranging from 8 to 61 stems per plot depending on the age of the stand concerned. Where there is an admixture of tamarack with the cedar, the stands are denser. The canopy is more open and consists of tamarack while the understory is denser and consists of cedar. The difference in the dominance of the two species is even more clearly expressed by the mean relative heights of the species growing in the plot: this value is 1.34 for tamarack and 0.97 for cedar. The basal area of this type of stand ranges from 21 to 44 dm^2, the mean value being 33 dm^2.

Grass and moss cover varies widely, and in dense stands, only litter and a few mosses (*Hylocomium splendens* and *Hylocomium umbratum*) are observable. In more open stands, some herbaceous plants characteristic of a cedar forest make their appearance. The most abundant of these are: *Mitella nuda*, *Viola incognita*, and *Rubus pubescens*.

Cedar forests rest on a fibric humisol with a mineral horizon approximately 80 cm thick. The profile comprises a dry fibric layer (15 cm) consisting mainly of forest litter and an underlying humic layer (50-60 cm) consisting of woody macroresidues. It is initially damp, then wet, and finally water-saturated. The groundwater table was not detected at the time of the survey. Root depth extends beyond the fibric layer, down to a mean depth of 24 cm. Examination of the roots reveals the presence of reiteration. The nutrient supply is clearly better than that available to stands of spruce forest as may be seen from a comparison of pH values, C/N ratios, and base saturation levels (Table 2). The rate of decomposition of organic matter, however, is virtually identical to that observed in spruce forest with litter.

Poplar forest

Poplar forest is the sole broadleaf forest type occurring in the Saint-Anaclet peatland. On the organic deposit, its mean density is 20 stems per plot, its mean height 17 m and its mean basal area 30 dm^2. As the poplar forest is a transitional type of stand, it usually displays several stories. Balsam poplar and trembling aspen constitute the dominant story, while the understories are made up of black spruce, balsam fir, or cedar. Low-growing strata are abundant, consisting mainly of shrubs and grasses; moss cover is virtually absent. *Cornus stolonifera* and *Rubus idaeus* are prominent shrub species while the most abundant herbaceous species are *Ribes lacustre*, *Rubus pubescens*, *Aster accuminatus*, *Eupatorium maculatum*, *Mitella nuda*, and *Galium triflorum*.

Table 2. Physical and chemical soil variables, mean values for the forest types occurring in the Saint-Anaclet peatland

Forest Type	Root Depth (cm)	pH ($CaCl_2$)	C/N Ratio	Base Saturation (%)	C.E.C.	Ca^{++}	K^+	Mg^{++}	Available P (ppm)	C_h/C_f Ratio
					(meq/100g)					
Spruce-litter (Samples: 2)	17	3.0	32.1	29.8	168.1	37.6	1.16	9.9	12	1.69
Spruce-mosses (Samples: 6)	18	2.6	45.2	17.5	145.6	14.9	1.73	7.1	12.7	1.29
Spruce-ericaceous (Samples: 4)	14	2.6	50.4	18.0	171.6	18.7	1.20	8.8	12.8	1.08
Cedar (Samples: 2)	24	4.3	19.8	67.0	169.4	100.7	0.68	12.0	7.0	1.70
Poplar (Samples: 2)	38	4.7	20.8	83.0	176.6	130.1	0.24	15.0	6.0	2.57

The soil of a poplar forest is a deep typic humisol with a surface layer that is 2 to 3 cm deep and consists of forest litter (leaves and twigs). The materials of the uppermost and intermediate horizons are extensively decomposed and damp. The presence of lumps in the first 35 cm is the result of earthworm activity. The rest of the structure of the profile is amorphous and water-saturated and contains fragments of tree trunks. Tree root systems extend to depths in excess of 40 cm. The nutrient supply available to the profile is rich (Table 2) and characterized by extensive decomposition of organic matter as may be seen from the C_{humic}/C_{fulvic} ratio which is equal to 2.57.

Tamarack-cedar

From an ecological standpoint, tamarack forests with cedar are nothing more than a variant of cedar forest type, and it was taken into account only for the purposes of the mensurational study. The number of stems ranges from 12 to 19 per plot, the mean height is 19 m, and the basal area, which consists mainly of tamarack, ranges from 25 to 37 dm^2. It was noted that tamarack trees were extensively damaged by porcupines.

Ecology of the forest types occurring in the Cabano peatland

Four forest types were defined in this peatland: spruce-cedar (8 plots), cedar (3 plots), tamarack-black spruce (4 plots), and tamarack-cedar (8 plots). The forest measurement characteristics of this peatland are summarized in Table 3 and the physicochemical data relating to its soils are shown in Table 4. With regard to the vegetation of this forest region, we note that the low-growing strata are characterized by the presence of the common species, including *Carex trisperma*, *Hylocomium splendes*, *Linnaea borealis*, *Mitella nuda*, *Rubus pubescens*, *Pleurozium schreberi*, and *Sphgagnum russowii*.

Spruce-cedar

The spruce-cedar type is a coniferous forest with the number of stems per plot ranging from 20 to 44. The canopy is dominated by black spruce averaging 14.5 m in height with a mean dbh of 15 cm and a mean relative height of 1.15 m. The understory consists of cedar trees with a mean height of 8.7 m, a mean dbh of 13.7 cm, and a relative height of 0.87. The basal area of the plot ranges between 15 and 30 dm^2, the mean value being 24 dm^2 (Table 3). In addition to the species found throughout the peatland, we note the occurrence of several preferential species, including *Vaccinium angustifolium*, *Maianthemum canadense*, and *Kalmia angustifolia*. The soil of this forest type is a deep typic humisol.

Table 3. Forest measurement characteristics of the forest types occurring in the Cabano peatland

Forest type	Number of plots*	Dbh (cm)	Height (m)	Number of stems	Basal area (dm^2)
Spruce-cedar	8	9.8	14.1	34	23.8
Cedar	3	11.8	10.3	25	26.5
Tamarack-spruce	4	10.9	14.6	29	26.2
Tamarack	8	11.3	14.3	28	24.7

Figures denote mean values. *Area of plot: 40 m^2

The organic deposit is more than 1 m deep. The profile consists of a thin layer of litter (needles and mosses) on the surface followed by a fibric layer 15 to 20 cm thick in the uppermost horizon. This layer is wet without being water-saturated and is made up of roots and mosses. The remainder of the profile consists of a humid layer devoid of structure that is thoroughly decomposed and water-saturated and contains substantial quantities of woody materials.

The physicochemical characteristics of the rhizosphere (Table 4) indicate a mean root depth of 22 cm. The pH is the lowest found in the peatland at 3.74 and confirmation is provided by a high C/N ratio (33.2) and a moderate base saturation level.

Cedar forest

The cedar forest is a dense, single-storied forest dominated by cedar. Mean stand height is 11 m, mean dbh is 11 cm, and the mean basal area of plot is 25 dm^2 (Table 3). The low-growing strata are represented by a sparse cover of shrubs including *Cornus stolonifera*, *Sorbus decora*, and *Thuja occidentalis*, and a less than 20 percent cover of grasses that consists of *Carex trisperma*, *Maianthemum canadense*, *Monesses uniflora*, and *Mitella nuda*. Finally, an extensive (over 60 percent) cover of moss is observable; this cover consists of *Hylocomium splendens*, *Rhytidiadelphus triquetrus*, and *Sphagnum wulfianum*. The soil in a cedar forest is a typic or terric humisol. In a typic humisol, the profile consists of a thin layer of litter, a fibric layer 15 to 20 cm thick, and a humic layer more than 80 cm thick. The fibric layer is wet and consists of mosses, including *Carex* and *Sphagnum* species, with a fibrous structure.

The humic layer is extensively decomposed, with substantial quantities of woody macroresidues. The groundwater table lies approximately 50 cm below the surface. The profile of a terric humisol is differentiated from a typic humisol by the presence of mineral soil at approximately 30 to 40 cm. It appears from the data relating to nutrient availability (Table 4), that depth of rooting does not exceed 30 cm. The pH of this soil is neutral; it is rich in exchangeable bases, especially calcium, and its C_h/C_f ratio indicates a fairly rapid decomposition of organic matter.

Tamarack-black spruce

Tamarack-black spruce are a dense forest with a canopy of tamarack (mean height: 13.6 m) and an understory of black spruce (mean height: 10.2 m). The mean basal area of a plot is 26.2 dm^2 and the number of stems per plot ranges from 20 to 40 (Table 3). The low-growing strata that make up the ground cover vary with stand density, but we note that several characteristic grasses and mosses occur, including *Coptis groenlandica*, *Chiogenes hispidula*, *Cornus canadensis*, and *Pleurozium schreberi*.

The soil found in such forest stands is a deep typic humisol. The fibric layer, which is approximately 15 cm thick, consists of dry and damp mosses. The humic layer is extensively decomposed and water-saturated, with many woody macroresidues. The groundwater table was not detected at the time of our survey. Depth of rooting is approximately 25 cm. Soil pH is dysic ($pH < 4.5$). With regard to the other characteristics (Table 4), this forest type is quite similar to the spruce-cedar type.

Tamarack-Eastern cedar

The density of this forest type is variable and its vertical structure is the same as that of the tamarack-black spruce type. The canopy is dominated by tamarack (mean height: 14 m) while eastern cedar (mean height: 8.7 m) constitutes the understory. The number of stems per plot ranges from 17 to 43, the mean value being 28. The mean basal area of a plot is 25 dm^2 (Table 3).

The composition and extent of cover in low-growing strata depend on stand density. Densely stocked plots are characterized by the presence of either litter or mosses such as *Pleurozium schreberi* and *Hylocomium splendens* while in more open plots, the species that are generally common to the peatland, including *Mitella nuda*, *Rubus pubescens*, and *Carex trisperma* among others, tend to occur.

The soil found in this type of forest is a deep typic humisol. The soil profile comprises a thin layer of litter (1 to 3 cm), a damper fibric layer (15 to 25 cm) that is derived from mosses, and lastly, an amorphous humic layer containing woody materials. The humic layer is wet or water-saturated. The groundwater table, when present, lay at a depth of approximately 70 cm in the profile. Mean rooting depth was 30 cm which is similar to the value observed in the cedar forest. The root stratum in this type of forest presents a euic reaction (pH > 4.5). It is rich in bases and similar in characteristics to a cedar forest (Table 4).

Soil fertility in the two peatlands

To compare the physicochemical characteristics of soils in the two peatlands, the variance analysis method was used. The findings of the multiple-comparison test and the main variables are shown in Table 5.

Here we see that there are statistically significant differences between the two peatlands with respect to available nutrients other than magnesium and phosphorus. The table shows that soils at Cabano are richer in exchangeable bases, with calcium clearly dominant and very abundant. Those soils are less acid and the trees are more deeply rooted. The higher

Table 4. Physical and chemical soil variables, mean values for the forest types occurring in the Cabano peatland

Forest Type	Root Depth (cm)	pH ($CaCl_2$)	C/N Ratio	Base Saturation (%)	C.E.C.	Ca^{++}	K^+	Mg^{++}	Available P (ppm)	C_h/C_f Ratio
					(meq/100g)					
Spruce-cedar (Samples: 2)	22	3.74	33.2	47.7	192.3	81.0	0.12	9.1	10.5	1.76
Cedar (Samples: 3)	30	5.02	25.5	75.2	191.6	134.3	0.32	8.1	6.7	2.05
Tamarack-black spruce (Samples: 3)	25	4.09	31.9	54.5	195.6	95.0	0.40	10.3	15.3	2.50
Tamarack-cedar (Samples: 7)	30	4.61	30.8	72.9	208.3	140.5	0.11	9.8	9.1	2.18

Table 5. Physical and chemical soil variables, comparison of the mean values found for the two forest peatlands

	Peatland	
	Saint-Anaclet	Cabano
Number of Samples	16	15
Variable		
Root Depth (cm)	23.0	29.0
pH ($CACl_2$)	3.1	4.5
C/N Ratio	38.5	30.3
Base Saturation (%)	33.5	66.3
C.E.C. (meq/100 g)	161.8	200.3
Ca^{++} (meq/100 g)	44.1	122.3
K^{+} (meq/100 g)	1.1	0.2
Mg^{++} (meq/100 g)	9.5[a]	9.5
Available P (ppm)	10.4	10.1
C_h/C_f Ratio	1.59	2.17

[a] ______ =Pairs of values that are not significantly different at the 5% threshold.

humification rate that characterizes the Cabano soils (the C_{humic}/C_{fulvic} ratio is equal to 2.17) implies a greater exchange capacity as well. In view of its position on a slope and the presence of seepage, this peatland could be classified as a wooded eutrophic fen, in contrast to the Saint-Anaclet peatland with a cover of spruce which is an oligotrophic bog.

Root system morphology

General features

The roots of the species considered in the context of this study are oriented in a horizontal plane with the exception of Eastern cedar (1): approximately one third of the cedars examined had roots, including central tap roots, that were set in an oblique plane, probably as a result of mechanical action (wind pressure, snow loading, and the like). The root systems analyzed (Table 6) can be divided into two groups on the basis of total number of roots and depth of rooting. Trees in the first group (BS(1) and EWC(1)) are more deeply rooted where the organic horizons are relatively dry, but are different in respect of their chemical composition.

These systems are characterized by a tiered structure and continuous distribution of roots along the central tap root; this gives rise to an orthotropic development strategy (Kahn 1975). The spatial orientation of the roots provides static equilibrium despite the relatively slender supporting roots (Table 7). The circular distribution of roots around the tap root suggests that the sharing of the food niche is organized in a vertical plane, a situation which prevents the exploitation of a single soil region (Henderson et al. 1983). The samples in the second group come from soils that are very similar in terms of their chemical composition. The root systems develop in the uppermost 10 to 20 cm of the Of horizon which as a rule is dry and dusty. In plot No. 4.2, for example, the groundwater table is located more than a metre down, but even so, the root systems of balsam firs (BF(1)) growing in that plot develop at the surface in accordance with a plagiotropic model, in contrast to the more orthotropic

Table 6. General characteristics of root systems

Species and Forest Type	Depth (cm)	N1	N2	N3	f	s	m	l	vl
							%		
BS (1) Spruce-mosses	39	40	22	0	29.0	33.9	25.8	8.1	3.2
BS (2) Spruce-litter	25	6	7	3	25.0	18.8	25.0	6.2	25.0
EWC (1) Tamarack-cedar	42	53	30	1	26.5	38.6	25.3	8.4	1.2
EWC (2) Spruce-litter	23	11	14	0	28.0	32.0	28.0	4.0	8.0
BF (1) Spruce-mosses	21	19	9	2	36.7	36.7	20.0	3.3	3.3
TL (1) Spruce-litter	22	18	9	7	29.4	29.4	11.8	11.6	11.8

Depth = Maximum rooting depth (cm)
N1 = Number of first-order roots
N2 = Number of second-order roots
N3 = Number of third-order roots
f = % of fine roots (diameter class at root collar 0 to 5 mm)
s = % of small roots (5 to 10 mm)
m = medium-sized roots (10 to 20 mm)
l = % of large roots (20 to 30 mm)
vl = % of very large roots (30 mm and over)

model suggested by Strong and La Roi (1983). Vartanian (1975) notes that both drought and excessively wet conditions inhibit tap root growth, but conversely stimulate rhizogenesis in lateral roots. In this particular instance, the balsam fir possesses a small percentage of large-diameter roots (Table 6), a feature which proportionally might be attributed to a younger system (assuming a relationship between age and diameter at the root collar of the tap root, Dc). Furthermore, the high C/N ratio found in spruce forests with mosses indicates a low degree of mineralization. This suggests a more pronounced shortage of nutrients which might be connected with the high proportion of small, fine roots found in balsam fir. Black spruce (BS(2)), tamarack (TL(1)), and Eastern cedar (EWC(2)) are all characterized by root systems displaying plagiotropic development as a result of the waterlogging of the underlying horizons. The roots of TL(1) and BS(2) are noticeably thick and extended as may be seen from the relatively high proportions of large roots (Table 6), root length, and root collar

Table 7. Morphometric measurements of root systems

Species	Dc*	Dmp* (mm)	De*	L* (cm)	Dsc*	Dsmp* (mm)	Dse*	Ls (cm)	Dtc* (mm)
BS (1)	9.1 (4.7)	6.2 (2.9)	4.2 (1.9)	20.8 (15.6)	28.2 (3.9)	17.9 (2.8)	10.8 (4.1)	36.7 (9.8)	66
BS (2)	12.7 (9.1)	6.5 (3.5)	5.0 (2.7)	23.8 (17.6)	53.7 (11.3)	33.3 (7.8)	20.0 (5.9)	49.3 (1.2)	78
EWC (1)	8.7 (4.4)	6.1 (3.5)	3.8 (2.5)	18.0 (11.6)	22.1 (5.5)	14.8 (4.3)	6.7 (3.5)	28.9 (7.2)	80
EWC (2)	6.9 (3.9)	4.2 (1.8)	2.9 (1.4)	12.0 (12.4)	23.8 (7.1)	11.3 (2.6)	5.2 (0.8)	37.8 (10.8)	51
BF (1)	7.2 (4.6)	4.6 (3.0)	3.4 (2.1)	19.3 (10.7)	26.0 (9.8)	12.2 (5.3)	8.0 (3.6)	40.7 (2.5)	41
TL (1)	11.8 (8.2)	6.6 (3.8)	5.1 (2.7)	27.7 (15.8)	51.9 (16.1)	35.2 (13.4)	24.0 (11.5)	46.4 (14.8)	107

Dc = Diameter of transport roots at the root collar
Dmp = Diameter of transport roots at midpoint
De = Diameter of transport roots at extremity
L = Length of transport roots
Dsc = Diameter of supporting roots at the root collar
Dsmp = Diameter of supporting roots at midpoint
Dse = Diameter of supporting roots at extremity
Ls = Length of supporting roots
Dtc = Diameter of tap root at the root collar
* = Mean and (standard deviation)

diameter in the case of transport and supporting roots (Table 7). In static terms, this situation leads to the development of systems that are comparatively strong and stable.

This type of development may serve to offset the absence of deep anchoring, which is virtually unattainable in an environment of the kind under discussion, given the probability of anerobic conditions and the level of the groundwater table (Lieffers and Rothwell 1986).

Reiteration

Oldeman (1974) defines reiteration "as the appearance of lateral axes that express differentiation sequences generated during actualization of the model." That is to say, it is an anachronistic phenomenon that modifies the original root-development model. This phenomenon, which is apparent in black spruce (1), is broadly distinguished by three modal diameter classes in the first-order roots depending on rooting depth.

The hierarchy of the system is the exact reverse of the situation obtained in the basic model in which the surface roots are presumed to be the largest and the smallest roots are supposedly the deepest (see the basic diagram of this species in Strong and La Roi (1983)). We are concerned here with a partial and essentially plagiotropic form of reiteration, inasmuch as it involves the formation of lateral axes.

In Eastern cedar, reiteration is less clearly defined but still apparent, especially in the first fifteen centimetres of the root stratum. In other root systems included in this investigation, reiteration is more or less pronounced in TL(1) and BF(1) but virtually nonexistent in EWC(2) and BS(2). This process appears to be related to the substantial accumulation of organic matter which is characteristic of acidic peatland environments. The low levels of decomposition and mineralization activity in such environments evidently result in a restricted nutrient supply; this includes episodes of reiteration as organic matter accumulates.

This neoformation of roots, however, does imply some expenditure of energy which, unless offset somehow, may produce a deficit in the energy balance. Given these conditions, it seems likely that the phenomenon in question is traumatic reiteration rather than adaptive reiteration. It should be noted that this reiterative anachronism also occurs in the lower levels of the plagiotropic hierarchy (second- and third-order roots). The significance of these observations is not entirely clear.

Volume increments of the three main species

Our study of growth and wood production was carried out to compare the yields that are currently obtained from the main species (black spruce, tamarack, and Eastern cedar). It comprises two parts:

- Comparison of volume increments;
- Comparison of height growth.

We note at this point that our findings describe the growth of the average tree (a product of mathematical operations) rather than the growth of an actual stand. We used variance analysis techniques, in particular the multiple-comparison test at the critical threshold of 5 percent (Sokal and Rohlf 1981) to compare the means of different variables and especially the current annual increment in volume.

Determination of volume increments and volume tables

Under certain conditions, the method of tariff differences provides a means of estimating increments in volume. Depending on the formulation adopted, it involves either the radial increments of trees at dbh or passage time. We selected the former because of the difficulties associated with the task of calculating the median value of passage time and restrictions in interpretation.

The basic data used to apply the method of tariff differences were the following:

- annual increment in diameter - i_d, which is equal to double the increment in radius - $2i_r$;
- the single-entry tariff and its first derivative - dv/ddbh;
- the bark factor - k, which is the ratio of the radius with bark included and the radius without bark.

From these data, the volume increment may be calculated by the following formula:

$$i_v = (dv / ddbh) \cdot i_d \cdot k \quad [1]$$

The dbh, height, radial increment, and thickness of bark were measured in the field in both the Saint-Anaclet and Cabano peatlands. Other variables such as volume, bark factor, and annual volume increment were calculated. For example, the coefficients of the tariffs were established from stem analysis data by the least-squares method after logarithmic transformation of the variables. The results are shown in Table 8.

Table 8. Volume table coefficients from the main species: single-entry tariff, vol = $\beta_1 \cdot (dbh+1)^{\beta 2}$ and two-entries tariff, vol = $\beta_3 \cdot (dbh+1)^{\beta 4} \cdot h^{\beta 5}$

	Saint-Anaclet tract			Cabano tract		
Parameter	BS	TL	EWC	BS	TL	EWC
n	899	238	122	236	178	21
			Single-entry tariff			
R*2	0.988	0.990	0.989	0.990	0.991	0.999
β_1	0.06862	0.08530	0.10295	0.08864	0.08320	0.09022
β_2	2.72619	2.68511	2.49637	2.65634	2.70737	2.53978
Se (%)	3.03	2.96	3.04	3.59	2.83	0.60
			Two-entries tariff			
R*2	0.996	0.998	0.996	0.997	0.998	0.999
β_3	0.07433	0.05803	0.08169	0.07343	0.05414	0.07983
β_4	1.94003	1.95454	1.94203	1.49323	1.79159	2.09666
β_5	0.80974	0.90168	0.75749	1.29942	1.07841	0.56038
Se (%)	1.83	1.34	1.92	1.92	1.45	0.54

n - number of observations; R*2 - coefficient of determination;
β_i - regression coefficients; Se - residual standard deviation.

The bark factor (k = ratio between the radius with bark included and the radius without bark) was also calculated from the stem analysis data. Lastly, the volume increment was calculated by means of equation [1] from the first derivative of the one entry tariff, the bark factor, and the mean periodic increment in radius over the previous five years. The main statistics relating to the three species and the two peatlands are set forth in Table 9.

Volume increment of three main species occurring in the two peatlands

Our first comparison deals with mean values for volume increments observed in the three main species in the Saint-Anaclet and Cabano peatlands. The results of the multiple-comparison test indicate (Table 10) that there are no significant differences between the two peatlands with respect to yields of the species in question.

When the same test, however, is used to compare yields obtained from the three species (Table 11), it appears that the yield obtained from tamarack is significantly greater than those obtained from black spruce and Eastern cedar. With respect to cedar and black spruce, the results of the same table indicate that yields are similar.

Table 9. Main statistics relating to trees measured

	Dbh (cm)	Height (m)	Volume (dm^3)	id (mm/yr)	Bark (mm)	Bark factor - k	iv (dm^3/yr)
Saint-Anaclet - black spruce (263 trees)							
(a)	12.3	10.3	69.8	1.45	3.46	1.02953	1.85
(b)	2.5	1.8	41.3	0.65	0.48	0.00358	1.25
(c)	7.3	5.5	13.8	0.40	2.20	1.02190	0.31
(d)	22.4	17.0	309.4	3.56	4.80	1.05187	7.71
Cabano - black spruce (61 trees)							
(a)	14.0	11.6	101.6	1.42	3.71	1.02748	2.23
(b)	3.64	2.2	66.6	0.58	0.96	0.00424	1.63
(c)	8.3	7.2	25.9	0.36	1.80	1.01744	0.35
(d)	25.7	16.0	332.9	3.00	6.20	1.03596	8.24
Saint-Anaclet - tamarack (33 trees)							
(a)	18.3	15.6	273.5	2.08	4.35	1.02563	6.85
(b)	6.6	3.9	241.3	0.94	0.97	0.00420	4.61
(c)	9.4	8.8	37.6	0.56	2.80	1.01937	0.81
(d)	34.2	22.2	1068.7	4.56	6.50	1.03483	18.67
Cabano - tamarack (80 trees)							
(a)	15.1	13.9	138.9	2.32	3.84	1.02681	5.74
(b)	4.7	2.5	104.7	0.86	1.01	0.00395	4.61
(c)	9.3	7.3	27.2	0.44	2.30	1.01488	0.46
(d)	29.5	19.3	514.6	4.30	6.80	1.03858	24.30
Saint-Anaclet - Eastern cedar (165 trees)							
(a)	16.9	11.4	160.4	1.84	3.64	1.02250	3.69
(b)	5.9	2.2	142.5	0.76	1.12	0.00339	2.87
(c)	7.3	4.2	11.3	0.40	2.00	1.01880	0.47
(d)	39.1	12.3	1007.3	4.72	6.50	1.03546	17.11
Cabano - Eastern cedar (117 trees)							
(a)	14.3	9.0	86.7	1.50	3.69	1.02691	2.32
(b)	4.1	1.6	84.0	0.38	0.94	0.00373	1.38
(c)	9.0	6.5	24.0	0.58	2.10	1.01849	0.44
(d)	34.7	16.0	754.7	2.56	5.30	1.03512	9.34

(a) arithmetic mean; (b) standard deviation; (c) minimum value of variable; (d) maximum value of variable

Volume increment of species in the main forest types

Black spruce

Current annual volume increments for black spruce in stands of spruce-litter, spruce-mosses, and spruce-ericaceous are shown in Figure 1. The best yield is obtained from the spruce-litter type, followed by spruce-mosses, and then spruce-ericaceous type. The multiple-comparison test, however, demonstrates that mean increments in volume in the spruce-litter type differ significantly only from the other two types of spruce forest.

Table 10. Annual volume increments by species and dbh class; mean values for the two forest peatlands

Dbh (cm)	Saint-Anaclet $i_v(dm^3)$/year	Cabano $i_v(dm^3)$/year	D.F.	F	P
Species - black spruce					
10	0.91	0.78[a]	1;101	0.747	0.389
12	1.58	1.47	1;88	0.414	0.522
14	2.41	2.04	1;67	3.379	0.071
16	3.42	3.07	1;36	0.535	0.469
20	4.55	4.5	1;8	0.001	0.990
Species - tamarack					
10	1.17	1.58	1;20	1.638	0.215
12	1.89	2.73	1;18	3.447	0.079
14	3.69	4.35	1;13	2.634	0.129
16	5.88	6.04	1;14	0.040	0.844
18	9.03	8.28	1;6	1.113	0.748
20	10.65	9.46	1;8	0.368	0.552
Species - Eastern cedar					
10	1.71	1.04	1;49	20.791	0.0001
12	1.80	1.65	1;47	0.603	0.441
14	2.32	2.19	1;50	0.278	0.600
16	3.18	2.77	1;26	0.867	0.360
18	3.38	3.26	1;28	0.106	0.747
20	4.19	4.10	1;20	0.025	0.876

[a] ____ = Pairs of values that are not significantly different at the 5% threshold.

Table 11. Annual volume increments by dbh class; mean values for the three species

Dbh(cm)	TL $i_v(dm^3/year)$	EWC $i_v(dm^3/year)$	BS $i_v(dm^3/year)$	D.F.	F	P
10	1.51	1.39[a]	0.90	2;173	21.68	0.0001
12	2.48	1.71	1.56	2;156	15.51	0.0001
14	4.22	2.27	2.31	2;133	40.38	0.0001
16	6.01	2.96	3.36	2;79	39.00	0.0001
18	8.38	3.33	3.95	2;41	55.48	0.0001
20	9.82	4.16	4.56	2;39	37.98	0.0001

[a] ____ = Pairs of values that are not significantly different at the 5% threshold.

Tamarack

Yields of tamarack by forest type (cedar forest, tamarack-cedar, and tamarack-black spruce) are shown in Figure 2. While the graph shows a wide range of variation in yield by dbh class, the three types cannot be differentiated by the multiple-comparison test.

Eastern cedar

As will be seen from Figure 3, yields obtained from Eastern cedar are very similar in the three forest types considered, namely cedar forest, tamarack-cedar, and spruce-cedar. This finding is confirmed by the multiple-comparison test.

Height growth

An important aspect of the wood productivity of a forest site is reflected in the height growth of the dominant trees. Height growth is known to be independent of stand density and silvicultural intervention.

In the context of this study, our analysis first deals with height growth in the three main species (black spruce, tamarack, and eastern cedar) and then with the height growth of different species by forest type. We should note that data on apical growth were obtained from stem analysis. The curves showing height plotted against age express mean apical growth per five-year age class.

Height growth of black spruce by forest type

Height growth in spruce occurring in the different forest types is shown in Figure 4. This figure reveals a readily identifiable height growth gradient for black spruce that diminishes quite sharply in the following sequence:

(a) spruce-litter and cedar forest;
(b) spruce-mosses;
(c) tamarack-cedar and spruce-cedar.

If we now take the same figure and add to it the height growth observed by Vézina and Linteau (1968) in spruces of classes II and IV, we can determine that the spruce-litter type and cedar forests should display the same productivity as spruce forests of site class II while the productivity of the spruce-mosses type should be assigned to site class VI. The least productive types appear to be spruce-cedar and tamarack-cedar.

Height growth of tamarack by forest type

Height growth in tamarack, which is shown in Figure 5, appears to be more homogeneous than in the case of black spruce, presumably because tamarack is a heliophilous species. Nevertheless, the figure reveals that the greatest height growth is observable in cedar forest and in spruce-cedar forests whereas height growth tends to diminish with age in spruce-litter and spruce-mosses forests. It is also noteworthy that at 50 years there is a 4-m difference in height between tamarack and black spruce in the most productive stands. The difference in apical growth tends to confirm the difference in volume yields.

Height growth of Eastern cedar by forest type

Height growth data for Eastern cedars, along with data for cedar forests and spruce forests with cedar, are shown in Figure 6. There is a striking difference between these two forest types with regard to the height growth of cedar; this difference is due in part to the peculiar social position of this species in the stands where it grows and to its tolerance for shade.

Height growth of species in spruce forests types

Examination of height growth in the species found in these two forest types (Figures 7 and 8) reveals that the height growth of tamarack is greater than that of black spruce in both types. Furthermore, height growth is greater in spruce-litter forests than in spruce-mosses forests.

Height growth of species in spruce-cedar type

Figure 9 shows the height growth of four species in this forest type. Tamarack and balsam fir stand out in comparison to black spruce and Eastern cedar. Possible explanations for this difference include an extended period of suppression in the case of black spruce and cedar as the total age of the trees in question is over 150 years.

Height growth of species in cedar type

A cedar forest is a forest type that is rich in species and displays excellent height growth. This situation is illustrated in Figure 10 for the six species included in our inventory, namely tamarack, balsam fir, white birch, black spruce, and eastern cedar. Figure 10 confirms previously observed facts such as a gradient in height growth, with tamarack attaining the most rapid growth and cedar the slowest.

Height growth of species in tamarack-cedar type

For this forest type, the height growth of three species was observed: tamarack, balsam fir, and black spruce. Figure 11 shows that height growth is similar for both tamarack and balsam fir, but slower for black spruce. This slow growth of the latter may be the result of the prolonged period of suppression undergone at the juvenile stage of its development.

CONCLUSIONS

Our selection of forest types for the locations of our experimental plots was based on criteria used in Finland (Seppälä 1986). The application of those criteria means that peatland is drained if the annual yield of the stand, in terms of volume, is 1.5 m^3/ha/year or more. At the same time, the state of the stand must be such that physiological rejuvenation by means of thinning is feasible.

Using these criteria as a guide, we eliminated inadequately stocked stands with highly variable vertical or "diametral" structures (poplar, cedar, and tamarack). Considering the feasibility of physiological rejuvenation, we eliminated young stands at the regeneration stage and cut-over areas. Taking into account the factors of yield and height increase, we eliminated the spruce-ericaceous type. In the Saint-Anaclet peatland, we ultimately accepted only spruce-litter and spruce-mosses as forest types suitable for our experimental observations.

This choice was based on the fact that the distribution of stems in rectangular plots measuring 20 by 15 m were normal (see Figure 12 for spruce-litter and Figure 13 for spruce-mosses), that these are even-aged stands of 50 and 80 years, respectively, that height growth in black spruce was comparable to that of the spruce in categories II and IV in the Vézina and Linteau's (1968) tables, and that the annual increment in volume was 3.4 m^3/ha/year in the spruce-litter forests and 1.4 m^3/ha/year in the spruce-mosses forests.

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APPENDIX

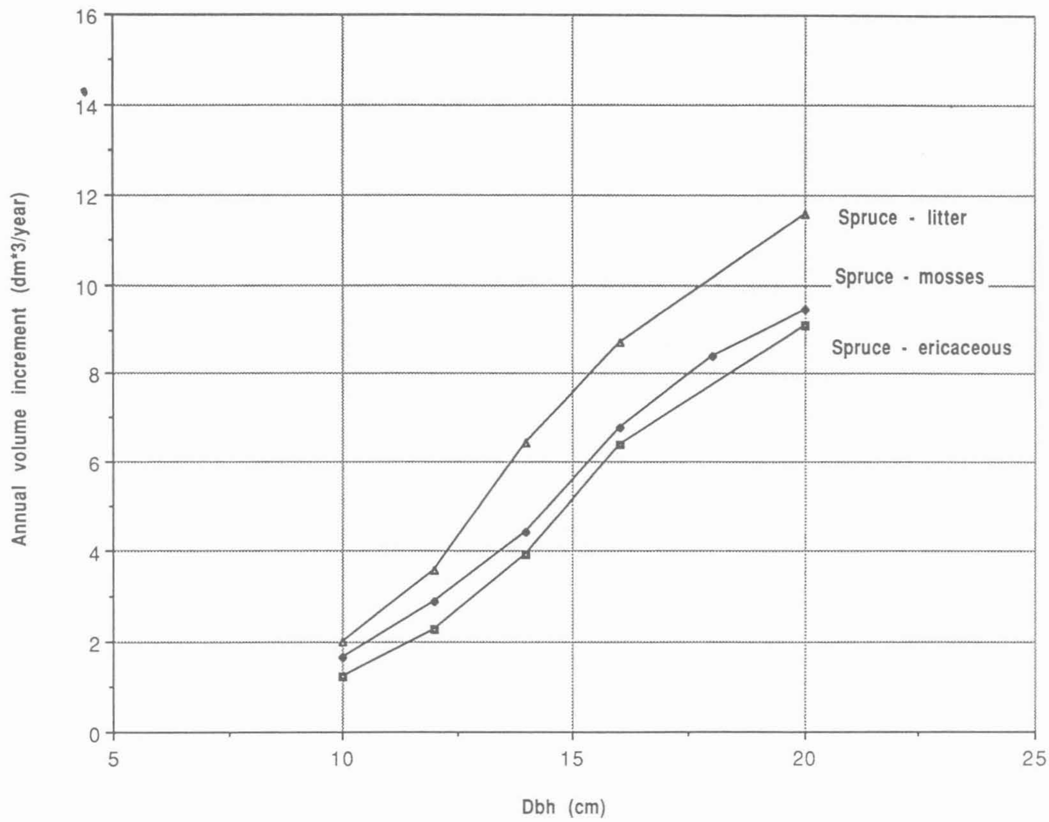

Figure 1. Annual volume increments of black spruce by forest type.

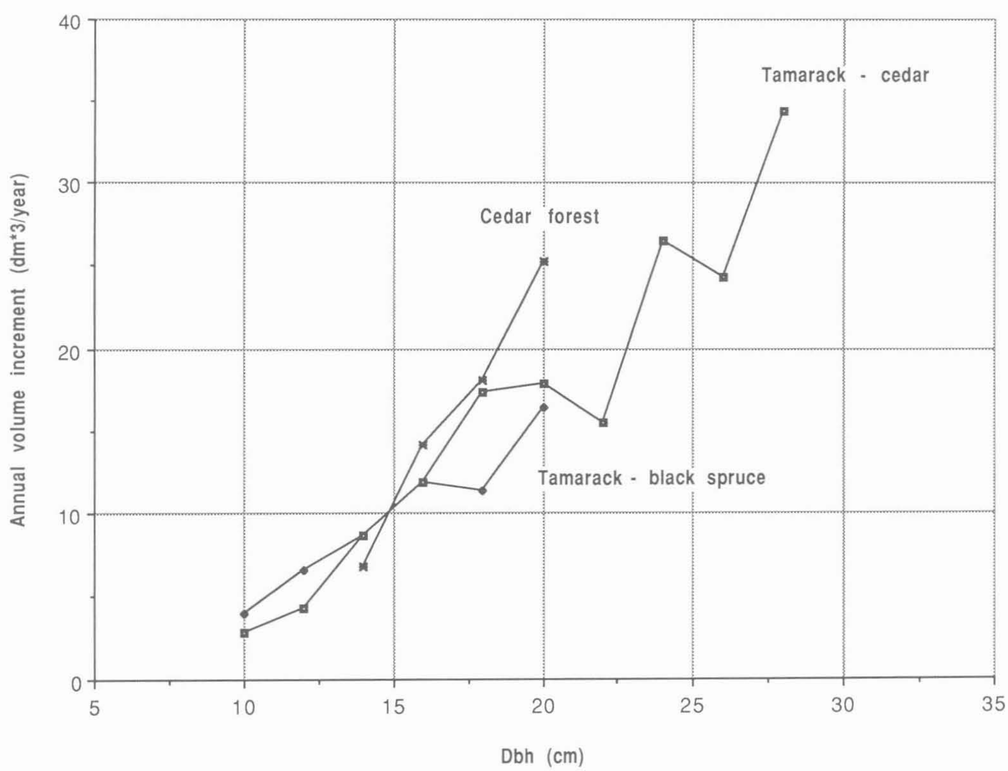

Figure 2. Annual volume increments of tamarack by forest type.

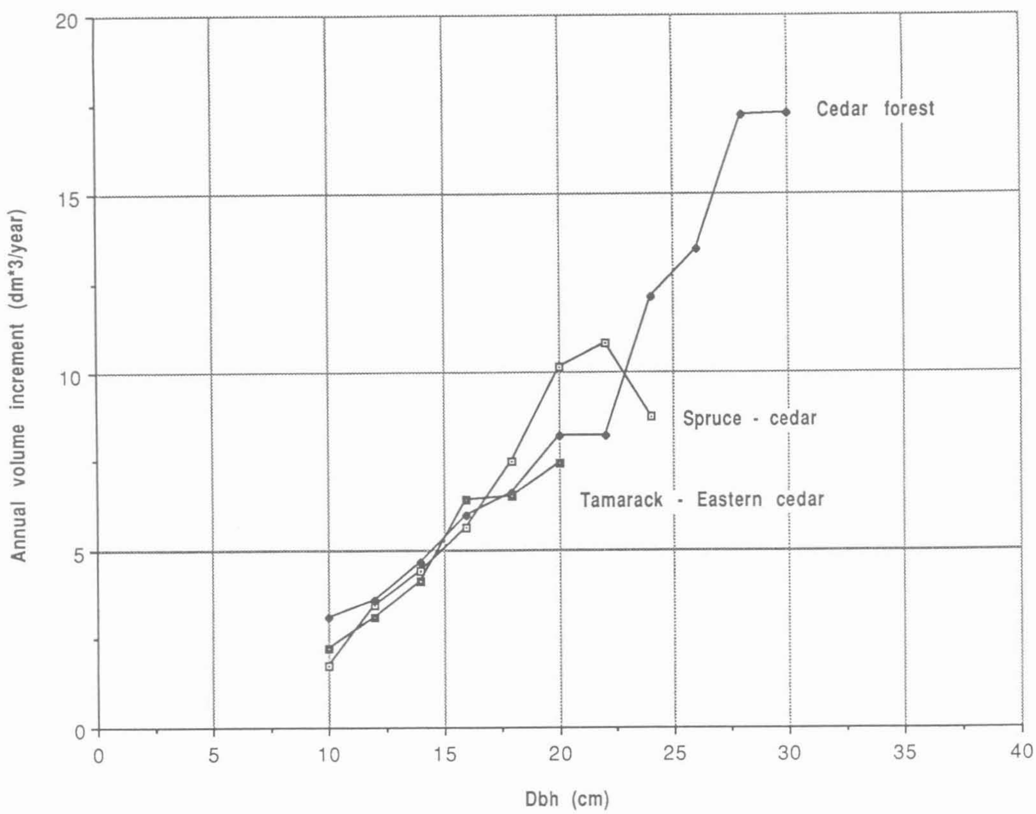

Figure 3. Annual volume increments of Eastern cedar by forest type.

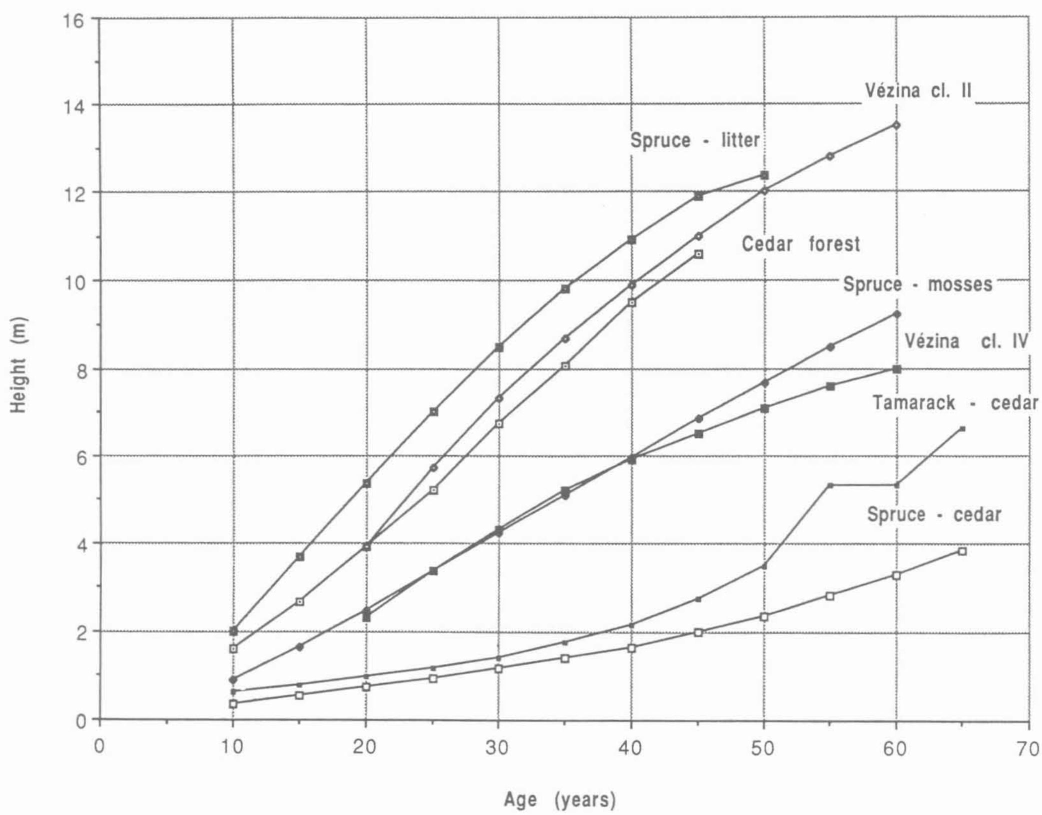

Figure 4. Height growth of black spruce by forest type.

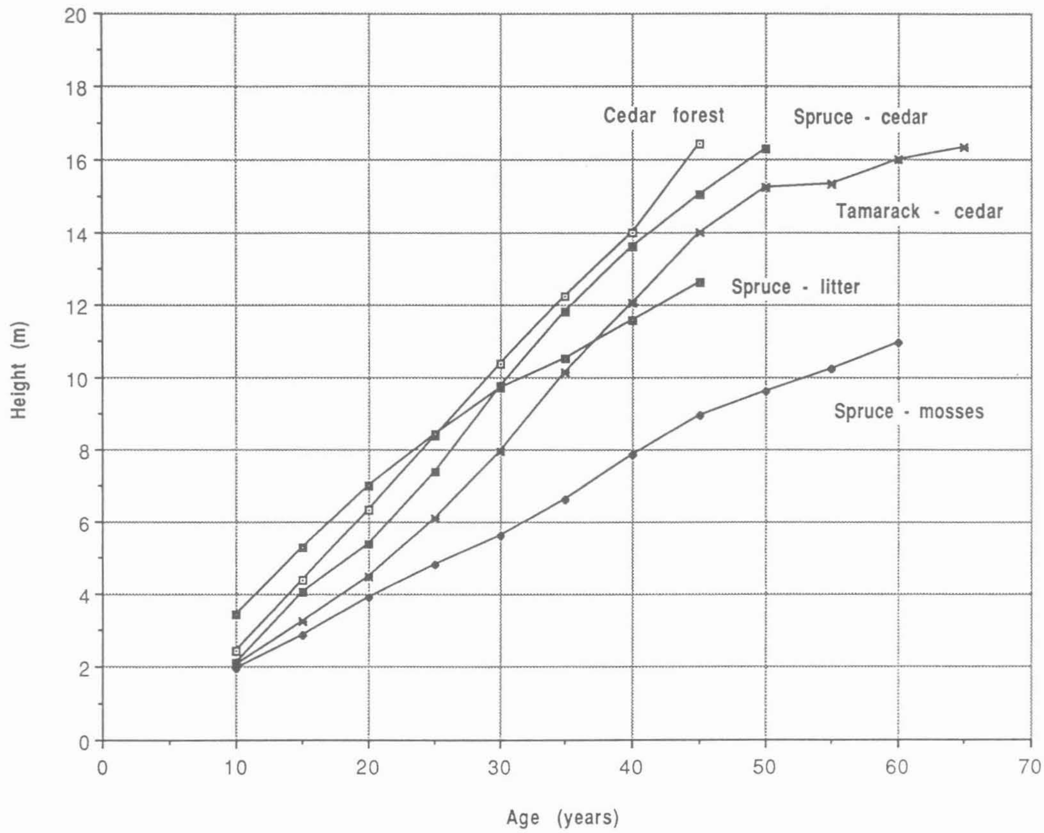

Figure 5. Height growth of tamarack by forest type.

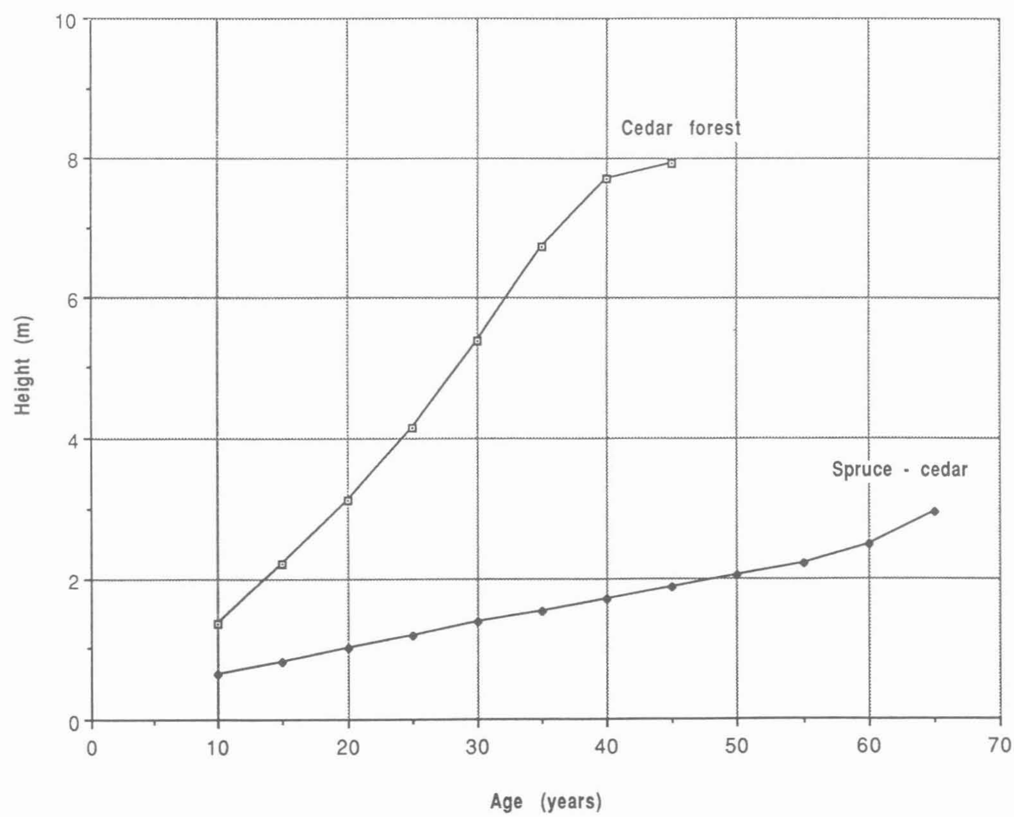

Figure 6. Height growth of Eastern cedar by forest type.

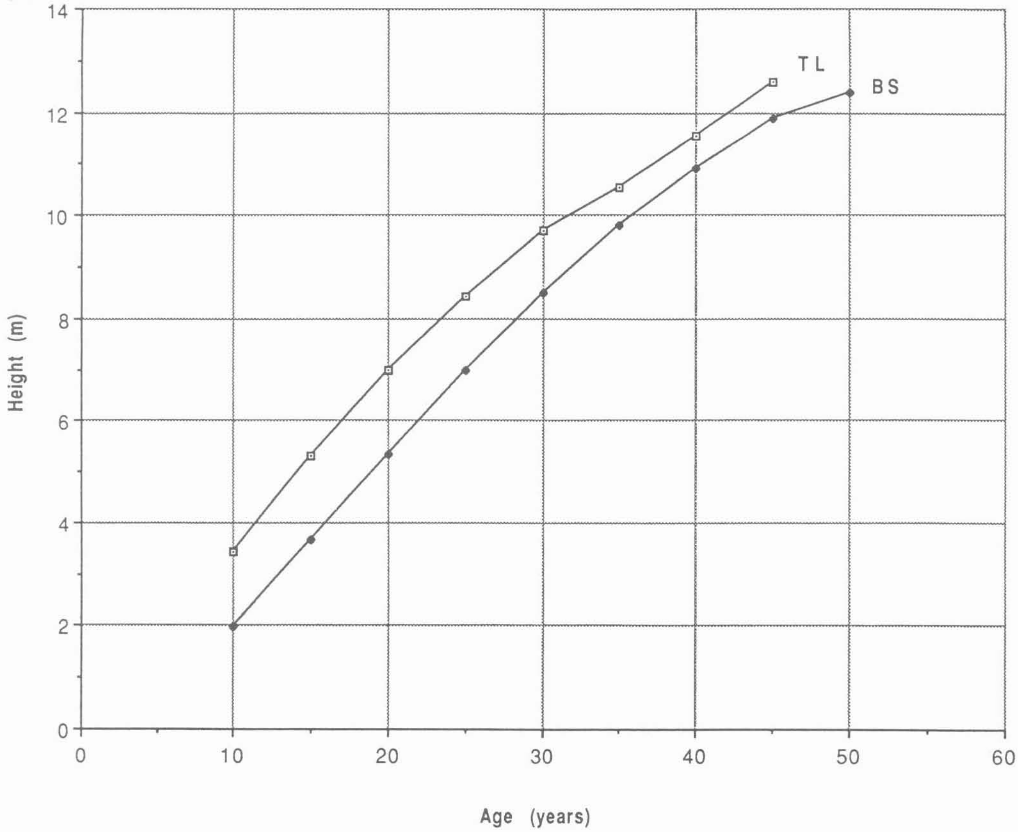

Figure 7. Height growth of species in spruce-litter type.

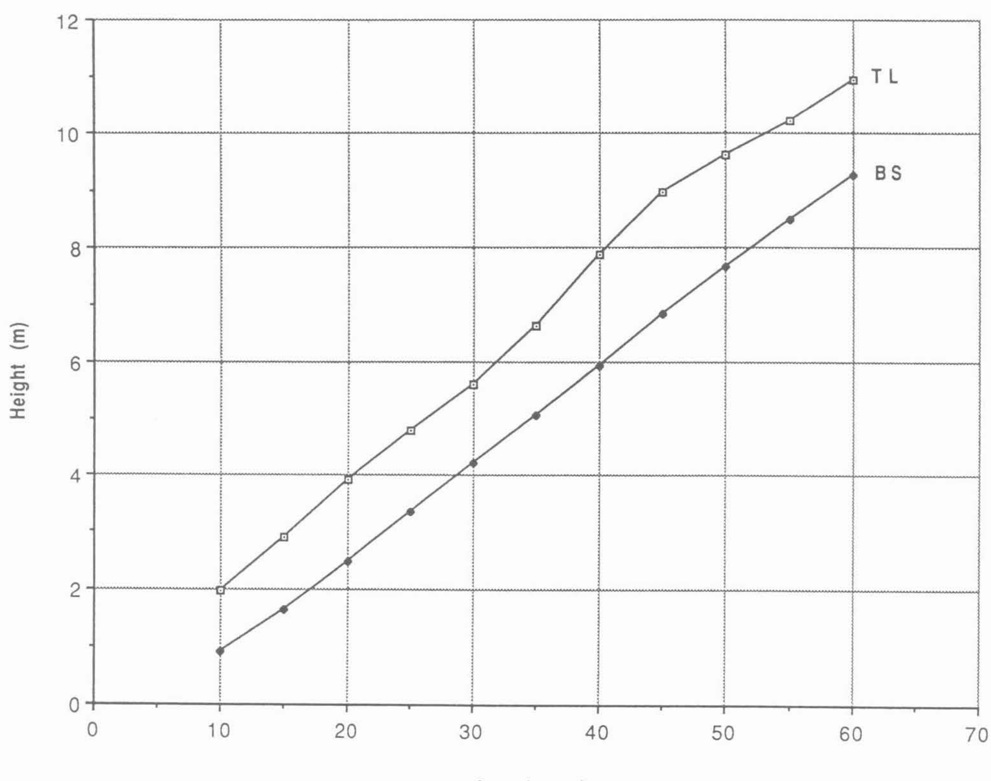

Figure 8. Height growth of species in spruce-mosses type.

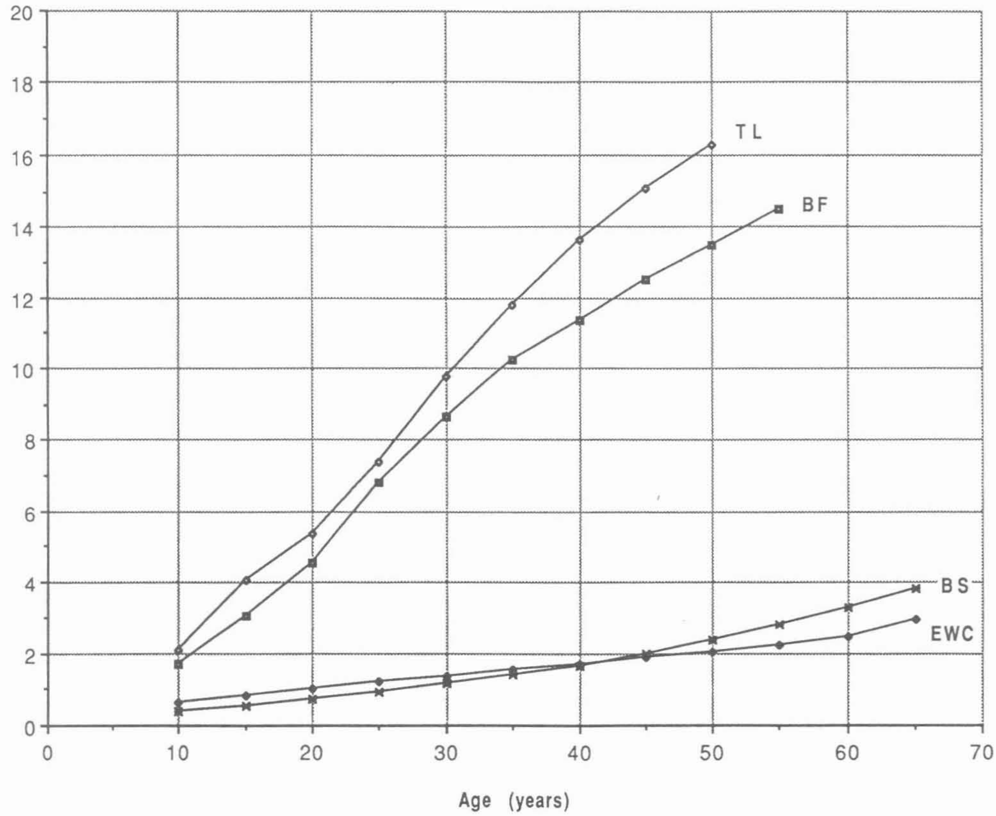

Figure 9. Height growth of species in spruce-cedar type.

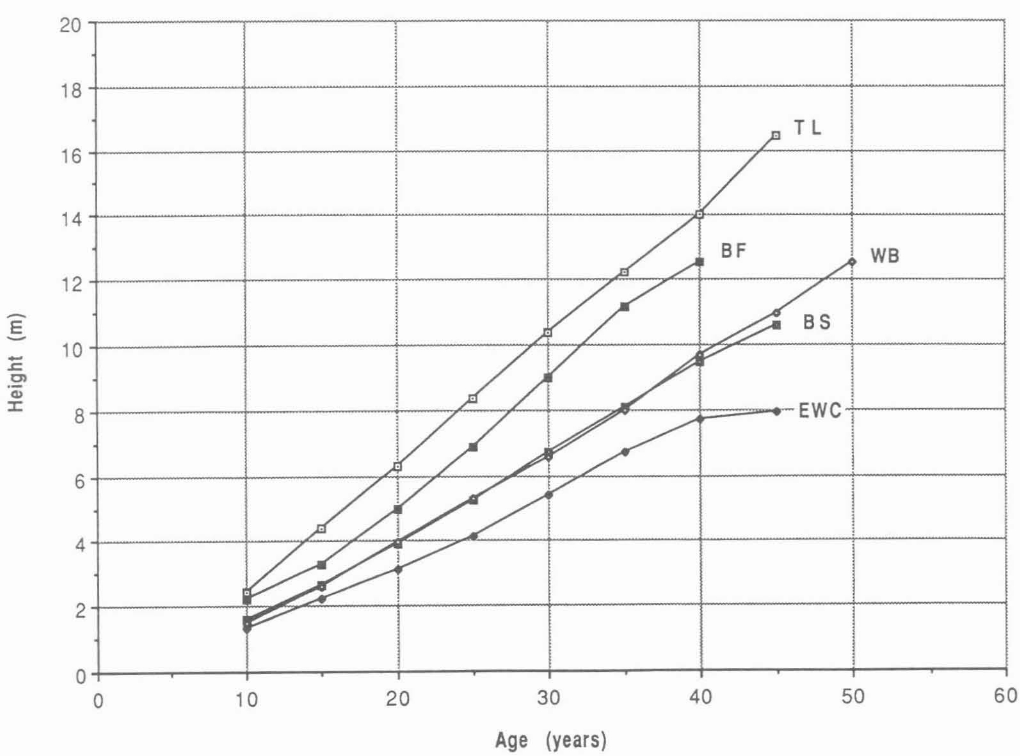

Figure 10. Height growth of species in cedar types.

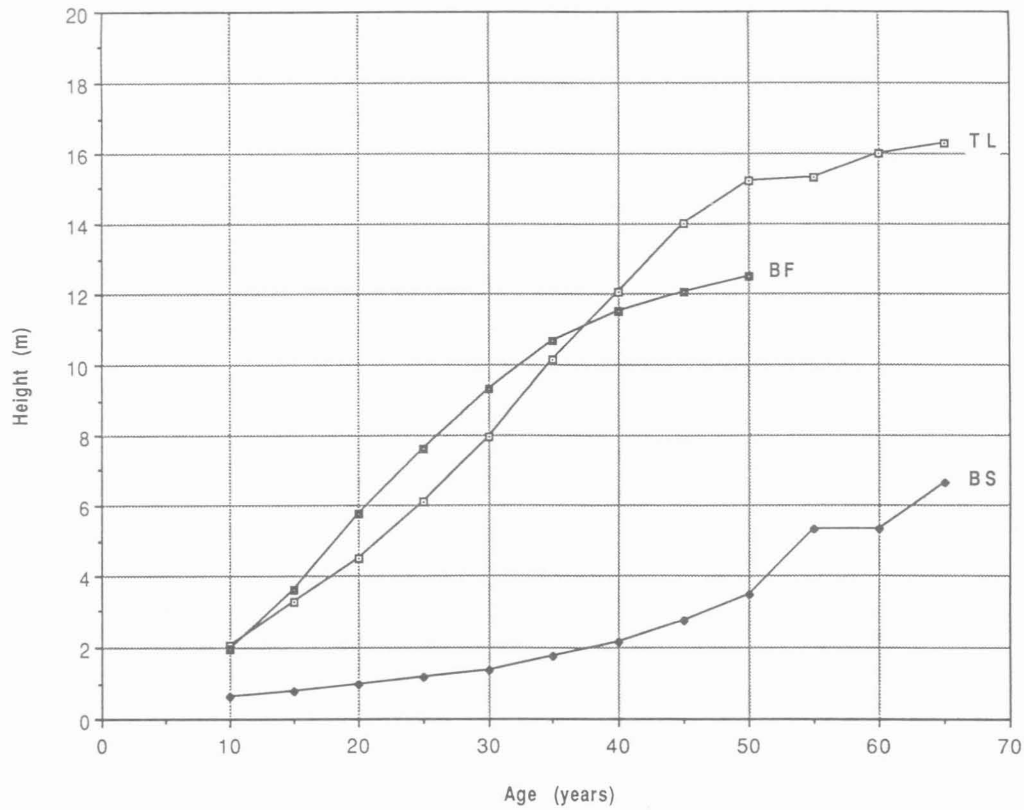

Figure 11. Height growth of species in tamarack-cedar type.

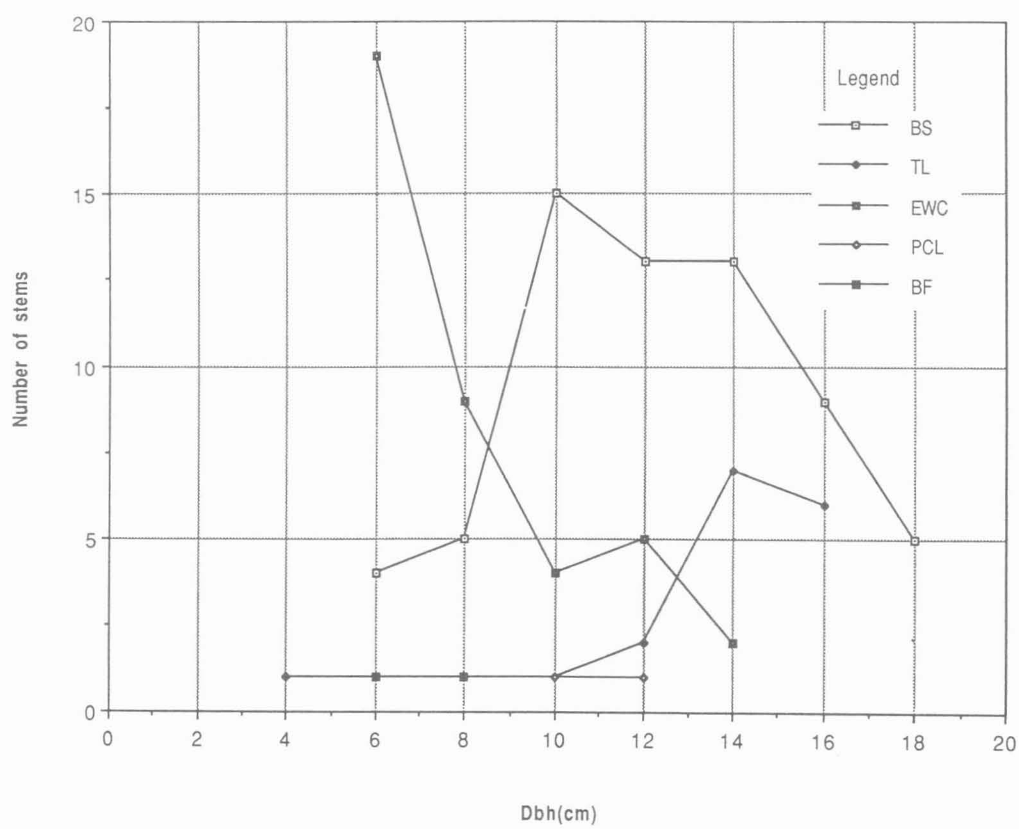

Figure 12. Stem diameter distribution in spruce-litter type.

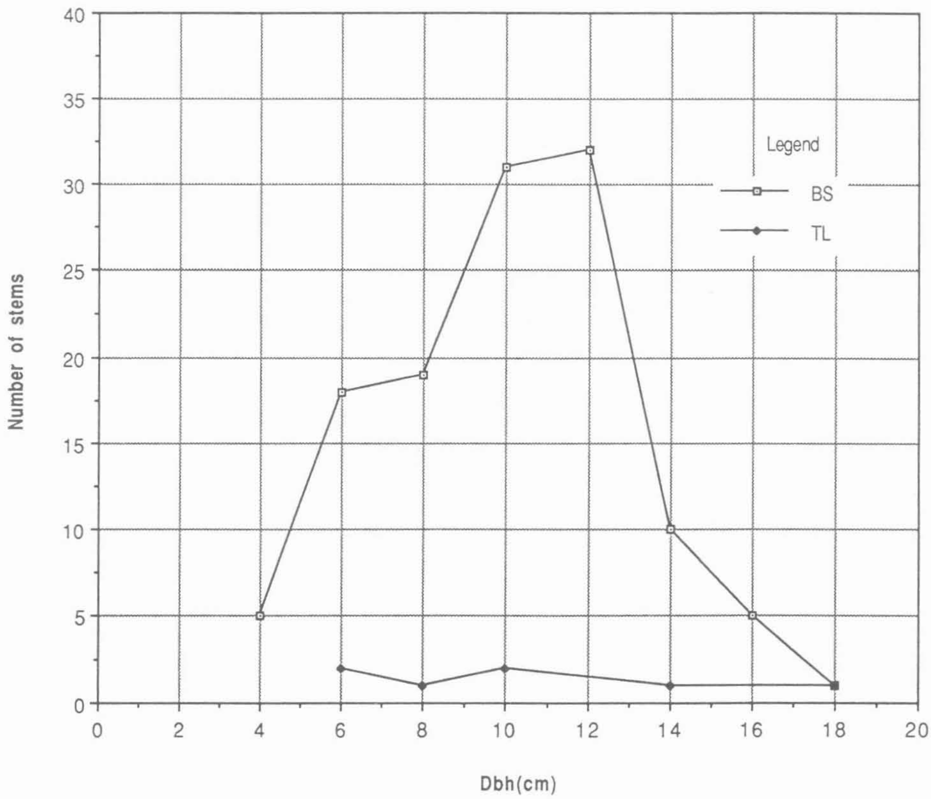

Figure 13. Stem diameter distribution in spruce-mosses type.

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