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FIBER 3.0: An Ecological Growth Model for Northeastern Forest Types

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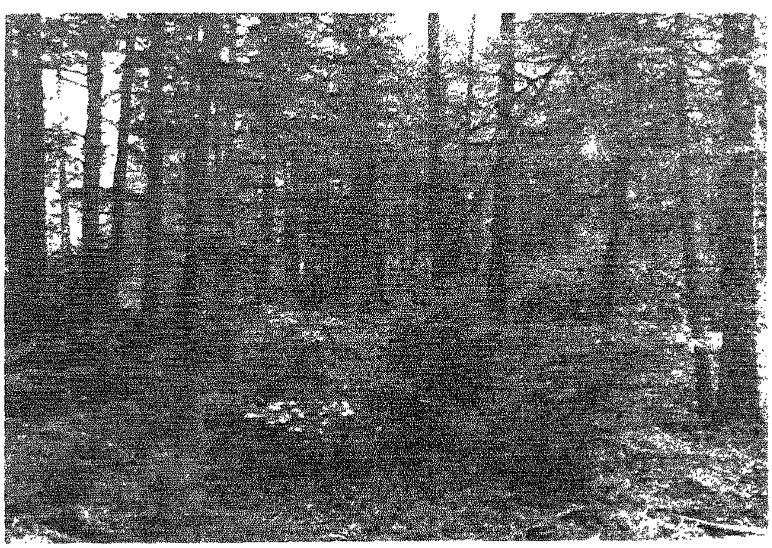

Abstract

FIBER, a stand projection growth model, simulates the growth and structural development of stands in the Northeast. The internal structure of the model is specified and constructed by the ecological land classifications of sugar maple—ash, beech—red maple, oak—white pine, spruce—fir, hemlock—spruce, and cedar—black spruce. Guidelines are provided on operational procedures for the major commercial species growing on these different ecological land classifications for a range of even-aged and uneven-aged silvicultural treatments and harvesting schedules.

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Cover Photo

New England stands depicting sugar maple—ash and hemlock—spruce habitats.

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Introduction

The original forest growth model, FIBER, was developed to predict the growth interactions among species within the spruce-fir, northern hardwood, and mixed hardwood-softwood stands in the Northeastern United States (Solomon et al. 1986a). A prototype model, FIBER 2.0, was modified and expanded to include a broader geographical area (Solomon et al. 1986b). This updated version, FIBER 3.0, allows forest managers the option to simulate the growth of stands over a complete range of treatments from clearcutting through partial harvests to unmanaged stands. Management practices and silviculture treatments defined in terms of Acceptable Growing Stock (AGS has the potential for a minimum-grade sawlog) and Unacceptable Growing Stock (UGS does not have sawlog potential) can now be applied over a range of stand densities, harvest intervals, and species composition within different ecological land classifications. Thinning and harvesting yields are presented by size classifications of poletimber and sawtimber, allowing the manager to specify products by species and diameter using local volume tables. The internal options allow the user to predict the growth and yield, over a specified time interval, for individual forest stands or large forested areas receiving similar management practices.

The species composition of the different ecological land classifications used in the construction of the model ranged from complete softwood stands to complete northern hardwood stands. Softwood stands were defined as those with 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 following checklist of species names and symbols are used in the model (Little 1979):

Common	Scientific	Symbols
Balsam fir	*Abies balsamea* (L.) Mill.	BF
Red spruce	*Picea rubens* Sarg.	RS
Black spruce	*Picea mariana* (Mill.) B.S.P.	BS
White spruce	*Picea glauca* (Moench.) Voss.	WS
Eastern hemlock	*Tsuga canadensis* (L.) Carr.	HE
Northern white-cedar	*Thuja occidentalis* L.	CE
Sugar maple	*Acer saccharum* Marsh.	SM
Red maple	*Acer rubrum* L.	RM
Yellow birch	*Betula alleghaniensis* Britton	YB
Paper birch	*Betula papyrifera* Marsh.	PB
American beech	*Fagus grandifolia* Ehrh.	BE
White ash	*Fraxinus americana* L.	WA
Aspen	*Populus tremuloides* Michx.	AS
Northern red oak	*Quercus rubra* L.	RO
Tamarack	*Larix laricina* (du Roi) K. Koch.	TA
White pine	*Pinus strobus* L.	WP
Other hardwoods:		OH
Gray birch	*Betula populifolia* Marsh.	
Striped maple	*Acer pensylvanicum* L.	
Pin cherry	*Prunus pensylvanica* L. F.	
Black ash	*Fraxinus nigra* Marsh.	

Some of the permanent remeasured growth plots used for the model development received harvesting practices that covered a broad range of densities from clearcut to fully stocked stands. Other stands, primarily the softwoods, were natural stands that had developed with only occasional management. As a result of the wide range in density, structure, and management practices, FIBER 3.0 can be applied within both even-age and multi-age types of management.

Stands representative of a complete range in species composition and ecological land classifications 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-foot 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 from one of the stocking charts presented in Figures 1-3 (Solomon et al. 1986b). 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).

Harvesting practices that can be used in the program include: thinning from above, thinning from below, selection cutting to a q-line (de Liocourt 1898), thinning uniformly across all diameter classes, or removal of trees from any diameter class, which can be used to represent a wide range of harvesting practices, including shelterwood and clearcutting.

Source of Data

Nearly 4,000 independent growth plots from northern Maine, New Hampshire, northern New York, Vermont, New Brunswick, and Nova Scotia (Fig. 4), were included to increase the flexibility and reliability of the prototype model (Solomon et al. 1986b). 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. Two data sources included in the development of FIBER were intensive management units from the Penobscot and Bartlett Experimental Forests.

Beginning in 1953, a series of 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.

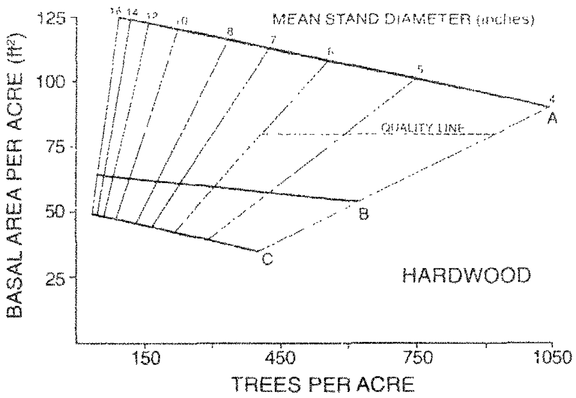

Figure 1.—Stocking chart for northern hardwoods is based on trees in the main crown canopy. The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand.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

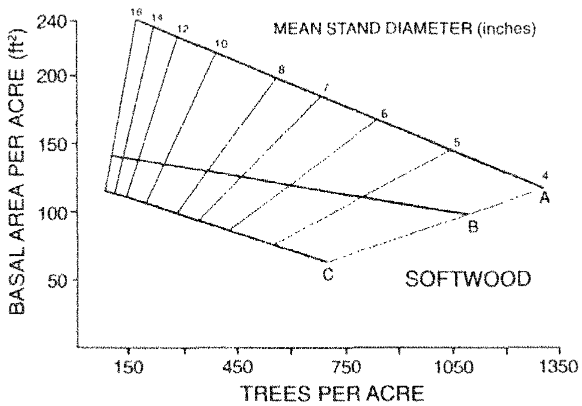

Figure 2.—Stocking chart for spruce—fir stands is based on trees in the main crown canopy. The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand.

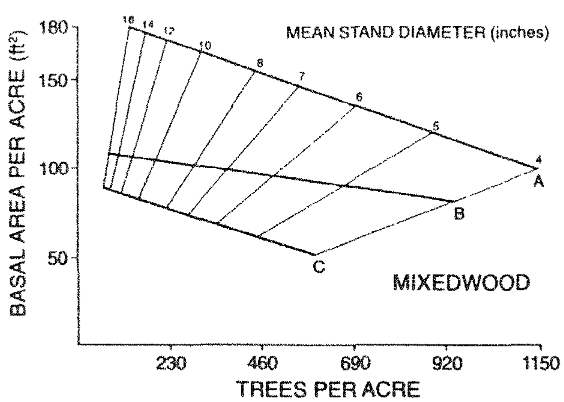

Figure 3.—Stocking chart for mixedwood stands is based on trees in the main crown canopy. The a line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand.

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, similar to the softwood study on the Penobscot Experimental Forest.

Ecological Land Classification

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. Instead of using site index, the data were separated into different ecological land classifications or habitats that ranged from the poorer wet black spruce stands to the better, pure northern hardwood stands. An expression of site index was not included as a variable in the development of FIBER. However, as described later, the user can specify a known site index and the growth rate of the stand will be increased or decreased in relation to the base site index.

Habitats are ecological land units defined by landform, soils, and typical climax tree species (Leak 1982). These units exhibit a characteristic successional pattern, indicative of the tree species that will most likely regenerate and compete on a given ecological unit. The relationships between tree species and soil/landform conditions vary with climate and bedrock mineralogy. Heavy disturbance, such as agricultural use and fire, may change the relationships of tree cover to soils and landform during the recovery period. Heavy cutting changes the successional stage, but not the characteristic successional sequence or climax forest type. In developing FIBER 3.0, the basic remeasured plot data were classified into a habitat based on the maximum basal area of the species composition at the beginning of any single remeasurement period. Each growth and ingrowth rate used to implement the model was developed by habitat. The six habitats used in FIBER 3.0 are:

1. Sugar maple—ash. This habitat includes those sites supporting typical northern hardwoods, beech-birch-maple, as well as richer sites supporting white ash and high proportions of sugar maple. The soils vary from deep, well-drained tills to moderately well-drained soils and enriched sites. On the basis of species composition, FIBER identifies this habitat as a hardwood type (less than 25 percent of the basal area in softwoods species), supporting more sugar maple than red maple, and at least 10 percent of the species composition in sugar maple and white ash.

2. Beech—red maple. Also a hardwood type, this habitat occurs on sandier and rockier well-drained tills than sugar maple—ash. Species composition tends toward beech, red maple, and birches with small amounts of sugar maple and very little ash. Softwoods are more common here than on sugar maple—ash sites. FIBER identifies

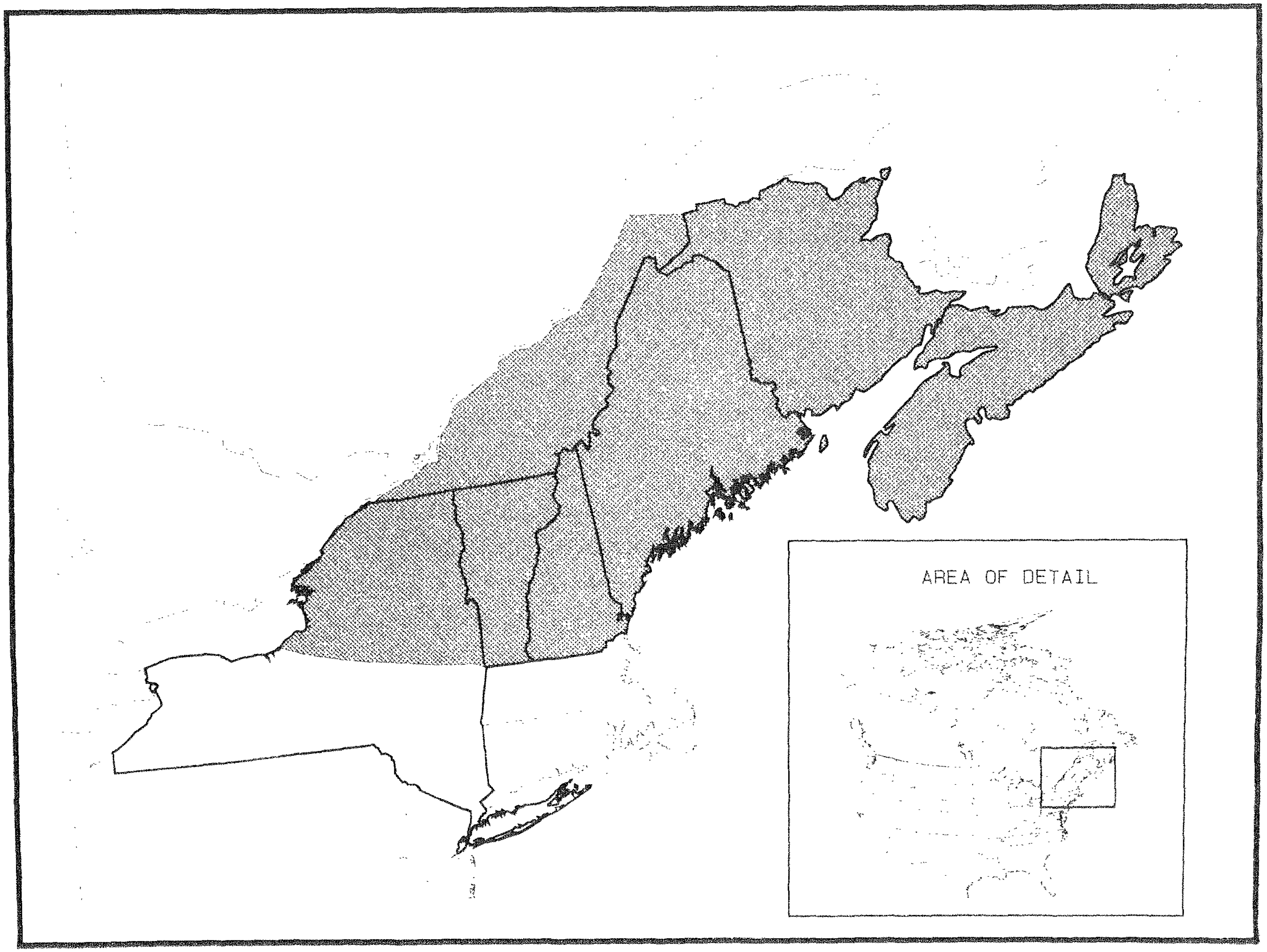

Figure 4.—Map of study area.

this habitat as a hardwood type when the criteria for sugar maple—ash or oak—white pine are not satisfied.

3. Oak—white pine. This habitat typically includes areas of sandy outwash, shallow bedrock, or very sandy till supporting eastern white pine and northern red oak. However, past agricultural disturbance may result in an oak—white pine community on better soils. Over time, hemlock becomes the predominant climax species. FIBER identifies a stand as oak—white pine habitat on a hardwood type when 10 percent or more of the basal area is oak; or when 20 percent or more of the basal area is in oak plus white pine. The user must select the habitat for a stand on a softwood type (more than 65 percent softwood species) when the percentage of white pine basal area is greater than that of any of the species groupings of the other softwood habitats.

4. Hemlock—red spruce. This habitat is characterized by shallow, wet, dry, or rocky soils supporting a mixedwood or softwood cover type (more than 25 percent softwood) where hemlock and red spruce are more abundant than white pine; red spruce, white spruce, and fir combined; or cedar and black spruce combined.

5. Spruce—fir. Shallow, wet, dry, or rocky soils typify this habitat. The habitat is identified in FIBER 3.0 as a mixedwood or softwood type where red spruce, white spruce, and balsam fir combined are the predominant softwood species as compared to white pine, cedar and black spruce combined, or hemlock and red spruce combined.

6. Cedar—black spruce. These are generally poorly drained areas in northern New England where cedar, black spruce, and tamarack are the predominant softwood species in mixedwood or softwood type. The basal area of these species is more than the basal area of white pine; hemlock and red spruce combined; red spruce, white spruce, and balsam fir combined.

Model Definitions

FIBER is a two-stage matrix model. Stage one of the model is a set of linear regression equations that predicts transition probabilities of tree species growth and mortality as a function of stand density, tree size, proportion of hardwoods, and elevation for each habitat classification. 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 in the second stage of the model (Solomon et al. 1986a).

Equation Development

For each species, a matrix U_t of predicted transition probabilities is applied to a stand table vector y_t, which contains the number of live trees at time t of that species in each d.b.h. class. By adding the ingrowth to this growth matrix, these two operations generate the stand table vector after 5 years of growth for each species:

$$y_{t+5} = U_t\,(y_t - h_t) + i_t \qquad (1)$$

$$\text{where}\quad U_t = \begin{bmatrix} a_{5t} & 0 & 0 & 0 & \dots & 0 & 0 & 0 \\ b_{5t} & a_{6t} & 0 & 0 & \dots & 0 & 0 & 0 \\ c_{5t} & b_{6t} & a_{7t} & 0 & \dots & 0 & 0 & 0 \\ 0 & c_{6t} & b_{7t} & a_{8t} & \dots & 0 & 0 & 0 \\ \vdots & & & & & & & \vdots \\ 0 & 0 & 0 & 0 & \dots & c_{n-2,t} & b_{n-1,t} & a_{nt} \end{bmatrix};\quad i_t = \begin{bmatrix} i_t \\ 0 \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

with...

a_{jt} = the probability that a tree survives and remains in diameter class j during the time interval from t to $t + 5$;
b_{jt} = the probability that a tree beginning in diameter class j at time t survives and progresses to diameter class $j + 1$ at time $t + 5$;
c_{jt} = the probability that a tree beginning in diameter class j at time t survives and progresses to diameter class $j + 2$ at time $t + 5$;
h_t = the vector of the number of live trees harvested from each diameter class at time t;
i_t = ingrowth in number of trees per acre into the 5-inch class during the time interval from t to $t + 5$.

The number of mortality trees, though not explicitly calculated in the growth equation (1), may be calculated according to the following vector equation:

$$z_{t+5} = m_t \cdot (y_t - h_t). \qquad (2)$$

In equation (2), $m_t = [m_{5t}, m_{6t}, ..., m_{nt}]'$ is the vector of mortality probabilities by diameter class, and the matrix operator (·) denotes *Hadamard* or element-by-element matrix product. Therefore, the number of trees that died in the 5-inch diameter class over the growth period would be computed as $z_{5,\,t+5} = m_{5t}\,(y_{5t} - h_{5t})$; other diameter classes are similarly computed.

Growth equations. The data sets described earlier were combined. Tree diameters were measured at 4.5 feet and placed in 1-inch classes that ranged from 5 to 32 inches. In subsequent inventories, each tree on the plot was categorized as ingrowth, survivor, or mortality. 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 for the 1-inch diameter classes by species. 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 the inventory at time t, and the residual basal area (RBA_t) after the inventory at time t. If there was no harvest at time the t, the IBA_t and the RBA_t were the same. Based on IBA_t, the plot data were grouped by basal area in 20 ft²/acre intervals starting at 10 ft². Plots with less than 10 ft² were grouped into 5 ft²/acre intervals.

The range from 5 to 320 ft²/acre of basal-area categories for these data sets was sufficient to provide growth response information for the general management alternatives. The plots grouped in each specific *IBA-RBA* category were considered to have the same growth rate. Plots with $RBA_t = 0$ for any growth period were not used in the data sets for model construction. Elevation was grouped in 400 ft intervals starting at 200 ft up to a maximum of 3,400 ft. A method of computing regression coefficients for categorical data developed by Grizzle et al (1969) was employed using the CATMOD procedure in SAS (SAS Institute Inc. 1989).

Let $u_{k_{jt}}$ denote a component of the growth matrix U_t; that is, $u_{1_{jt}} = a_{jt}$, $u_{2_{jt}} = b_{jt}$, $u_{3_{jt}} = m_t$ where m_{jt} is implicitly calculated in U_t. Thus, $u_{k_{jt}}$ for each diameter class j by species is assumed to have a multinomial distribution, and is modeled by linear functions of the form:

$$u_{k_{jt}} = \begin{cases} \beta_{k,0}+\beta_{k,1}*D_j+\beta_{k,2}*D_j^2+\beta_{k,3}*IBA_t+\beta_{k,4}*RBA_t+\beta_{k,5} \\ *RBA_t^2+\beta_{k,6}*P_t+\beta_{k,7}*E_t+\beta_{k,8}*X1+\beta_{k,9}*X1*D_j+\beta_{k,10} \\ *X2*E_t+\beta_{k,11}*X2+\beta_{k,12}*X2*D_j+\beta_{k,13}*X2*E_t+\beta_{k,14} \\ *X3+\beta_{k,15}*X3*D_j+\beta_{k,16}*X3*E_t+\beta_{k,17}*X4+\beta_{k,18}*X4*D_j \\ +\beta_{k,19}*X4*E_t+\beta_{k,20}*X5+\beta_{k,21}*X5*D_j+\beta_{k,22}*X5*E_t \end{cases} \quad (3)$$

where

D_j = midpoint of the diameter class j (inches).

IBA_t = initial stand basal area before harvest at time t (ft²/acre),

RBA_t = residual stand basal area after harvest at time t (ft²/acre),

P_t = proportion of hardwoods in the stand based on IBA_t at time t,

E_t = elevation of the plot in feet,

β_k = regression coefficients to be estimated, and

X1, X2, X3, X4, X5 = dummy variables for the six different habitats (Table 1).

The entries of U_t can be found from the equations (3) using the growth coefficients in Table 10 (Appendix) that were developed from the data sets for each ecological habitat. The following example predicts the transition probability of a 10-inch red spruce tree staying in the diameter class ($k = 1$), growing one diameter class ($k = 2$), and growing two classes (c_{jt}), or dying ($k = 3$), over a 5-year period on a spruce—fir habitat. The stand has an IBA_t = 140 ft², an RBA_t = 90 ft², with 20 percent hardwoods and is growing at 1,000-ft elevation.

$$a_{10,t} = \begin{cases} 4.8e\text{-}1\text{-}4.0e\text{-}2*10\text{-}6.4e\text{-}4*10*10\text{-}2.9e\text{-}4*140 \\ +3.6e\text{-}3*90\text{-}6.0e\text{-}6*90*90\text{-}1.8e\text{-}3*20+8.8e\text{-}5 \\ *1000+4.4e\text{-}1*0\text{-}2.2e\text{-}2*0\text{-}6.0e\text{-}5*0\text{-}1.4e\text{-}1*0 \\ +2.8e\text{-}2*0\text{-}3.0e\text{-}5*0\text{-}3.6e\text{-}2*0+1.4e\text{-}3*0+1.5e \\ \text{-}5*0+2.6e\text{-}1*0\text{-}1.7e\text{-}2*0+7.4e\text{-}5*0+9.2e\text{-}2*0 \\ \text{-}1.3e\text{-}2*0+7.8e\text{-}4*0 \end{cases}$$

$$= 0.30$$

$$b_{10,t} = \begin{cases} 4.5e\text{-}1+5.1e\text{-}2*10\text{-}1.4e\text{-}3*10*10\text{-}9.9e\text{-}4*140 \\ \text{-}1.8e\text{-}3*90+3.8e\text{-}6*90*90+1.0e\text{-}3*20\text{-}9.0e\text{-}5 \\ *1000\text{-}3.6e\text{-}1*0\text{-}1.9e\text{-}3*0+7.0e\text{-}5*0+6.5e\text{-}2*0 \\ \text{-}3.1e\text{-}2*0+9.9e\text{-}5*0+1.1e\text{-}1*0\text{-}1.2e\text{-}2*0\text{-}6.0e \\ \text{-}5*0\text{-}1.5e\text{-}1*0\text{-}6.8e\text{-}3*0\text{-}7.0e\text{-}5*0\text{-}2.8e\text{-}2*0 \\ \text{-}5.4e\text{-}3*0\text{-}1.0e\text{-}4*0 \end{cases}$$

$$= 0.48$$

$$m_{10,t} = \begin{cases} 4.2e\text{-}2\text{-}6.2e\text{-}3*10+4.4e\text{-}4*10*10+6.4e\text{-}4*140 \\ \text{-}9.8e\text{-}4*90+1.4e\text{-}6*90*90+4.9e\text{-}4*20\text{-}3.0e\text{-}6 \\ *1000\text{-}4.8e\text{-}2*0+1.2e\text{-}2*0\text{-}9.3e\text{-}7*0+4.4e\text{-}2*0 \\ +2.3e\text{-}3*0\text{-}4.0e\text{-}5*0\text{-}6.6e\text{-}2*0+1.1e\text{-}2*0+1.3e \\ \text{-}5*0\text{-}5.9e\text{-}2*0+1.2e\text{-}2*0\text{-}4.0e\text{-}6*0\text{-}3.5e\text{-}2*0 \\ +8.6e\text{-}3*0+1.5e\text{-}5*0 \end{cases}$$

$$= 0.04$$

$$c_{10,t} = 1\text{-}a_{10,t}\text{-}b_{10,t}\text{-}m_{10,t} = 1.00\text{-}0.48\text{-}0.30\text{-}0.04 = 0.18$$

Stocking charts. FIBER contains a maximum density limit for each habitat based on the stocking charts for softwood, hardwood, and mixedwood forest types (Figs. 1-3). When stands grow above the A-line (the level of average maximum stocking), stand growth slows to a rate influenced by the degree of "overstocking." Mortality increases as the basal area in these stands increases to a maximum value at 20 ft² over the A-line and remains the same until the basal area of the stand is reduced below A-line stocking. Then mortality is again predicted from the equations.

Tree size by species. FIBER contains species and habitat-specific limits on maximum tree size to prevent trees from growing too big. Maximum tree diameter (Table 2) for each species/habitat combination was defined using the maximum diameter observed in the data base, and personal experience from numerous old-growth research plots.

In combination with the maximum diameter, a habitat-specific controlling diameter (Table 3) defines the d.b.h. at which large trees begin senescence. Diameter classes are allocated a linear-increasing mortality rate between the controlling diameter and specified maximum diameter.

Mortality. Excessive mortality rates can occur for stands with composition and structure that are outside the range of those observed in the FIBER data base. If this occurs, the mortality rate is limited to a maximum of 15 percent for any given diameter class. If the stand has less than 80 ft² of basal area, then maximum mortality is reduced from 10 percent at 80 ft² to 2.5 percent at 20 ft². Below 20 ft², maximum mortality remains at 2.5 percent.

Table 1.—Number of plots, maximum elevation, base site index, and representative index species, by habitat

Habitat	Number of plots	Maximum elevation	Base site index Age	Base site index Species	Dummy variables X1	X2	X3	X4	X5
Beech—red maple	380	2600	60	Red maple	1	0	0	0	0
Cedar—black spruce	335	1800	40	Black spruce	0	1	0	0	0
Hemlock—red spruce	435	2000	50	Red spruce	0	0	1	0	0
Oak—white pine	253	1800	60	White pine	0	0	0	1	0
Sugar maple—ash	567	2600	70	Sugar maple	0	0	0	0	1
Spruce—fir	1907	3000	50	Red maple	0	0	0	0	0

Table 2.—Maximum diameter used in reduction of growth transition probabilities, by species and habitat

	Species																
Habitat	BF	RS	BS	WS	HE	CE	WP	TA	SM	RM	YB	PB	BE	WA	AS	RO	OH
BE-RM	18	22	10	15	20	15	25	10	30	25	32	20	28	30	20	20	15
CE-BS	18	24	18	25	25	32	25	20	23	20	25	15	15	15	25	10	20
HE-RS	18	24	10	20	32	20	30	10	29	28	30	20	25	23	18	20	20
WP-RO	18	24	10	15	32	20	32	10	15	20	17	20	17	17	20	32	24
SM-WA	18	20	10	18	20	15	25	10	32	25	32	20	28	30	20	20	20
SP-BF	20	30	15	30	30	32	32	20	32	25	32	20	25	20	25	20	24

Table 3.—Diameters used in FIBER, by species and habitat to control growth reductions

	Species																
Habitat	BF	RS	BS	WS	HE	CE	WP	TA	SM	RM	YB	PB	BE	WA	AS	RO	OH
BE-RM	10	17	5	10	15	10	20	5	25	20	27	12	23	25	10	15	8
CE-BS	10	19	13	20	20	27	20	15	18	15	20	7	10	10	15	5	12
HE-RS	10	19	5	15	27	15	25	5	24	23	25	12	20	18	8	15	12
WP-RO	10	19	5	10	27	15	27	5	10	15	12	12	12	12	10	26	16
SM-WA	10	15	5	13	15	10	20	5	27	20	27	12	23	25	10	15	12
SP-BF	15	25	10	25	25	27	27	15	27	20	27	12	20	15	15	15	16

All of the species in the data sets did not meet the same maximum-size diameter and did not have a sufficient number of trees in the larger diameter classes. To decrease the growth rate and increase the mortality of the larger trees over time, c_{ij} was set to zero; b_{ij} was linearly reduced from the predicted equation value to zero within the range of reduction to the maximum-size diameter classes of each species (Tables 2 and 3) and added to a_{ij}; and $m_{ij} = 1 - a_{ij} - b_{ij}$. The amount removed from each transition probability was recomputed ensuring that partial trees will not accumulate in the largest or 32-inch class.

Site index. To model difference in growth rate due to species composition on each habitat class, b_{ij} and c_{ij} were modified if the site index differed from the value of the base site index species (Table 1):

$$b_{ij}^{*} = b_{ij}SI/x \quad \text{and} \quad c_{ij}^{*} = c_{ij}SI/x$$

where

b_{ij}^{*} = b_{ij} adjusted for site index,
c_{ij}^{*} = c_{ij} adjusted for site index,
SI = site index, and
x = base site index for representative species on each habitat.

Then

$$a_{ij}^{*} = a_{ij}(1.0-m_{ij}) / (a_{ij}+b_{ij}^{*}+c_{ij}^{*})$$
$$b_{ij}^{**} = b_{ij}(1.0-m_{ij}) / (a_{ij}+b_{ij}^{*}+c_{ij}^{*})$$
$$c_{ij}^{**} = c_{ij}(1.0-m_{ij}) / (a_{ij}+b_{ij}^{*}+c_{ij}^{*})$$

This procedure assures that, a_{ij}^{*}, b_{ij}^{**}, and c_{ij}^{**} are all less than 1 and that $a_{ij}^{*} + b_{ij}^{**} + c_{ij}^{**} + m_{ij} = 1.0$. It also leaves mortality unaffected by site index.

FIBER 3.0 grows each tree species on the six different habitats using the transition probabilities developed from the data base. When the data base lacks sufficient observations of any species in a given habitat, FIBER 3.0 uses transition probabilities for that species from an alternative habitat that is the closest ecological habitat classification to the original (Table 4).

Ingrowth equations. For the ingrowth component of equation (1), a threshold diameter of 5.5 inches was used for one data set and 4.5 inches for all other data sets. At time *t*, ingrowth i_t for a particular species is calculated as a function of initial basal area (IBA_t), residual basal area (RBA_t), percentage of hardwoods (P_t), percentage of the stand made up by the ingrowth species (S_t), elevation (E_t) and habitat type (X). Coefficients (α_i) for the ingrowth equation (4) are shown in Table 11 (Appendix) and can be computed as:

$$i_t = \alpha_0+\alpha_1*IBA_t+\alpha_2*RBA_t+\alpha_3*P_t+\alpha_4*S_t+\alpha_5*E_t+\alpha_6*X1+\alpha_7*X2+\alpha_8*X3+\alpha_9*X4+\alpha_{10}*X5 \qquad (4)$$

Because of lack of data, the ingrowth equations (4) at some elevations give unrealistic predictions for ingrowth. At these elevations, FIBER 3.0 computes ingrowth of these "problem" species as if this species/habitat combination were growing at 1,500 ft elevation—an elevation with more precise predictive equations (Table 5).

FIBER adjusts the amount of ingrowth for certain species/habitat combinations to prohibit trees from ingrowing on

Table 4.—Alternative habitats used to grow species on unnatural habitats due to inadequate data

		Alternative habitat	
Habitat	Species	Growth	Ingrowth
Beech—red maple	Black spruce	Spruce—fir	**
	Cedar	Oak—white pine	**
	White pine	Hemlock—red spruce	Spruce—fir
	Tamarack	Spruce—fir	**
	White ash	—	Spruce—fir
	Red oak	Spruce—fir	—
Cedar—black spruce	White pine	Hemlock—red spruce	Spruce—fir
	Beech	—	**
	White ash	Spruce—fir	Spruce—fir
	Red oak	Spruce—fir	**
Hemlock—red spruce	Black spruce	Spruce—fir	**
	White pine	—	Spruce—fir
	Tamarack	Spruce—fir	—
	White ash	Spruce—fir	Spruce—fir
	Red oak	Spruce—fir	—
Oak—white pine	Black spruce	Spruce—fir	**
	Cedar	—	**
	Tamarack	Spruce—fir	**
	White ash	Spruce—fir	Spruce—fir
Sugar maple—ash	Black spruce	Spruce—fir	**
	Cedar	Oak—white pine	**
	White pine	Hemlock—red spuce	Spruce—fir
	Tamarack	Spruce—fir	**
	Red oak	Spruce—fir	—

— No change in habitat
**Indicates zero ingrowth

habitats where they are not naturally expected to grow (Table 6). For example, black spruce is not allowed to ingrow on a beech—red maple site while balsam fir ingrowth on the same site is reduced. The ingrowth reduction in FIBER allows the species to comprise no more than 5 percent of the stand basal area. Once this level is reached, ingrowth for these species is temporarily "turned off" until the species basal area is less than 1 percent of the stand composition in basal area. A special rule applies to red maple ingrowth on sugar maple—ash habitats. If the basal area of red maple exceeds that of sugar maple, red maple ingrowth is set to zero. Also, ingrowth is constrained for certain species (Table 7) if the stand basal area is less than 80 ft². The ingrowth of these species increases as stand basal area decreases. Extrapolation of some ingrowth equations in FIBER may generate negative values, which are considered as zero ingrowth.

Table 5.—Ingrowth, by species and habitat

	Species																
Habitat	BF	RS	BS	WS	HE	CE	WP	TA	SM	RM	YB	PB	BE	WA	AS	RO	OH
BE-RM	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
CE-BS	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0
HE-RS	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
WP-RO	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0
SM-WA	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
SP-BF	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	1	0

1 - Computed at 1,500 feet elevation.
0 - Computed at user-specified elevations.

Table 6.—Ingrowth constraints, by habitat and species

	Species																
Habitat	BF	RS	BS	WS	HE	CE	WP	TA	SM	RM	YB	PB	BE	WA	AS	RO	OH
BE-RM	R	U	P	U	R	P	U	P	U	U	U	U	U	U	U	R	R
CE-BS	U	U	U	U	U	U	U	R	R	U	U	U	P	U	U	P	R
HE-RS	U	U	P	U	U	U	U	R	R	U	U	U	U	U	U	U	R
WP-RO	R	R	P	U	U	P	U	P	R	U	R	U	U	U	U	U	R
SM-WA	R	U	P	U	R	P	U	P	U	U	U	U	U	U	U	R	R
SP-BF	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	R

U = unrestrained
R = restrained
P = prohibited

Table 7.—Species/habitat combinations where ingrowth is increased when the stand basal area is less than 80 ft². A one (1) indicates a species with increased ingrowth, and a zero (0) indicates species that do not receive the ingrowth correction.

	Species																
Habitat	BF	RS	BS	WS	HE	CE	WP	TA	SM	RM	YB	PB	BE	WA	AS	RO	OH
BE-RM	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CE-BS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HE-RS	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
WP-RO	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	1	0
SM-WA	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0
SP-BF	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0

Model Reliability

Validation of FIBER 3.0 was accomplished by numerous comparisons with available data sets, long-term simulations to examine the reliability of predictive characteristics of the model, and general evaluation of species' responses in view of their silvical requirements (Table 8).

A sample was stratified into habitat and residual basal area classes for a formal comparison of FIBER's reliability in predicting cubic volumes over a 15-year period. The maximum deviation is about 20 percent, and most were much smaller. Deviation for individual species was, of course, considerably larger. The largest deviations occurred where the number of plots were small. In addition, deviations tend to be largest in softwood or mixedwood stands in the hemlock—red spruce and oak—white pine habitat types. In these types, small deviations in the proportions of hardwoods or softwoods can have large impacts on basal area and volume. There may be some tendency for FIBER to underestimate volume production in the highest basal-area classes found only in softwood stands due to less plots available in the data set for model construction. Also, when making comparison to predicted values, only a few plots were available in these high-density classes.

Table 8.—Predicted and actual cubic-foot volumes (and percent differences) over a 15-year period, by habitat type and residual basal area class

Residual BA (ft^2)	Type	BE-RM	CE-BS	HE-RS	RO-WP	SM-WA	SP-BF
20	Actual	1197 (20)[a]	787 (5)	1000 (5)	517 (9)	1135 (19)	1175 (66)
	Predicted	1137	842	1111	598	1210	1267
	Dev. %	-5.1	7.1	11.1	15.8	6.7	7.8
60	Actual	1925 (34)	1534 (21)	1795 (13)	1288 (7)	1994 (51)	2269 (177)
	Predicted	1876	1615	1795	1171	1962	2075
	Dev. %	-2.5	5.3	0.0	-9.0	-1.6	-8.6
100	Actual	2509 (17)	2391 (34)	3098 (4)	2232 (7)	2558 (40)	3055 (126)
	Predicted	2600	2386	2470	2197	2803	2977
	Dev. %	3.6	-0.2	-20.3	-1.6	9.6	-2.6
140	Actual		2997 (21)	3734 (1)	3790 (7)	3549 (7)	3728 (40)
	Predicted		3074	3465	4048	3257	3846
	Dev. %		2.6	-7.2	6.8	-8.2	3.2
180	Actual		3828 (10)	4966 (1)	4372 (14)		3775 (8)
	Predicted		3823	4140	4762		4440
	Dev. %		-0.1	-16.6	8.9		17.6
220	Actual		5018 (4)		5028 (20)		6308 (1)
	Predicted		4649		4865		5798
	Dev. %		-7.3		-3.2		-8.1
260	Actual		5547 (1)		5306		
	Predicted		4270		4593		
	Dev. %		-23.0		-13.4		

[a]Number of plots in parentheses.

```
                    FIBER Main Menu
                    - - - - - - - - -

1. Output menu.
2. Control file menu.
3. Stand variables menu.
4. Project growth.
   Caution: Save variables before projection.
   After this, stand variables will include stand growth.
5. Exit program.
6. Delete a file.

Enter choice:  1
```

```
                    ESC - Exit.
```

Figure 5.—FIBER Main Menu.

```
                    Output Menu

1. Output to printer.
2. Output to file.
3. Lines per page.
4. Maximum line width.
5. Output stand table.
6. Return to main menu.
Enter choice: 2

Enter filename, please. The default extension is .PRN.
*.PRN

ESC - Exit: F1 - Change choice: Enter - Select:
Template - Matching files.
```

Figure 6.—Output Menu.

Model Application

To install the program, the user should copy files from the distribution disk into a FIBER directory on a hard drive. Files can be copied by means of an install batch file (*a*:install *a c*) where *a* is the diskette drive and *c* is the destination disk. The "readme.txt" file contains important information about FIBER 3.0. The program also can be run in batch mode by using the command "fiber3< sample.in" where "sample.in" (example on distribution diskette) is the input to the FIBER 3.0 program.

The model accepts inventory and stand data for one or several combined stands, provides a wide range of silvicultural options, and projects growth (including ingrowth) over specified time periods. These operations are implemented through a main menu that directs the user through a series of actions. Six options outlined in the FIBER Main Menu (Fig. 5) include: 1) output menu, 2) control file menu, 3) stand variables menu, 4) project growth, 5) exit program, and 6) delete a file. Several keys, including function keys, have been mapped to aid the user in navigating through the program (Table 12—Appendix).

Output Menu

The output from the program is managed through the Output Menu (Fig. 6). Output generated for each projection includes the following reports:

1. Initial conditions before the projection.
2. Initial stand table.
3. Interval stand table(s) every 5 years, if requested.
4. If thinned, post thinning stand table(s).
5. Final stand table.
6. Summary of yields in terms of product size and quality.

The options available to the user are: 1) output to printer, 2) output to file, 3) lines per page, 4) maximum line width, 5) output stand table, and 6) return to main menu.

Output to printer. Choosing "output to printer" displays a dialog box asking for either the COM port or the printer name. Normally 'PRN' selects the printer attached to the system.

```
                    Output Stand Table
Enter filename to contain trees/acre/dcl/species.
Default extension is .TPA
SAMPLENEW.TPA

                              Format of TPA file

Start of column with species values: 1    Field length:  2

Start of column with dbh values:     4    Field length:  2

Start of column with tpa values:     7    Field length:  8

Start of column with gs values:      16   Field length:  1

Title for the file:
Smith property:  Hardwood stand
```

Figure 7.—Output Stand Table.

```
Smith property:  Hardwood stand.

RS  5     20.00 2           PB  7      6.00 1
RS  7     20.00 2           PB  8      6.00 1
RS  8      3.00 1           PB  9      3.00 1
RS 13      3.00 1           PB 10      6.00 1
HE  5      6.00 1           PB 11     15.00 1
HE  6      6.00 1           PB 12      3.00 1
HE  8      3.00 1           PB 13      6.00 1
RM  5      3.00 1           BE  5     18.00 1
RM  6      3.00 1           BE  6     21.00 1
RM  7      6.00 1           BE  7     15.00 1
RM 10      3.00 1           BE  8     12.00 1
RM 13      3.00 1           BE  9      6.00 1
YB  5      6.00 1           BE 11      3.00 1
YB  7      3.00 1           BE 16      3.00 1
YB  8      3.00 1
YB  9      6.00 1
YB 10      9.00 1
```

Figure 8.—Stand Data File.

Output to file. A selection of "output to file" shows a dialog box requesting an output file name instead of the printer, since output cannot go to both. If the file name includes wildcards (asterisk (*) or question marks (?)), another dialog box displays a list of matching files that can be selected by using the arrow keys to scroll and pressing enter to select a file as in Table 12 (Appendix). Pressing the F1 key returns to the first dialog box. If the file already exists, the user is prompted for permission to overwrite the file and direct the output to the existing file. The file later can be printed using the DOS print command.

Lines per page. Selecting "lines per page" brings up a screen asking for the lines per page on the printout. This number must be greater than 20 with maximum value of 999 and a default value of 53. Using the maximum value will eliminate most of the page breaks which conserves paper but makes the printout more difficult to read.

Maximum line width. Selecting "maximum line width" allows the user either 80 or 132 columns of output.

Output stand table. A screen entitled "output stand table" allows the user to save the stand at the beginning or the end of a projection for use in other programs (Fig. 7). This screen requests the name for the file, the columns of the species, the diameter, trees per acre, the growing stock classification, and the title line in the file. This stand data file consists of a header record showing title of the file followed by data records consisting of a two-character species code, a two-digit diameter at breast height, number of trees per acre, and the growing stock classification (Fig. 8).

Control File Menu

This menu manages the control files. Through five choices in the menu (Fig. 9), the user can: 1) use an existing control file, 2) copy existing variables to a control file, 3) input stand table, 4) create a new control file, or 5) return to the Main Menu.

Use an existing control file. This brings up a dialog box requesting the name of the file to use (Fig. 9). Using wildcards in the name for the file and pressing enter brings up a list of possible existing files. The file

```
                    Control File Menu

1. Use an existing control file.
2. Copy existing variables to a control file.
3. Input stand table.
4. Create a new control file.
5. Return to the main menu.

Enter choice:  1

Enter filename, please.  The default extension is .CTL
SAMPLE.CTL
```

```
ESC - Exit:  F1 - Change choice:  Enter - Select:
Template - Matching files.
```

Figure 9.—Control File Menu.

```
                    Input Stand Table

Enter filename containing trees/acre/dcl/species.
Default extension is .TPA
SAMPLE.TPA

                                     Format of TPA file
Start of column with species values: 1     Field length: 2

Start of column with dbh values:     4     Field length: 2

Start of column with tpa values:     7     Field length: 8

Start of column with gs values:      16    Field length: 1

What strata is to be used? FIRST
      number or "FIRST" or "ALL"
Title shown in the file:
Smith property: Hardwood stand
```

Figure 10.—Input Stand Table.

is an ASCII file with a FORTRAN record format. The first line of the file must be "& Example" and the format is the variable name followed by an equal sign, then the value(s) of the variable.

Copy existing variables to a control file. This display requests a file name to be used. The system allows replacement, but does query the user if the file already exists.

Input stand table. Information on how to read a tree list appears on the screen and requests the name of the file, the columns of the species, the diameter, trees per acre and the growing stock classification (Fig. 10). If the growing stock classification is not '2', the tree is placed in the acceptable growing stock classification. This data file consists of a header record showing title of the file followed by data records consisting of a two-character species code, a two-digit diameter at breast height, number of trees per acre, and the growing stock classification (Fig. 8). The user is allowed to use input from other programs or start several projections from the same stand. The program maintains the projected stand as the current stand, so it is possible to continue with the projected stand, revert to the initial stand conditions, or select a different stand.

Create a new control file. The Stand Variables Menu is displayed and includes the stand table, the stand projection, and the initial silvicultural variables. A complete control file can be built to control the program during execution by completing the first five menu options of the Stand Variables Menu and using option 7 to save the file (Fig. 11). Option 7 prompts for a file name. If the selected file already exists, a query is made for permission to overwrite.

Stand Variables Menu

From the menu, enter, edit, or view stand variables. The menu has nine options (Fig. 11) that allow the user to: 1) select species to grow, 2) stand table, 3) stand projection, 4) silvicultural control variables, 5) species removal priority, 6) view current

```
                    Stand Variables Menu

        1. Species selected to grow.
        2. Stand table.
        3. Stand proJection.
        4. Silvicultural control variables.
        5. Species removal priority.
        6. View current stand.
        7. Save current values.
        8. Clear all variables.
        9. Return to main menu.

      Enter choice:  1


    ESC - Exit:  F1 - Main menu.
```

Figure 11.—Stand Variables Menu.

Table 9.—Percent of ingrowth at the 5-inch diameter class placed in unacceptable growing stock (UGS), by species

Species	UGS
	Percent
Balsam fir	4
Red spruce	7
Black spruce	14
White spruce	25
Hemlock	14
Northern white-cedar	10
Sugar maple	13
Red maple	18
Yellow birch	21
Paper birch	9
American beech	26
White ash	5
Aspen	14
Northern red oak	7
Tamarack	14
White pine	15
Other hardwoods	25

stand, 7) save current values, 8) clear all variables, or 9) return to main menu.

Species selected to grow. Species either present in the stand or able to ingrow are specified by Y. Species not present or unable to ingrow are specified by N. The percent of the ingrowth to be assigned to the unacceptable growing stock can be prescribed by the user, otherwise default values are used (Frieswyk and Malley 1985) (Table 9) (Fig. 12). As a guide, the percentage of UGS in the current stand is displayed as a percentage of basal area. A column titled "Percent Basal Area" updates the percentage of basal area calculated for each species from the initial stand table and subsequent silvicultural operations and growth projections.

Stand table. To edit or view trees per acre for each species chosen on the 'Species Selected to Grow' screen, the stand table screen allows the user to enter or view trees per acre in the appropriate d.b.h. class (Fig. 13). Using the tab key, select basal area or cubic foot as the measure of stand density. To display the species selected to grow, the (F2) tab or shift tab keys will scroll to the next species. Entries are separate for UGS and AGS. Basal areas or cubic-foot volumes (Total, AGS, UGS) are calculated at the bottom of the screen.

Stand projection. This screen asks for stand information needed as input for growth projection (Fig. 14). In addition to a title for each page of the output, the user can specify the habitat: sugar maple—ash, beech—red maple, hemlock—red spruce, spruce—fir, cedar—black spruce, and oak—white pine. These primary forest communities in New England reflect differences in climate and soils, and they define general successional trends — toward hardwoods or softwoods for example. If the user is unsure of the habitat, UNKNOWN may be entered and the program calculates an estimated habitat (discussed earlier) except for softwood stands dominated by white pine where the user must select a habitat. Based on stand composition of the initial stand a warning is issued if the calculated habitat is different from the user-specified

Species in stand composition		Species Selected to Grow Percent UGS Ingrowth	Current	Percent Basal area
Balsam Fir	N			
Red Spruce	Y	0	68	15
Black Spruce	N			
White Spruce	N			
HEmlock	Y	0	0	4
CEdar	N			
White Pine	N			
Tamarack	N			
Sugar Maple	N			
Red Maple	Y	0	0	9
Yellow Birch	Y	0	0	12
Paper Birch	Y	0	0	32
BEech	Y	0	0	29
White Ash	N			
ASpen	N			
Red Oak	N			
Other Hardwood	N			

ESC - Exit: F1 - Stand variables menu.

Figure 12.—Species Selected to Grow.

Stand Table
Stand density measured in: Basal area
Species RS Red Spruce

DIA	Trees per acre AGS	UGS	DIA	Trees per acre AGS	UGS
5	.00	20.00	19	.00	.00
6	.00	.00	20	.00	.00
7	.00	20.00	21	.00	.00
8	3.00	.00	22	.00	.00
9	.00	.00	23	.00	.00
10	.00	.00	24	.00	.00
11	.00	.00	25	.00	.00
12	.00	.00	26	.00	.00
13	3.00	.00	27	.00	.00
14	.00	.00	28	.00	.00
15	.00	.00	29	.00	.00
16	.00	.00	30	.00	.00
17	.00	.00	31	.00	.00
18	.00	.00	32	.00	.00

ESC - Exit: F1 - Stand variables menu: Tab - Species.

Stand density: Total= 81.8 AGS= 73.8 UGS= 8.1 sq.ft.

Figure 13.—Stand Table.

habitat. The screen also asks for elevation, age distribution (even-aged, uneven-aged), stand age or years since last major disturbance, site index (Table 1), diameter display for the print file (whether d.b.h. classes are grouped or presented singly), length of growth projection (years), interval between printed/displayed intermediate reports of stand conditions, harvest diameter (the quadratic mean stand diameter at which growth projection ends and final yields are summarized), and the silvicultural treatment. Table 1 shows the maximum elevation values, by habitat and base site index with a maximum range from 20 to 90. The minimal length of projection is 5 years and the maximum quadratic mean stand diameter is 20 inches. Because the program keeps the projected stand as the current stand, the stand table can be captured at more frequent reporting intervals by setting the projection length to the report interval (Fig. 14). Then project the stand, output the stand table, and repeat the process until the desired maximum projection length is achieved.

The treatment options are defined in both the stand projection section and the silvicultural control variables section as follows with some of the specifications, such as removal priority and starting diameter class, described under subsequent screens:

1. Thinning from above: or 2. Thinning from below: the specified residual basal area or cubic-foot volume is attained by beginning with a chosen starting d.b.h. class and working toward an ending d.b.h. class until the specified residual stand density is obtained or the ending d.b.h. class is reached. The removal operation proceeds between the given d.b.h. classes by removing UGS from high- to low-priority species, then AGS from high- to low-priority species. Then the removal operation moves to the next d.b.h. class. For several species with the same removal priority, the cut is allocated among these species in proportion to their basal area. An entire d.b.h. class is removed before moving to the next class, with the exception of zero priority species (which are never cut).

3. Uniform thinning: the required cut to attain a specified residual stand is allotted

```
                        Stand Projection
    Title for print out:
    Smith property:  Hardwood stand
    Habitat type: BEECH-RED MAPLE

    Elevation: 1000

    Age distribution: Even-age

    Stand age or years since last major harvest: 55

    Site index for the stand: 60

    Diameter display for print file: GROUP

    Projection length: 50

    Report interval: 20

    Harvest diameter: 20

    Silvicultural treatment: Below

                 ESC - Exit:  F1 - Continue.
```

Figure 14.—Stand Projection.

```
                Silvicultural Control Variables

  Silvicultural treatment: Below

  Thin on: Time interval

  Time interval: 10

  Mode of thinning: Interactive

  Starting Diameter: 6      Ending Diameter: 9

  Thin stand by Basal area

  Present stand = 82 sq.ft.     Thin stand to = 70 sq.ft.

  Present AGS   = 74 sq.ft.

  Present UGS   =  8 sq.ft.

          ESC - Exit:  F1 - Stand variables menu.
```

Figure 15.—Silvicultural Control Variables.

uniformly among diameter classes within a given species. The residual level can be across all d.b.h. classes or regulated by the B-line in the stocking charts (Figs. 1-3). If a d.b.h. class lacks sufficient basal area or volume, the remaining amount to be removed is distributed evenly among the other d.b.h. classes. The specified cut is obtained by removing high- to low-priority UGS, and then high- to low-priority AGS.

4. Q-line harvest: utilizing a user-specified residual basal area per acre, maximum tree d.b.h., and a *q* (de Liocourt 1898, Leak 1963) calculated from an uneven-aged stand, the program calculates a theoretical residual number of trees per d.b.h. class. If the specified basal area is not reached, the program uniformly removes excess trees above the q-line per d.b.h. class in order of species removal priority, first UGS and then AGS, until the specified residual basal area is reached. All trees above the user-specified maximum d.b.h. are included in the removal in reaching the specified basal area.

5. Diameter-class removal: used interactively, this option allows the user to specify numbers of trees (AGS or UGS) remaining by species and d.b.h. class (Fig. 13). These values may be changed; however, the number of trees may not be greater than the number present before a cut.

6. No thinning: this option allows growth projection of an uncut stand.

Silvicultural control variables. This screen (Fig. 15) contains specifications for the silvicultural treatments, beginning with one of the six silvicultural options described above in the stand projection section. The user then specifies and chooses whether to treat at a certain time interval or when the stand reaches a certain stocking level, either cubic feet or basal area per acre. Next, the user specifies the mode of treatment as interactive or batch. The starting and ending d.b.h. classes are chosen if thinning from above or below or the maximum d.b.h. if using q-line harvest. The screen provides the current cubic feet or basal area in the stand, and the user specifies the residual thinning level, except for even-aged stands where the basal-area level can be controlled by the b-line in the stocking charts.

Species Removal Priority

Species in stand composition		Percent UGS Ingrowth	Percent UGS Current	Percent basal area	Removal priority 1-low 9-high
Balsam Fir	N				
Red Spruce	Y	0	68	15	7
Black Spruce	N				
White Spruce	N				
HEmlock	Y	0	0	4	6
CEdar	N				
White Pine	N				
Tamarack	N				
Sugar Maple	N				
Red Maple	Y	0	0	9	9
Yellow Birch	Y	0	0	12	1
Paper Birch	Y	0	0	32	2
BEech	Y	0	0	29	6
White Ash	N				
ASpen	N				
Red Oak	N				
Other Hardwood	N				

ESC - Exit: F1 - Stand variables menu.

Figure 16.—Species Removal Priority.

```
Thinning control

     1. Continue to grow stand.
     2. Return to pre-thin stand.
     3. No more thinning but continue growing.
     4. Change cutting priorities and percents.
     5. Return to main menu.

Enter choice:  1
```

ESC - Exit: Enter - Continue.

Figure 17.—Thinning Control.

Species removal priority. At this point, the program moves to selection 5 in the Stand Variables Menu (Fig. 11) listing all the species, and allows the user to specify the removal priority for each species ranging from 9 (high removal priority) to 1 (low removal priority) (Fig. 16); a zero priority means no cutting of either AGS or UGS of that species. This screen also can be accessed after viewing the post-thinning stand and before continuing stand growth allowing the user to change harvesting priority. After modifying the control information, changes may be saved following the "Save Current Values" option.

View current stand. This option shows the current stand to the user in a compact form. The stand can then be reassessed for omissions or errors in the stand. Corrections are made by using one of the above options.

Save current values. To save current variables, request the name of the file. After modifying the control information, you should save the information and re-read the file. Re-reading the file causes the program to close the buffer properly. Note: saving the control file or the tree stand information at the end of a projection, results in the projected stand information being saved, not the original stand information. The program prompts for permission to overwrite if the file already exists.

Clear all variables. All values are set to zero or set to the default values as is appropriate and the user may start over from the beginning.

Project Growth

Project growth using present stand variables. This is the fourth option in the FIBER Main Menu (Fig. 5). Using the stand variables and treatment specifications outlined above, the program initiates the growth projection process. The interactive mode allows the user to view the stand conditions before each treatment and to continue the treatments or change the treatment specifications (Fig. 15). After the treatment, the new stand is displayed. Then the user has the choice of thinning control: 1) continue to grow stand, 2) return to pre-thin stand, 3) no more thinning but continue growing, 4) change cutting priorities and percents, or 5) return to main menu (Fig. 17). At the specified harvest diameter or the end of the specified projection period, whichever comes first, the program provides the option to view the yields, including the treatment, and the final standing yields measured in cubic feet, board feet, or basal area. The default cubic foot and board foot volumes (9-and 11-inch diameter class for softwood and hardwood, respectively) by species, are found in separate Tables 13 and 14 (Appendix). These values are found in "bdfoot.tab" and "volume.tab", respectively and are representative volumes from the compartment management studies on both the Bartlett and Penobscot Experimental Forests. However, the user may desire to use local volumes to make the program predict better. To make these changes, modify the appropriate file using an ASCII text editor. These two files must be located in the same directory where the FIBER program executes, so spacing is important as the table is read with formatted read statements. Board foot volume values (>0) by species and diameter in Table 14 are considered as AGS sawtimber yields. Zero board foot volume values place cubic foot and basal area yields in pulpwood. UGS yields are considered as pulpwood with no sawtimber board foot volume.

Exit Program

This option terminates the FIBER program. Closes all files. Resets the screen if possible. Returns to the DOS prompt.

Delete a File

This allows the user to delete a file. The program does query if the file should really be deleted. If the user has opened a print file and the program still has use of the file, the user will not be able to delete it and the program will issue a message to that effect. Warning: this option does delete the file and you may or may not be able to recover it, except through an undelete command in DOS.

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APPENDIX

Table 10.—Regression coefficients for equations used to predict the a-, b-, m-values in the stand projection matrices

Variable[a]	Balsam fir			Red spruce			Black spruce			White spruce			Hemlock			N.white-cedar		
	a	b	m	a	b	m	a	b	m	a	b	m	a	b	m	a	b	m
Intercept	1.1e-1	7.3e-1	1.1e-1	4.8e-1	4.5e-1	4.2e-2	7.7e-1	3.3e-1	-7.1e-2	1.7e-1	6.7e-1	8.8e-2	2.3e-1	6.5e-1	8.3e-2	7.6e-1	2.1e-1	2.0e-2
D	2.9e-2	-9.7e-3	-1.3e-2	-4.0e-2	5.1e-2	-6.2e-3	3.2e-2	-6.3e-2	2.3e-2	-1.5e-2	2.3e-2	-5.9e-3	-3.2e-2	2.0e-2	1.2e-2	1.2e-2	-1.0e-2	-2.5e-4
D2	-2.3e-3	7.7e-4	1.0e-3	6.4e-4	-1.4e-3	4.4e-4	-3.0e-3	2.7e-3	-2.4e-4	1.8e-4	-1.4e-3	7.2e-4	7.4e-4	-8.9e-4	-2.0e-6	-6.8e-4	3.2e-4	1.7e-4
IBA	-6.4e-4	-1.6e-3	2.0e-3	-2.9e-4	-9.9e-4	6.4e-4	-3.4e-3	1.4e-3	1.4e-3	-4.7e-4	-1.8e-3	1.1e-3	-7.6e-4	1.0e-3	-5.3e-4	-4.2e-4	-6.0e-5	2.0e-4
RBA	6.7e-3	-3.6e-3	-2.3e-3	3.6e-3	-1.8e-3	-9.8e-4	2.3e-3	-2.0e-5	-1.5e-3	4.7e-3	-6.0e-4	-1.8e-3	7.3e-3	-4.6e-3	-1.3e-3	2.0e-3	-1.1e-3	-5.1e-4
RBA2	-2.0e-5	1.3e-5	9.0e-7	-6.0e-6	3.8e-6	1.4e-6	7.0e-6	-9.5e-6	1.1e-6	-1.0e-5	3.4e-6	2.4e-6	-2.0e-5	3.7e-6	7.4e-6	-3.7e-6	2.0e-6	9.4e-7
P	-2.9e-3	2.6e-3	1.0e-4	-1.8e-3	1.0e-3	4.9e-4	-4.1e-3	2.1e-3	1.1e-3	-1.0e-3	-1.1e-3	1.1e-3	-2.4e-3	2.1e-3	1.8e-4	-2.3e-3	6.2e-4	1.2e-3
E	-1.0e-5	3.5e-5	-2.0e-5	8.8e-5	-9.0e-5	-3.0e-6	-1.3e-4	1.7e-4	-2.0e-5	-1.0e-5	3.6e-5	-2.0e-5	3.5e-5	-1.5e-4	1.3e-5	-7.0e-5	6.8e-5	-5.0e-6
X1	6.1e-2	1.1e-1	-1.3e-1	4.4e-1	-3.6e-1	-4.8e-2	0.0e+0	0.0e+0	0.0e+0	1.3e-1	6.5e-3	-1.0e-1	-3.3e-1	4.4e-1	-7.5e-2	0.0e+0	0.0e+0	0.0e+0
D*X1	-9.5e-3	-3.2e-2	2.4e-2	-2.2e-2	-1.9e-3	1.2e-2	0.0e+0	0.0e+0	0.0e+0	-5.4e-2	2.7e-2	1.5e-2	9.0e-3	-1.1e-2	-2.9e-3	0.0e+0	0.0e+0	0.0e+0
E*X1	6.6e-5	-9.0e-5	2.5e-5	-6.0e-5	7.0e-5	-9.3e-7	0.0e+0	0.0e+0	0.0e+0	3.6e-4	-3.1e-4	-1.0e-5	1.3e-4	-9.0e-5	1.8e-5	0.0e+0	0.0e+0	0.0e+0
X2	-1.1e-1	1.6e-1	-1.8e-2	-1.4e-1	6.5e-2	4.4e-2	-1.0e-1	2.4e-3	4.2e-2	-1.2e-2	-7.0e-2	5.4e-2	-2.8e-1	-1.8e-2	2.7e-1	-6.4e-2	3.6e-2	1.6e-2
D*X2	6.6e-3	-2.4e-2	1.1e-2	2.8e-2	-3.1e-2	2.3e-3	3.3e-2	-7.0e-4	-1.6e-2	9.1e-3	-1.2e-2	9.9e-4	9.5e-3	1.1e-3	-1.2e-2	6.9e-3	-3.0e-3	-2.3e-3
E*X2	-2.0e-5	6.0e-5	-4.0e-5	-3.0e-5	9.9e-5	-4.0e-5	7.1e-5	-1.2e-4	3.3e-5	-4.0e-5	8.8e-5	-3.0e-5	1.6e-4	6.6e-5	-2.1e-4	-6.0e-5	5.9e-5	2.7e-6
X3	1.2e-1	1.6e-1	-2.4e-1	-3.6e-2	1.1e-1	-6.6e-2	0.0e+0	0.0e+0	0.0e+0	2.2e-1	-4.4e-1	1.1e-1	-8.1e-2	6.2e-2	-9.2e-3	1.8e-1	-9.4e-2	-6.6e-2
D*X3	-3.1e-2	-3.7e-2	6.6e-2	1.4e-3	-1.2e-2	1.1e-2	0.0e+0	0.0e+0	0.0e+0	-1.4e-2	2.7e-2	-5.2e-3	-4.0e-5	5.5e-3	-2.2e-3	-2.2e-2	8.2e-3	1.3e-2
E*X3	-3.0e-5	1.1e-4	-1.7e-4	1.5e-5	-6.0e-5	1.3e-5	0.0e+0	0.0e+0	0.0e+0	3.0e-4	-1.5e-4	-1.0e-4	-1.0e-5	9.5e-5	-3.0e-5	-1.8e-4	1.4e-4	-3.0e-5
X4	3.4e-1	-1.6e-1	-1.0e-1	2.6e-1	-1.5e-1	-5.9e-2	0.0e+0	0.0e+0	0.0e+0	1.2e-1	-9.3e-2	-4.3e-2	-1.5e-3	-8.4e-2	4.6e-2	2.5e-1	-1.2e-1	-6.4e-2
D*X4	-4.1e-2	3.9e-3	2.0e-2	-1.7e-2	-6.8e-3	1.2e-2	0.0e+0	0.0e+0	0.0e+0	2.1e-2	-2.5e-2	2.5e-3	2.6e-3	6.0e-3	-9.0e-3	-3.6e-2	1.6e-2	9.9e-3
E*X4	7.6e-5	-6.0e-5	-1.0e-6	7.4e-5	-7.0e-5	-4.0e-6	0.0e+0	0.0e+0	0.0e+0	-1.3e-4	2.9e-5	7.2e-5	6.1e-6	8.1e-5	-4.3e-7	-6.0e-5	5.5e-6	1.8e-5
X5	-1.4e-1	3.4e-1	-1.3e-1	9.2e-2	-2.8e-2	-3.5e-2	0.0e+0	0.0e+0	0.0e+0	-1.7e-1	-2.8e-1	1.5e-1	1.4e-1	-2.5e-1	3.8e-2	0.0e+0	0.0e+0	0.0e+0
D*X5	-1.3e-2	-1.9e-2	1.7e-2	-1.3e-2	-5.4e-3	8.6e-3	0.0e+0	0.0e+0	0.0e+0	1.4e-2	5.1e-3	-8.7e-3	-8.7e-3	1.1e-2	-2.7e-3	0.0e+0	0.0e+0	0.0e+0
E*X5	1.4e-4	-1.8e-4	4.0e-5	7.8e-5	-1.0e-4	1.5e-5	0.0e+0	0.0e+0	0.0e+0	4.7e-5	2.3e-5	-2.0e-5	-2.0e-5	9.6e-5	-2.0e-5	0.0e+0	0.0e+0	0.0e+0

Continued

Table 10.—Continued

Variable[a]	White pine a	White pine b	White pine m	Tamarack a	Tamarack b	Tamarack m	Sugar maple a	Sugar maple b	Sugar maple m	Red maple a	Red maple b	Red maple m	Yellow birch a	Yellow birch b	Yellow birch m	Paper birch a	Paper birch b	Paper birch m
Intercept	6.0e-1	1.8e-1	1.2e-1	1.1e+0	4.3e-2	-5.8e-2	5.3e-2	5.3e-1	1.6e-1	5.0e-1	3.1e-1	7.7e-2	1.9e-1	6.5e-1	6.4e-2	4.7e-1	4.3e-1	5.5e-2
D	-6.7e-2	7.6e-2	-6.6e-3	-1.4e-1	6.0e-2	4.3e-2	5.8e-3	-7.8e-3	1.1e-3	-3.1e-2	1.4e-2	1.9e-2	7.1e-3	-2.3e-2	9.3e-3	-5.6e-3	-1.3e-2	1.3e-2
D2	2.0e-3	-2.6e-3	3.6e-4	4.9e-3	-1.6e-3	-1.7e-3	1.3e-4	-4.3e-4	1.7e-4	6.4e-4	-8.7e-4	-3.9e-4	1.6e-5	1.2e-4	-1.1e-4	-6.0e-4	6.4e-4	-2.0e-4
IBA	-3.1e-4	-1.1e-3	8.9e-4	2.0e-3	-2.4e-3	1.2e-4	1.4e-3	-3.2e-3	1.2e-3	-2.8e-3	1.7e-3	3.0e-4	3.0e-4	-2.4e-3	1.1e-3	-2.8e-3	1.5e-3	4.0e-4
RBA	1.8e-3	9.4e-4	-1.5e-3	3.4e-3	-8.3e-4	-1.2e-3	3.4e-5	5.6e-3	-2.5e-3	7.4e-3	-1.4e-3	-2.9e-3	2.9e-3	2.6e-3	-2.5e-3	8.7e-3	-4.9e-3	-1.7e-3
RBA2	2.2e-6	-6.0e-6	1.6e-6	-2.0e-5	1.1e-5	4.5e-6	9.0e-6	-3.0e-5	7.1e-6	-1.0e-5	-1.0e-5	1.2e-5	-1.0e-6	-1.0e-5	6.3e-6	-2.0e-5	1.0e-5	4.6e-6
P	-2.6e-3	-6.2e-4	1.5e-3	-5.3e-3	5.3e-3	-3.0e-5	1.0e-3	1.3e-3	-9.8e-4	1.3e-3	-9.9e-4	-2.6e-4	-1.5e-3	2.0e-3	-3.7e-4	1.7e-4	1.1e-4	-2.1e-4
E	2.3e-5	-1.3e-4	6.4e-5	2.2e-4	-1.1e-4	-6.0e-5	-9.0e-5	1.1e-4	-1.0e-5	-1.4e-4	1.3e-4	-7.8e-6	-7.0e-6	-7.6e-6	7.6e-6	9.0e-6	6.5e-9	-9.0e-6
X1	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	5.1e-1	-4.8e-1	-1.5e-3	-1.6e-1	1.7e-1	-1.5e-2	3.0e-1	-3.1e-1	2.4e-2	1.4e-1	-1.1e-1	-3.6e-2
D*X1	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	-3.0e-2	2.3e-2	1.1e-3	-2.9e-3	1.1e-2	-3.8e-3	2.0e-3	-2.6e-3	-2.6e-4	2.6e-4	5.0e-3	-1.1e-3
E*X1	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	-5.0e-5	4.6e-6	2.8e-5	1.4e-4	-1.5e-4	1.7e-5	-1.5e-4	1.8e-4	-2.0e-5	-1.2e-4	1.1e-4	1.2e-5
X2	0.0e+0	0.0e+0	0.0e+0	-1.9e-1	3.2e-1	-6.7e-2	2.3e-3	-7.2e-2	2.7e-2	-2.7e-1	2.9e-1	-1.8e-2	-2.8e-1	1.1e-2	1.3e-1	-5.6e-1	2.6e-1	1.9e-1
D*X2	0.0e+0	0.0e+0	0.0e+0	4.6e-2	-4.2e-2	-1.7e-3	-1.1e-2	9.2e-3	5.4e-4	2.8e-2	-3.1e-2	3.6e-3	1.3e-2	-1.5e-3	-6.0e-3	2.4e-2	-9.7e-3	-8.3e-3
E*X2	0.0e+0	0.0e+0	0.0e+0	-2.8e-4	1.6e-4	6.2e-5	8.0e-6	8.6e-5	-3.0e-5	2.4e-5	-1.2e-4	3.0e-5	3.5e-5	-9.0e-7	-1.0e-5	1.8e-4	-1.0e-4	-6.0e-5
X3	2.0e-1	-2.3e-1	2.0e-2	0.0e+0	0.0e+0	0.0e+0	3.7e-1	-3.2e-1	-8.0e-3	-5.8e-2	9.6e-2	-4.8e-2	1.8e-1	-3.0e-1	7.6e-2	-4.5e-1	4.6e-1	-1.6e-2
D*X3	-1.3e-2	1.3e-2	-8.4e-4	0.0e+0	0.0e+0	0.0e+0	-3.0e-2	3.0e-2	-1.5e-3	-3.7e-3	-2.0e-3	8.4e-3	-1.8e-2	1.7e-2	-1.4e-3	2.4e-2	-2.5e-2	4.1e-3
E*X3	-5.0e-5	6.0e-5	-2.0e-5	0.0e+0	0.0e+0	0.0e+0	2.4e-5	-1.8e-4	8.1e-5	1.0e-4	-1.3e-4	2.0e-7	2.5e-5	-4.1e-6	-8.0e-6	1.4e-4	-1.6e-4	-4.0e-6
X4	2.7e-1	-2.4e-1	-2.7e-2	0.0e+0	0.0e+0	0.0e+0	-6.1e-1	7.7e-1	-6.1e-2	4.5e-1	-3.8e-1	-2.7e-2	1.1e-1	-3.0e-1	-8.5e-2	4.4e-1	-3.5e-1	-5.5e-2
D*X4	-2.3e-2	2.6e-2	-5.5e-4	0.0e+0	0.0e+0	0.0e+0	-5.6e-3	-2.4e-2	1.4e-2	-5.8e-2	4.6e-2	2.7e-3	-2.6e-2	1.8e-2	4.9e-3	-5.8e-2	4.7e-2	5.1e-3
E*X4	5.9e-5	4.1e-5	-6.0e-5	0.0e+0	0.0e+0	0.0e+0	5.5e-4	-5.6e-4	4.0e-7	1.4e-4	-1.5e-4	1.9e-5	2.6e-4	-9.0e-5	-8.0e-5	-5.0e-5	2.9e-6	3.6e-5
X5	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	2.4e-3	-6.6e-2	2.0e-2	-5.3e-1	2.4e-1	1.1e-1	5.7e-3	-1.5e-1	8.7e-2	-5.5e-1	5.0e-1	-1.3e-2
D*X5	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	-8.8e-3	1.3e-2	-2.6e-3	1.4e-2	7-.2e-3	-2.8e-3	5.1e-3	-4.4e-3	-8.4e-4	1.8e-2	-2.0e-2	3.1e-3
E*X5	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	0.0e+0	3.9e-5	-3.0e-5	-5.9e-7	1.6e-4	-5.0e-5	-4.0e-5	-6.0e-5	1.3e-4	-4.0e-5	8.2e-5	-8.0e-5	1.3e-5

Continued

Table 10.—Continued

Variable[a]	Beech			White ash			Aspen			Red oak			Other hardwoods		
	a	b	m	a	b	m	a	b	m	a	b	m	a	b	m
Intercept	1.9e-1	3.4e-1	2.4e-1	2.2e-1	5.0e-1	1.4e-1	5.9e-2	6.1e-1	1.8e-1	1.0e+0	1.7e-2	-3.0e-2	8.8e-1	1.0e-1	6.0e-2
D	1.5e-2	-1.6e-2	3.5e-3	-1.5e-4	-2.7e-2	6.7e-3	-8.5e-3	1.7e-2	-7.7e-3	-1.8e-3	-1.4e-2	1.4e-2	-7.2e-2	3.8e-2	9.3e-3
D2	-4.3e-4	-4.0e-5	1.2e-4	4.8e-5	1.2e-3	-3.2e-4	-5.0e-4	-1.4e-4	4.1e-4	-4.2e-3	2.8e-3	3.6e-4	2.9e-3	-1.7e-3	-4.2e-4
IBA	-1.1e-3	-1.5e-4	4.9e-4	7.7e-4	7.4e-4	-3.5e-4	2.8e-4	-2.2e-3	1.1e-3	-1.0e-2	6.0e-3	1.9e-3	-4.1e-3	1.4e-3	1.7e-3
RBA	4.0e-3	1.6e-3	-2.2e-3	-6.1e-3	5.6e-3	-6.0e-5	3.6e-3	-1.1e-3	-1.2e-3	1.1e-2	-5.6e-3	-2.5e-3	5.4e-3	-1.9e-3	-2.1e-3
RBA2	9.5e-7	-2.0e-5	7.4e-6	-.8e-5	-4.0e-5	1.6e-6	-6.0e-6	6.2e-6	-6.7e-7	-1.0e-6	-1.8e-6	1.7e-6	-7.9e-7	-9.5e-7	7.0e-7
P	-7.1e-4	2.4e-3	-1.1e-3	5.5e-4	-6.0e-5	-1.9e-4	8.0e-4	1.4e-3	-1.0e-3	1.4e-3	-2.6e-4	-5.9e-4	2.2e-3	-1.6e-3	-1.4e-4
E	-1.1e-4	1.6e-4	-4.0e-5	1.4e-4	-1.6e-4	1.4e-5	8.6e-5	-9.0e-5	5.1e-8	-1.9e-4	8.0e-5	7.6e-5	-1.0e-4	4.3e-5	2.7e-5
X1	-8.8e-2	2.2e-1	-7.2e-2	1.1e+0	-1.0e+0	-3.0e-2	-1.8e-1	3.5e-1	-1.1e-1	0.0e+0	0.0e+0	0.0e+0	6.6e-1	-7.3e-1	1.5e-2
D*X1	2.2e-3	-2.4e-3	-1.6e-4	-4.8e-2	6.9e-2	-1.2e-2	6.4e-3	-1.8e-2	6.9e-3	0.0e+0	0.0e+0	0.0e+0	-8.2e-2	1.0e-1	-1.4e-2
E*X1	1.2e-4	-1.9e-4	5.1e-5	-5.3e-4	4.1e-4	5.5e-5	6.3e-5	-1.2e-4	3.7e-5	0.0e+0	0.0e+0	0.0e+0	-1.1e-4	1.1e-4	2.4e-5
X2	1.2e-1	1.8e-1	-2.2e-1	0.0e+0	0.0e+0	0.0e+0	-4.7e-1	4.2e-1	1.6e-2	0.0e+0	0.0e+0	0.0e+0	2.4e-1	-1.7e-1	-7.0e-2
D*X2	-1.8e-2	-4.8e-3	1.9e-2	0.0e+0	0.0e+0	0.0e+0	3.3e-2	-2.8e-2	-6.8e-4	0.0e+0	0.0e+0	0.0e+0	-1.7e-2	1.0e-2	6.6e-3
E*X2	-3.5e-4	3.1e-4	3.4e-5	0.0e+0	0.0e+0	0.0e+0	-2.0e-5	-9.0e-5	3.7e-5	0.0e+0	0.0e+0	0.0e+0	8.0e-5	-3.0e-5	-2.0e-5
X3	1.0e-1	1.5e-1	-1.4e-1	0.0e+0	0.0e+0	0.0e+0	1.4e-1	3.1e-1	-2.5e-1	0.0e+0	0.0e+0	0.0e+0	2.1e-1	-1.4e-1	-4.0e-2
D*X3	-1.2e-2	-7.0e-3	1.2e-2	0.0e+0	0.0e+0	0.0e+0	-7.6e-3	-1.6e-2	1.4e-2	0.0e+0	0.0e+0	0.0e+0	-3.2e-2	2.2e-2	1.9e-3
E*X3	-5.0e-5	-5.0e-5	4.2e-5	0.0e+0	0.0e+0	0.0e+0	-1.7e-4	-1.9e-4	1.9e-4	0.0e+0	0.0e+0	0.0e+0	-1.0e-4	-5.0e-5	1.5e-4
X4	2.4e-1	2.5e-3	-1.3e-1	0.0e+0	0.0e+0	0.0e+0	-3.6e-1	-4.0e-2	2.5e-1	-4.5e-1	3.1e-1	8.4e-2	-1.2e-1	5.3e-2	-3.1e-3
D*X4	-1.8e-2	-1.0e-2	1.3e-2	0.0e+0	0.0e+0	0.0e+0	4.0e-2	-1.0e-2	-2.2e-2	3.9e-2	-2.5e-2	-7.6e-3	-9.3e-3	1.1e-2	2.4e-3
E*X4	-1.2e-4	6.7e-5	4.6e-5	0.0e+0	0.0e+0	0.0e+0	-7.0e-5	-1.0e-5	8.7e-5	2.2e-4	-1.1e-4	-8.0e-5	-3.0e-5	3.1e-5	-5.0e-6
X5	-1.6e-1	2.3e-1	-4.2e-2	9.6e-2	5.7e-2	-5.0e-2	1.3e-1	3.1e-1	-1.9e-1	0.0e+0	0.0e+0	0.0e+0	7.2e-2	-2.5e-1	1.3e-1
D*X5	1.4e-2	-1.2e-2	-1.2e-3	7.5e-3	-2.5e-2	6.2e-3	-9.6e-3	-5.7e-3	6.2e-3	0.0e+0	0.0e+0	0.0e+0	-4.4e-2	4.3e-2	-5.3e-3
E*X5	-5.7e-5	-9.0e-5	3.4e-5	-1.8e-4	2.3e-4	-4.0e-5	-8.0e-6	-2.4e-4	1.1e-4	0.0e+0	0.0e+0	0.0e+0	1.3e-4	-3.0e-5	-4.0e-5

[a] D = DBH class
IBA = Initial basal area
RBA = Residual area
P = Percentage of hardwoods in stand
E = Elevation
X = Habitat variable

Table 11.—Regression coefficients by species for ingrowth equations

Species	Intercept	Initial basal area	Residual basal area	Percent hardwood	Percent species	Elevation	Dummy variables X1	X2	X3	X4	X5
Balsam fir	14.41361	-0.01446	-0.00384	-0.07171	0.18592	-0.00219	-2.45262	-4.84186	-4.59332	-7.28939	-2.24857
Red spruce	4.17812	-0.02684	-0.00612	-0.03630	0.18263	0.00135	0.06033	-1.26455	0.00000	-1.68838	-0.52045
Black spruce	-6.26970	-0.01271	0.01536	0.02948	0.12989	0.00540	0.00000	1.81220	0.00000	0.00000	0.00000
White spruce	1.60990	-0.01486	0.00880	0.00126	0.05577	0.00033	-0.20076	0.24765	-0.70626	-0.56487	-0.95112
Hemlock	3.51426	0.03037	-0.04477	0.01821	0.04123	-0.00268	4.72794	0.44250	2.12127	1.94227	1.50252
N. white-cedar	4.20116	-0.00203	0.00004	0.00287	0.03995	-0.00343	0.22589	1.55208	-1.26515	-1.31481	-1.25085
White pine	0.51234	-0.00401	-0.00127	-0.00121	0.00046	0.00051	0.00000	0.00000	0.00000	0.42679	0.00000
Tamarack	0.94736	-0.00235	-0.00866	-0.01750	-0.03176	0.00100	0.00000	1.19223	0.00000	-0.21932	0.00000
Sugar maple	1.93435	-0.02685	-0.00535	-0.03452	0.06189	0.00240	1.26819	0.68080	0.88940	2.82390	2.99840
Red maple	4.44520	0.02608	-0.03911	-0.01751	0.04875	-0.00076	1.56869	-1.16001	-0.36763	-1.43372	-0.14122
Yellow birch	0.66068	-0.01417	0.00491	0.00342	0.01411	0.00077	0.46315	0.62789	0.01057	1.32708	-0.46179
Paper birch	1.72647	-0.00234	-0.00855	-0.00275	0.03360	0.00036	0.18667	-0.06902	0.06570	-0.37391	-0.64809
Beech	-0.20872	0.05039	-0.05166	0.03293	0.02523	-0.00048	4.11998	0.00000	0.80954	-1.19065	0.16330
White ash	2.28246	-0.00464	-0.00897	-0.01464	0.00376	0.00030	0.00000	0.00000	0.00000	0.00000	0.19110
Aspen	1.05690	-0.05165	0.01328	-0.04103	0.16423	0.00275	0.00000	0.00000	0.00000	0.00000	0.00000
N. red oak	-1.33261	-0.01438	0.00547	0.00644	0.05151	0.00249	0.00000	0.00000	0.00000	-0.56229	0.00000
Other hardwoods	1.26268	-0.00823	0.00136	-0.00060	0.04726	0.00077	1.04046	0.47645	0.48756	-0.51703	0.38146

Table 12.—Definition of keys used in FIBER 3.0

Screen	Key	Function
All	ESC	Terminates the program, but closes files.
	F1	Exits present screen or dialog and continues program.
	Tab	Display choices from a list of values.
	Shift Tab	Display choices in the opposite order from Tab.
Menu	Up arrow	Changes the menu number higher.
	Down arrow	Changes the menu number lower.
	Enter	Selects that menu choice.
File listing	Up Arrow	Highlight the file above the present file.
	Down Arrow	Highlight the file below the present file.
	Page Down	Show next screen of files, if possible.
	Page Up	Show previous screen of files, if possible.
	Enter	Selects the highlighted value for the filename.
	F1	Exits the listing to previous dialog box.
Yes/No response	Y, y, N, n	Valid responses.
	Enter	Selects a valid response.
Dialog boxes	Enter	Change lines.
	F1	Exits the dialog box.
	!	Exits the dialog box.
Tree input	Up arrow	Moves up the screen, if possible.
	Page up	Moves up the screen, if possible.
	Enter	Accepts the value and moves to next field.
	Tab	Will change to next species.
	F2	Will change to next species.
	Left arrow	Moves left one field.
	Right arrow	Moves right one field.
	Down arrow	Move down a row.
	Page down	Move down a page.
	Space	Removes a number.
	!	Exits tree input screen.

Table 13.—Tenths of cubic-foot volume table ("volume.tab")

	Species																
DCL	BF	SP	BS	WS	HE	CE	WP	TA	SM	RM	YB	PB	BE	WA	AS	RO	OH
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	20	16	16	16	14	14	26	21	15	15	16	16	15	15	16	15	15
6	34	29	29	29	24	26	32	31	29	30	30	36	32	25	36	29	27
7	52	47	47	47	36	42	45	47	49	50	48	59	51	46	59	49	42
8	73	65	65	65	50	64	67	67	68	70	65	82	69	66	82	68	58
9	100	101	101	101	69	80	88	90	97	101	91	112	103	100	112	97	74
10	133	136	136	136	90	98	110	118	125	132	117	142	137	133	142	125	93
11	170	166	166	166	116	120	141	151	164	162	144	175	162	165	175	164	116
12	206	196	196	196	147	148	174	186	202	192	170	207	187	197	207	202	144
13	248	249	249	249	181	169	212	225	232	219	205	249	230	243	249	232	177
14	299	301	301	301	216	191	253	267	261	245	240	290	272	288	290	261	218
15	346	341	341	341	257	233	297	309	317	298	284	313	310	325	313	317	261
16	392	381	381	381	298	267	342	353	373	351	328	335	348	361	335	373	307
17	451	446	446	446	342	305	387	407	419	394	370	379	389	411	379	419	359
18	530	511	511	511	388	343	432	450	466	437	412	422	430	461	422	466	422
19	610	571	571	571	438	382	478	502	515	489	458	471	485	507	471	515	492
20	610	631	631	631	490	424	530	565	564	540	504	520	540	553	520	564	530
21	610	695	695	695	560	469	575	618	624	591	557	575	597	611	575	624	600
22	610	759	759	759	620	517	640	690	683	642	609	630	653	669	630	683	680
23	610	831	831	831	700	566	740	780	748	703	667	690	715	733	690	748	770
24	610	903	903	903	780	618	820	860	813	764	725	750	777	796	750	813	840
25	610	982	982	982	860	672	900	900	884	830	788	815	845	865	815	884	930
26	610	1060	1060	1060	950	728	980	980	954	896	851	880	912	934	880	954	1030
27	610	1145	1145	1145	1030	786	1162	1030	1030	968	919	950	985	1009	950	1030	1140
28	610	1229	1229	1229	1130	847	1251	1100	1106	1040	987	1020	1058	1084	1020	1106	1240
29	610	1320	1320	1320	1230	909	1346	1100	1188	1117	1060	1096	1136	1164	1096	1188	1350
30	610	1411	1411	1411	1340	974	1441	1100	1270	1193	1171	1171	1214	1244	1171	1270	1470
31	610	1502	1502	1502	1450	1042	1525	1100	1352	1269	1282	1246	1292	1324	1246	1352	1590
32	610	1593	1593	1593	1560	1111	1652	1100	1434	1345	1393	1321	1370	1404	1321	1434	1710

Table 14.—Board-foot volume table ("bdfoot.tab")

DCL	Species																
	BF	RS	BS	WS	HE	CE	WP	TA	SM	RM	YB	PB	BE	WA	AS	RO	OH
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	43	43	43	43	30	35	50	37	0	0	0	0	0	0	0	0	0
10	63	63	63	63	47	48	70	55	0	0	0	0	0	0	0	0	0
11	88	88	88	88	79	63	89	83	73	73	67	79	78	59	79	73	76
12	113	113	113	113	111	80	113	112	98	93	87	99	98	79	99	98	96
13	144	144	144	144	136	97	142	140	129	119	114	126	123	107	126	129	123
14	174	174	174	174	160	117	172	167	159	145	140	153	148	135	153	159	149
15	209	209	209	209	189	137	206	199	192	176	171	181	177	173	181	192	178
16	243	243	243	243	217	157	243	230	225	207	201	208	206	211	208	225	207
17	280	280	280	280	248	178	278	264	263	239	233	239	238	250	239	263	239
18	317	317	317	317	279	200	330	298	301	270	264	270	270	289	270	301	270
19	358	358	358	358	314	225	365	336	339	307	299	306	305	330	306	339	307
20	399	399	399	399	348	251	395	374	377	344	333	342	339	370	342	377	343
21	445	445	445	445	386	280	432	416	424	383	372	382	379	419	382	424	383
22	490	490	490	490	423	310	470	457	471	422	411	422	418	468	422	471	422
23	541	541	541	541	465	340	505	503	520	466	452	465	462	520	465	520	466
24	591	591	591	591	506	365	545	549	569	510	493	508	505	572	508	569	509
25	647	647	647	647	552	396	585	600	624	558	540	556	553	632	556	624	557
26	703	703	703	703	597	433	625	650	678	606	587	604	600	692	604	678	605
27	765	765	765	765	645	467	665	705	739	659	636	656	652	755	656	739	657
28	827	827	827	827	693	502	705	760	799	711	685	707	704	817	707	799	709
29	891	891	891	891	719	539	745	805	862	770	741	765	760	889	765	862	767
30	955	955	955	955	745	577	785	850	924	828	797	822	815	961	822	924	825
31	1016	1016	1016	1016	806	616	846	911	985	889	858	883	876	1022	883	985	886
32	1079	1079	1079	1079	869	656	909	974	1048	952	921	946	939	1085	946	1048	949