PRELIMINARY YIELD FUNCTIONS AND TABLES FOR PEATLAND BLACK SPRUCE IN ONTARIO

B. Payandeh

FORESTRY CANADA

ONTARIO REGION

GREAT LAKES FORESTRY CENTRE

1990

INFORMATION REPORT 0-X-405

Catalogue No. Fo46-14/405E
ISBN 0-662-17052-0
ISSN 0832-7122

Additional copies of this publication
are available at no charge from:

Communications Services
Forestry Canada, Ontario Region
Great Lakes Forestry Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Microfiches of this publication may be purchased from:

Micromedia Inc.
Place du Portage
165, Hôtel-de-Ville
Hull, Quebec
J8X 3X2

Payandeh, B. 1990. Preliminary yield functions and tables for peatland black spruce. For. Can., Ont. Region, Sault Ste. Marie, Ont. Inf. Rep. O-X-405. 10 p. + appendices

ABSTRACT

Data from 425 permanent growth plots established in the early 1970s in the peatland forest types of northern Ontario were analyzed. Stepwise and all-possible-subset linear regression and nonlinear regression models were used to develop tree and stand yield functions and tables.

In general, the high natural variability of the stands combined with the sampling methods used (point sampling) resulted in yield equations with somewhat low precision. Although the linear mixed models (containing both continuous and discrete variables) produced better fit than nonlinear models in some cases, the latter were chosen for construction of the yield tables because of their flexibility and their adaptability to natural growth processes. Monserud's (1984) logistic model provided better fit than the Richards (1959) growth model for nearly all yield components. None of the site factors (i.e., categorical variables) proved significant in the nonlinear models.

The resulting yield equations and tables are in close agreement with earlier work by Evert (1967). They also produce growth patterns similar to those developed for northern Minnesota. Foresters concerned with managing peatland black spruce resources in northern Ontario should find such preliminary growth and yield information of value in their resource management.

RÉSUMÉ

On a analysé des données obtenues de 425 placettes d'échantillonnage permanentes établies au début des années 70 dans des peuplements forestiers de tourbière du nord de l'Ontario. En utilisant des modèles de régression non linéaire et linéaire avec les techniques pas-à-pas et de tous les sous-ensembles possibles, on a construit des fonctions et des tables de rendement pour les arbres et les peuplements.

En général, la précision des équations de rendement est plutôt faible en raison des méthodes d'échantillonnage employées (échantillonnage par points) et de la forte variabilité naturelle des peuplements. Même si les modèles linéaires mixtes (contenant à la fois des variables continues et discontinues) donnaient un meilleur ajustement dans certains cas, les modèles non linéaires ont été choisis pour calculer les tables de rendement en raison de leur souplesse et de leur adaptabilité aux processus naturels de croissance. Pour presque toutes les composantes du rendement, le modèle logistique de Monserud (1984) a donné un meilleur ajustement que le modèle de l'accroissement de Richards (1959). Aucun des facteurs stationnels (c'est-à-dire variables catégoriques) n'était significatif dans les modèles non linéaires.

Les équations et tables de rendement produits sont en étroit accord avec les résultats antérieurs obtenus pour l'épinette noire de la zone argileuse (*clay belt*). L'évolution correspondante de la croissance est similaire à celle représentée par les modèles établis pour le nord du Minnesota. L'information préliminaire présentée sur la croissance et la production devriat être utile aux forestiers intéressés à l'aménagement des épinettes noires sur les sols de tourbière dans le nord de l'Ontario.

TABLE OF CONTENTS

INTRODUCTION

Black spruce (**Picea mariana** [Mill.] B.S.P.) is the most important pulpwood species in Ontario; with 1.2 billion m^3 standing volume, it represents about 30% of the total growing stock of all pulpwood species (Anon. 1986). Because of its desirable pulping qualities, black spruce makes up more than 60% of the roundwood utilized by the pulp and paper industry in Ontario.

Nearly 50% of the black spruce in northern Ontario occurs on peatland sites (Ketcheson and Jeglum 1972). Because of excess water, poor aeration, inadequate nutrient availability and adverse climatic conditions, its productivity on such sites is very low (Lebarron 1945, McEwen 1969, Payandeh 1973a). However, productivity can be improved by drainage, fertilization and/or thinning (Averell and McGrew 1929; Stanek 1968; McEwen 1969; Payandeh 1973a,b, 1989).

Although yield tables indicating the current productivity of black spruce stands in Ontario were prepared by Evert (1967) and by Plonski (1974), such tables were based entirely on the productive capacity of unmanaged stands. The tables were, of necessity, based on extensive surveys of the interrelationships among the various growth elements. To provide more precise mensurational information on growth and yield of peatland black spruce in northern Ontario, an assessment was undertaken by staff of Forestry Canada, Ontario Region. The purpose of this report is to present the preliminary growth and yield tables and equations that were derived from this study.

MATERIALS AND METHODS

Four hundred and twenty-five permanent growth plots were established during the 1969-1973 field seasons in Cochrane District (Fig. 1). Most plots were located in stands 2 ha in area or larger without significant gaps in the canopy. The plots covered a wide range of stand ages, stand conditions, densities, site indices, etc., as indicated in Table 1.

Horizontal point sampling (Beers and Miller 1964, Husch et al. 1982) with a 5, 10 or 20 basal area factor (1.15, 2.30 and 4.60 m^2/ha) was used to establish the growth plots. The choice of basal area factor was made in accordance with the stand size and density such that, on average, 8-15 trees per plot were included. Application of a variable basal area factor was considered at the beginning of the study in order to optimize the number of "in" trees per plot. This practice was abandoned after the first field season when it was realized that not only would it increase the sample variability but it might also introduce bias to the estimator. In most cases, a basal area factor of 10 (2.3 m^2/ha) was used.

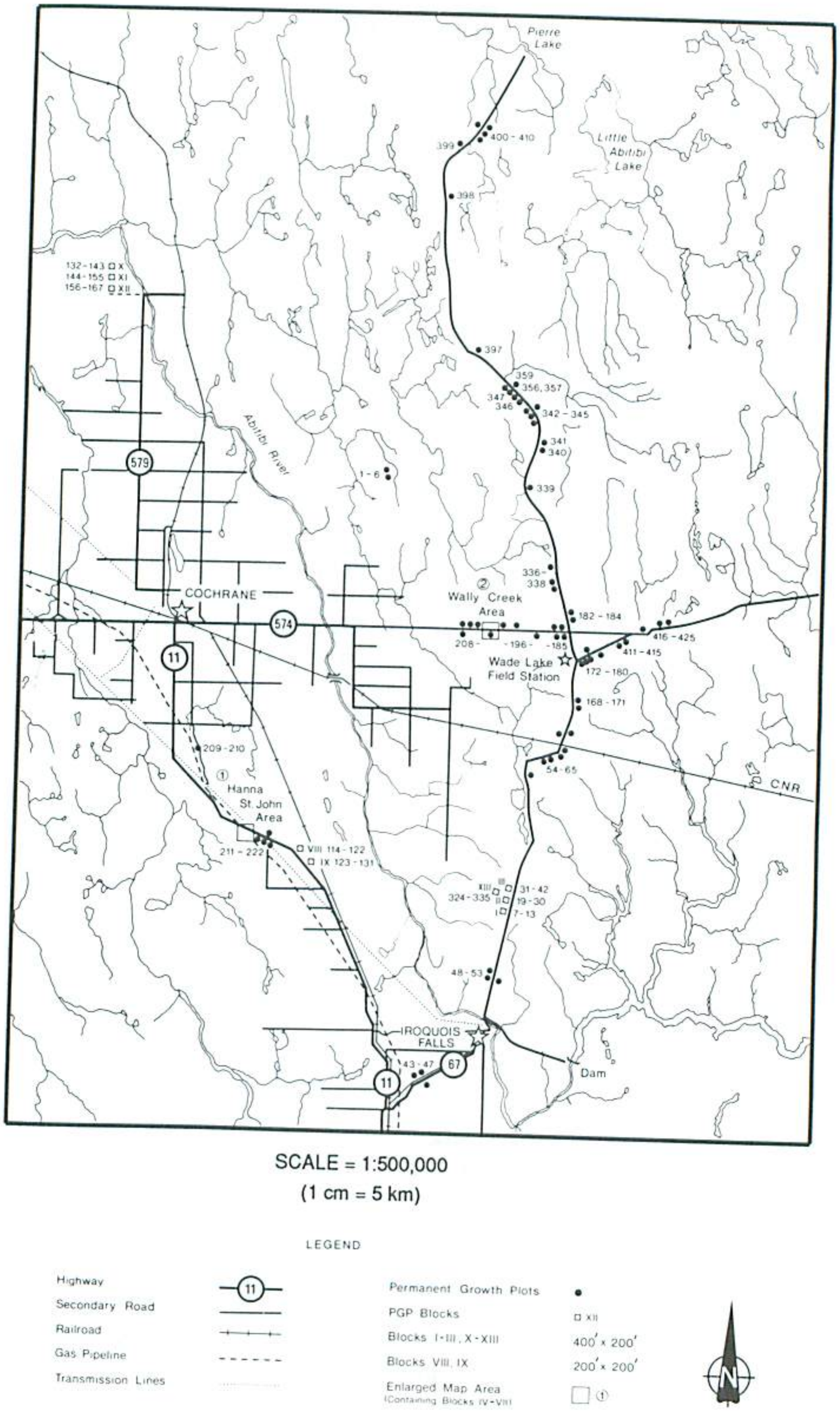

Figure 1. Location of permanent growth plots established in peatland black spruce stands in Cochrane District and its vicinity.

Table 1. Statistical summary of permanent growth plots of peatland black spruce in northern Ontario.

Stand characteristics	Minimum	Maximum	Mean	Coefficient of variation (%)
Diameter (cm)	2.88	26.54	12.16	39.91
Height (m)	2.84	17.96	9.14	29.62
Site index (m)	1.59	15.38	5.26	46.01
Age (years)	32	200	105	33.73
Density (trees/ha)	210	20390	2841	81.53
Total basal area (m^2/ha)	2.30	78.05	24.37	48.91
Merchantable basal area (m^2/ha)	0.00	64.28	18.39	71.92
Total volume (m^3/ha)	5.16	423.52	111.33	62.45
Merchantable volume (m^3/ha)	0.00	392.33	80.54	84.86

A Spiegal relascope with automatic slope correction was used for tree tallies. All borderline trees were checked by tape to ensure their status. All "in" trees were marked with white paint at breast height (1.30 m) so that current and subsequent measurements could be taken at the same point. All tallied trees in the plot were numbered with aluminum tags facing the plot center, which was marked with a 1-m-high aluminum stake. The horizontal distance from the center of trees (at breast height) and the plot center and bearings of at least three tallied trees were recorded as an aid in possible relocation of "lost" plot centers for the next remeasurement. An example of a plot tally sheet, which shows the type of data collected, is given in Appendix A.

About one third of the plots were established within blocks alongside the existing experimental and/or highway drainage ditches. Another one third of the plots were established in stands to be drained and/or fertilized. Fertilization plots consisted of 0.04-ha fixed-area circular plots centered on a growth plot (point) with a buffer zone of about 1 m around it. The remaining plots were scattered throughout the area to provide an optimum range of stand age, site conditions, density, etc. About 70% of the plots established near the drainage ditches were fertilized with several levels of nitrogen (N), phosphorus (P) and potassium (K).

Detailed mensurational data were collected on individual tree and stand characteristics so as to provide a basis for developing empirical growth models for predicting volume and value growth on both an individual tree and a stand basis.

Data gathered on each plot included, among other things, plot number, average stand age (A), landform [LF], slope percent (SL), slope position [SLP], slope length (SLL), aspect [AS], and peat characteristics such as depth (PD), composition [PC] and degree of humification [HU], moisture regime [PM], peatland cover class [CV], and lesser vegetation [LV]. Discrete or categorical variables are enclosed in square brackets.

For each "in" tree (i.e., one that is included in the sample on the basis of probability proportional to the tree size) ≥4 cm DBH (diameter at breast height, i.e., at 1.30 m) the data recorded included tree number, species code, and tree status (e.g., pulpwood, sawlog, cull, cut or dead, etc.). Outside-bark DBH was measured to the nearest 0.25 mm with a diameter tape. In addition, the following data were collected on three to five dominant and codominant trees in each plot. Total height (H) was measured to the nearest 30 cm, with sectional measuring poles for trees less than 10 m tall and with a Spiegal relascope for taller trees. Each tree was classified in one of 10 crown classes [CCL] and one of the three crown condition classes [CCN] (see Appendices for description). Average tree crown width (CW) was estimated visually to the nearest 30 cm. Height to the base of live crown (HTL) (i.e., the general level at which the leaf surface of the crown begins) was measured in a manner similar to that in which tree total height was measured (i.e., with sectional measuring poles or Spiegal relascope). Finally, tree age at stump height (i.e., at 30 cm above ground) was determined on increment cores taken at this level with an Addo-X-Tree Ring Measuring Machine.

Total (TV) and merchantable (MV) volumes were calculated by means of the tree volume equations of Honer et al. (1983). Merchantable volume was based on a stump height of 15 cm and a minimum top diameter of 7.5 cm.

Complete measurements were taken on 927 dominant and codominant trees. The data on these trees were used to calculate average plot site index (SI) on the basis of existing site index formulae (Payandeh 1978). Although several of the site variables and peat characteristics were initially classified into 10 to 12 categories according to Hills (1955), a preliminary screening of the data by means of a multi-way frequency table (Fienberg 1981, Hill 1982) indicated that many classes contained few or no observed data. The initial categories within each variable, therefore, were combined to reduce the number of categories and to avoid classes with low observed frequencies (see Appendix B). Combining classes of categorical variables because of similarities and/or low frequency is both valid and necessary for regression analysis. Since each class is represented by a dummy variable that carries one degree of freedom regardless of its frequency, classes with low frequencies should be avoided; otherwise, they would influence the resulting regression relationship disproportionately. The variable "percent slope" was also transformed into two categories of slope: 1) slope, if the slope was >5%, and 2) flat, otherwise. It was found that two or three categorical variables conveniently summarized all the observed data, as shown in Appendix B.

Most statistical analyses of categorical variables, particularly regression analyses, require proper transformation (i.e., assigning of dummy variables to various classes of each variable) (see Draper and Smith 1966, Chatterjee and Price 1977, Sokal and Rohlf 1981). In the present analysis (k-1) dummy variables were used to distinguish among k distinct classes.

Various growth and yield components were calculated on an individual tree basis as well as on a stand basis. Both linear and nonlinear regression models were employed. In the case of linear models, stepwise and all-possible-subset regression analyses were used, with dummy variables representing the categorical variables. In general the following linear regression models were used for various tree and stand yield and growth components:

$$Y = f \text{ (site factors only)} \quad (1)$$
$$Y = f \text{ (site factors, tree and/or stand characteristics)} \quad (2)$$
$$\ln Y = f \text{ (as in (2) above, plus } \ln \text{ transformation)} \quad (3)$$

where site variables in the above models were mostly categorical variables such as landform, slope position, aspect, peat depth, peat composition, peat degree of humification, peat moisture regime and peatland cover type. Categorical variables describing individual tree characteristics included tree status, defects, crown class and crown condition, etc., as summarized in Appendix B.

The nonlinear regression models (Draper and Smith 1966, Ratkowsky 1983) were of the sigmoidal type and included an extension of the Richards growth function (Richards 1959, Ek 1971, Payandeh 1988) and Monserud's (1984) logistic model, given below:

$$Y = \beta_1 S^{\beta_2/(1+e^{[\beta_3+\beta_4 \ln(A)+\beta_5 \ln(s)]})} + E \quad (4)$$

where: Y = a yield characteristic such as basal area or volume/ha, S = site index (height at index age 50 years), A = stand age (years), $\ln$ = natural logarithm, e = base of natural logarithm, β_1-β_5 = parameters of the model to be estimated, and E = error term of the model.

Model (4) produces polymorphic sigmoidal yield curves. A constrained form of its reciprocal was used to express stand density or number of trees/ha over age.

RESULTS AND DISCUSSION

Table 1 provides the statistical summary of the data used. Results of linear regression analyses expressing major tree attributes as functions of site factors, tree and stand characteristics indicated that such categorical variables are poor predictors of tree attributes, except in the case of tree diameter and height, for which three or four site factors explained 60 to 65% of the variability, respectively.

Table 2 contains the summary of stepwise linear regression equations of peatland black spruce stand-yield characteristics. Three to four stand variables and one site factor (peat depth or peatland cover type) accounted for 56 to 96% of the variability in the yield characteristics concerned. Stand density (i.e., number of trees/ha) and total basal area/ha were highly variable (R^2 = 0.56 and R^2 = 0.57, respectively), perhaps mainly as a result of the sampling scheme used, i.e., point sampling. However, the goodness of fit values for merchantable basal area and for volumes were extremely good.

Table 2. Summary of multiple linear regression equations expressing peatland black spruce stand yield characteristics as a function of site factors and stand characteristics (qualitative and quantitative variables).

Yield characteristic	Regression equation[a]	R^2	SEE
Density (trees/ha)	$N = 4825 - 255.91\ QM + 147.38\ S + 269.00\ [PD]$	0.56	1.39
Total basal area (m^2/ha)	$BA_t = -23.87 + 0.0036\ N + 1.61\ QM + 0.10\ A + 1.10\ S + 5.27\ [CV2]$	0.57	7.18
Merchantable basal area (m^2/ha)	$BA_m = 0.99 - 256\ [CV1] - 0.0021\ N + 1.0085\ BA_t$	0.96	2.53
Total volume (m^3/ha)	$V_t = -55.48 + 4.55\ BA_t + 0.27\ A + 6.99\ S - 20.58\ [CV1]$	0.95	14.73
Merchantable volume (m^3/ha)	$V_m = -2.96 + 0.86\ V_t - 23.23\ [CV1]$	0.96	12.92

[a] N = stand density (i.e., number of trees/ha), QM = quadratic mean diameter BA_t = total basal area (m^2/ha), BA_m = merchantable basal area (m^2/ha), V_t = total volume (m^3/ha), V_m = merchantable volume (m^3/ha), and A = stand age (years). Other variables are defined in the text and in Appendix B.

Table 3 summarizes the nonlinear regression equations that express yield characteristics as a function of site quality and stand age. Although the goodness of fit of some of the resulting logistic models is not as high as for their linear counterparts (compare Tables 2 and 3), nevertheless, they were chosen for construction of the yield tables because of the following shortcomings of the linear equations:

a) stand age accounted for only a small portion of the variability when it was included in the linear yield equations

b) site index and/or stand age were not included as significant variables in linear models of stand density, total basal area and merchantable volume equations

c) peatland cover type and peat depth were included in the linear yield equations as significant variables that accounted for up to 5% of the variability in the response variable.

Table 3. Summary of nonlinear regression equations expressing peatland black spruce stand yield characteristics as a function of site index and stand age.

Yield characteristic	Regression equation[a]	R^2	SEE
Stand height (m)	$H = 15.24\ S^{0.84}/(1+e^{(6.16 - 0.972 \ln (A) - 0.009 \ln (S))})$	0.90	0.79
Density (trees/ha)	$N = 1395.7 + 2839\ S^{-2.82}\ (1+e^{(8.9-1.86 \ln (A) + 1.95 \ln (S))})$	0.52	9.63
Total basal area (m²/ha)	$BA_t = 40.9\ S^{-.15}/(1+e^{(18.78-3.16 \ln (A)-3.4 \ln(S))})$	0.46	5.48
Merchantable basal area (m²/ha)	$BA_m = 1.08\ BA_t^{0.98}/(1+e^{(40.16 - 7.08 \ln(A) - 5.61 \ln(S))})$	0.93	3.16
Total volume (m³/ha)	$V_t = 22.24\ S^{-0.053}\ BA_t^{0.97}/(1+e^{(8.03 - 1.08 \ln(A) - 1.19 \ln(S))})$	0.98	7.96
Merchantable volume (m³/ha)	$V_m = 0.83\ V_t^{1.02}/(1+e^{(43.05 - 7.56 \ln (A) - 6.14 \ln(S))})$	0.98	8.94

[a] S = site index, A = age (years)

For the above reasons it was not possible to construct standard yield tables (i.e., yield components expressed as functions of site index and age) for the full range of site index and stand age. In addition, the nonlinear models were chosen because of their flexibility (cf. Payandeh 1983) and ability to describe growth of a stand over time.

Inclusion of site factors as categorical variables in the nonlinear models did not prove significant. In the case of stand density, the model form had to be constrained with a minimum number of trees/ha so that it would not result in gross underestimation of density for older stands.

A set of preliminary yield tables (Appendix C) for site indices of 3, 6 and 9 m was generated from the yield equations given in Table 3. Figure 2 shows stand development as a function of age for an average peatland black spruce site (i.e., site index = 5 m) for the major stand characteristics. The resulting yield tables are in close agreement with earlier work by Evert (1967). They also produce growth patterns similar to those developed for northern Minnesota (Perala 1971).

The equations and tables in the present report provide preliminary yield information for peatland black spruce in northern Ontario. Foresters concerned with managing northern Ontario's peatland should find such information useful.

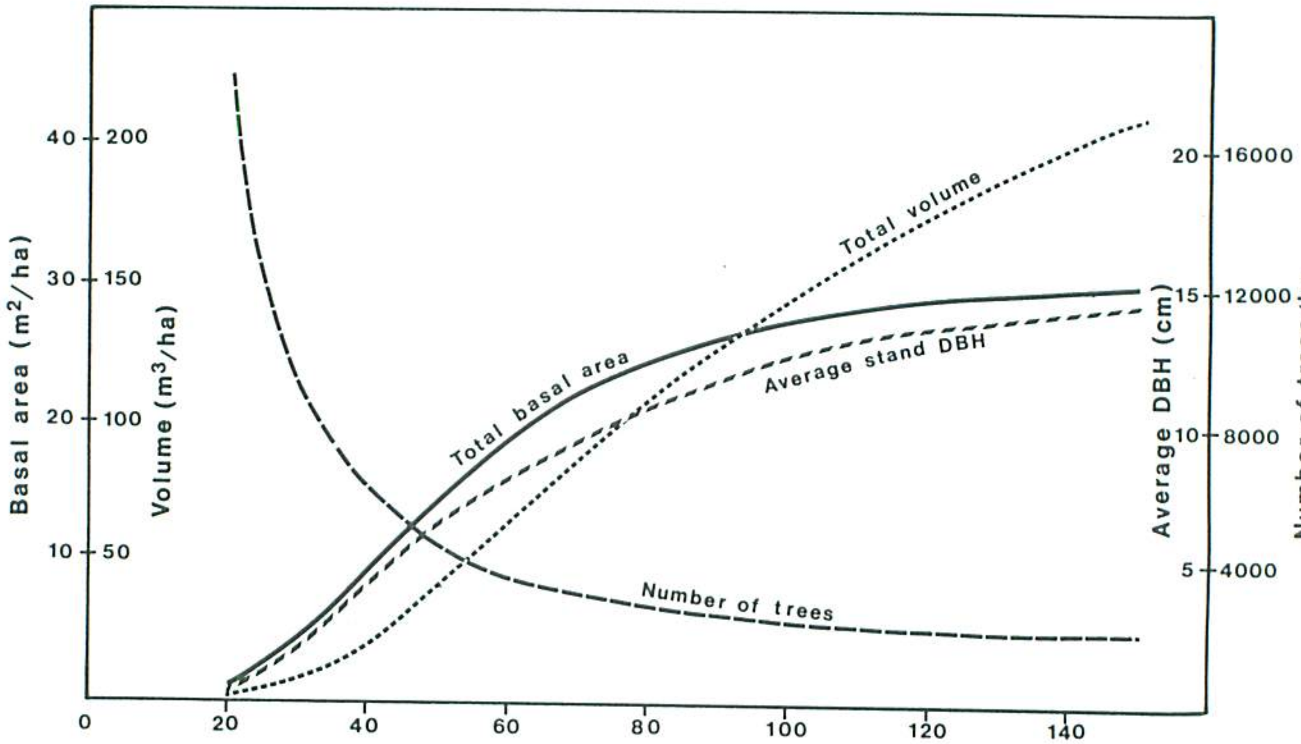

Figure 2. Plot of main yield components against stand age (years) for peatland black spruce in northern Ontario for a site index of 5 m.

ACKNOWLEDGMENT

The author would like to thank Glenn MacPherson, John Crozier and Jim Field for assistance in field data collection and analysis, and Glen Kubik, David Basham and Jim Field for programming and data analysis.

LITERATURE CITED

Anon. 1986. The forest resources of Ontario. Ont. Min. Nat. Resour., For. Resour. Gr., Toronto, Ont. 91 p.

Averell, J.L. and McGrew, P.C. 1929. The reaction of swamp forests to drainage in northern Minnesota. Minn. State Dep. Drain. Waters, St. Paul, Minn. 6 p.

Beers, T.W. and Miller, C.I. 1964. Point sampling: research results, theory and applications. Purdue Univ. Agric. Exp. Stn., Lafayette, Ind. Res. Bull. 786.

Chatterjee, S. and Price, B. 1977. Regression analysis by example. John Wiley & Sons, New York. 228 p.

Draper, N.R. and Smith, H. 1966. Applied regression analysis. John Wiley & Sons, New York. 407 p.

Ek, A.R. 1971. A formula for white spruce site index curves. Univ. Wisc., Madison. Res. Notes No. 161. 2 p.

Evert, F. 1967. Total cubic foot variable density yield table for black spruce in the Ontario Clay Belt. Can. Dep. For. Rur. Dev., For. Br., Ont. Region, Inf. Rep. 0-X-33, 35 p.

Fienberg, S.E. 1981. The analysis of cross-classified categorical data. 2nd ed. MIT Press, Cambridge, Mass. 198 p.

Hill, M.A. 1982. BMDP statistical software 1982 edition. Univ. Calif. Press, Berkeley, Calif. 725 p.

Hills, G.A. 1955. Field methods for investigating site. Ont. Dep. Lands For., Toronto, Ont. Site Res. Man. 4. 120 p.

Honer, T.G., Ker, M.F. and Alemdag, I.S. 1983. Metric timber tables for the commercial tree species of central and eastern Canada. Dep. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M-X-140.

Husch, B., Miller, C.I. and Beers, T.W. 1982. Forest mensuration. 3rd ed. The Ronald Press Co. New York. 407 p.

Ketcheson, D.E. and Jeglum, J.K. 1972. Estimates of black spruce and peatland areas in Ontario. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. 0-X-172. 29 p.

Lebarron, R.K. 1945. Adjustment for black spruce root system to increasing depth of peat. Ecology 26:309-311.

McEwen, J.K. 1969. Effect of drainage on a black spruce stand. Ont. Dep. Lands For., Toronto, Ont. Sect. Rep. No. 71.

Monserud, R.A. 1984. Height growth and site index curves for inland Douglas-fir based on stem analysis and forest habitat types. For. Sci. 30(4):943-965.

Payandeh, B. 1973a. Analysis of a forest drainage experiment in northern Ontario. I: Growth analysis. Can. J. For. Res. 3(3):387-398.

Payandeh, B. 1973b. Analysis of a forest drainage experiment in northern Ontario. II: An economic analysis. Can. J. For. Res. 3(3):399-408.

Payandeh, B. 1978. A site index formula for peatland black spruce in northern Ontario. For. Chron. 54(1):39-41.

Payandeh, B. 1983. Some applications of nonlinear regression models in forestry research. For. Chron. 59(5):244-248.

Payandeh, B. 1988. Preliminary yield functions and tables for spruce-fir stands of northwestern Ontario. Gov't of Can., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. 0-X-389. 11 p. + appendices.

Payandeh, B. 1989. Growth of black spruce trees following fertilization on drained peatland. For. Chron. 65(2):102-106.

Perala, D.A. 1971. Growth and yield of black spruce on organic soils in Minnesota. USDA For. Serv., North Central For. Exp. Stn., St. Paul, Minn., Res. Pap. NC-56, 16 p., illus.

Plonski, W.L. 1974. Normal yield tables (metric) for major forest species of Ontario. Ont. Min. Nat. Resour., Div. For., Toronto, Ont. 40 p.

Ratkowsky, D.A. 1983. Nonlinear regression modeling--a unified approach. Marcel Dekker Inc., New York. 276 p.

Richards, F.J. 1959. A flexible growth function for empirical use. J. Exp. Bot. 10(29):290-300.

Sokal, R.R. and Rohlf, F.J. 1981. Biometry. 2nd ed. W.H. Freeman and Co., San Francisco. 859 p.

Stanek, W. 1968. A forest drainage experiment in northern Ontario. Pulp Pap. Mag. Can. 69:58-62.

APPENDICES

APPENDIX A

An example of a plot tally sheet for preliminary growth and yield assessment of peatland black spruce in northern Ontario.

Crew Crozier, Dunn Date 30 Day 7 Month 1975 Location: Cochrane (county-district)

Plot No. [1] Township [4] Major sp. [6] 2nd sp. [8] Minor sp. [10]

BAF [12] Avg stand age [13] Site: Landform [16] Slope % [17] Slope position [19]

Slope length [20] Aspect [22] Soil series [23] [29] [30] Soil moisture [32]

Soil texture [26] Soil permeability [28] Disturbance Date Ground cover

Plot radius factors: 5 BAF = 3.889; 10 BAF = 2.750; 20 BAF = 1.945 feet.

Tree No.		Spe- cies		Tree status	DBHob				Defects	Total height			Tree form		Double bark thick- ness			Crown class	Crown condition	Crown width		Ht to live crown		Distance to nearest neighbor			Tree age				
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64

Location notes; marked tree, species, size, distance, etc.
Distance from plot center:

APPENDIX B

Initial description and codes for site factors, peat characteristics, lesser vegetation and final categorical and dummy variables used.

Initial code and description		Final categorical and dummy variables
	Landforms	
0	Bog and swamp	landform class 1, LF = [1] (peatland)
1	Glacio-lacustrine plain (sand and gravel)	landform class 2, LF = [0] (upland)
2	Glacio-lacustrine (silt and clay)	
3	Littoral landscape (dunes, beaches and bars)	
4	Moraine landscape (ground and recessional moraines, drumlins, knob and kettle ridge)	
5	Flattened till plain	
6	Glacio-fluvial deposits (meltwater stream beds and outwash plains)	
7	Esker and kame landscape	
8	Limestone plain	
9	Other bedrock landscape	
	Moisture Regime	
1	Oversaturated--water level above surface for six months or more	peat moisture class 1, [PM1 PM2] = [1 0] (saturated)
2	Saturated--water level at or above surface	
3	Very wet--water below surface - not lower than 10 cm	
4	Wet--water level 10-19 cm below surface	

(cont'd)

APPENDIX B (cont'd)

Initial code and description		Final categorical and dummy variables
	Moisture Regime (concl.)	
5	Very moist--water level 20-25 cm below surface	peat moisture class 2, [PM1 PM2] = [0 1] (very moist)
6	Moist--water level 26-34 cm below surface	peat moisture class 3, [PM1 PM2] = [0 0] (fresh)
7	Moderately moist--water level 35-60 cm below surface	
8	Fresh--water level 61-120 cm below surface	
9	Moderately dry--water level 121-180 cm below surface	
0	Dry--water level 180 cm below surface	
	Peat depth	
	Initially measured to nearest 25 mm ≤30 cm	peat depth class 1, PD = [1]
	Initially measured to nearest 25 mm >30 cm	peat depth class 2, PD = [0]
	Peat composition	
1	Sphagnum	peat composition class 1, PC = [1]
2	Sphagnum-sedge, sphagnum principally	peat composition class 2, PC = [0]
3	Sphagnum-sedge and wood	
4	Sedge peat	
5	Sedge-sphagnum	
6	Eutrophic sedge-sphagnum peat--extremely rich areas	
7	Sedge-woody peat	
8	Woody-sphagnum and/or sedge peat	
9	Others not specified	

(cont'd)

Initial code and description		Final categorical and dummy variables
	Lesser vegetation	
1	Sphagnum-Chamaedaphne	lesser vegetation class 1, LV = [1]
2	Sphagnum-Ledum-Chamaedaphne	
3	Sphagnum-Ledum-Alnus	lesser vegetation class 2, LV = [0]
4	Sphagnum-Feather moss	
5	Feather moss	
6	Feather moss-Petasites	
7	Feather moss-Cornus	
8	Aster-Cornus	
9	Others not specified	
	Peat (degree of humification)	
1	Completely unhumified and dye-free peat; when squeezed in hand only clear, colorless water runs between the fingers	humification class 1, [HU1 HU2] = [1 0]
2	Almost completely unhumified and dye-free peat; when squeezed in hand almost clear; only weakly yellow-brown water runs	
3	Very little humification or very weak dye-yielding peat; with squeezing there is distinctly cloudy brown water, but no peat substance from between the fingers; the remainder is not pasty (viscous)	
4	Weakly humified or somewhat dye-yielding peat; with squeezing, dark muddy water runs, but still no peat substance; the remainder is somewhat viscous	humification class 2, [HU1 HU2] = [1 0]

(cont'd)

Initial code and description	Final categorical and dummy variables
Peat (degree of humification) (cont'd)	
5 Fairly humified or fairly dye-yielding peat; plant structure still evident, but somewhat hazy; with squeezing there is some peat substance, but mainly muddy brown water from between the fingers; the remainder is strongly viscous	humification class 3, [HU1 HU2] = [0 0]
6 Fairly humified or fairly dye-yielding peat, with unclear plant structures; with squeezing some 1/3 of the peat substance passes between fingers; the remainder is viscous	
7 Strongly humified, or strongly dye-yielding peat, of which plant structure is still recognizable; with squeezing some 1/2 of peat substance passes between fingers	
8 Very strongly humified or strongly dye-yielding peat with very unclear plant structures; with squeezing 2/3 passes through the fingers; the remainder, mainly from more resistant constituents, persists as root fibers, wood remains, etc.	
9 Almost completely humified or almost wholly dye-yielding peat without recognizable plant structures; nearly the entire peat mass passes between fingers with squeezing	

(cont'd)

Initial code and description	Final categorical and dummy variables
Peat (degree of humification) (concl.)	
10 Completely humified peat or wholly dye-yielding peat without any plant structures; with squeezing the whole peat mass passes between the fingers	humification class 3, [HU1 HU2] = [0 0]
Peatland cover type	
1 Stagnant black spruce of varying size and density	Cover type class 1, [CV1 CV2] = [1 0]
2 Immature black spruce--unmerchantable, but growing at a good rate	Cover type class 2, [CV1 CV2] = [0 1]
3 Mature black spruce--merchantable-size trees, vigorous	Cover type class 2, [CV1 CV2] = [0 1]
4 Overmature black spruce--merchantable, but many trees (20% or more) are falling down	Cover type class 2, [CV1 CV2] = [0 1]
5 Mixed, generally black spruce and balsam fir including white birch growing on shallow peat on slopes or upland	Cover type class 3, [CV1 CV2] = [0 0]
6 Open bog--primarily treeless, sphagnum origin	Cover type class 3, [CV1 CV2] = [0 0]
7 Fen--treeless minerotrophic, sedge predominates	Cover type class 3, [CV1 CV2] = [0 0]
8 Carr--brushy area--alder, willow, etc.	Cover type class 3, [CV1 CV2] = [0 0]
9 Marshes--open sedgy areas, water above surface for most of the year	Cover type class 3, [CV1 CV2] = [0 0]
0 Others--not specified	Cover type class 3, [CV1 CV2] = [0 0]

(cont'd)

APPENDIX B (concl.)

Initial code and description		Final categorical and dummy variables
		Tree Crown Condition
1	Good--at least 2/3 filled, with foliage of healthy green color and normal size	Condition class 1, [CCN1 CCN2] = [1 0]
2	Medium	Condition class 2, [CCN1 CCN2] = [0 0]
3	Poor--less than 1/3 filled with foliage of poor color and less than normal size	Condition class 3, [CCN1 CCN2] = [0 0]
		Tree Crown Class
1	Dominant	Dominant, CCL1 = [1]
2	Codominant	Nondominant, CCL2 = [0]
3	Intermediate	
4	Suppressed	
5	Regeneration (undergrowth)	
6	Understory tree	
7	Understory suppressed	
8	Open-grown	
9	Others	

APPENDIX C

Table C1. Estimates of preliminary yield per hectare for peatland black spruce forest types in northern Ontario.

SITE INDEX: 3 m

Stand age (yr)	Density (trees/ ha)	DBH (cm)	Height (m)	Basal area (m^2)		Volume (m^3)	
				(>1.5 cm)	(≥10 cm)	(>1.5 cm)	(≥10 cm)
20	31959	0.23	1.45	0.13	0.00	0.09	0.00
30	15841	0.61	2.12	0.47	0.00	0.49	0.00
40	9908	1.21	2.75	1.14	0.00	1.52	0.00
50	7060	2.00	3.36	2.23	0.00	3.59	0.00
60	5468	2.97	3.94	3.78	0.03	7.09	0.03
70	4485	4.04	4.50	5.76	0.13	12.29	0.16
80	3834	5.18	5.05	8.08	0.44	19.26	0.67
90	3379	6.32	5.57	10.61	1.23	27.88	2.28
100	3049	7.43	6.08	13.21	2.86	37.87	6.22
110	2802	8.46	6.56	15.76	5.54	48.84	13.92
120	2611	9.41	7.04	18.14	9.10	60.41	25.84
130	2460	10.25	7.50	20.32	13.00	72.23	40.84
140	2340	11.00	7.94	22.26	16.71	84.04	56.97
150	2242	11.66	8.37	23.95	19.91	95.65	72.68

Table C2. Preliminary estimates of yield per hectare for peatland black spruce forest types in northern Ontario.

SITE INDEX: 6 m

Stand age (yr)	Density (trees/ ha)	DBH (cm)	Height (m)	Basal area (m^2)		Volume (m^3)	
				(>1.5 cm)	(≥10 cm)	(>1.5 cm)	(≥10 cm)
20	18067	0.92	2.62	1.21	0.00	1.63	0.00
30	9248	2.33	3.82	3.95	0.01	7.52	0.01
40	6002	4.19	4.96	8.27	0.16	19.98	0.27
50	4443	6.15	6.06	13.20	1.17	38.33	2.70
60	3572	7.94	7.11	17.70	4.62	59.74	13.73
70	3034	9.45	8.12	21.29	10.93	81.55	38.98
80	2678	10.67	9.10	23.96	17.53	102.28	70.79
90	2429	11.65	10.04	25.88	22.34	121.43	89.97
100	2249	12.42	10.96	27.25	25.35	138.98	121.46
110	2113	13.04	11.84	28.24	27.20	155.10	139.68
120	2009	13.55	12.69	28.96	28.36	169.99	155.08
130	1926	13.96	13.52	29.48	29.12	183.83	168.56
140	1860	14.30	14.32	29.88	29.64	196.79	180.68
150	1807	14.58	15.10	30.18	30.02	208.99	191.75

APPENDIX C

Table C3. Preliminary estimates of yield per hectare for peatland black spruce forest types in northern Ontario.

SITE INDEX: 9 m

Stand age (yr)	Density (trees/ha)	DBH (cm)	Height (m)	Basal area (m^2)		Volume (m^3)	
				(>1.5 cm)	(≥10 cm)	(>1.5 cm)	(≥10 cm)
20	13104	1.98	3.70	4.06	0.01	7.77	0.01
30	6907	4.46	5.39	10.77	0.26	28.91	0.55
40	4626	6.92	7.01	17.39	2.80	59.17	8.65
50	3531	8.90	8.55	21.99	10.62	89.86	42.14
60	2918	10.40	10.04	24.80	19.19	117.36	87.64
70	2540	11.47	11.47	26.48	24.13	141.46	122.19
80	2290	12.36	12.85	27.50	26.51	162.76	146.83
90	2115	13.01	14.18	28.14	27.69	181.90	166.07
100	1988	13.52	15.47	28.55	28.34	199.32	182.22
110	1893	13.93	16.71	28.84	28.72	215.36	196.37
120	1820	14.25	17.91	29.03	28.96	230.02	209.06
130	1762	14.52	19.08	29.17	29.13	244.16	220.60
140	1715	14.74	20.21	29.27	29.24	257.22	231.19
150	1678	14.93	21.30	29.35	29.32	269.52	240.96