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FIBER HANDBOOK: A Growth Model for Spruce-Fir and Northern Hardwood Forest Types

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Abstract

A matrix model, FIBER, has been developed to provide the forest manager with a means of simulating the management and growth of forest stands in the Northeast. Instructional material is presented for the management of even-aged and multi-aged spruce-fir, mixedwood, and northern hardwood stands. FIBER allows the user to simulate a range of silvicultural treatments for a variety of species compositions growing on different sites. The internal structure of the model is defined and explanations on the use of FIBER are offered. Examples of input, interim procedures, and final output are shown.

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Introduction

A stand projection growth model, FIBER, was developed to predict the growth interactions among species within spruce-fir, northern hardwood, and mixedwood forest types (Solomon et al. 1986). This prototype model has been modifed by further testing of independent variables for the regression equations and by the inclusion of data sets from a broader geographical area, which allowed for additional species (Solomon and Hosmer 1986). The model allows the forest manager to simulate the growth of trees for management practices and silvicultural treatments over a range of stand densities, harvest intervals, species compositions, and sites. These options allow the user to predict the growth and yield, over a specified time interval, of either individual forest stands or large forested areas receiving similar management practices.

The species composition of the forest stands used in the construction of the model ranged from complete softwood stands to complete northern hardwood stands. Softwood stands were defined as those having at least 65 percent of their basal area in softwood species; hardwood stands had at most 25 percent of their basal area in softwood species; and mixedwood stands had 25 to 65 percent of their basal area in softwood species.

The species groups available in the model are:

Balsam fir	*Abies balsamea* (L.) Mill
Spruce	
Black	*Picea mariana* (Mill.) B.S.P.
Red	*Picea rubens* Sarg.
White	*Picea glauca* (Moench) Voss
Eastern hemlock	*Tsuga canadensis* (L.) Carr.
Northern white-cedar	*Thuja occidentalis* L.
Sugar maple	*Acer saccharum* Marsh.
Red maple	*Acer rubrum* L.
Yellow birch	*Betula alleghaniensis* Britton
Paper birch	*Betula papyrifera* Marsh.
American beech	*Fagus grandifolia* Ehrh.
White ash	*Fraxinus americana* L.
Aspen	*Populus tremuloides* Michx.
Other hardwoods	
Gray birch	*Betula populifolia* Marsh.
Striped maple	*Acer pennsylvanicum* L.
Pin cherry	*Prunus pensylvanica* L.F.
Black ash	*Fraxinus nigra* Marsh.
Other softwoods	
Tamarack	*Larix laricinia* (Du Roi) K. Koch
White pine	*Pinus strobus* L.

The data used to develop this model came from a wide range of site conditions across the Northeast. The model was constructed to cover a range in the site indices of 30 to 70 for softwood, 35 to 75 for mixedwood, and 40 to 80 for hardwood at base age 50 years.

Some of the stands used for the model development were the result of harvesting practices that resembled different forms of forest management. Other stands, primarily the softwoods, were natural stands that had developed with only occasional management. As a result of the range in management practices, FIBER can be applied within both even-age and multi-age types of management.

Softwood, mixedwood, and hardwood stands can be managed or controlled within the model by allowing the stand to grow to a specified stocking level, as measured by square feet of basal area or cubic volume, or by allowing the stand to grow for a specified time (years). The forest manager can control the level of residual basal area and cubic volume through thinning, by specifying a desired level or by using B lines as presented in the stocking charts (Figs.1–3). The quality line for hardwoods may be used to maintain a higher density and better quality in younger and smaller diameter stands (Solomon and Leak 1986).

Thinning practices that can be used in the program include: thinning from above, thinning from below, thinning to a q-line (de Liocourt 1898), removal of trees from any diameter class, or thinning uniformly across all diameter classes.

Sources of Data

Beginning in 1953, a series of 359 permanent plots was established within a softwood forest on the Penobscot Experimental Forest, Bradley, Maine. The 1/5-acre (0.08–ha) plots were both randomly and systematically located within forest stands (compartments) to be used for various silvicultural practices. Harvests were conducted in each compartment at 5-, 10-, or 20-year intervals (Frank and Blum 1978). Each plot was remeasured at 5-year intervals regardless of harvest cycle; if there was a harvest, the plot was remeasured both before and after the harvest.

A study of multi-aged northern hardwoods was begun in 1964 using forty-eight 1/3-acre (0.14–ha) plots (Solomon 1977) located on the Bartlett Experimental Forest, Bartlett, New Hampshire. Each plot was measured, thinned uniformly across size classes to a predetermined residual basal area and size structure, and remeasured at 5-year intervals, as in the softwood study.

Independent data sets of more than 2,500 growth plots from northern Maine, New Hampshire, northern New York, and Vermont also were included to increase the flexibility and reliability of the prototype model (Solomon et al. 1986). Each plot was measured from 1959 to 1974 at 5-year intervals; the data sets covered a wide range of species compositions, sites, management options, and densities (Fig. 4).

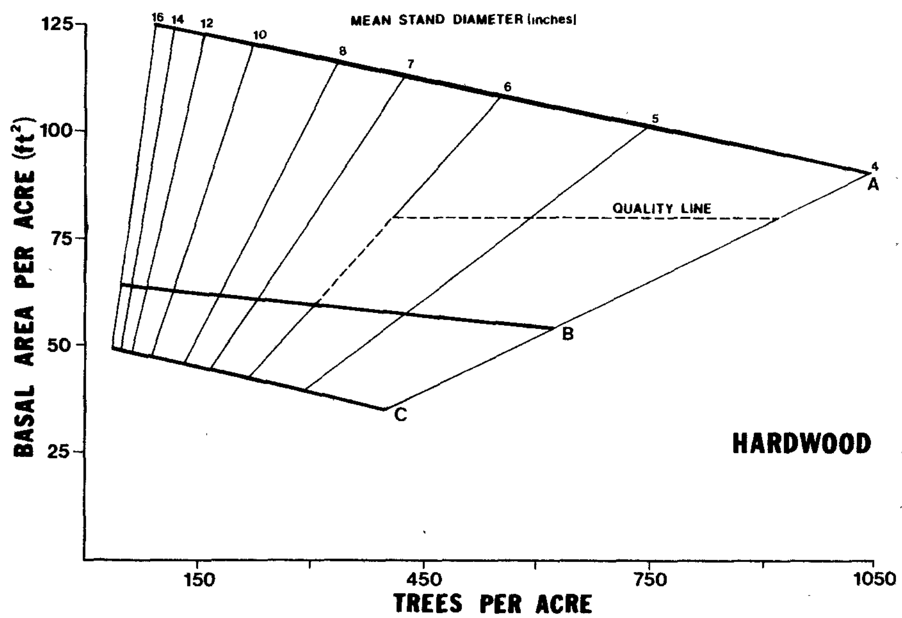

Figure 1.—Stocking chart for northern hardwoods is based on trees in the main crown canopy. The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand. The quality line defines the stocking measure in young stands for maintaining quality development.

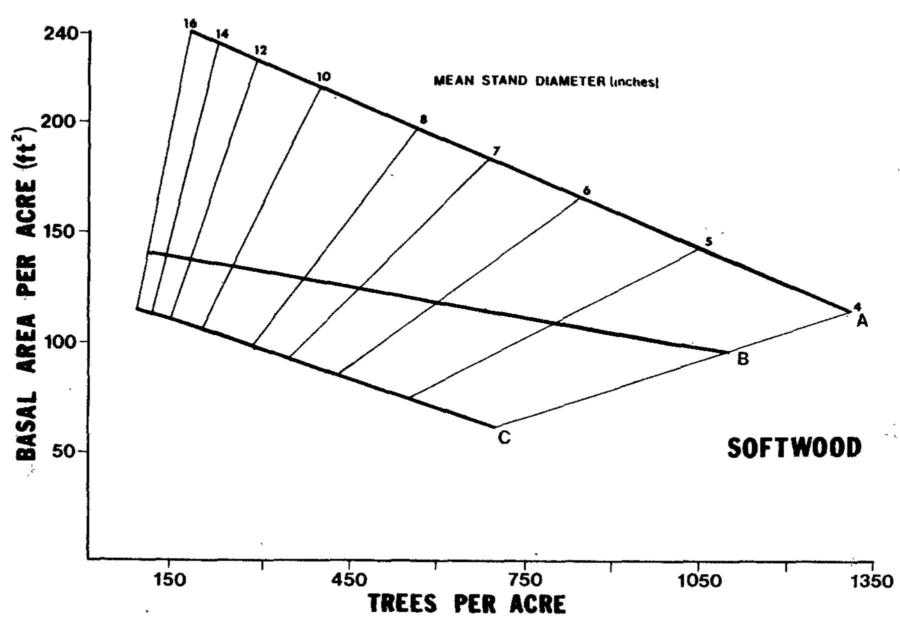

Figure 2.—Stocking chart for spruce-fir stands is based on trees in the main crown canopy. The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand.

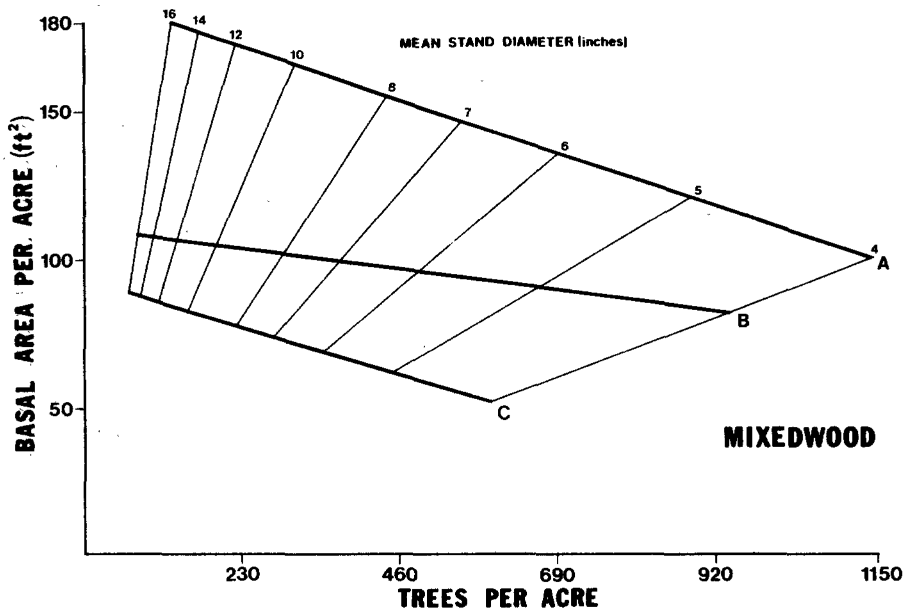

Figure 3.—Stocking chart for mixedwood stands is based on trees in the main crown canopy. The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand.

In the Northeast, softwood stands often are found on poorer sites, and northern hardwood stands on better sites, with a mixture of both species on intermediate sites. The soils on sites used for study locations ranged from poorly drained to well drained.[1] Site index was not calculated for each plot within the data sets. However, some softwood stands had site indices of 40 to 50 for red spruce at base age 50 years, and hardwood stands had site indices of 50 to 60 for sugar maple at base age 50 years. The data ranged from the poorer spruce-cedar stands to the better, pure northern hardwood stands. An expression of site index was not included as a variable in the development of FIBER since site measurements were not recorded on all plots used in model construction.

Model Definitions

FIBER is a two-stage matrix model. One stage of the model is a set of linear regression equations that predict transition probabilities of tree growth and mortality as a function of stand density, tree size, and proportion of hardwoods.

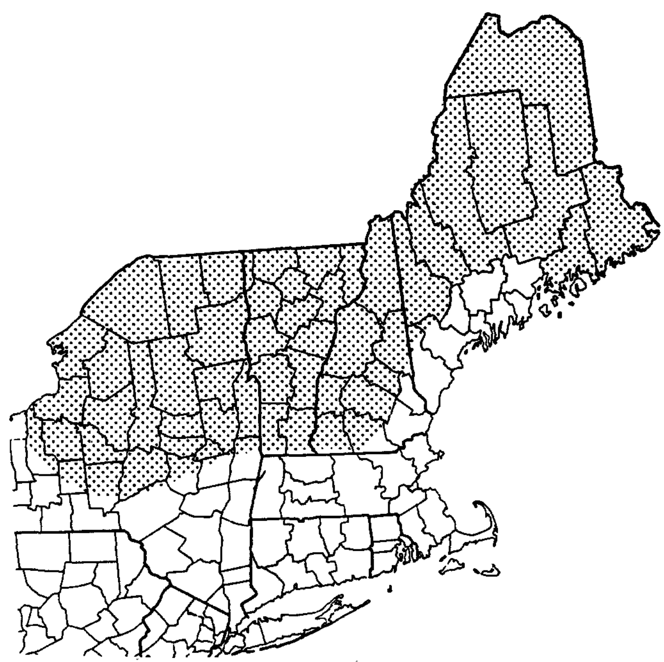

Figure 4.—Dotted area is geographic region of growth-plot data used for model construction and testing.

[1] For definitions of poorly drained and well drained see the county soil surveys published by the USDA Soil Conservation Service.

These predicted probabilities are the elements of stand projection matrices that are used to project the distribution of stand diameters over a 5-year period (Solomon et al. 1986). This two-stage matrix model is a modification and extension of an earlier matrix model (Buongiorno and Michie 1980).

For each species, a matrix G_t of transition probabilities was applied to a stand table vector $\mathbf{y}_t$, which displays the number of trees of that species in each d.b.h. class. By adding the ingrowth, these two operations generate the stand table vector after 5 years of growth for each species:

$$(1) \qquad \mathbf{y}_{t+5} = G_t \mathbf{y}_t + I_t$$

$$\text{where } G_t = \begin{bmatrix} a_{5,t} & 0 & 0 & 0 & \cdots \\ b_{5,t} & a_{6,t} & 0 & 0 & \cdots \\ c_{5,t} & b_{6,t} & a_{7,t} & 0 & \cdots \\ 0 & c_{6,t} & b_{7,t} & a_{8,t} & \cdots \\ \cdot & \cdot & \cdot & \cdot & \\ \cdot & \cdot & \cdot & \cdot & \\ \cdot & \cdot & \cdot & \cdot & \end{bmatrix} ; \; I_t = \begin{bmatrix} k \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{bmatrix},$$

with

$a_{i,t}$ = the probability that a tree survives and is in the i^{th} diameter class during the time interval from t to t+5;

$b_{i,t}$ = the probability that a tree survives and is in diameter class i at time t and in diameter class i+1 at time t+5;

$c_{i,t}$ = the probability that a tree survives and is in diameter class i at time t and in diameter class i+2 at time t+5; and

k = ingrowth into the 5-inch class during the time interval from t to t+5.

The data sets described earlier were combined. Tree diameters were measured at 4.5 feet (1.3 m) and placed in 1-inch classes, which ranged from 5 to 30 inches (12.7 to 76.2 cm). In subsequent inventories, each tree on the plot was categorized as ingrowth, survivor, or mortality (m). For a given plot, the diameter distribution for any one species was sparse; therefore, the pooling of plots was required to obtain more reliable estimates of a, b, c, and m. Because the growth response of forest stands may vary by magnitude of change in density (Solomon 1977; Solomon and Frank 1983), the plots were categorized by both the initial basal area (IBA_t) prior to harvest and the residual basal area (RBA_t) after a harvest. If there was no harvest at time t, the IBA_t and RBA_t were the same. The plot data were grouped by basal area in 20 ft^2/acre intervals. The range from 20 to 260 ft^2/acre (4.6 to 59.6 m^2/ha) of basal-area categories for these data sets was sufficient to provide growth response information for the general management alternatives. The plots grouped in any specific IBA–RBA category were considered to have the same growth rate.

For each species, linear equations were developed to predict: ingrowth into the smallest class (k); the probability of a tree remaining in its present diameter class (a_{it}); the probability of a tree growing into the next diameter class (b_{it}); the probability of a tree growing two diameter classes larger (c_{it}); and the probability of a tree dying (m_{it}). Note that the mortality rate is not included in the G_t matrix but is inherent in the model since $m_{it} = 1.0 - a_{it} - b_{it} - c_{it}$.

The set of probabilities associated with diameter class i is assumed to have a multinomial distribution, and is modeled by linear functions of the form:

$$a_{it} = \beta_{01} + \beta_{11}\, IBA_t + \beta_{21}\, RBA_t + \beta_{31}\, D_i + \beta_{41}\, P_t + \beta_{51}\, D^2_i + \beta_{61}\, RBA^2_t$$

$$b_{it} = \beta_{02} + \beta_{12}\, IBA_t + \beta_{22}\, RBA_t + \beta_{32}\, D_i + \beta_{42}\, P_t + \beta_{52}\, D^2_i + \beta_{62}\, RBA^2_t$$

$$c_{it} = \beta_{03} + \beta_{13}\, IBA_t + \beta_{23}\, RBA_t + \beta_{33}\, D_i + \beta_{43}\, P_t + \beta_{53}\, D^2_i + \beta_{63}\, RBA^2_t$$

$$m_{it} = \beta_{04} + \beta_{14}\, IBA_t + \beta_{24}\, RBA_t + \beta_{34}\, D_i + \beta_{44}\, P_t + \beta_{54}\, D^2_i + \beta_{64}\, RBA^2_t$$

where

IBA_t = initial stand basal area prior to harvest at time t (ft^2/acre),

RBA_t = residual stand basal area after harvest at time t (ft^2/acre),

D_i = midpoint of the diameter class i (inches),

P_t = proportion of hardwoods in the stand at time t, and

β_{jk} = regression coefficients to be estimated.

The entries of G_t can be found from these equations using the coefficients in Table 1 of the Appendix that were developed from the combined data sets of softwood, mixedwood, and hardwood.

Not all of the species in the data sets ranged to the same maximum-size diameter and did not have a sufficient number of trees in the larger diameter classes. Thus, the a, b, c, and m equations did not accurately describe the movement of trees in these larger classes. To decrease the growth rate and increase the mortality of the larger trees over time in mature stands (RBA > 125 ft^2/acre), the a-, b-, and c- values were linearly reduced from the predicted equation value to zero within the range of the maximum-size diameter classes of each species (Table 2). The amount removed from these transition probabilities was added to mortality (m) as the stand matures, ensuring that partial trees will not accumulate in the 30-inch class.

To model differences in growth rate due to species composition on different sites, the b- and c-values were modified if the site index value differed from the average value of that forest type:

$$b^* = b\ SI/x \quad \text{and} \quad c^* = c\ SI/x$$

where

SI = site index,

$$x = \begin{cases} 50 \text{ for softwood stands} \\ 55 \text{ for mixedwood stands} \\ 60 \text{ for hardwood stands.} \end{cases}$$

Then

$$a^* = a\ (1.0 - m)/(a + b^* + c^*)$$

$$b^{**} = b^*\ (1.0 - m)/(a + b^* + c^*)$$

$$c^{**} = c^*\ (1.0 - m)/(a + b^* + c^*).$$

This procedure assures that a^*, b^{**}, and c^{**} are all less than 1 and that $a^* + b^{**} + c^{**} + m = 1.0$. It also leaves mortality unaffected by site index.

When the stand reaches age 80 or the number of iterations equals 80 years, the "shorter lived" species of paper birch, aspen, and other hardwoods are forced out of the stand. The c-value is forced to zero by 100 years, the b-value by 110 years, and the a-value by 130 years. All of the amounts removed are added to mortality (m). If the RBA falls below 60 ft^2/acre, ingrowth trees of these species are allowed to enter and grow in the stand for another 80 to 130 years.

For ingrowth, a threshold diameter of 5.5 inches (14.0 cm) was used for one large data set and 4.5 inches (11.4 cm) for the other smaller data sets. After testing several variables and combinations of variables, separate linear equations were developed for each species:

$$k = \alpha_0 + \alpha_1\ RBA_t + \alpha_2\ P_t + \alpha_3\ PS_t,$$

where PS_t is the proportion of that species in the stand at time t (Table 1).

Model Reliability

To validate the predictions of the model, the data set was stratified by species and forest type. The actual growth on each plot was compared to the predicted growth over a 15-year period (Table 3). The predicted final volume differed from the actual volume by 0.8 to 14.1 percent. The poorest predictions were in the lowest basal-area categories. This was primarily due to large amounts of ingrowth, but predictions are expected to improve as more data sets are included.

Overall, the model predicted the growth of softwood and hardwood stands more accurately than the growth of mixedwood stands. This, too, is to be expected since detailed studies have not been conducted in mixedwood stands. As the results of thinning studies in smaller size stands become available, the predictabilty of the lower basal-area categories should improve.

The largest differences between the actual and predicted values are for balsam fir and spruce in hardwood and mixedwood stands. Since the harvesting practices and true site were not known for every plot, some softwood plots could have been considered as hardwood stands after thinning. The softwood species may have been removed, leaving the residual hardwood in the remaining stand. Thus, more spruce and fir ingrowth resulted in the actual stand than in the predicted stand.

Model Application

The model projects forest stands through time in 5-year intervals (Fig. 5). The user can input an inventory of one or several stands and grow these stands for the entire rotation period or for any specified number of years. FIBER will prompt the user with a menu that will determine the scope of each run. A control file that stores all of the information pertaining to each run is written to disk. The user is asked to provide the file name of this control file and whether it is a new or existing file. On subsequent runs, the user can use this file to duplicate an earlier run, modify the file to meet new criteria, or create a new set of control information. There also is the opportunity to select either the printer or a disk file as the primary output device.

The user is asked to choose from one of the options from the following menu:

(1) HELP	(7) SITE INDEX
(2) NEW CONTROL	(8) PERCENT CULL
(3) TITLE	(9) THINNING
(4) STOCKING	(10) DISPLAY CONTROL
(5) GROWTH PERIOD	(11) DISPLAY STAND
(6) STAND AGE	<12> EXECUTE

Option 12 is the default value and will be in effect if a carriage return is entered. There are default values to a variety of questions in this section and they are all designated on the console by being enclosed in < >. Entering a minus sign in response to any question will terminate the program.

Option (1):

Help — A summary of instructions for creating a control file will be printed on the console. After every 15 to 20 lines, the program waits for a carriage return to be entered before continuing.

Option (2):

New — An entire control file containing the information requested in options 3 through 9 will be created. If a file of this name already exists, the user will be given the choice of renaming the file, returning to the menu, or continuing, which will cause the existing file to be destroyed.

A first-time user should only use options 1 or 2 to start. Options 3 through 9 allow you to modify the control file without creating a new file.

Option (3):

Title — A title for this run that will appear at the top of each page of output.

Option (4):

Stocking choice — A list of the species that will be allowed in this stand projection must be supplied. This is accomplished by entering a one (1) for the species to be included and a zero (0) for species not included.

There are three choices for inputting the initial stand diameter distribution.

(1) User inputs diameter lists for each species. The program prompts the user by giving the species and asking for the number of trees in each diameter class of 5 through 17 inches on the first line, and then asking for the entries for the 18- through 30-inch diameter class on a second line. A carriage return will enter zeros for the remainder of the line. The model uses real numbers so fractional parts of a tree may be entered. However, any entry less than 0.1 is changed to a zero.

(2) The user is prompted to input the total number of stems for a given species and the percentage of these trees in diameter classes 5, 6, 7, 8, 9, 10, 11, 12, 13 to 15, 16 to 19, and 20+. These percentages are checked to see if they total 100; if they do not, the user is asked to re-enter them.

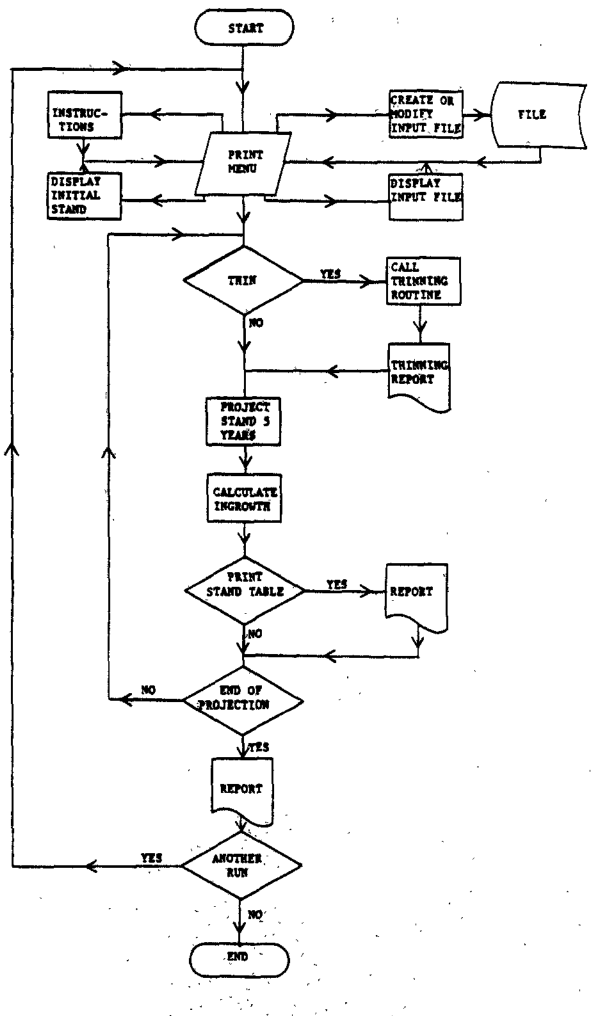

Figure 5.—General logic for main program of FIBER.

<3> The user can input several plots of various sizes and obtain an average plot to represent the initial stand. These plots can be a mixture of fixed plots or prism plots. If they are fixed plots, the user must supply the inverse of the plot size. For prism plots, the basal-area factor must be given. This option also allows the user to enter the tree list in 1- or 2-inch diameter classes. The stand entered in 2-inch classes will be adjusted into 1-inch classes programmatically.

The diameter classes by species are displayed on the terminal and the user may modify the stand, if desired. The modification process redisplays the stand information just entered, species by species. The user can change the entries for each species or preserve the values by entering a carriage return. After checking each species group, the stand is again displayed and the user is given the choice of further modification or continuing with entering other projection information.

Option (5):

Report interval — The number of years of growth between the stand table reports sent to the printer. This must be a multiple of 5 years. The default value is 10 years.

Projection length — The total number of years that the model is to grow the stand. This, too, must be a multiple of 5 years.

Harvest diameter — The quadratic mean stand diameter of the stand when it is harvested. The model will continue to grow the stand until it reaches this diameter or reaches the projected age.

Managed/unmanaged — Will thinning operations be conducted? (Y), <N>.

Option (6):

Even-aged/multi-aged — Is the stand managed as an even-aged or multi-aged stand.

Stand age — For even-aged stands, enter the age. For multi-aged stands, enter the approximate number of years since the last major harvest, or a carriage return <cr> will continue the program if this information is not available.

Option (7):

Forest type — If the forest type and site are known as spruce-fir or northern hardwoods, the model will operate within the range of the specified type regardless of the species present. If the forest type is unknown, the model will determine the forest type based on the initial stand composition.

Site index — Enter the site index for the stand within the following ranges for each forest type:

softwood	30 to 70, <50>
hardwood	40 to 80, <60>
mixedwood	35 to 75, <55>.

Option (8):

Percent cull — The percentage of sawtimber for each species that can be considered as cull and be moved to the pulpwood category upon harvesting. The default value, <cr>, will enter zero values for cull.

Option (9):

Thinning specification — The user can choose to control the thinning by square feet of basal area or cubic feet of volume.

When to thin — There are two ways to control when to thin the stand. One choice is to specify the number of years to run prior to thinning (0, 5, 10, 15. . .). The other choice is to specify a basal area or volume level for the stand to attain before thinning.

Interactive/batch thin control — If the user desires, the model will stop before each thinning, display the stand and ask for any silvicultural treatment desired. This process is referred to as the "interactive" control and, if chosen, the input phase is ended and control is returned to the menu.

If the user chooses to specify a treatment for the entire projection period, the model will not display the thinning information to the terminal but will send it to the printer. This version is the "batch" option.

Silvicultural treatment

No thinning—this is the default value; it causes the model to grow the stand until the next thinning (if in the interactive mode) or continue until the end of the projection (if in the batch mode).

Thin from above—the amount of basal area or cubic feet to remove from each species is specified. The model begins removing trees from a user-specified diameter class and continues to smaller classes until the specified residual level is reached or until a species has been completely harvested. If a species is removed, the remaining amount to be thinned is distributed over the species with the highest priority.

Thin from below—similar to thinning from above except that the process begins at the user-specified diameter class and works to larger classes.

Diameter class removal—if the user is controlling the thinning interactively, this option allows the user to specify the number of trees to remove from a given species and diameter class.

Uniform thinning—the amount to thin for each species is divided evenly among all diameter classes with at least 0.1 of a tree. If a given diameter class does not have enough trees in it to satisfy the thin, the remaining amount to be thinned is distributed evenly over the remaining diameter classes. Once a species is completely removed by thinning, the remaining amount is divided among the species with the highest thinning priority.

q-line thinning—refers to a value that gives the slope of a negative exponential curve using the diameter distribution of your stand. This term was first used by de Liocourt (1898) and a method of calculating q is given by Leak (1963). This method can only be used for multi-aged stands. A theoretical tree distribution is developed with the same q-value as the current stand. This stand will have the desired basal area after thinning and will have no entries larger than a user-specified maximum diameter class for the stand. The number of trees to remove is then calculated for each diameter class by calculating the difference between the actual tree list and the theoretical tree list. The trees are removed from the stand according to a priority list. After this first pass, the user has the option to lower the 2-inch q-value by 0.1 if the stand structure has not met the management objective. The residual basal area and stand structure are given and the user can lower the 2-inch q-value by 0.1 for a second time. The stand values are presented and no further thinning is allowed without a growth period.

Maximum diameter class

Users who specify thinning to the q-line are asked to enter a maximum diameter class to retain in the stand. If this is less than the largest class in the current stand, all trees above the specified class will be removed. If the specified value is larger than any tree in the stand, the stand may be at a lower stocking level than specified after thinning. For thinning from above, the user gives a diameter class for the thinning to start and then smaller diameter classes are thinned. Thinning from below is similar except the thinning starts in the specified size class and then moves to larger classes.

Thinning level to retain

If q-line thinning was specified, the user is asked to input the desired level of basal area to retain. For the other thinning modes, the user has two choices depending on the type of management. One choice is to specify the residual stand in either basal area or volume, depending on the response to the thinning specification question earlier. The second choice, for even-aged stands, is to thin to the B line, based on stocking charts for softwood, mixedwood and hardwood stands (Figs. 1–3).

Percentage to thin

For thinning from above, from below, or uniformly, a percentage of the total amount to remove must be specified and is then taken from the species. These values range from 0 to 100 percent with the sum of all species groups totaling 100 percent. By changing these percentages the user can fully control removals from the stand. If the percentage to be removed from any species category is greater than the amount contained in it, the remainder is divided among the species with the highest priority of removal.

Priority thinning list

The user is asked to specify a priority of removal for each of the species groups in a range of 1 (low) to 9 (high). The same priority may be specified for more than one species group. If q-line thinning was chosen, these priorities are used to determine which species to remove first to obtain the desired diameter distribution. For thinning from above, below, or uniformly, this priority list is used only when, for a particular species, the percentage to thin times the amount to remove gives a value that is more than is present in that species. The excess amount to remove is then reassigned to other species by first considering species that had been targeted for thinning (by giving a nonzero percent-to-thin value) and that have the highest priority. If these species have not been totally removed, the extra amount to remove will be divided evenly among those with the highest priority; otherwise the next lower priority species on the "to be thinned" list are considered. If all of the species that are on the thin list have been removed, the extra amount is taken from species not previously targeted for thinning, according to priority.

If the thinnings are being controlled interactively, after each thinning the user is given the option of returning to the prethinning conditions to attempt an alternative method.

At this point, the control file on disk is complete and control is returned to the menu. The remaining options are:

Option (10):

Display control — Displays the contents of the control file named at the beginning of this run.

Option (11):

Display stand — Prints the initial stand table on the console and a chance to modify is given.

Option <12>:

Execute — Starts the growth projection according to the criteria contained in the control file.

An example of creating a control file for a hardwood stand and sample terminal output are shown in Table 4 (items in italics are entered by the user). The yield tables for intermediate thinnings and standing and total yields are given. The volume and board-foot values are obtained from local tables for the Penobscot Experimental Forest (softwood species) and the Bartlett Experimental Forest (hardwood species).[2] The cubic foot sawlog volume includes the whole tree, whereas the board-foot volume represents only sawlog material and not the volume of the tops. In order to estimate the top volume, the board-foot volume should be converted to cubic feet and subtracted from the total cubic feet in sawlog volume. At the end of a projection the user is asked if he or she desires another run on this control

[2] Volume and board-foot values were determined using the International 1/4-inch rule.

file. A Y response will return the menu, allowing the user to make the necessary changes for the next run. If an N or a <cr> response is given, the user is asked if a new control file is desired. A Y response will return the user to entering the file name of the control file and the destination of the printed output; an N or a <cr> response terminates the run.

For every execution of FIBER, a file designed for a printer is created. This file consists of 132 characters per line plus a carriage control character and can be sent directly to a printer or stored in a disk file to be printed later. A summary of the control information is printed first, then the initial stand table, stand tables at the specified intervals, final stand tables, and the yields. For every thinning that occurs, a prethin stand table, the thinning criteria, a postthin stand table, and the yield from this thinning are written. The stand tables in this printer file are more detailed than the ones shown in Table 4. These stand tables show basal area, volume, and board-foot values by species and diameter class.

Beginning users may find it helpful to complete the sample worksheet before running the program (Table 5). This form contains the questions in the order that they will be prompted by the program for the answers. Values do not have to be given for species categories that are not selected at the beginning of projection.

Model Limits

The model predicts well within the range of the data sets for managed stands. However, for some combinations of IBA, RBA, and proportion of hardwoods the equations predict unlikely values of a, b, or c when required to predict growth outside the development data sets at very high densities. Since a_{it}, b_{it}, c_{it}, and m_{it} are probabilities, their true values are non-negative. At high densities, the predicted a-, b-, c-, or m- values might be negative, in which case, the value is set equal to zero and the values were standardized to sum to 1.

Due to insufficient data for mature unmanaged stands over a long time period, constraints were placed on the model to prevent the predictions from becoming unreasonable values. After the stand basal area reaches 15 square feet over the A line on the stocking charts, (Figs. 1–3), the c-value is linearly reduced from the predicted equation value to zero before the stand grows to 20 square feet over the A line. This reduction in the c-value is added to m. Similarly, if the stand should grow to more than 20 square feet over the A line, then the b-value also is linearly reduced to zero before the stand grows to 40 square feet over the A line. Half of the amount removed from the b-value also is added to m with the other half added to the a-value. These two procedures force the projected stand to return below the A line in the stocking charts.

Since the ingrowth equations were developed in managed stands, the ingrowth equations for unmanaged stands had to be modified as the RBA increased beyond the range of the original data (Table 6). When the residual basal area was more than the first number of the range, the predicted ingrowth value was linearly reduced to zero by the second value in the range given. For most species groups, the predicted value went to zero before reaching these constraints. However, these constraints are still in the model should different ingrowth equations be implemented.

These limitations are governed by forest type, which can change over time depending on composition and site index unless the user specified a forest type. The rules for changing the forest type are presented in Table 7. If the conditions stated are not met, the forest type remains the same.

Since all of the development data plots were greater than 20 ft^2/acre (4.6 m^2/ha), the model is programmed to terminate if a stand goes below this density level during a projection. This limitation prevents the acquisition of possible erroneous information and does not appear to impose a restriction on the usefulness of the model.

Conclusion

A two-stage stand projection model, FIBER, has been developed to predict the growth and yields for spruce-fir, northern hardwood, and mixtures of these forest types in the Northeast. It is a matrix model using linear equations to predict ingrowth, the probability of survivor growth, and the probability of mortality by species. The model incorporates transition probabilities, that change over time, to project future diameter distributions and to predict volumes. The model can be applied to managed and unmanaged stands, both even-aged and multi-aged, over a range of densities, site indices, species mixtures, and treatment intervals. A variety of thinning options are possible, including thinning by diameter class. Both thinning and harvest yields are presented. Volume tables are in separate files and can be modified easily for local conditions. The model has been designed for use by researchers, educational institutions, and forest managers of both small woodlots and large forested land areas.

An attempt has been made to make FIBER as "user friendly" as possible. The model is written in Fortran 77, requires 256K, and has been tested on the following computers:

Mainframe: IBM 4341

Operating System: VM/CMS

Availability: Magnetic Tape; EBCDIC, 9-track Electronic Transfer via BITNET

Micros:

IBM PC and compatables

Operating system: MS–DOS 2.0

Availability: 5 1/4 floppy disk

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Table 1.—Regression coefficients for equations used to predict the a-, b-, c-values and ingrowth in the stand projection matrices

Species	Dependent variable	Independent variable[a]							
		Intercept	IBA	RBA	D	P	D^2	RBA^2	PS
Fir	a	.2120	.00274	.00107	.0163	−.1784	−.00134	−.0000110	—
	b	.5851	−.00388	.00071	.0089	.1231	−.00051	.0000082	—
	c	.0368	.00012	−.00089	.0038	.0284	−.00016	.0000026	—
	k	10.9188	—	−.01367	—	−9.0919	—	—	24.9297
Spruce	a	.5841	.00047	.00069	−.0276	−.0709	.00091	−.0000017	—
	b	.2981	−.00100	.00043	.0407	.0152	−.00157	−.0000009	—
	c	.0184	.00030	−.00056	−.0005	.0207	.00011	.0000008	—
	k	3.7023	—	−.02406	—	−2.8019	—	—	−23.9716
Hemlock	a	.4832	−.00069	.00336	−.0515	−.2678	.00173	.0000024	—
	b	.3808	.00030	−.00091	.0554	.2030	−.00198	−.0000109	—
	c	.0865	.00015	−.00157	−.0008	.0483	.00008	.0000056	—
	k	2.1978	—	−.01177	—	.7598	—	—	7.5607
Cedar	a	.5859	.00084	.00084	−.0005	−.1013	.00021	−.0000053	—
	b	.3528	−.00152	−.00017	.0076	.0412	−.00054	.0000052	—
	c	.0159	.00050	−.00068	−.0022	.0546	.00014	.0000007	—
	k	−.5786	—	.01253	—	.0790	—	—	5.9740
Other softwood	a	.7094	.00066	.00052	.0049	−.0190	−.00259	.0000020	—
	b	.1521	−.00095	.00072	.0163	−.0229	.00102	−.0000065	—
	c	.0468	.00009	−.00061	−.0088	.0272	.00083	.0000025	—
	k	1.1028	—	−.00697	—	−.1562	—	—	1.3388
Sugar maple	a	.0558	.00084	.00609	−.0287	.0959	.00109	−.0000242	—
	b	.5776	−.00325	.00061	.0384	−.0484	−.00151	.0000042	—
	c	.2109	.00141	−.00461	.0015	−.0074	−.00003	.0000132	—
	k	2.6186	—	−.02633	—	2.1191	—	—	5.8985
Red maple	a	.3373	.00038	.00409	−.0127	−.0821	.00013	−.0000125	—
	b	.4092	−.00076	−.00182	.0379	.0827	−.00155	.0000041	—
	c	.0984	.00017	−.00129	−.0069	.0079	.00053	.0000044	—
	k	1.8908	—	−.00826	—	.2620	—	—	11.3853
Yellow birch	a	.3290	.00308	.00117	−.0143	−.1577	.00076	−.0000083	—
	b	.4479	−.00466	.00365	.0166	.1598	−.00101	−.0000070	—
	c	.1216	.00094	−.00273	−.0031	.0057	.00017	.0000084	—
	k	1.3759	—	−.00777	—	.5803	—	—	2.2950
Paper birch	a	.4148	−.00069	.00446	.0111	−.1206	−.00009	−.0000129	—
	b	.3944	−.00080	−.00131	.0031	.1560	−.00079	.0000045	—
	c	.0655	.00076	−.00149	−.0060	−.0034	.00044	.0000036	—
	k	1.9167	—	−.01243	—	1.2839	—	—	7.6810
Beech	a	.3343	−.00208	.00743	−.0413	.0006	.00194	−.0000202	—
	b	.3914	.00225	−.00488	.0474	.0877	−.00259	.0000070	—
	c	.1726	.00040	−.00292	.0014	−.0565	−.00005	.0000123	—
	k	2.3648	—	−.02853	—	2.8110	—	—	7.4906

Table 1.—Cont.

Species	Dependent variable	Independent variable[a] Intercept	IBA	RBA	D	P	D^2	RBA^2	PS
White ash	a	.9332	.00054	−.00917	−.0427	−.0114	.00152	.0000427	—
	b	−.5138	−.00199	.01801	.0211	.2982	−.00121	−.0000789	—
	c	.2608	.00038	−.00443	.0210	−.1331	−.00049	.0000181	—
	k	2.7543	—	−.01308	—	.1310	—	—	−4.4739
Aspen	a	.2687	−.00050	.00366	−.0093	−.0363	−.00013	−.0000072	—
	b	.4028	−.00533	.00318	.0320	.1088	−.00118	.0000037	—
	c	.1197	.00292	−.00401	−.0005	−.0462	.00031	.0000036	—
	k	2.8556	—	−.03879	—	−2.2737	—	—	17.3895
Other hardwoods	a	−.3593	−.01269	.01764	.1698	−.1392	−.00899	−.0000158	—
	b	.4994	.01311	−.01439	−.0594	.0839	.00367	.0000022	—
	c	.0683	.00154	−.00266	.0010	−.0302	.00040	.0000051	—
	k	2.4589	—	−.01641	—	1.6005	—	—	1.2478

[a]IBA = initial basal area; RBA = residual basal area; D = diameter class; P = proportion hardwood composition; PS = proportion of species in the composition.

Table 2.—Linear reductions of transition probabilities a, b, and c within the range of maximum diameter classes for trees in stands with more than 125 ft^2/acre

Transition probability	D.b.h. class	Species
	Inches	
c	15–20	All species
b	15–25	Balsam fir, paper birch, aspen, other hardwoods
	20–30	All other species
a	20–30	All species

Table 3.—Actual and predicted average stand volume (ft^3/acre) after 15 years, by species, residual basal-area class, and forest type

Residual basal area (ft^2/acre)	Yield	Species[a]														Percent error
		BF	SP	HE	CE	OS	SM	RM	YB	PB	BE	WA	AS	OH	Total	
							SOFTWOOD									
40(n = 94)	Initial	286	270	9	152	10	2	19	22	19	1	0	4	1	796	
	Actual	667	596	24	179	16	7	31	34	35	2	0	8	4	1605	8.7
	Predicted	605	529	19	182	14	6	36	31	30	2	0	9	2	1465	
80(n = 191)	Initial	545	662	21	218	38	9	38	51	34	4	1	17	9	1648	
	Actual	899	1069	31	251	51	12	60	57	47	6	1	16	11	2511	3.2
	Predicted	833	1051	33	252	46	13	60	61	45	5	1	20	11	2430	
120(n = 135)	Initial	864	866	59	377	44	31	70	103	88	5	0	20	5	2532	
	Actual	1128	1193	70	405	49	29	100	98	94	4	1	22	2	3195	1.3
	Predicted	1092	1186	73	417	25	35	94	106	97	6	0	17	6	3155	
160(n = 29)	Initial	727	1035	40	1148	69	1	72	63	75	6	0	57	2	3295	
	Actual	759	1245	54	1232	67	2	95	39	71	0	0	52	3	3618	– 3.0
	Predicted	853	1288	54	1234	26	2	85	62	71	5	0	45	3	3727	
							MIXEDWOOD									
40(n = 54)	Initial	184	139	10	40	2	88	89	159	69	66	4	26	19	896	
	Actual	486	338	21	59	4	167	143	203	113	88	9	28	29	1689	14.1
	Predicted	363	259	22	52	3	148	151	193	102	96	5	37	20	1452	
80(n = 74)	Initial	390	289	32	77	1	249	163	317	60	114	4	27	24	1748	
	Actual	751	457	59	88	1	348	227	363	82	132	5	34	27	2574	8.8
	Predicted	586	428	53	89	1	333	231	350	75	138	5	30	30	2348	
120(n = 45)	Intial	670	489	45	46	32	243	228	352	129	143	7	256	34	2674	
	Actual	757	676	53	65	38	273	250	347	140	139	11	229	24	3004	– 5.4
	Predicted	839	641	61	57	29	263	294	349	157	156	12	269	39	3167	
160(n = 6)	Initial	454	618	320	289	0	561	107	266	143	194	28	439	50	3469	
	Actual	718	827	343	327	0	423	133	255	169	82	34	434	37	3787	12.9
	Predicted	569	769	238	235	0	402	129	219	132	188	34	331	53	3299	
							HARDWOOD									
40(n = 59)	Initial	42	27	3	0	0	215	92	227	75	184	9	31	4	909	
	Actual	146	78	5	0	0	400	192	339	126	261	16	52	6	1620	12.9
	Predicted	96	51	10	0	0	358	159	296	118	249	14	49	11	1411	
80(n = 69)	Initial	62	51	7	4	0	541	177	383	39	535	23	29	6	1858	
	Actual	113	82	12	3	0	774	230	417	58	561	34	34	10	2326	– 0.8
	Predicted	96	73	11	4	0	736	252	438	52	607	33	34	10	2346	
120(n = 20)	Initial	104	39	21	1	0	1077	72	406	14	942	77	0	16	2769	
	Actual	128	68	23	2	0	1004	99	430	10	984	90	0	7	2846	– 6.7
	Predicted	147	55	32	2	0	1136	97	434	16	1006	95	0	16	3036	

[a]BF = balsam fir; SP = spruce; HE = eastern hemlock; CE = northern white-cedar; OS = other softwoods; SM = sugar maple; RM = red maple; YB = yellow birch; PB = paper birch; BE = American beech; WA = white ash; AS = aspen; OH = other hardwoods

Table 4.—Input/output for a hardwood stand thinned to 40 ft²/acre and then projected for 50 years (Items in italics are entered by the user)

FIBER
Version 2.0

Please choose the output device <1> printer (2) diskfile
2
Please enter the disk file name:
FIBER.PRT
Please enter control file name:
SAMPLE.CTL
Is control file <1> old (2) new?
2

Choose one of the following:

(1)	HELP	(7)	SITE INDEX
(2)	NEW FILE	(8)	PERCENT CULL
(3)	TITLE	(9)	THINNING
(4)	GROWTH PERIOD	(10)	DISPLAY CONTROL
(5)	STOCKING	(11)	DISPLAY STAND
(6)	STAND AGE	<12>	EXECUTE

2
Enter title:
HARDWOOD STAND THINNED THEN ALLOWED TO GROW FOR 50 YEARS
Choose one stocking choice:
(1) Input a tree list.
(2) Input % stocking by dbh class.
<3> Input several plots to be averaged.
1

Please specify which species are to be included in the treelist
Enter a 1 for those to be included, a 0 for those not to be included.
BF SP HE CE OS SM RM YB PB BE WA AS OH
0 1 1 0 0 0 1 1 1 1 0 0 0
entering a <cr> will make whole line 0
First line is diameter classes 5–17, second is 18–30
Please enter the number of trees in each of the 5–17 inch classes for SPRUCE (13 values)
0 0 0 3 0 0 0 0 3 0 0 0 0
Please enter the number of trees in the remaining classes 18–30 for SPRUCE (13 values)
<cr>
Please enter the number of trees in each of the 5–17 inch classes for HEMLOCK (13 VALUES)
6 6 0 3 0 0 0 0 0 0 0 0 0
Please enter the number of trees in the remaining classes 18–30 for HEMLOCK (13 values)
<cr>
Please enter the number of trees in each of the 5–17 inch classes for RED MAPLE (13 values)
3 3 6 0 0 3 0 0 3 0 0 0 0
Please enter the number of trees in the remaining classes 18–30 for RED MAPLE (13 values)
<cr>
Please enter the number of trees in each of the 5–17 inch classes for YELLOW BIRCH (13 values)
6 0 3 3 6 9 0 0 0 0 0 0 0
Please enter the number of trees in the remaining classes 18–30 for YELLOW BIRCH (13 values)
<cr>
Please enter the number of trees in each of the 5–17 inch classes for PAPER BIRCH (13 values)
0 0 6 6 3 6 15 3 6
Please enter the number of trees in the remaining classes 18–30 for PAPER BIRCH (13 values)
<cr>
Please enter the number of trees in each of the 5–17 inch classes for BEECH (13 values)
18 21 15 12 6 0 3 0 0 0 0 0 3
Please enter the number of trees in the remaining classes 18–30 for BEECH (13 values)
<cr>

HARDWOOD STAND THINNED THEN ALLOWED TO GROW FOR FIFTY YEARS.
INITIAL STAND CONDITIONS Stand age: 0
DIAMETER CLASSES

	5	6	7	8	9	10	11	12	13–15	16–19	20+	TOTAL	SQ. FT.	CU.FT.
SP	0	0	0	3	0	0	0	0	3	0	0	6	3.81	91.5
HE	6	6	0	3	0	0	0	0	0	0	0	15	3.04	37.8
RM	3	3	6	0	0	3	0	0	3	0	0	18	7.00	148.8
YB	6	0	3	3	6	9	0	0	0	0	0	27	10.23	203.4
PB	0	0	6	6	3	6	15	3	6	0	0	45	26.08	677.4
BE	18	21	15	12	6	0	3	0	0	3	0	78	23.59	468.3
TOT	33	30	30	27	15	18	18	3	12	3	0	189	73.76	1627.2

Mean stand diameter = 8.46

Table 4.—Cont.

<cr> to continue
<cr>
Do you want to change initial stand?
N
Please enter the report interval in years <10>:
20
Projection length (years)?
50
Harvest diameter <30>?
<cr>
Will you be growing this stand:
  (1) under management?
  <2> unmanaged?
1
Is stand (1) even-aged or <2> multi-aged?
<cr>
Enter the approximate age of the stand or
the number of years since major harvest.
(If unknown then enter <cr>)
<cr>
Is the stand on a (1) softwood site (2) hardwood site
  or <3> unknown?
2
Enter in the site index for your hardwood stand
(40–80,<60>)
<cr>
Enter the percent cull for each species
SP HE RM YB PB BE
5 5 5 10 10 5
Will you specify thinning levels in (1) basal area,
or in <2> cubic feet?
1
Do you wish to thin on a (1) time interval or
at a <2> stocking level?
1
Enter in the time interval
0
Do you want to control each thinning interactively?
  (1) INTERACTIVE
  <2> BATCH
1

Choose one of the following:
  (1) HELP (7) SITE INDEX
  (2) NEW CONTROL (8) PERCENT CULL
  (3) TITLE (9) THINNING
  (4) GROWTH PERIOD (10) DISPLAY CONTROL
  (5) STOCKING (11) DISPLAY STAND
  (6) STAND AGE <12> EXECUTE
<cr>

Executing. . .

HARDWOOD STAND THINNED THEN ALLOWED TO GROW FOR FIFTY YEARS.
PRE-THINNING STAND CONDITIONS 0th YEAR Stand age: 0
DIAMETER CLASSES

	5	6	7	8	9	10	11	12	13–15	16–19	20+	TOTAL	SQ. FT.	CU.FT.
SP	0	0	0	3	0	0	0	0	3	0	0	6	3.81	91.5
HE	6	6	0	3	0	0	0	0	0	0	0	15	3.04	37.8
RM	3	3	6	0	0	3	0	0	3	0	0	18	7.00	148.8
YB	6	0	3	3	6	9	0	0	0	0	0	27	10.23	203.4
PB	0	0	6	6	3	6	15	3	6	0	0	45	26.08	677.4
BE	18	21	15	12	6	0	3	0	0	3	0	78	23.59	468.3
TOT	33	30	30	27	15	18	18	3	12	3	0	189	73.76	1627.2

Mean stand diameter = 8.46 q-value = 1.4 (2-inch q-value = 1.8)

<cr> to continue
<cr>

Please choose a type of thinning:
  (1) Thin from above (4) Thin along q-line
  (2) Thin from below (5) Thin by diameter class
  (3) Thin uniformly <6> No thinning
1
Enter the diameter class to start thinning <30>
20

Table 4.—Cont.

Enter the total amount to retain:
40
Please enter the percentage to thin for each species

SP	HE	RM	YB	PB	BE
10	*10*	*10*	*20*	*20*	*30*

Enter thinning priority for each species (1 to 9)

SP	*HE*	*RM*	*YB*	*PB*	*BE*
9	*9*	*7*	*5*	*5*	*3*

Thinning. . .

HARDWOOD STAND THINNED THEN ALLOWED TO GROW FOR FIFTY YEARS.
POST-THINNING STAND CONDITIONS 0th YEAR Stand age: 0
DIAMETER CLASSES

	5	6	7	8	9	10	11	12	13–15	16–19	20+	TOTAL	SQ. FT.	CU.FT.
SP	0	0	0	0	0	0	0	0	0	0	0	0	.00	.0
HE	0	0	0	0	0	0	0	0	0	0	0	0	.00	.0
RM	3	3	6	0	0	1	0	0	0	0	0	13	3.15	56.7
YB	6	0	3	3	1	0	0	0	0	0	0	13	3.11	52.6
PB	0	0	6	6	3	6	15	1	0	0	0	37	18.98	486.6
BE	18	21	15	8	0	0	0	0	0	0	0	62	13.38	225.9
TOT	27	24	30	17	4	7	15	1	0	0	0	125	38.61	821.8

Mean stand diameter = 7.53 q-value = 1.5 (2-inch q-value = 2.1)

<cr> to continue
<cr>
Do you wish to:
(1) thin on a time interval <2> at a stocking level
(3) return to pre-thin (4) no more thinning
4

Growing. . .

HARDWOOD STAND THINNED THEN ALLOWED TO GROW FOR FIFTY YEARS.
FINAL STAND CONDITIONS 50th YEAR Stand age: 50
DIAMETER CLASSES

	5	6	7	8	9	10	11	12	13–15	16–19	20+	TOTAL	SQ. FT.	CU.FT.
SP	0	0	0	0	0	0	0	0	0	0	0	0	.00	.0
HE	3	3	2	2	2	2	2	2	2	0	0	21	9.41	158.6
RM	5	5	4	3	3	3	2	2	4	1	0	32	15.49	344.5
YB	2	2	2	2	2	2	2	2	4	1	0	21	11.41	240.3
PB	11	11	10	8	6	4	4	4	15	5	0	77	42.49	1044.8
BE	9	9	9	8	8	8	8	8	14	1	0	82	43.26	1006.9
TOT	30	30	27	24	21	19	19	18	38	7	0	233	122.06	2795.1

Mean stand diameter = 9.80 q-value = 1.4 (2-inch q-value = 1.6)

Table 4.—Cont.

<cr> to continue
<cr>
Do you wnat to see the yields for this run?
Y

HARDWOOD STAND THINNED THEN ALLOWED TO GROW FOR FIFTY YEARS

Standing yield

	PULPWOOD		SAWTIMBER		
	B.A.	CU.FT.	B.A.	CU.FT.	BOARD FEET
SPRUCE	.0	.0	.0	.0	.0
HEMLOCK	2.0	26.4	7.4	132.2	851.3
RED MAPLE	5.7	107.7	9.8	236.8	1142.3
YELLOW BIRCH	3.9	73.1	7.5	167.3	890.6
PAPER BIRCH	14.6	323.1	27.9	721.8	4039.6
BEECH	13.2	262.7	30.0	744.2	3561.3
TOTAL	39.4	792.9	82.7	2002.2	10485.1

<cr> to continue
<cr>

Total yield from thinnings

	PULPWOOD		SAWTIMBER		
	B.A.	CU.FT.	B.A.	CU.FT.	BOARD FEET
SPRUCE	.2	4.6	3.6	86.9	432.0
HEMLOCK	2.0	23.5	1.0	14.3	.0
RED MAPLE	.2	4.6	3.7	87.5	357.0
YELLOW BIRCH	2.7	56.0	4.4	94.8	.0
PAPER BIRCH	.7	19.1	6.4	171.7	954.0
BEECH	4.4	97.1	5.9	145.3	852.0
TOTAL	10.2	204.9	24.9	600.5	2595.0

<cr> to continue
<cr>

Total yield

	PULPWOOD		SAWTIMBER		
	B.A.	CU.FT.	B.A.	CU.FT.	BOARD FEET
SPRUCE	.2	4.6	3.6	86.9	432.0
HEMLOCK	4.0	49.9	8.4	146.4	851.3
RED MAPLE	5.9	112.3	13.5	324.3	1499.3
YELLOW BIRCH	6.6	129.1	11.9	262.0	890.6
PAPER BIRCH	15.3	342.1	34.3	893.5	4993.6
BEECH	17.6	359.7	35.9	889.6	4413.3
TOTAL	49.6	997.8	107.6	2602.7	13080.1

Do you want another run on this control file?
N
Do you want to use another control file?
<cr>
Stop - Program terminated

Table 5.—FIBER worksheet

OUTPUT: <1> PRINTER (2) DISKFILE: _________
CONTROL FILE: ______________ <1> OLD (2) NEW
TITLE: ____
SPECIES
CHOICE: BF SP HE CE OS SM RM YB PB BE WA AS OH
— — — — — — — — — — — — —
INPUT CHOICE: a) DIAMETER LIST BY SPECIES
b) # STEMS BY SPECIES AND % IN DIAMETER CLASS
c) PRISM PLOTS OR FIXED PLOTS
(1) BAF OR INVERSE OF PLOT SIZE
(2) 1- or 2-INCH CLASSES
REPORT INTERVAL (5,10,15. . . .):
PROJECTION LENGTH:
HARVEST DIAMETER:
MANAGED OR UNMANAGED:
STAND STRUCTURE: (1) EVEN-AGED
<2> MULTI-AGED
STAND AGE:
FOREST TYPE: (1) SPRUCE-FIR (2) NORTHERN HARDWOODS <3> UNKNOWN
SITE INDEX:
BF SP HE CE OS SM RM YB PB BE WA AS OH
PERCENT
CULL: — — — — — — — — — — — — —
THINNING SPECIFICATIONS: (1) SQUARE FEET
<2> CUBIC FEET
WHEN TO THIN: (1) YEARS TO RUN PRIOR TO THIN _____
<2> STAND DENSITY LEVEL _____

INTERACTIVE _____, BATCH _____
SILVICULTURAL TREATMENT:
ABOVE _____ q-LINE _____
BELOW _____ DIAMETER CLASS _____
UNIFORM _____ NONE _____
MAXIMUM DIAMETER CLASS FOR q-LINE _____
STARTING DIAMETER CLASS FOR ABOVE, BELOW
THINNING LEVEL TO RETAIN: (1) BA _____ VOL _____
(2) B-LINE FOR EVEN-AGED STANDS
BF SP HE CE OS SM RM YB PB BE WA AS OH
PERCENT
THINNED: — — — — — — — — — — — — —
PRIORITY
LIST (1–9): — — — — — — — — — — — — —

Table 6.—Basal-area range, by forest type and species, at which ingrowth is forced to zero

Species	Softwood	Mixedwood	Hardwood
		- - - - - - - - - *ft²/acre* - - - - - - - - -	
Fir	190–220	160–190	110–140
Spruce	190–220	130–160	110–140
Cedar	190–220	130–160	110–140
Aspen	80–110	80–110	80–110
All other	150–180	130–160	110–140

Table 7.—Criteria for allowing a change in forest type

Current forest type	Condition	New forest type
Softwood	Site index for softwood ≥50 for hardwood composition ≥50%	Mixedwood
Mixedwood	Site index for softwood ≤50 and hardwood composition ≤35%	Softwood
	Site index for hardwood ≥60 for hardwood composition ≥75%	Hardwood
Hardwood	Site index for hardwood ≤60 and hardwood composition <50%	Mixedwood

Solomon, Dale S.; Hosmer, Richard A.; Hayslett, Homer T., Jr. 1987 **FIBER handbook: a growth model for spruce-fir and northern hardwood types**. NE-RP-602. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 19 p.

A matrix model, FIBER, has been developed to provide the forest manager with a means of simulating the management and growth of forest stands in the Northeast. Instructional material is presented for the management of even-aged and multi-aged spruce-fir, mixedwood, and northern hardwood stands. FIBER allows the user to simulate a range of silvicultural treatments for a variety of species compositions growing on different sites. The internal structure of the model is defined and explanations on the use of FIBER are offered. Examples of input, interim procedures, and final output are shown.

ODC: 562.2:564:228.3

Keywords: Growth; model; mixed species; spruce; northern hardwoods

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