STAND TABLE PROJECTION MODELS FOR NORTHWESTERN ONTARIO'S FOREST TYPES

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ABSTRACT

Growth data from 347 permanent plots were used to develop a system of nonlinear difference equations for estimating the main growth components of a stand, namely: ingrowth, mortality and survivor growth per 5 cm diameter class for northwestern Ontario's forest types. Net 5-year change in the number of trees in a diameter class was treated as the primary dependent variable. Application of the resulting equations to actual tree tallies from a plot or stand leads to 5-year growth projection, i.e., a projected stand table. For projection periods longer than 5 years, the new stand table developed from the previous 5-year projection is used as the initial condition for the next 5-year projection, etc.

To reduce the computational efforts involved in applying the system of equations, a computer program is included which can be used to produce detailed stand tables from sample plot (or point) data by 5-year growth periods for any length of time. Various thinning options with which one may evaluate the effects of different intermediate harvest rules on the final stand structure and total growth and yield are also included in the program.

To demonstrate the application of the results of this study, stand table projections for the two sample stands are provided and the effects of different harvesting rules on the stand structure are discussed.

RÉSUMÉ

On a utilisé les données de croissance de 347 placettes d'échantillonnage permanentes pour mettre au point un système d'équations différentielles non linéaires permettant d'évaluer les principales composantes de croissance d'un peuplement, soit la croissance dans les classes supérieures, la mortalité et la croissance des survivants par classe de 5 cm de diamètre des types forestiers du nord-ouest de l'Ontario. Le changement net du nombre d'arbres dans une classe donnée de diamètre au cours d'une période de 5 ans fut considéré comme la principale variable dépendante. L'application des équations qui en résultent aux enregistreurs d'arbres d'une placette ou d'un peuplement mène à une projection de croissance de 5 ans, c.-à-d. à un tableau d'inventaire projeté. Pour des périodes de projection de plus de 5 ans, le nouveau tableau d'inventaire mis au point à partir de la projection quinquennale précédente est utilisé comme condition initiale pour la projection quinquennale suivante, et ainsi de suite.

Un programme informatisé pour diminuer les efforts de calcul dans l'application du système d'équations est inclus et pourra servir à préparer des tableaux d'inventaire détaillés à partir de données provenant de placettes (ou points) d'échantillonnage, par périodes de croissance de 5 ans, pour n'importe quelle durée. Le programme contient en plus diverses options d'éclaircie, avec lesquelles on pourra évaluer les effets qu'auront les règlements d'exploitation sur la structure finale du peuplement et sur la croissance et le rendement global.

Pour démontrer l'application des résultats de cette étude, l'auteur fournit des projections de tableaux d'inventaire des deux peuplements échantillonnés; il traite aussi de l'influence des règlements d'exploitation sur la structure des peuplements.

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INTRODUCTION

Much of northwestern Ontario's productive forest land is occupied by mixed pulpwood stands. Although the annual rate of harvest from these stands is still well below the allowable cut, it has been projected (Anon. 1966) that much greater demands will be placed on this forest resource by the turn of the century. Such demands will result from a sharp increase in wood use by Canada's pulp and paper industry and an ever increasing demand for the recreational use of forest lands in Ontario. In addition it is speculated that forest biomass will be used to produce up to 25% of Canada's energy needs by the year 2000[1].

For proper management of such a complex forest resource, information is needed on its extent, composition and growth and yield. Although several major studies have been undertaken on these forest types over the past 30 years, no comprehensive growth and yield information has been published to date.

In 1948, several pulp and paper companies jointly requested that the Ontario District of the then Forestry Branch, Department of Mines and Resources, provide growth and yield information on the forest types of the Nipigon area (Bedell and MacLean 1952). The companies involved agreed to collect the information while the Forestry Branch agreed to compile and analyze it. In 1974 it was agreed that, as a primary objective, Environment Canada's Forest Management Institute would prepare separate stand development tables for American Can of Canada Ltd. and Kimberly-Clark of Canada Ltd. It was also agreed that, once the primary objective was satisfied, the data could be used for further growth and yield analysis.

Evert (1975) prepared stand development curves and tables for each company by forest type, but without stratification by site. This useful report was well received by both companies and thus satisfied the primary objective. Evert (1976a) later prepared variable density yield tables for the jack pine (*Pinus banksiana* Lamb.) cover type for three broad site classes. He also developed (Evert 1976b) equations and tables indicating loss of volume due to regular mortality for each of five cover types within the pulpwood stands.

Although Evert's (1975, 1976a, 1976b) reports provided badly needed growth and yield information, it was felt that further analysis of the data could provide more specific information.

The purpose of this report is to present results of further analysis of the data wherein regression models were developed for

[1]Notes for an address by Hon. Len Marchand, Minister of Environment Canada, at Yale University, New Haven, Conn. April 4, 1978, (21 ms. pages)

predicting stand growth components by diameter class--namely ingrowth, mortality and accretion or survivor growth. Such a system of equations can provide a useful mechanism to predict short-term growth and structural changes in stand size-class distribution. Two examples are given to demonstrate the application of such models in stand growth projection, as well as a FØRTRAN program to facilitate the computations involved. Before describing the results, however, it is desirable to review briefly approaches to stand growth modeling.

STAND GROWTH MODELING

Forest stand growth and yield has been the subject of extensive research for many years in various countries (c.f. Vuokila 1966, Curtis 1972). Bella (1970) suggests that perhaps more data have been gathered on growth, yield and stand development than on any other aspect of forestry research. Ek and Monserud (1975) grouped stand growth modeling approaches into five categories: 1) traditional yield table methodology, 2) differential or difference equations, 3) stochastic processes, 4) distributional methods, and 5) individual tree simulation models. The stand table projection approach developed here falls in the second category. Several of the major papers in this area are discussed briefly below.

Over the past two decades, differential or difference equations have been used to describe the rate of change of various stand components. Buckman (1962) expressed the growth rate of even-aged stands as a function of age, site index and stocking in a differential expression, numerical integration of which will provide yield prediction over time. In a similar manner, Clutter (1963) developed rate equations which, when integrated, result in closed form expressions for yield prediction.

Moser (1972) developed nonlinear regression models for the three basic growth components: ingrowth, mortality and survivor growth of an uneven-aged hardwood stand in Wisconsin. He used a simple negative exponential decay function to describe mortality in terms of changes in the number of trees present. The number of ingrowth trees was estimated by using an exponential model expressed as a function of average tree size in the stand. Survivor basal area growth was estimated on a stand basis by using the derivative form of the Richards (1959) growth function as described by Piennar (1965).

Leary (1968) developed a system of nonlinear ordinary differential equations for predicting survivor growth of northern hardwood stands by size class. The main assumption in his model was that growth of a size class was affected by competition only from larger size classes.

Ek (1974) developed nonlinear difference models for ingrowth, mortality and survivor growth of uneven-aged hardwood stands in terms of 2 in. (5 cm) diameter class increments. Such a system of equations is recursive while those of Leary (1968, 1970) and Moser (1972) are simultaneous. The main advantage of this approach is that it facilitates the application of mathematical programming methodology to develop optimal tree size class distributions as demonstrated by Adams and Ek (1974). This follows from the fact that, in a recursive system, the distribution at any point in time is a function only of initial conditions.

MATERIALS AND METHODS

The data set used was that previously described by Evert (1975). Briefly, the data consisted of records on 347 permanent circular growth plots established in 1948 in northwestern Ontario and maintained by American Can of Canada Ltd. and Kimberly-Clark of Canada Ltd. Plot sizes varied from .04 to .08 ha in size. Each plot had been remeasured from one to three times, usually at 5-year intervals. Plot data consisted of cover type[2], broad site classes according to Hills' (1954) site classification, initial stand age, tree species and diameter at breast height (DBH) of all trees >1.5 cm DBH.

An estimate of plot site index based on average stand DBH-age relationship derived from Plonski's (1956) yield tables was obtained and applied according to plot cover type, i.e., site index expression for black spruce was used for black spruce cover type, that of jack pine was used for jack pine, mixed softwood and mixedwood cover types, and finally, the site index expression for aspen (*Populus* spp.) was used for hardwood cover type. Equations expressing height as a function of DBH and site index were also developed from Plonski's tables and used to estimate individual tree height according to cover type as above. Individual tree volumes were then derived from Honer's (1967) tree volume equations.

Various stand characteristics such as age, average height, number of trees, basal area (total, i.e., all trees >1.5 cm DBH and merchantable, i.e., all trees >10 cm DBH) and volume (total and

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[2]Five major cover types were used as follows:

1) Black spruce	75% or more black spruce
2) Jack pine	75% or more jack pine
3) Mixed softwood	25% to 75% jack pine, the remainder spruce
4) Mixedwood	25% to 75% softwood, the remainder hardwood
5) Hardwood	75% or more hardwood.

merchantable, 7.5 cm top diameter) were calculated for each plot and all measurement periods. Site index was calculated on the basis of the first measurement only. A summary of various stand characteristics is given in Appendix A.

Data for each plot and for all measurement periods were grouped into 5 cm diameter classes. Such distributions consisted of up to 12 diameter classes per plot, starting at the 10 cm diameter class, i.e., all trees 7.5 cm $\leq$ DBH <12.5 cm and ending with the 60+ cm diameter class, i.e., trees with DBH $\geq$57.5 cm. A record was also kept of all trees <7.5 cm DBH; some of these constituted "stand ingrowth", i.e., those trees which grew into the lowest diameter class (10 cm) considered here, from one measuement period to the next. The entire data set produced 954 diameter class distributions for all plots and measurement periods. A cursory examination of the data indicated that diameter class distributions were mainly of the negative exponential type, although unimodal and bimodal shape distributions were not uncommon.

The data were analyzed in a manner similar to that described by Ek (1974). The net change in number of trees, as defined below, was considered the main dependent variable:

Δn = stand ingrowth - mortality - upgrowth + ingrowth

where: Stand ingrowth (n_s) is defined as trees with DBH less than 7.5 cm in a measurement period in which trees grew enough to have DBHs between 7.5 cm and 12.5 cm in the next measurement period, i.e., in 5 years.

Mortality (n_m) is defined as trees in a diameter class which were alive during a given measurement period, but died during the next 5 years, i.e., by the next measurement period.

Upgrowth (n_u) is defined as trees measured in a diameter class in a given period which grew to the next larger diameter class by the next measurement, i.e., in 5 years.

Ingrowth (n_i) is defined as upgrowth from next lower diameter class measured.

In addition to the above, total number of trees, average height, total and merchantable basal area (m^2/ha) were calculated for each diameter class and for each measurement period. A summary of the various characteristics of each diameter class for the first growth period and for diameter classes of 10, 30 and 50 cm is given in Appendix B to illustrate the magnitude and relative variability of the characteristics under consideration.

ANALYSIS AND RESULTS

Nonlinear regression analysis (cf. Draper and Smith 1966) was employed to develop empirical models for each growth component under consideration. Several regression models expressing each of the growth components in question as a function of stand and/or diameter class characteristics were examined. Independent variables used were various forms of: stand density N, total basal area G, site Index S, and number of trees/diameter class n, basal area/diameter class g, etc. at the beginning of the growth period. The final regression equations for each growth component were chosen on the basis of R^2, standard error, percent bias values and logical form.

Several of the initial regression analyses were conducted on the basis of both the entire data set, i.e., diameter class distributions for all plots and all remeasurement periods totaling more than 4000 observations, and the reduced data set consisting of the diameter class distribution data from the first 5-year growth period only. Comparison of results indicated no appreciable gain by using the entire data set rather than the reduced data set. Since the latter provided more than 1600 observations per growth component, this sample size was considered more than sufficient for empirical modeling of this type; therefore, all subsequent analyses were carried out on the reduced data set. In this way, difficulties involved in using correlated observations from repeated measurements (see Seegrist and Arner 1978) were avoided and the cost of analysis was reduced considerably.

The final regression equations chosen for the main growth components are summarized in Table 1 and briefly described below. As indicated earlier, several different regression models were examined and the final equations were chosen on the basis of R^2, percent bias values and the biological interpretation possible from model forms.

The first equation of Table 1 suggests that stand ingrowth is largely a function of stand density, site index and total basal area. More specifically, it indicates that stand ingrowth increases as stand density and site index increase, but it decreases exponentially as total basal area increases. Therefore, it might be interpreted that, for a given site, a large number of small trees will produce a large number of ingrowth trees. Ek (1974) obtained similar results for northern hardwood stands in Wisconsin, except that his equation did not include site index.

The mortality data set was the most difficult set to model as evidenced by the magnitude of its variability (see Appendix B). Nevertheless, after numerous trials a model similar to that used by Ek (1974) was found to describe the data reasonably well. Equation 2 of Table 1 indicates a higher mortality rate for more frequently occurring small trees in the stand. However, while inclusion of site index in the mortality equation did not reduce the residual variation appreciably, the R^2 value obtained here was considerably higher than

Table 1. Summary of regression models for various growth components for pulpwood stands of northwestern Ontario[a]

Growth component (5-year period)	Regression equation[b]	R^2	Standard error	% bias
Stand ingrowth	$n_s = 0.001193\ N^{1.31304}\ S^{.48937}\ e^{-.0002}\ G^{2.3105}$	0.70	64.63	5.7
Mortality	$n_m = 0.06805\ n^{.9728}\ ((G/N)/(g/n))^{1.1273}$	0.44	32.47	-6.9
Upgrowth	$n_u = 0.012353\ n^{1.06899}\ S^{.67229}$	0.69	31.63	-2.9
Volume	$v = 1.7367\ g^{.8986}\ S^{.63172}$	0.76	19.31	-.03

[a] Based on the first 5-year growth period of 347 permanent growth plots established and maintained by the American Can Company of Canada Ltd. and Kimberly-Clark Company of Canada Ltd. in northwestern Ontario.

[b] Where: n_s, n_m, n_u are the main growth components of stand ingrowth, mortality and upgrowth as defined in the text in terms of numbers of trees/ha for a 5-year growth period.

v = merchantable volume/diameter class (m^3/ha)

n = number of trees per hectare/diameter class at the beginning of the growth period

g = total basal area/diameter class at the beginning of the growth period (m^2/ha)

G = total stand basal area at the beginning of the growth period (m^3/ha)

N = stand density or number of trees/ha

S = site index (m)

that obtained by Ek (1974). The ratio of [(G/N)/(g/n)] in the mortality equation is equivalent to the stand quadratic mean diameter over the diameter class quadratic mean diameter. That is, as stated above, the mortality rate for smaller-than-average trees in the stand is much higher than that for larger-than-average trees.

Of the several models examined for upgrowth, a simple power function of number of trees per diameter class times site index, i.e., equation 3, Table 1, produced the best fit to the data. Attempts to introduce expressions of size or dominance of a class in relation to average tree size in the model failed to improve residual variation appreciably. Therefore, on the basis of equation 3, it may be interpreted that, for a given site, the number of trees growing from one diameter class to the next larger one is a simple function of the number of trees in that diameter class at the beginning of the growth period. As indicated earlier, the upgrowth equation serves as a diameter class ingrowth model also. That is, the ingrowth for a diameter class is the same as the upgrowth for the next lower diameter class.

In addition to the three main growth components, i.e., stand ingrowth, mortality and upgrowth, an equation was developed expressing merchantable volume per diameter class as a function of site index and total basal area per diameter class (equation 4, Table 1). This equation is used to estimate the initial volume per diameter class, the sum of these making up the initial stand merchantable volume (m^3/ha). Since the future diameter of individual trees within each diameter class cannot be predicted from equations given in Table 1, the projected volume by diameter class is calculated by substituting diameter class basal area g in equation 4 for the midpoint diameter class basal area of $n\ (.000078)d^2$; where: n = number of trees in a diameter class at the end of the growth period, and d = midpoint of the diameter class, e.g., 10 cm, 20 cm, etc. This method of projecting future basal area and volume will result in a definite bias, especially for long projection periods. However, for short projection periods (e.g., 20 years or less) the magnitude of such a bias was considered acceptable.

APPLICATION OF RESULTS

Once the various growth components have been expressed in functional forms such as those given in Table 1, they may be used to project future stand structure and yield from one growth period to the next by projecting and incorporating the various growth components. Although the equations derived here provide an estimate of changes in various stand components on a 5-year basis, they may be used to project stand structure and yield for any growth period.

This is accomplished by constructing a new stand table at the end of each growth period, adding the number of ingrowth trees to the number of survivors in that class that did not move to the next higher diameter class. This new stand table then provides the initial conditions for the next growth period and so on. Basal area and volume per ha at the end of each growth period are then estimated as described above and based on equation 4 of Table 1.

Note that solution of equation 1 of Table 1 will provide an estimate of stand ingrowth as defined earlier. That is, the estimated number of trees for stand ingrowth should be added only to the number of survivors in the 10 cm diameter class. As stated earlier, diameter class ingrowth is equal to upgrowth calculated for the next lower diameter class, e.g., upgrowth computed for the 20 cm class will be ingrowth for the 25 cm diameter class and so on.

To facilitate the computational effort involved in applying equations 1-4 of Table 1 for prediction, a FØRTRAN program, "STDPRØ", was written (Appendix C) to project future stand structure from actual plot or stand data and for any growth period. In addition, the program allows for specification of precommercial thinning and/or intermediate harvest during the growth period, the effects of which on stand structure and total production of the stand may be examined easily. The amount of cut may be expressed by number of trees, basal area or basal area percent. Trees to be cut may be selected from among the smallest trees, the largest trees or trees of all sizes in the stand. The input for the program may be tree tallies in stand table form from either fixed plot or point samples. The input and output may be expressed in either S.I. or English units.

To demonstrate the application of the results of this study two examples are discussed here. In the first example tree tallies from a .2 acre (.08 ha) circular plot from a 96-year-old stand of jack pine cover type from northern Ontario with an estimated site index ≈16 m was used to project the stand structure over a 19-year growth period. Stand tables were projected with and without intermediate harvest cutting, using the program given in Appendix C. In the case of intermediate harvest, approximately 50% of the trees in the stand, regardless of size, were removed at the end of the second growth period, i.e., at age 98.

In the second example, tree tallies were used from a point sample plot with a 10 basal area factor prism from a 48-year-old stand in the mixed softwood cover type with an estimated site index ≈18 m. Stand tables were projected for a 17-year growth period with and without intermediate harvesting, with approximately 250 trees per ha of the largest trees in the stand to be cut at the end of the 7-year growth period.

Table 2. Summary of stand table projection for two stands in northern Ontario for growth periods of 19 and 17 years, respectively, with and without intermediate harvesting.

Stand projection and treatments	Stand Description: Initial stand		Preharvest year 2 or 7		Intermediate harvest		Residual year 2 or 7		Final residual year 17 or 19		Total yield	
	No. of trees (/ha)	Volume (m^3/ha)	No. of trees (/ha)	Volume (m^3/ha)	No. of trees (/ha)	Volume (m^3/ha)	No. of trees (/ha)	Volume (m^3/ha)	No. of trees (/ha)	Volume (m^3/ha)	No. of trees (/ha)	Volume (m^3/ha)
Example 1, 19-year projection with no intermediate harvest	1037	301.4	--	--	--	--	--	--	797	314.6	797	314.6
Example 1, 19-year projection with harvest at ≈50% of trees/ha at the end of year 2	1037	301.4	1014	304.5	509	164.5	505	140.0	425	171.1	934	335.6
Example 2, 17-year projection with no intermediate harvest	1499	322.4	--	--	--	--	--	--	1250	357.3	1250	357.3
Example 2, 17-year projection with harvest at ≈250 of largest trees in stand	1499	322.4	1464	333.8	247	129.6	1157	204.1	1194	246.9	1441	376.5

Detailed program output of stand table projections for the above examples is given in Tables 1-4 of Appendix D. These results are also summarized in Table 2 and discussed below.

Table 2 indicates that, in the case of example 1, if the initial stand with 1037 trees per ha and a merchantable volume of 301.4 m^3 per ha is left to grow for a 19-year period, on the average it will lose about 240 trees per ha from mortality, and the growth of the residual stand will make up for the loss from mortality plus 13.2 m^3 per ha net growth. On the other hand, if this stand is harvested at the rate of about 50% of the trees per ha in year 2, its total yield will be 335.6 m^3 per ha from 934 trees. That is, the intermediate harvesting in effect will increase the total yield by about 7% (335.6 ÷ 315.6 = 1.067) owing to partial salvage of mortality and increase in growth rate of the residual stands.

Similarly, Table 2 indicates that, in the case of example 2, the stand in question, if uncut for a 17-year period, will lose about 249 trees per ha from mortality but its total volume will increase by about 10% (357.3 ÷ 322.4 = 1.10). On the other hand, if 247 per ha of the largest trees in this stand are harvested at year 7, a total yield of 376.5 m^3 per ha or about 17% (376.5 ÷ 322.4 = 1.167) increase in total yield will result. Here again, the intermediate harvesting results in 7% (17 - 10 = 7%) net gain in total yield owing to increased rate of growth of the residual stand and partial salvage of mortality. Note that in this case the number of trees increased from 1250 (no intermediate harvest) to 1441 (with intermediate harvesting).

CONCLUSIONS

The results of this study should provide specific growth and yield information for northwestern Ontario's forest types. In addition, the system of equations derived may be used to develop optimal tree size class distributions for various harvesting options. This study should provide forest managers with a valuable tool for planning management strategies for northwestern Ontario's forest resources.

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APPENDICES

APPENDIX A

Statistical summary of the initial measurements of the 347 permanent growth plots from northwestern Ontario[a]

Stand characteristics	Minimum	Maximum	Mean	Variance	Coefficient of variation (%)
Average diameter[b] (cm)	4.2	29.6	13.7	18.4	31
Average height (m)	3.5	27.4	12.7	14.0	26
Average age[b] (year)	28	200	83	1228	42
Site index (m)	2.7	22.8	12.0	13.7	27
No. of trees (/ha)	580	12565	2988	4034333	67
Total basal area (m^2/ha)	8.4	56.6	34.2	74.9	25
Merchantable basal area (m^2/ha)	0.2	55.3	29.8	117.4	36
Total volume (m^3/ha)	25.1	675.3	262.0	11163	40
Merchantable volume (m^3/ha)	0.8	638.4	218.5	12293	51

[a] Based on data from 229 plots of American Can Company Ltd. of Canada and 118 plots of Kimberly-Clark Company of Canada.

[b] Only diameter and stand age were based on actual field measurements; other stand characteristics estimated or calculated as outlined in the text.

APPENDIX B

Summary of various characteristics for the first 5-year growth period and for diameter classes of 10, 30 and 50 cm of the 347 permanent growth plots from northwestern Ontario.

Statistic	Diameter class (cm)	Stand ingrowth	Mortality	Upgrowth	Ingrowth	Net change	Total				Merchantable			
		(No. of trees/ha)					No. of trees/ha	Height (m)	Basal area (m^2)	Volume (m^3)	No. of trees/ha	Height (m)	Basal area (m^2)	Volume (m^3)
Minimum	10		0	0	0	-531	0	0	0	0	0	0	0	0
	30	0	0	0	0	-74	0	0	0	0	0	0	0	0
	50		0	0	0	-24	0	0	0	0	0	0	0	0
Maximum	10		370	617	716	568	3681	14.42	27.24	147.14	1779	15.29	15.37	66.12
	30	716	74	59	98	98	355	28.27	26.01	270.23	355	28.27	26.01	255.62
	50		12	12	37	61	37	36.26	9.43	157.06	37	36.26	9.43	157.06
Mean	10		59.67	82.91	74.13	-68.64	781.65	11.13	5.60	29.65	377.70	12.13	3.46	14.15
	30	74.13	1.55	3.62	9.36	4.16	28.83	24.68	2.40	25.80	27.83	24.68	2.40	24.41
	50		0.06	0.06	0.41	0.27	0.61	32.44	0.15	2.14	0.61	32.44	0.15	2.04
Variance	10		4664	7714	13185	23827	463383	1.86	24.33	648.06	99176	3.56	8.31	135.66
	30	131.85	43.21	82.08	279.83	283.78	2277	154.81	13.65	1653	2277	154.81	13.65	14.80
	50		1.24	2.05	6.35	10.59	16.24	36.61	0.78	156.31	16.24	36.61	0.78	142.88
Coefficient of variation (%)	10		114	105	155	225	87	12	88	86	83	16	83	82
	30	155	420	250	179	405	166	51	154	158	171	50	154	158
	50		1856	2386	615	1205	661	19	589	584	661	19	589	586

APPENDIX C

A FORTRAN program for stand table projection and evaluation of various harvesting rules for the northwestern Ontario forest types.

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C*******                          *STDPRO*                             ***
C     *  THIS PROGRAM GENERATES STAND TABLES BASED ON REGRESSION MODELS *
C     *DEVELOPED FOR VARIOUS STAND COMPONENTS FOR NORTHWESTERN ONTARIO'S*
C     *FOREST TYPES.  FUTURE STAND STRUCTURE AND YIELD ARE PROJECTED    *
C     *FROM ACTUAL PLOT OR STAND DATA, FOR ANY GROWTH PERIOD.  INTERMED-*
C     *IATE HARVEST MAY BE EXPRESSED AS NUMBER OF TREES, BASAL AREA, OR *
C     *BASAL AREA PER CENT, AND ITS EFFECTS ON STAND STRUCTURE AND TOTAL*
C     *YIELD EXAMINED.  TREES TO BE CUT MAY BE SELECTED FROM THE SMALLEST
C     *TREES, LARGEST TREES OR ALL TREES.  INPUT IS TREE TALLIES IN STAND
C     *TABLE FORM FROM EITHER FIXED PLOT OR POINT SAMPLES.  INPUT AND   *
C     *OUTPUT MAY BE EXPRESSED IN EITHER MERIC OR ENGLISH UNITS.        *
C*****                                                                 ***
      INTEGER*2 PLTYPE,PERIOD,THIN1,THIN2,TIMTHN,UNIT,IDCLNT(12)/12*0/,
     1          INOT/0/,ISTING,IMORT(13),IUPGTH(13),IINGTH(13),
     2          INDCNT(12),INEWNT,PERTHN,PRTTHN
      LOGICAL*1 PART,EXTRA,SPLIT
      DATA IMORT(13),IUPGTH(13),IINGTH(13)/3*0/
      REAL DCLNOT(12),NOT/0./,STING,MORT(13),UPGRTH(13),INGRTH(13),
     1     NDCNOT(12),NEWNOT,STINOT/0.0/,PORTN
      DATA MORT(13),UPGRTH(13),INGRTH(13)/3*0.0/,DCLNOT/12*0.0/
      REAL TITLE(20),SIZBAF,STDAGE,SI,THNAMT,DBH,DIAMET,BAT/0./,
     1     DCLBAT(12)/12*0./,NDCBAT(12),NEWBAT,DCLVOL(13)
      REAL MIDPTS(12)/10.,15.,20.,25.,30.,35.,40.,45.,50.,55.,60.,70./
      REAL CONV/1./,BAFAC/.785398E-4/,BACONV/1./,NCONV/1./
C**********************************************************************
C     VARIABLE DEFINITIONS
C
C     TITLE  - RUN IDENTIFICATION AND INFORMATION
C     PLTYPE - PLOT TYPE: 1 - FIXED AREA; 2 - POINT SAMPLE
C     SIZBAF - PLOT SIZE IF PLTYPE = 1; PLOT BAF IF PLTYPE = 2
C     UNIT   - MEASUREMENT UNITS SYSTEM: 1 - ENGLISH; 2 - METRIC
C     STDAGE - STAND AGE
C     SI     - SITE INDEX
C     PERIOD - PROJECTION PERIOD
C     THIN1  - TYPE OF THINNING (CUTTING) CODE:
C                   0 - NONE
C                   1 - FROM LOWEST DIAMETER CLASSES
C                   2 - FROM HIGHEST DIAMETER CLASSES
C                   3 - FROM ALL DIAMETER CLASSES
C     THIN2  - TYPE OF AMOUNT OF THINNING CODE:
C                   0 - NONE
C                   1 - % BASAL AREA
C                   2 - ACTUAL BASAL AREA PER UNIT AREA
C                   3 - # OF TREES PER UNIT AREA
C     THNAMT - AMOUNT OF THINNING DEPENDING ON THIN2 CODE
C     TIMTHN - TIME OF THINNING
C     DBH    - DIAMETER
C     DIAMET - DIAMETER IN METRIC UNITS
C     STINOT - # OF TREES WITH DBH LESS THAN LOWEST DIAMETER CLASS FOR
C                STAND INGROWTH
C     DCLNOT - # OF TREES BY DIAMETER CLASS (PER UNIT AREA) (REAL)
C     IDCLNT - SAME AS ABOVE (INTEGER)
C     NOT    - TOTAL # OF TREES (PER UNIT AREA) (REAL)
C     INOT   - SAME AS ABOVE (INTEGER)
C     DCLBAT - TOTAL BASAL AREA FOR DIAMETER CLASS (PER UNIT AREA)
C     BAT    - TOTAL BASAL AREA FOR PLOT (PER UNIT AREA)
C     DCLVOL - MERCHANTABLE VOLUME FOR DIAMETER CLASS (PER UNIT AREA)
C     VOL    - TOTAL MERCHANTABLE VOLUME FOR PLOT (PER UNIT AREA)
C     NDCNOT - NEW # OF TREES BY DIAMETER CLASS AFTER PROJECTION INTER.
C     INDCNT - SAME AS ABOVE (INTEGER)
C     NEWNOT - NEW TOTAL # OF TREES AFTER PROJECTION INTERVAL (REAL)
C     INEWNT - SAME AS ABOVE (INTEGER)
C     NDCBAT - NEW TOTAL BASAL AREA BY DIAMETER CLASS AFTER PROJECTION
C     NEWBAT - NEW TOTAL BASAL AREA OF PLOT AFTER PROJECTION INTERVAL
C     STING  - STAND INGROWTH FOR PROJECTION INTERVAL (REAL)
C     ISTING - SAME AS ABOVE (INTEGER)
C     MORT   - MORTALITY - # OF TREES BY DIAMETER CLASS AND TOTAL (REAL)
C     IMORT  - SAME AS ABOVE (INTEGER)
C     INGRTH - INGROWTH -
C     IINGH  - SAME AS ABOVE (INTEGER)
C     UPGRTH - UPGROWTH -
C     IUPGTH - SAME AS ABOVE (INTEGER)
C
C     EXTRA  - FLAG FOR INDICATING EXTRA PARTIAL FINAL INTERVAL
C     PART   - FLAG FOR INDICATING THINNING/CUT WITHIN INTERVAL
C     SPLIT  - FLAG FOR 2ND PART OF SPLIT INTERVAL DUE TO THINNING/CUT
C     NPER   - # OF 5 YEAR INTERVALS IN PERIOD
C     NEXTRA - # OF EXTRA YEARS IN FINAL PARTIAL PERIOD
C     PERTHN - 5 YEAR INTERVAL IN WHICH THINNING/CUT OCCURS
C     PORTN  - PORTION OF GROWTH INTERVAL TO BE USED
C     MIDPTS - MID-POINTS OF DIAMETER CLASSES
C     CONV   - LINEAR CONVERSION FACTOR TO METRIC (INCHES TO CM)
C     NCONV  - AREA CONVERSION FACTOR TO METRIC (ACRES TO HECTARES)
C     BAFAC  - FACTOR USED IN BASAL AREA CALCULATION (ENGLISH OR METRIC
C     BACONV - BASAL AREA CONVERSION FACTOR (SQ. FT. TO SQ. M.)
C
C**********************************************************************
C
      WRITE(6,899)
  899 FORMAT(1H1,45X,'STAND TABLE PROJECTION',/,1H ,45X,22('-'))
C
C     READ AND THEN PRINT RUN IDENTIFICATION
C
      READ(5,800) TITLE
  800 FORMAT(20A4)
      WRITE(6,900) TITLE
  900 FORMAT(1H0,20X,20A4)
      WRITE(6,901) (I,I=10,60,5)
  901 FORMAT(1H0,'GROWTH OR YIELD',32X,'DIAMETER CLASS(CM)',/,1H ,
     1       'COMPONENTS(/HA)',5X,92('-'),/,1H ,20X,11(2X,I3,2X),2X,
     2       '60+', 2X,' TOTAL ',/,1H ,112('-'))
```

(continued)

```
C       READ PLOT, DATA, AND THINNING (CUTTING) INFORMATION
C
        READ(5,*) PLTYPE,SIZBAF,UNIT,STDAGE,SI
        READ(5,*) PERIOD,THIN1,THIN2,THNAMT,TIMTHN
C
C       CHECK INPUT UNITS
C
        IF(UNIT.EQ.2) GO TO 1
C
C       SET CONVERSION FACTORS FOR CONVERTING TO METRIC  AND CONVERT
C       INPUT TO METRIC
        NCONV=.404686
        CONV=2.54
        BAFAC=.005454
        BACONV=.092903
        SI=SI*.3048
        IF(THIN2.EQ.2) THNAMT=THNAMT*.229568
        IF(THIN2.EQ.3) THNAMT=IFIX(THNAMT/.404686)
C
C       READ IN TREE DATA
C
    1   READ(5,801,END=10) DBH
  801   FORMAT(F4.2)
        DIAMET=DBH*CONV
C
C       CHECK FOR TREE SMALLER THAN LOWEST DIAMETER CLASS WHICH IS
C       COUNTED SEPARATELY FOR USE IN DETERMINING STAND INGROWTH
C
        IF(DIAMET.GT.7.5) GO TO 100
        IF(PLTYPE.EQ.1) STINOT=STINOT+1
        IF(PLTYPE.EQ.2) STINOT=STINOT+(SIZBAF/(DBH*DBH*BAFAC))
        GO TO 1
C
C       DETERMINE DIAMETER CLASS
C
  100   DO 2 L=1,11
        IF(DIAMET.GT.2.5+L*5 .AND. DIAMET.LE.7.5+L*5) GO TO 3
    2   CONTINUE
        L=12
C
C       COUNT TREE AND CALCULATE AND ACCUMULATE TREE BASAL AREA
C
    3   GO TO (4,5),PLTYPE
    4   DCLNOT(L)=DCLNOT(L)+1
        DCLBAT(L)=DCLBAT(L)+DBH*DBH
        GO TO 1
    5   DCLNOT(L)=DCLNOT(L)+(SIZBAF/(DBH*DBH*BAFAC))
        DCLBAT(L)=DCLBAT(L)+SIZBAF
        GO TO 1
C
C       FOR EACH DIAMETER CLASS DETERMINE FINAL COUNT AND TOTAL AND
C       FINAL BASAL AREA AND TOTAL
   10   DO 11 I=1,12
        IF(DCLNOT(I).EQ.0) GO TO 11
        IF(PLTYPE.EQ.1) DCLNOT(I)=DCLNOT(I)/SIZBAF
        DCLNOT(I)=DCLNOT(I)/NCONV
        NOT=NOT+DCLNOT(I)
        IDCLNT(I)=DCLNOT(I)+.5
        INOT=INOT+IDCLNT(I)
        IF(PLTYPE.EQ.1) DCLBAT(I)=DCLBAT(I)*BAFAC/SIZBAF
        DCLBAT(I)=DCLBAT(I)*BACONV/NCONV
        BAT=BAT+DCLBAT(I)
   11   CONTINUE
C
C       CALCULATE VOLUMES AND OUTPUT INITIAL STAND STATISTICS
C
        CALL CALVOL(IDCLNT,DCLBAT,SI,DCLVOL)
        CALL OUTDCL(IDCLNT,DCLBAT,DCLVOL,INOT,BAT,DCLVOL(13),1)
C
C       DETERMINE FINAL (CONVERTED) EXTRA TREE COUNT FOR STAND INGROWTH
C
        IF(PLTYPE.EQ.1) STINOT=STINOT/SIZBAF
        STINOT=STINOT/NCONV
C*********************************************************************
C       FIND NUMBER OF PROJECTION INTERVALS
C
        EXTRA=.FALSE.
        PART=.FALSE.
        SPLIT=.FALSE.
        NPER=PERIOD/5
        NEXTRA=PERIOD-NPER*5
        IF (NEXTRA.EQ.0) GO TO 110
           EXTRA=.TRUE.
           NPER=NPER+1
C
C       ESTABLISH WHERE THINNING OCCURS
  110   PERTHN=TIMTHN/5
        PRTTHN=TIMTHN-PERTHN*5
        IF (PRTTHN.EQ.0) GO TO 111
        PERTHN=PERTHN+1
           IF (PERIOD.GT.TIMTHN) PART=.TRUE.
C
C       FOR EACH INTERVAL IN PERIOD
  111   DO 20 IP = 1, NPER
           IYRS=IP*5
           PORTN=1.
C
C       CHECK FOR THINNING AND SET UP SPLIT INTERVAL IF NECESSARY
           IF (IP.NE.PERTHN) GO TO 113
              IF (.NOT. PART) GO TO 113
              SPLIT=.TRUE.
              PORTN=PRTTHN/5.
              IYRS=(IP-1)*5+PRTTHN
              GO TO 114
C       SECOND HALF OF SPLIT INTERVAL
  112      SPLIT=.FALSE.
```

(continued)

```
      PORTN=1.-PORTN
      IF (IP.EQ.NPER .AND. EXTRA) PORTN=PORTN-(1.-NEXTRA/5.)
      IYRS=IP*5
      GO TO 114
C     CHECK FOR FINAL PARTIAL INTERVAL
  113 IF (IP.EQ.NPER .AND. EXTRA) PORTN=NEXTRA/5.
C
C     ESTIMATE STAND INGROWTH,MORTALITY AND UPGROWTH FOR INTERVAL
C
  114 STING=.0011928*(NOT+STINOT/MCONV)**1.3139436*SI**.48937435*
     +        EXP(-.0002*BAT**2.3104763)*.9429*PORTN
      ISTING=STING+.5
      DO 12 I=1,12
      IF(DCLNOT(I).LE.0.0) GO TO 120
      MORT(I)=.06804803*DCLNOT(I)**.97280350*((BAT/NOT)/(DCLBAT(I)/
     +           DCLNOT(I)))**1.1273127*1.069*PORTN
      UPGRTH(I)=.035354*DCLNOT(I)**0.94999*SI**.586413*0.9615*PORTN
      GO TO 121
  120 MORT(I)=0
      UPGRTH(I)=0
  121 IMORT(I)=MORT(I)+.5
      IUPGTH(I)=UPGRTH(I)+.5
   12 CONTINUE
C
C     FIND NEW NUMBER OF TREES AND INGROWTH AT END OF INTERVAL
C
      NDCNOT(1)=DCLNOT(1)+STING-MORT(1)-UPGRTH(1)
      INDCNT(1)=NDCNOT(1)+.5
      INGRTH(1)=STING
      IINGTH(1)=ISTING
      DO 13 I=2,11
      INGRTH(I)=UPGRTH(I-1)
      IINGTH(I)=IUPGTH(I-1)
      NDCNOT(I)=DCLNOT(I)+INGRTH(I)-MORT(I)-UPGRTH(I)
   13 INDCNT(I)=NDCNOT(I)+.5
      INGRTH(12)=UPGRTH(11)
      IINGTH(12)=IUPGTH(11)
      NDCNOT(12)=DCLNOT(12)+INGRTH(12)-MORT(12)
      INDCNT(12)=NDCNOT(12)+.5
C
C     FIND TOTALS AND NEW TOTAL BASAL AREA
C
      NEWNOT=0
      INEWNT=0
      NEWBAT=0
      DO 14 I=1,12
      NEWNOT=NEWNOT+NDCNOT(I)
      INEWNT=INEWNT+INDCNT(I)
      MORT(13)=MORT(13)+MORT(I)
      IMORT(13)=IMORT(13)+IMORT(I)
      IF(I.LT.12) UPGRTH(13)=UPGRTH(13)+UPGRTH(I)
      IF(I.LT.12) IUPGTH(13)=IUPGTH(13)+IUPGTH(I)
      INGRTH(13)=INGRTH(13)+INGRTH(I)
      IINGTH(13)=IINGTH(13)+IINGTH(I)
      NDCBAT(I)=NDCNOT(I)*(MIDPTS(I)**2*.78539816E-4)
   14 NEWBAT=NEWBAT+NDCBAT(I)
C
C     OUTPUT PROJECTION INTERVAL INFORMATION
C
      IF(IP.EQ.NPER .AND. EXTRA) IYRS=(IP-1)*5+NEXTRA
      IAGE=STDAGE+IYRS
      WRITE(6,90) IYRS,IAGE
   90 FORMAT(1H0,35X,'YEAR ''',I2,''' GROWTH PERIOD, STAND AGE = ',I3)
      WRITE(6,91) (IMORT(I),I=1,13)
   91 FORMAT(1H0,'MORTALITY',11X,12(1X,I5,1X),I6)
      WRITE(6,92) (IUPGTH(I),I=1,13)
   92 FORMAT(1H ,'UPGROWTH',12X,12(1X,I5,1X),I6)
      WRITE(6,93) (IINGTH(I),I=1,13)
   93 FORMAT(1H ,'INGROWTH',12X,12(1X,I5,1X),I6)
      WRITE(6,94) ISTING
   94 FORMAT(1H ,'STAND INGROWTH',1X,I6)
C
C     CHECK FOR THINNING OR CUTTING
C
      IF(IP.EQ.PERTHN .AND. (.NOT.PART.OR.(PART.AND.SPLIT)))
     1  CALL THNCUT(THIN1,THIN2,THNAMT,NDCNOT,NEWNOT,INDCNT,INEWNT,
     2               NDCBAT,NEWBAT,SI)
C
C     UPDATE DIAMETER CLASS INFORMATION
C
      DO 15 I=1,12
      DCLNOT(I)=NDCNOT(I)
      IDCLNT(I)=INDCNT(I)
   15 DCLBAT(I)=NDCBAT(I)
C
C     REINITIALIZE MORTALITY, UPGROWTH AND INGROWTH AND RESET TOTALS TO
C     FINAL TOTALS OF THIS PERIOD, FOR BEGINNING NEW PERIOD
C
      NOT=NEWNOT
      INOT=INEWNT
      BAT=NEWBAT
      MORT(13)=0.
      IMORT(13)=0
      UPGRTH(13)=0.
      IUPGTH(13)=0
      INGRTH(13)=0.
      IINGTH(13)=0
      IF(SPLIT) GO TO 112
   20 CONTINUE
C
C     CALCULATE FINAL VOLUMES & OUTPUT FINAL DIAMETER CLASS INFORMATION
C
      CALL CALVOL(IDCLNT,DCLBAT,SI,DCLVOL)
      CALL OUTDCL(IDCLNT,DCLBAT,DCLVOL,INOT,BAT,DCLVOL(13),5)
      STOP
      END
```

(continued)

```
      SUBROUTINE OUTDCL(NOT,BAT,VOL,TNOT,TBAT,TVOL,TYPE)
C
C     THIS SUBROUTINE PRINTS OUT FOR EACH DIAMETER CLASS AND TOTAL
C     THE NUMBER OF TREES, TOTAL BASAL AREA AND MERCHANTABLE VOLUME
C
      INTEGER*2 NOT(12),TNOT
      INTEGER TYPE
      REAL BAT(12),VOL(12)
      REAL*8 HEAD(5)/'INITIAL''','PRE-CUT''','POSTCUT''','CUT''',
     1              'FINAL'''/
C
C     NOT    - NUMBER OF TREES FOR DIAMETER CLASSES
C     BAT    - TOTAL BASAL AREA FOR DIAMETER CLASSES
C     VOL    - MERCHANTABLE VOLUME FOR DIAMETER CLASSES
C     TNOT   - TOTAL NUMBER OF TREES FOR PLOT
C     TBAT   - TOTAL BASAL AREA FOR PLOT
C     TVOL   TOTAL MERCHANTABLE VOLUME FOR PLOT
C     TYPE   - TIME OR TYPE OF STAND DATA
C               1 - INITIAL
C               2 - BEFORE THINNING OR CUTTING
C               3 - RESIDUAL AFTER THINNING OR CUTTING
C               4 - THINNED OR CUT PORTION
C               5 - FINAL
C     HEAD   - HEADINGS OF OUTPUT TYPES
C
      WRITE(6,90) HEAD(TYPE)
   90 FORMAT(1H0,46X,'STAND TABLE ''',A8)
      WRITE(6,92) NOT,TNOT
   92 FORMAT(1H0,'NUMBER OF TREES',5X,12(1X,I5,1X),I6)
      WRITE(6,93) BAT,TBAT
   93 FORMAT(1H0,'TOTAL BASAL AREA',4X,12(F6.1,1X),F6.1)
      WRITE(6,94) VOL,TVOL
   94 FORMAT(1H0,'MERCHANTABLE VOLUME',1X,12(F6.1,1X),F6.1)
      RETURN
      END


      SUBROUTINE CALVOL(IDCLNT,DCLBAT,SI,DCLVOL)
C
C     THIS SUBROUTINE CALCULATES MERCHANTABLE VOLUMES FOR DIAMETER
C     CLASSES AND TOTAL
C
      INTEGER*2 IDCLNT(13)
      REAL DCLBAT(13),SI,DCLVOL(13)
C
C     DCLBAT - TOTAL BASAL AREAS OF DIAMETER CLASSES PER UNIT AREA
C     SI     - SITE INDEX FOR PLOT
C     DCLVOL - MERCHANTABLE VOLUMES OF DIAMETER CLASSES PER UNIT AREA
C
      DCLVOL(13)=0.
      DO 1 I=1,12
      DCLVOL(I)=1.7367477*DCLBAT(I)**.89859295*SI**.63171721
      IF(IDCLNT(I).EQ.0) DCLVOL(I)=0.0
      DCLVOL(13)=DCLVOL(13)+DCLVOL(I)
    1 CONTINUE
      RETURN
      END


      SUBROUTINE THNCUT(TYPE,TOFAMT,AMOUNT,DCLNOT,TNOT,IDCLNT,ITNOT,
     1                  DCLBAT,TBAT,SI)
C
C     THIS SUBROUTINE CALCULATES RESULTS OF THINNING/CUTTING STAND
C     ACCORDING TO INPUT SPECIFICATIONS: TYPE- 1 LOWEST 2 HIGHEST
C     3 ALL DIAMETER CLASSES; TOFAMT - 1 % 2 ABSOLUTE 3 NUMBER OF TREES
C     AMOUNT, GIVEN NUMBER OF TREES FOR DIAMETER CLASSES (DCLNOT)
C     AND TOTAL (TNOT), TOTAL BASAL AREA FOR DIAMETER CLASSES (DCLBAT)
C     AND TOTAL (TBAT) AND SITE INDEX (SI).  THE RESIDUAL STAND DIAMETER
C     CLASS AND TOTAL INFORMATION ARE RETURNED AS REVISED INPUT
C     PARAMETERS (DCLNOT,TNOT,DCLBAT,TBAT)
C
      INTEGER*2 TYPE,TOFAMT,IDCLNT(12),ITNOT,NOTCUT(13)
      REAL TNOT,DCLBAT(12),TBAT,DCLVOL(13),BATCUT(13),VOLCUT(13),
     1     DCLNOT(12)
      REAL*8 HEAD1(3)/'LOWEST','HIGHEST','ALL'/,
     1       HEAD2(3)/'% OF BA','TOTAL BA','# TREES'/
C*********************************************************************
C
C     NOTCUT - # OF TREES CUT OR THINNED BY DIAMETER CLASS AND TOTAL
C     BATCUT - TOTAL BASAL AREA OF CUT TREES BY DIAMETER CLASS AND TOTAL
C     VOLCUT - TOTAL MERCH VOLUME OF CUT TREES BY DIAMETER CLASS & TOTAL
C     PC     - PER CENTAGE OF TOTAL BASAL AREA OR # OF TREES TO BE CUT
C     PCAMNT - AMOUNT ASSOCIATED WITH PER CENTAGE
C     HEAD1  - HEADING LABELS FOR METHOD OF THINNING(CUTTING)
C     HEAD2  - HEADING LABELS FOR TYPE OF BASIS OF THINNING (CUTTING)
C
C*********************************************************************
C
C     NO THINNING OR CUTTING ?
C
      IF(TYPE.EQ.0) RETURN
      CALL CALVOL(IDCLNT,DCLBAT,SI,DCLVOL)
      CALL OUTDCL(IDCLNT,DCLBAT,DCLVOL,ITNOT,TBAT,DCLVOL(13),2)
C
C     DETERMINE FRACTION AND ACTUAL AMOUNT OF CUT DEPENDING
C     ON TYPE OF THINNING/CUT
C
      PC=AMOUNT/100.
      PCAMNT=AMOUNT
      GO TO (1,2,3),TOFAMT
    1 PCAMNT=PC*TBAT
      GO TO 4
    2 PC=AMOUNT/TBAT
      GO TO 4
    3 PC=AMOUNT/TNOT
```

(continued)

```
C
C     INITIALIZE NO. OF TREES AND BASAL AREA OF TREES TO BE CUT
C
    4 DO 5 I=1,12
      NOTCUT(I)=0
    5 BATCUT(I)=0.
      NOTCUT(13)=0
      BATCUT(13)=0.
C
C     GO TO SECTION FOR TYPE OF CUT
C
      GO TO (10,10,20),TYPE
C
C     CUTTING FROM HIGHEST OR LOWEST CLASSES
C
   10 DO 13 J=1,12
C     LOWEST CLASSES
      I=J
C     HIGHEST CLASSES
      IF(TYPE.EQ.2) I=12-J+1
      IF(IDCLNT(I).EQ.0) GO TO 13
C     DETERMINE AVERAGE BASAL AREA PER TREE FOR DIAMETER CLASS
      AVGBAT=DCLBAT(I)/IDCLNT(I)
C
C     GO TO SECTION FOR TYPE OF AMOUNT OF CUT
      GO TO (11,11,12),TOFAMT
C
C     PER CENTAGE OR ABSOLUTE AMOUNT TYPE OF CUT
C
C     CHECK IF FULL AMOUNT WITHIN BA OF HALF A TREE HAS BEEN CUT
   11 IF(PCAMNT-BATCUT(13).LT. .5*AVGBAT) GO TO 40
C     CHECK IF ALL TREES IN A DIAMETER CLASS HAVE BEEN CUT
      IF(NOTCUT(I).GE.IDCLNT(I)) GO TO 13
C
C     COUNT AND ACCUMULATE NUMBER OF TREES CUT AND ASSOCIATED BASAL AREA
C
  110 NOTCUT(I)=NOTCUT(I)+1
      NOTCUT(13)=NOTCUT(13)+1
      BATCUT(I)=BATCUT(I)+AVGBAT
      BATCUT(13)=BATCUT(13)+AVGBAT
      GO TO (11,11,12),TOFAMT
C
C     NUMBER OF TREES TYPE OF CUT
C
C     CHECK IF FULL NUMBER OF TREES HAVE BEEN CUT
   12 IF(NOTCUT(13).GE.PCAMNT) GO TO 40
C     CHECK IF ALL TREES IN A DIAMETER CLASS HAVE BEEN CUT
      IF(NOTCUT(I).GE.IDCLNT(I)) GO TO 13
      GO TO 110
   13 CONTINUE
      GO TO 40
C
C     EQUAL PROPORTION FROM ALL CLASSES TYPE OF CUT
C
   20 DO 23 I=1,12
      IF(DCLNOT(I).EQ.0) GO TO 23
C     FIND AVERAGE TOTAL BASAL AREA OF A TREE IN DIAMETER CLASS
      AVGBAT=DCLBAT(I)/IDCLNT(I)
C
C     GO TO SECTION FOR TYPE OF AMOUNT OF CUT
C
      GO TO (21,21,22),TOFAMT
C
C     PER CENTAGE OR ABSOLUTE AMOUNT TYPE OF CUT
C
C     FIND APPROXIMATE TOTAL BASAL AREA CUT
   21 BATCUT(I)=PC*DCLBAT(I)
C     FIND EXACT NUMBER OF TREES CUT IN DIAMETER CLASS AND TOTAL SO FAR
      NOTCUT(I)=BATCUT(I)/AVGBAT+.5
      NOTCUT(13)=NOTCUT(13)+NOTCUT(I)
C     FIND ASSOCIATED TOTAL BASAL AREA CUT AND ACCUMULATE TOTAL
      BATCUT(I)=NOTCUT(I)*AVGBAT
      BATCUT(13)=BATCUT(13)+BATCUT(I)
      GO TO 23
C
C     EQUAL PROPORTION FROM ALL CLASSES TYPE OF CUT
C
C     FIND NUMBER OF TREES CUT AND TOTAL AND ASSOCIATED TOTAL BASAL
C     AREA AND TOTAL
   22 NOTCUT(I)=PC*DCLNOT(I)+.5
      NOTCUT(13)=NOTCUT(13)+NOTCUT(I)
      BATCUT(I)=NOTCUT(I)*AVGBAT
      BATCUT(13)=BATCUT(13)+BATCUT(I)
   23 CONTINUE
C
C     FIND MERCH. VOLUMES FOR CUT TREES BY DIAMETER CLASS AND TOTAL
C
   40 CALL CALVOL(NOTCUT,BATCUT,SI,VOLCUT)
C
C     REVISE DIAMETER CLASS INFORMATION BY REMOVING CUT TREES
C
      TNOT=0.0
      ITNOT=0
      DO 41 I=1,12
      DCLNOT(I)=DCLNOT(I)-NOTCUT(I)
      IF(IFIX(DCLNOT(I)+.5).EQ.0) DCLNOT(I)=0.0
      TNOT=TNOT+DCLNOT(I)
      IDCLNT(I)=DCLNOT(I)+.5
      ITNOT=ITNOT+IDCLNT(I)
      DCLBAT(I)=DCLBAT(I)-BATCUT(I)
   41 DCLVOL(I)=DCLVOL(I)-VOLCUT(I)
      TBAT=TBAT-BATCUT(13)
      DCLVOL(13)=DCLVOL(13)-VOLCUT(13)
C
```

(continued)

APPENDIX C (concluded)

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C     PRINT OUT NUMBER OF TREES, TOTAL BASAL AREA AND MERCH. VOLUME
C     BY DIAMETER CLASS AND TOTAL FOR RESIDUAL AND CUT PORTIONS
C
      CALL OUTDCL(IDCLNT,DCLBAT,DCLVOL,ITNOT,TBAT,DCLVOL(13),3)
      CALL OUTDCL(NOTCUT,BATCUT,VOLCUT,NOTCUT(13),BATCUT(13),VOLCUT(13),
     1            4)
      WRITE(6,90) HEAD1(TYPE)
   90 FORMAT(1H0,32X,'THINNING(CUTTING) OF ',A8,' DIAMETER CLASSES')
      WRITE(6,91) HEAD2(TOFAMT),AMOUNT
   91 FORMAT(1H0,32X,'AMOUNT OF THINNING BASED ON ',A8,' = ',F7.1)
      RETURN
      END
```

APPENDIX D

Table 1. Stand table projection for a 96-year-old stand (jack pine cover type) in northwestern Ontario for a 19-year growth period with no intermediate harvesting.

Growth or yield components per ha	Diameter class (cm)										
	10	15	20	25	30	35	40	45	50	60+	Total
				STAND TABLE 'INITIAL'							
Number of trees	49	148	395	383	62	0	0	0	0	0	1037
Total basal area	0.5	2.7	13.0	18.5	3.9	0.0	0.0	0.0	0.0	0.0	38.5
Merchantable volume	5.0	24.6	100.0	137.4	34.4	0.0	0.0	0.0	0.0	0.0	301.4
				YEAR '5' GROWTH PERIOD, STAND AGE = 101							
Mortality	15	21	28	18	2	0	0	0	0	0	84
Upgrowth	7	20	51	49	9	0	0	0	0	0	136
Ingrowth	23[a]	7	20	51	49	9	0	0	0	0	159
				YEAR '10' GROWTH PERIOD, STAND AGE = 106							
Mortality	20	18	27	18	3	0	0	0	0	0	86
Upgrowth	7	16	43	47	14	1	0	0	0	0	128
Ingrowth	21[a]	7	16	43	47	14	1	0	0	0	149
				YEAR '15' GROWTH PERIOD, STAND AGE = 111							
Mortality	19	15	25	18	5	1	0	0	0	0	83
Upgrowth	6	12	37	45	18	3	0	0	0	0	121
Ingrowth	20[a]	6	12	37	45	18	3	0	0	0	141
				YEAR '19' GROWTH PERIOD, STAND AGE = 115							
Mortality	15	10	18	15	5	1	0	0	0	0	64
Upgrowth	4	7	24	33	16	4	1	0	0	0	89
Ingrowth	15[a]	4	7	24	33	16	4	1	0	0	104
				STAND TABLE 'FINAL'							
Number of trees	33	53	197	295	164	46	8	1	0	0	797
Total basal area	0.3	0.9	6.2	14.5	11.6	4.5	1.0	0.1	0	0	39.0
Merchantable volume	3.0	9.5	51.5	110.7	90.6	38.4	9.6	1.4	0	0	314.6

[a] Stand ingrowth is the same as upgrowth to 10 cm diameter class.

(continued)

APPENDIX D (continued)

Table 2. Stand table projection for a 96-year-old stand (jack pine cover type) in northwestern Ontario for a 19-year growth period with approximately 50% of the trees harvested at the end of 2-year growth period.

Growth or yield components per ha	Diameter class (cm)									
	10	15	20	25	30	35	40	45	50	60+	Total
				STAND TABLE 'INITIAL'							
Number of trees	49	148	395	383	62	0	0	0	0	0	1037
Total basal area	0.5	2.7	13.0	18.5	3.9	0.0	0.0	0.0	0.0	0.0	38.5
Merchantable volume	5.0	24.6	100.0	137.4	34.4	0.0	0.0	0.0	0.0	0.0	301.4
				YEAR '2' GROWTH PERIOD, STAND AGE = 98							
Mortality	6	8	11	7	1	0	0	0	0	0	33
Upgrowth	3	8	20	20	3	0	0	0	0	0	54
Ingrowth	9[a]	3	8	20	20	3	0	0	0	0	63
				STAND TABLE 'PRE-CUT'							
Number of trees	50	135	372	377	77	3	0	0	0	0	1014
Total basal area	0.4	2.4	11.7	18.5	5.4	0.3	0.0	0.0	0.0	0.0	38.7
Merchantable volume	4.3	21.8	91.1	137.6	45.9	3.7	0.0	0.0	0.0	0.0	304.5
				STAND TABLE 'POSTCUT'							
Number of trees	25	67	186	188	38	1	0	0	0	0	505
Total basal area	0.2	1.2	5.8	9.2	2.7	0.1	0.0	0.0	0.0	0.0	19.2
Merchantable volume	2.0	10.0	42.2	63.6	21.0	1.1	0.0	0.0	0.0	0.0	140.0
				STAND TABLE 'CUT'							
Number of trees	25	68	186	189	39	2	0	0	0	0	509
Total basal area	0.2	1.2	5.8	9.3	2.8	0.2	0.0	0.0	0.0	0.0	19.5
Merchantable volume	2.3	11.8	48.9	74.0	24.9	2.6	0.0	0.0	0.0	0.0	164.5
				YEAR '5' GROWTH PERIOD, STAND AGE = 101							
Mortality	6	6	9	5	1	0	0	0	0	0	27
Upgrowth	2	6	15	15	3	0	0	0	0	0	41
Ingrowth	15[a]	2	6	15	15	3	0	0	0	0	56
				YEAR '10' GROWTH PERIOD, STAND AGE = 106							
Mortality	13	9	14	9	2	0	0	0	0	0	47
Upgrowth	5	8	22	24	7	1	0	0	0	0	67
Ingrowth	25[a]	5	8	22	24	7	1	0	0	0	92
				YEAR '15' GROWTH PERIOD, STAND AGE = 111							
Mortality	17	8	12	9	2	0	0	0	0	0	48
Upgrowth	6	6	19	23	9	2	0	0	0	0	65
Ingrowth	24[a]	6	6	19	23	9	2	0	0	0	89
				YEAR '19' GROWTH PERIOD, STAND AGE = 115							
Mortality	15	5	9	7	2	0	0	0	0	0	38
Upgrowth	5	4	13	17	8	2	0	0	0	0	49
Ingrowth	18[a]	5	4	13	17	8	2	0	0	0	67
				STAND TABLE 'FINAL'							
Number of trees	39	31	98	147	82	24	4	0	0	0	425
Total basal area	0.3	0.5	3.1	7.2	5.8	2.3	0.5	0	0.0	0.0	19.8
Merchantable volume	3.4	5.8	27.5	59.0	48.7	21.1	5.5	0.0	0.0	0.0	171.1

[a] Stand ingrowth is the same as upgrowth in the 10 cm diameter class.

(continued)

Table 3. Stand table projection for a 48-year-old stand (mixed softwood cover type) in northwestern Ontario for a 17-year growth period with no intermediate harvest cutting.

Growth or yield components per ha	Diameter class (cm) 10	15	20	25	30	35	40	45	50	60+	Total
				STAND TABLE 'INITIAL'							
Number of trees	523	397	273	270	36	0	0	0	0	0	1499
Total basal area	4.6	6.9	9.2	13.8	2.3	0.0	0.0	0.0	0.0	0.0	36.7
Merchantable volume	42.8	61.7	79.9	115.0	23.0	0.0	0.0	0.0	0.0	0.0	322.4
				YEAR '5' GROWTH PERIOD, STAND AGE = 53							
Mortality	102	36	12	7	1	0	0	0	0	0	158
Upgrowth	71	55	39	38	6	0	0	0	0	0	209
Ingrowth	94[a]	71	55	39	38	6	0	0	0	0	303
				YEAR '10' GROWTH PERIOD, STAND AGE = 58							
Mortality	105	36	14	8	1	0	0	0	0	0	164
Upgrowth	61	52	39	37	10	1	0	0	0	0	200
Ingrowth	90[a]	61	52	39	37	10	1	0	0	0	290
				YEAR '15' GROWTH PERIOD, STAND AGE = 63							
Mortality	97	37	15	9	2	0	0	0	0	0	160
Upgrowth	51	49	39	36	14	2	0	0	0	0	191
Ingrowth	81[a]	51	49	39	36	14	2	0	0	0	272
				YEAR '17' GROWTH PERIOD, STAND AGE = 65							
Mortality	35	15	7	4	1	0	0	0	0	0	62
Upgrowth	17	18	15	14	7	2	0	0	0	0	73
Ingrowth	29[a]	17	18	15	14	7	2	0	0	0	102
				STAND TABLE 'FINAL'							
Number of trees	278	300	267	249	120	31	5	0	0	0	1250
Total basal area	2.2	5.3	8.4	12.2	8.5	3.0	0.6	0.0	0.0	0.0	40.2
Merchantable volume	22.0	48.7	73.6	103.1	74.4	29.0	6.6	0.0	0.0	0.0	357.3

[a] Stand ingrowth is the same as upgrowth to 10 cm diameter class.

(continued)

APPENDIX D (concluded)

Table 4. Stand table projection for a 48-year-old stand (mixed softwood cover type) in northwestern Ontario for a 17-year growth period with commercial thinning of approximately 250 of the largest trees/ha at the end of the 7-year growth period.

Growth or yield components per ha	Diameter class (cm)								
	10	15	20	25	30	35	40	60+	Total
STAND TABLE 'INITIAL'									
Number of trees	523	397	273	270	36	0	0	0	1499
Total basal area	4.6	6.9	9.2	13.8	2.3	0.0	0.0	0.0	36.7
Merchantable volume	42.8	61.7	79.9	115.0	23.0	0.0	0.0	0.0	322.4
YEAR '5' GROWTH PERIOD, STAND AGE = 53									
Mortality	102	36	12	7	1	0	0	0	158
Upgrowth	71	55	39	38	6	0	0	0	209
Ingrowth	94[a]	71	55	39	38	6	0	0	303
YEAR '7' GROWTH PERIOD, STAND AGE = 55									
Mortality	42	14	6	3	1	0	0	0	66
Upgrowth	24	21	16	15	4	0	0	0	80
Ingrowth	36[a]	24	21	16	15	4	0	0	116
STAND TABLE 'PRE-CUT'									
Number of trees	413	366	277	261	78	9	0	0	1404
Total basal area	3.2	6.5	8.7	12.8	5.5	0.9	0.0	0.0	37.7
Merchantable volume	31.4	58.3	76.2	107.7	50.4	9.8	0.0	0.0	333.8
STAND TABLE 'POSTCUT'									
Number of trees	413	366	277	101	0	0	0	0	1157
Total basal area	3.2	6.5	8.7	5.0	0.0	0.0	0.0	0.0	23.4
Merchantable volume	31.4	58.3	76.2	38.3	0.0	0.0	0.0	0.0	204.1
STAND TABLE 'CUT'									
Number of trees	0	0	0	160	78	9	0	0	247
Total basal area	0.0	0.0	0.0	7.8	5.5	0.9	0.0	0.0	14.2
Merchantable volume	0.0	0.0	0.0	69.4	50.4	9.8	0.0	0.0	129.6
YEAR '10' GROWTH PERIOD, STAND AGE = 58									
Mortality	44	16	6	1	0	0	0	0	67
Upgrowth	34	31	23	9	0	0	0	0	97
Ingrowth	84[a]	34	31	23	9	0	0	0	181
YEAR '15' GROWTH PERIOD, STAND AGE = 63									
Mortality	78	26	11	3	0	0	0	0	118
Upgrowth	58	49	39	17	2	0	0	0	165
Ingrowth	137[a]	58	49	39	17	2	0	0	302
YEAR '17' GROWTH PERIOD, STAND AGE = 65									
Mortality	33	11	5	1	0	0	0	0	50
Upgrowth	23	19	16	8	2	0	0	0	68
Ingrowth	52[a]	23	19	16	8	2	0	0	120
STAND TABLE 'FINAL'									
Number of trees	415	330	276	140	30	3	0	0	1194
Total basal area	3.3	5.8	8.7	6.9	2.1	0.3	0.0	0.0	27.0
Merchantable volume	31.5	53.1	75.8	61.5	21.5	3.5	0.0	0.0	246.9

[a] Stand ingrowth is the same as upgrowth to 10 cm diameter class.