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User's Guide for the Northern Hardwood Stand Models: **SIMSAP and SIMTIM**

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Abstract

SIMSAP and SIMTIM are computer programs that have been developed to simulate the stand growth and development of natural and treated even-aged northern hardwood stands. SIMSAP begins with species distributions by quality classes in sapling stands after regeneration. SIMTIM, the poletimber-sawtimber-harvest phase, uses stocking guides based on quadratic mean stand diameter, number of trees, and basal area per acre of trees in the main crown canopy. Using available data, the connecting phases of the models have been tested to determine the effects of silvicultural treatments (or no treatment) on long-term stand response. The models are coded in FORTRAN 77 and are available on mainframe and IBM compatible microcomputers with a minimum of 256 K.

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Introduction

SIMSAP and SIMTIM form a forest stand growth model for even-aged northern hardwood stands (Solomon 1977a, Solomon and Leak 1986). The models can be applied to northern hardwood stands across New England to simulate growth beginning with a sapling stand (SIMSAP), continuing to a poletimber-sawtimber stand, and terminating at a user-specified quadratic mean stand diameter or stand age (SIMTIM).

The major species from the northern hardwood stands across New England used to construct the models were:

Yellow birch	<i>Betula alleghaniensis</i> Britton
Sugar maple	<i>Acer saccharum</i> Marsh.
White ash	<i>Fraxinus americana</i> L.
Paper birch	<i>Betula papyrifera</i> Marsh.
Red maple	<i>Acer rubrum</i> L.
Beech	<i>Fagus grandifolia</i> Ehrh.
Aspen	<i>Populus tremuloides</i> Michx.
Hemlock	<i>Tsuga canadensis</i> (L.) Carr.
Red spruce	<i>Picea rubens</i> Sarg.

The programs that were used to construct the models have been modified to allow interactive input data to be stored for later use. The user is prompted for information after which the data are checked for reasonable values. Both models are written in FORTRAN 77 and have on-line instructions available. SIMSAP/SIMTIM utilize MS-DOS on IBM PC-compatible microcomputers¹ with at least 256 K or on any mainframe (Solomon 1986).

SIMSAP Components

The development of the sapling stand has been described as a compound exponential process (Leak 1969a) that provides a basis for determining changes in numbers of stems by species group during the sapling stage. Available data on potential quality classes are used. After a weeding treatment is applied, the shape of the exponential curve will change, thus changing the rate of mortality. Also, a pruning treatment will change the quality distribution of the stems in the residual stand.

The initial stand information needed is the site index and species composition. The site index is defined as height of sugar maple at base age 50, and species composition is expressed as a percentage of the basal area in the initial stand at 1 inch d.b.h.

The silvicultural treatments available are weeding and pruning operations. The pruning option, if specified, will prune all yellow birch and sugar maple crop trees less than veneer grade to one log length. If weeding is desired, the user must supply a beginning average stand diameter; upper and lower bounds of number of acceptable stems, within which limits weeding will not be canceled; number of crop trees to be released; average number of competitors to remove per crop tree; and the removal priorities of beech, yellow birch, sugar maple, red maple, paper birch, and white ash.

The sapling-stand phase of the model is a series of subroutines that can be categorized as: (1) determination of initial stem numbers and qualities, (2) computation of mortality patterns, (3) application of an optional weeding treatment, and (4) determination of diameter distribution and elimination of understory trees.

Stem Numbers and Quality

SIMSAP begins the sapling-stand phase by determining the number of stems in the stand at a quadratic mean stand diameter (QMD) of 1.0 inch, and proportions the stems by species with veneer-, sawlog-, and bulk-product potential. The subroutine SAPST draws an initial observation at random from a normal distribution that represents a stand with a 1.0-inch mean stand diameter and 4,922 trees per acre, with a standard deviation of 779 trees² (Leak 1969b, Marquis 1967). The species composition remains constant for this phase of the simulator. The range of percentage of trees in potential stem qualities by species has been estimated (Solomon 1974) (Table 1). The subroutine picks uniformly distributed random numbers within the indicated ranges and sets these equal to the proportions of veneer-, sawlog-, and bulk-quality stems.

Table 1. — Ranges in the percentage of number of trees, by species, in various potential product classes

Species	Veneer	Sawlog	Bulk
Beech	5	8	87
Yellow birch	4-10	11-19	71-85
Sugar maple	3-5	12-27	68-85
Red maple	14	18	68
Paper birch	7-38	25-28	34-68
White ash	30	16	54

¹The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

²Leak, William B. 1967. Final report. Estimation of the exponential rate of tree dropout in young even-aged northern hardwoods. Durham, NH: USDA Forest Service, Northeastern Forest Experiment Station. 10 p.

Mortality

The number of stems (x) in a sapling northern hardwood stand decreases as stand diameter increases according to a negative exponential probability distribution (Leak 1969a, b) that has the form:

$$f(x) = re^{-rx}$$

The negative exponential parameter "r," for commercial stems alone and for all species together, is estimated by subroutine RPAR. Subroutine DROP applies mortality losses from an initial diameter of 1.0 inch to either the diameter at which weeding is applied or to the 3.0-inch mean diameter that marks the end of the sapling stage.

The average value of "r" for all species together is a constant 0.5685. For the commercial number of stems (CN) (average of 3,466 per acre), "r" can be estimated by (Solomon 1977a):

$$r = \begin{cases} 0.4428 + 0.0255 (CN - 3466)/1768 & \text{for } CN > 3466. \\ 0.4428 - 0.0682 (3466 - CN)/1768 & \text{for } CN < 3466. \end{cases}$$

If we have the initial number (N_1), initial diameter (D_1), and the final diameter (D_2), the final number of stems of all species (N_2) can be calculated in subroutine DROP from:

$$N_2 = N_1 \exp[r(D_1 - D_2)].$$

Multiplying the number (N_2) by the species and quality-class proportions gives the number of trees per species and class.

Silvicultural Treatments

A user may apply the subroutine CLEAN at any specified mean stand diameter between 1.0 and 3.0 inches by specifying a high and low number of acceptable stems. Acceptable stems depend on the management and product objectives implemented by the forest manager. The management decision must be made for top-grade products such as mill-wood, sawlogs, or veneer logs. The product decisions would be based on a sufficient number of the desired tolerant, intermediate, or intolerant species to accomplish the management objective. A stand should have more than the minimum number of acceptable stems so that after silvicultural treatments the residual stand will be composed of the desired species to accomplish the management objectives. A stand with less than the minimum number of acceptable stems should be considered for regeneration. Beyond a maximum number of acceptable stems, sufficient quantities of the desired species exist and a weeding treatment is not required to accomplish the management objectives. The user may also specify the number of crop trees, species priorities, and number of competitors to be removed per crop tree. Crop trees are stems with grade 1 or 2 potential, and the number of trees to remove is computed by multiply-

ing the number of crop trees times the number of trees to be removed around each crop tree. Also, pruning may be applied to the first log of all yellow birches and sugar maples with grade 2 potential, thereby increasing their potential to grade 1.

The number of trees at the end of the sapling stage is estimated by using the exponential parameter "r" calculated by comparing the number of stems remaining after weeding with the average number in an undisturbed stand. According to the stocking guide, no mortality is expected if the number of stems is 400 or less (5-inch mean stand diameter). Therefore, the exponential to apply after weeding to project the final number of trees would be:

$$r = 0.4428 (\text{residual remaining} - 400.0)/(XN - 400.0)$$

with

$$\log_{10} XN = 4.016316 - 0.2273 (\text{mean diameter})$$

where XN is the average number of trees in an untouched stand for a given stand diameter.

In projecting numbers of trees, no mortality losses are applied to crop trees. The negative exponential losses are applied only to those residual stems not classed as crop trees. Thus, the final result from subroutine CLEAN is numbers of stems by species and quality classes at a mean stand d.b.h. of 3.0 inches.

Diameter Distribution

In managing even-aged northern hardwoods beyond the sapling stage, silvicultural work is applied primarily to trees that make up the main crown canopy. Thus, the subroutine DIAMD assigns trees to diameter classes and eliminates the understory trees. This step results in a loss in number of stems, an increase in average stand diameter, and changes in species composition.

On the basis of plot data from young northern hardwood stands about 3.0 inches mean stand diameter (Leak 1969a), the observed ranges in percentage of trees by diameter class have been grouped in Table 2. Subroutine DIAMD chooses a random observation within each range, and determines numbers of trees by diameter class and species. Then, the 1-, 2-, or 3-inch (cumulative) class is dropped to reduce the stand to 760 trees per acre or less. This procedure brings the stand into the lower end of the northern hardwood stocking guide (Fig. 1) at an average diameter of approximately 5 inches. Beech or sugar maple designated as crop trees, and released by weeding, are not eliminated as understory.

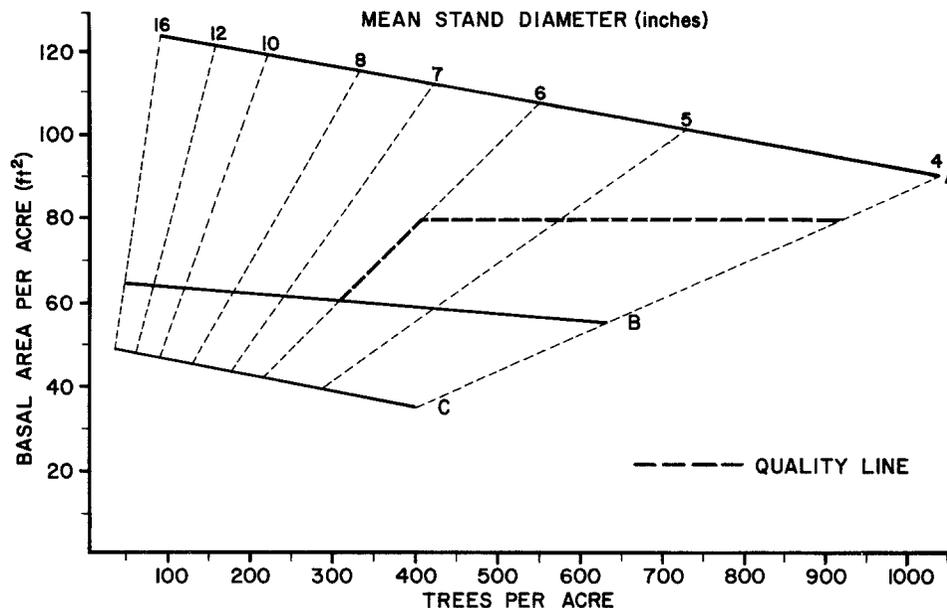


Figure 1.—Stocking chart for northern hardwoods is based on trees in the main crown canopy. The A line is average maximum stocking. The B line is recommended minimum stocking for adequate growth response per acre. The C line defines the minimum amount of acceptable growing stock for a manageable stand.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

Finally, the subroutine determines numbers of remaining trees by species and product class, as well as the final average diameter and basal area per acre. This information can

Table 2. — Range in percentage of number of trees in each diameter class for stands with 2.5- to 3.0-inch average diameter, by species

Diameter class (inches)	Beech and sugar maple	Yellow birch, red maple, and white ash	Paper birch and others
1	34-71	0-54	0-20
2	20-34	0-34	0-30
3	6-14	3-27	0-25
4	1-10	10-37	0-25
5	0-8	0-34	12-50
6	0-3	0-25	0-50
7	remainder ^a	0-20	0-50
8	—	0-20	0-14
		remainder	remainder

^a Remainder is the remaining percentage if the diameter classes do not add to 100 percent.

serve as part of the input into the poletimber-sawtimber-harvest phase of the simulator.

Sapling MAIN Program

The MAIN program estimates number of years required to reach the end of the sapling stage. These time estimates are based on site index and the application or nonapplication of weeding; computations are made by simple interpolation between the following site index values (Leak et al. 1969):

Site Index	Weeded (Years)	Unweeded (Years)
50	44	59
60	38	50
70	33	44
80	29	40

SIMSAP Application

SIMSAP will prompt the user with a menu that can be used to determine the scope of each run. All of the input data will be stored on disk in a direct access file. The user is asked to provide the name of this file and whether it is an existing file or a new file. On subsequent runs the user can use this file to either duplicate an earlier run or make modifications to run the simulation under different conditions. The output for the run can be directed to either a disk file, a printer, or to the console.

The user selects an option from the following menu:

- (1) HELP
- (2) NEW FILE
- (3) TITLE
- (4) INITIAL STAND
- (5) SITE INDEX
- (6) WEEDING
- (7) PRUNING
- (8) RANDOM #
- (9) # REPEAT RUNS
- (10) DISPLAY FILE

<11> EXECUTE

All items enclosed in <> (option 11) are default values and will be in effect if a carriage return is entered. Entering a minus sign in response to any question will terminate the program.

Option (1):

Help
A summary of instructions for creating the input data file is printed on the console. After every 15 to 20 lines, the program waits for a carriage return before continuing.

Option (2):

New File
A new input file is to be created from the information contained in options 3 thru 9. 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 erased.

When the user has specified a new input data file, only options 1 and 2 are available. After the file is created or if the file has been designated as an existing file, options 3 thru 9 will allow modifications to that file without having to re-create the whole file.

Option (3):

Title
A title of up to 80 characters will appear at the top of each page of output.

Option (4):

Initial Stand
The user enters the percentage of the basal area of each species in the stand at 1-inch quadratic mean stand diameter. The species groups are: beech (BE),

yellow birch (YB), sugar maple (SM), red maple (RM), paper birch (PB), white ash (WA), pin cherry (PC), striped maple (STMAP), aspen (ASP), other (OTH), and red maple sprouts (RMSP). If the percentages do not add to 100, the user is asked to reenter the percentages.

Option (5):

Site Index

The site index for the stand is based on sugar maple at base age 50 and must range between 40 and 80.

Option (6):

Weeding

DBH

The quadratic mean stand diameter at which to start weeding must be between 1.0 and 3.0 inches.

Max # acceptable stems

No weeding will be applied if the number of acceptable stems is greater than this number when the stand reaches the weeding d.b.h.

Min # acceptable stems

No weeding will occur if the number of acceptable stems is less than this number when the stand reaches the weeding d.b.h.

crop trees

The number of crop trees per acre to be released.

competitors

The average number of competitors removed per crop tree to ensure survival of the crop tree.

Priority

Removal priority for each species: beech, yellow birch, sugar maple, red maple, paper birch, and white ash. Priorities range from 1 (first) to 6 (last) and numbers may **not** be repeated. A zero may be used for species without crop trees.

Option (7):

Pruning	(1) The released yellow birch and sugar maple trees less than veneer quality are pruned to one log during weeding to increase quality. (2) No pruning will be done.
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Option (8):

Random #	The random number generator in the model requires an odd, nine-digit number to begin.
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Option (9):

# Repeat Runs	Because of the randomness within the model, the stand can be run through several simulations and each will be slightly different. The user can use these results to obtain an average stand value.
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Option (10):

Display File	A summary of the input data will be displayed on the console.
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Option <11>:

Execute	The input data are then used to start the simulation.
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An example of creating the input data file and the subsequent simulation is shown in Table 3. The entries in italics are made by the user. All input is free format, that is, data need only be separated by one or more blanks or a comma. There is no need to align the entry under a column heading other than for the user's own convenience. At the completion of the model run, the user is asked if another simulation is desired with this stand. If the answer is yes (Y), the program returns to the menu. If the answer is no <N>, the user is asked if a simulation with a new input data file is desired. A Y response will return the user to entering a file name for the input file and a designation for the output. An N response will terminate the program.

SIMSAP Output

The output of SIMSAP (Table 3) starts with a copy of the input data. The model indicates the number of yellow birch and sugar maple trees to be pruned. An appropriate message is printed when weeding was not conducted or when the number of acceptable stems was not within the allow-

able range. After a weeding, the diameter at which it occurred is given, along with the number of crop trees by species, number of trees cut, and the number of remaining trees.

At the end of the sapling phase, the smaller diameter classes that were dropped from the understory are noted and the final stand characteristics: number of trees, basal area per acre, QMD, and number of years to reach the end of the sapling phase are presented. For commercial species, the number of trees and percentage of composition are given by three quality classes which may be considered as veneer, sawlog, and bulk product. The number of trees and percentage of composition of the noncommercial species are printed without quality classes.

SIMTIM Components

The poletimber-sawtimber-harvest phase of the simulator (SIMTIM) grows the stand from the end of the sapling phase, approximately 4.5 inches QMD, to harvest diameter or rotation age. The program covers three main steps: (1) stand growth projection, (2) thinning and harvesting options, and (3) paper birch-aspen mortality.

The overall framework of the model is a distance-independent stand model. Input consists of site index, specifications on the thinning regime, and stand characteristics of age, basal area, QMD, and percentage of basal area by species and quality. The model projects these stand characteristics by positioning the stand within the northern hardwood stocking chart (Fig. 1) and relating stand development to stocking (Solomon and Leak 1986). The lines in Figure 1 are developed from trees within the main crown canopy of northern hardwood stands. The main crown canopy is defined as all trees on the plot that are not overtopped or suppressed.

The user is required to input the following information:

- Forest stand name;
- Site index between 40 and 80 for sugar maple at base age 50;
- Average number of trees per acre, usually between 25 and 1,500 trees;
- Basal area per acre to the nearest tenth of a square foot between 20 and 130 square feet;
- Quadratic mean stand diameter to the nearest tenth of an inch between 4 and 16 inches;
- Species composition list;
- Stand age in years;
- Final harvest age in years, and final quadratic mean diameter to the nearest tenth of an inch;
- Specified intervals in years for report to be presented;
- Any odd nine-digit number for the mortality function.

The species composition list is entered by quality classes of I, II, and III, in the following order: beech, yellow birch, sugar maple, red maple, paper birch, aspen, white ash, conifer, and other. There is one quality class of eight values per line expressed to the nearest tenth of a percent (Table 4).

Stand Growth

Stand growth provides the forest manager with an estimate of the growth of northern hardwood stands. The growth rate of different species may increase or decrease depending upon the age and density of the stand. Thus, stand growth, as computed from accretion, ingrowth, and mortality, is proportioned into species growth rate based on the residual basal area of the stand and stand age. Changing species composition does not change stand growth, but changes the amount of growth allotted to individual species which then repropotions the species composition.

The changes in growth rates for stands growing on different sites are modeled as a proportion of the site index of the stand to site index 60 for northern hardwoods. The stand basal area is adjusted by that ratio since the stand growth within the model is based upon northern hardwood stands growing on a site index 60 for sugar maple base age 50.

The amount of stocking, represented by the basal area, number of trees, and quadratic mean stand diameter, can be followed through time with the stocking chart (Fig. 1). The growth simulation within the model computes the number of trees per acre at both the A and B line. The A line represents a fully stocked stand without any form of management. The B line is based on optimum stand growth from different studies of northern hardwood growth. The number of trees at both the A and B line can be represented as a function of the natural logarithmic value of the quadratic mean stand diameter:

$$\begin{aligned} \text{A line number of trees} &= e^{(9.491 - 1.786 * \ln \text{QMD})} \\ \text{B line number of trees} &= e^{(9.082 - 1.887 * \ln \text{QMD})} \end{aligned}$$

where

QMD = the diameter at breast height of the tree of average basal area.

The C line represents a managed stand with a minimum level of acceptable growing stock (sawlog potential) that will grow to the B line in 10 years. The quality line maintains a higher level of basal area stocking for smaller quadratic mean diameters. Thinning a stand to the quality line when less than 6 inches in diameter provides clear bole form on younger, smaller high-quality species (Leak et al. 1987).

The stand growth components of accretion and ingrowth (ft²/acre/year) can be expressed as:

$$\text{Accretion} = 2.153 + 0.005 (\ln \text{BA}) - 0.0076 (\text{SAW})$$

$$\text{Ingrowth} = 3.200 - 0.643 (\ln \text{BA}) - 0.0012 (\text{SAW})$$

where

BA = residual basal area in square feet,

SAW = percentage of stand in sawtimber-size trees,

Accretion = d.b.h. increment in basal area of trees present at the initial inventory, plus ingrowth accretion,

Ingrowth = trees that grew larger than threshold size (5.0 inches) between inventories.

The R² values were 0.73 and 0.97; the standard errors of the mean were 0.0187 and 0.0138, respectively. These growth equations are based on information from managed stands of northern hardwoods (Marquis 1969; Solomon 1977b, c). The residual basal areas ranged from 20 to 100 square feet per acre for these stands that were 20 to 80 years old. The percentage of sawtimber ranged from zero to 60. Stand mortality increases as the basal area and mean stand diameter increase and the stand grows from the B to the A line. The estimate of actual stand mortality is based on the assumption that mortality at minimum stocking (B line) is zero, and that mortality of a stand above the B line is in some way proportional to its position between the A and B line.

$$\text{Stand mortality} = \left[\frac{\text{BA} - \text{BAB}}{\text{BAA} + \text{MF} - \text{BAB}} \right]^X (\text{GG} - \text{BAGA})$$

where

BA = basal area of stand,

BAB = basal area at B line for the present QMD,

BAA = basal area at A line for the present QMD,

GG = gross growth,

BAGA = annual net basal area growth at A line for the present QMD,

MF = mortality factor,

X = a random exponent between 1 and 1.5.

When X = 1, mortality is computed in direct proportion to the position of the stand between the A and B line. When X is greater than 1, the mortality rate increases as the A line is approached and passed. The mortality factor (MF) ranged from -2.5 for stands with basal area of 60 square feet per acre or less up to 2.0 for stands with 100 square feet per acre or more.

Thinning and Harvesting Options

The user can specify the order of removing the eight species categories from the three quality classes. The numbers from 1 to 24 in the 3 x 8 matrix can be arranged to indicate removal priority. A number can be given that specifies the

location in the removal order for the user to switch from complete species-quality class removal to proportional removal of remaining species quality classes. This can be used to maintain species composition as well as quality within species.

Thinning is regulated by basal area in the stocking chart (Fig. 2). The user options include no thinning, thin when the stand reaches the A line, or when the stand reaches a user-specified basal area above the B line. The user must specify the quadratic mean diameter to the nearest tenth of an inch for the first thinning to begin. The thinning is to the B line except when it may be regulated by the quality line up to a 6-inch quadratic mean stand diameter. When thinning is controlled by the quality line, the stand is thinned to 80 square feet for stands with quadratic mean diameters less than or equal to 6 inches, and then is thinned to the B line for stands with quadratic mean diameters greater than 6 inches. The final harvest, specified by the user, may be based on time (number of years) or occur at the predetermined quadratic mean stand diameter.

Paper Birch — Aspen Mortality

When the stand reaches 80 years of age, simulated mortality of any remaining paper birch and aspen is accelerated by subroutine PBMORT to represent the short life span of these two species. Five percent of the initial amount of each species is removed per year, resulting in complete removal

of both species between 80 and 100 years of age (Solomon and Leak 1969). Mortality losses are applied proportionally across all quality classes. The user has the opportunity to circumvent this accelerated mortality by specifying that paper birch and aspen be removed first in thinnings after age 70. Percentages of the remaining species are adjusted so that they continue to sum to 100 percent.

SIMTIM Application

SIMTIM is designed similar to SIMSAP in that it too uses a direct access file to store the input data and uses a menu to create or modify this input file. The user must provide a name for the input file, and specify whether it is a new or an already existing file. The user must specify where output is to go: the console, the printer, or a disk file. The menu for SIMTIM is presented to the user:

- | | |
|-------------------|-------------------------|
| (1) HELP | (6) INITIAL COMPOSITION |
| (2) NEW FILE | (7) THINNING |
| (3) TITLE | (8) ROTATION |
| (4) SITE INDEX | (9) RANDOM # |
| (5) INITIAL STAND | (10) DISPLAY FILE |
| <11> EXECUTE | |

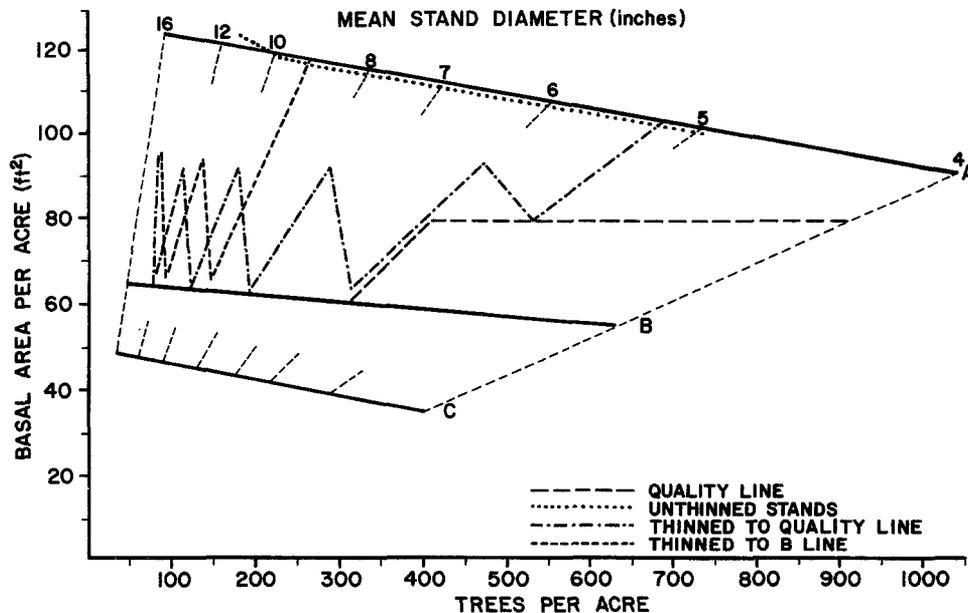


Figure 2.—Comparison of growth response for unthinned stands, stands thinned to the quality line starting at 5.0 inches quadratic mean stand diameter, and thinned to the B line starting at 9.0 inches quadratic mean stand diameter.

Option (1):

Help A summary of instructions will be printed on the console. The program will wait after every 15 to 20 lines for a carriage return to be entered before continuing.

species groups are: beech (BE), yellow birch (YB), sugar maple (SM), red maple (RM), paper birch-aspen (PBA), white ash (WA), conifer (CON), and other (OTH). The three quality classes are to be defined by the user. The total composition for the 24 entries must equal 100 percent.

Option (2):

New file If a file of the above specified name already exists, the user will be given the choice of renaming and creating a new file, returning to the menu, or continuing, which will cause the existing file to be erased. When the input data file has been designated as being new, the user can only select options 1 or 2. Options 3 through 9 allow modifications to this input file after it has been created.

Option (7):

Thinning

Type (0) - no thinning will be done.
(1) - thin when the stand reaches the A line of the stocking chart (Fig. 1).
<2> - thin at a user specified level above the B line. This value must be between 5 and 40 square feet.

Option (3):

Title A title of up to 80 characters that will appear on the top of all pages of output.

When

The user-specified quadratic mean stand diameter must be reached before the first thinning will occur. After the first thinning, control will be according to the option selected above.

Option (4):

Site index The site index for the stand based on sugar maple at age 50 (40 to 80).

Residual level

<1> - thin to the B line.
(2) - for stands with a quadratic mean stand diameter less than 6.0 inches the stand will be thinned to a quality line (Fig. 1) at 80 square feet. For stands over 6.0 inches, the residual level will be given by the B line.

Option (5):

Initial stand

Trees per acre The average number of trees per acre in the initial stand (25 to 1,500).

Order of removal

The eight species and three quality classes are numbered from 1 to 24 in the following manner:

Basal area The initial basal area in square feet per acre (20 to 130).

Mean stand diameter The quadratic mean stand diameter to the nearest tenth of an inch (4.0 to 16.0).

Quality Class	Species							
	BE	YB	SM	RM	PBA	WA	CON	OTH
1	1	2	3	4	5	6	7	8
2	9	10	11	12	13	14	15	16
3	17	18	19	20	21	22	23	24

Option (6):

Initial composition The initial species composition of the stand by eight species groups and three quality classes. The

The user is asked to list these numbers in the order that they want the species-quality classes removed. The default order is: 24, 20, 17, 23, 18, 19, 21, 22, 16, 12, 9,

15, 13, 14, 10, 11, 8, 4, 1, 7, 5, 6, 2, 3. All numbers should be entered or the remaining default order will be used.

includes the basal area, number of trees per acre, and quadratic mean stand diameter.

Thin split

A number from 1 to 24 is specified that represents a position within the removal order (that is, thin split = 12, refers to species quality group 15 above, the 12th entry in the priority list). All species-quality groups prior to this entry will be removed entirely until the residual level is obtained, while for the groups after this entry, only an amount proportional to the amount of the species group in the stand will be removed.

Option (9):

Random number

The random number generator within the model requires a nine-digit odd integer to begin.

Option (10):

Display file

A summary of the input data will be displayed on the console.

Option <11>:

Execute

Simulation begins using the criteria contained in the input data file.

Paper birch

Paper birch and aspen mortality is increased between years 80 and 100 until all of both species are removed. There is an option which will allow the user to salvage this mortality if desired.

(0) - For any thinning after the stand is 70 years old, the model will automatically give highest priority of removal to paper birch and aspen for salvage.

<1> - The priorities remain as entered, thereby maintaining the user-specified order of removal.

An example of creating the input data file and the subsequent simulation is shown in Table 4. As with SIMSAP, all data may be entered free-format and are shown in italics in the table. At the end of the simulation the user is asked if the yields are to be displayed. A yes (Y) response will cause the standing yield, sum of thinning yields, and total yield to be printed on the console and simultaneously go to the primary output device. The program waits for a carriage return between tables. Next, the user is asked if they wish to run another simulation with this stand. If the answer is Y, the program returns to the menu. If the answer is no <N>, the user is asked if a simulation with a new input data file is desired. A Y response will return the user to entering a file name for the input file and a designation for the output. An N response will cause termination of the program.

SIMTIM Output

The output of SIMTIM (Table 4) is made up of a copy of the input data, intermediate reports of stand characteristics, intermediate thinning reports, and a final harvest report. At user-specified intervals, reports of the stand age; quadratic mean stand diameter; number of trees in the stand, at the A and B line; basal area of the stand, at the A and B line; and the percent sawtimber are all printed.

Option (8):

Rotation

Rotation age

The age at which the final harvest is to occur.

Harvest diameter

The quadratic mean stand diameter of final harvest. The final harvest will be at rotation age or harvest diameter, whichever occurs first.

When a thinning occurs, the age of the stand and the stand characteristics are given. Also presented are the number of trees thinned, the basal area removed, and a yield table by species and quality class showing the percent removed, square feet of basal area, cubic-foot volume and board-foot volume.

Report interval

A summary of the stand characteristics will be sent to the user-specified output. This summary

At the final harvest, a summary of the stand conditions is printed along with the standing yield, the total yield from all thinnings, and the sum of the standing yield plus all thinnings. These yields are presented by species and quality class in units of square feet of basal area, cubic-foot volume, and board-foot volume.

Square feet of basal area is converted to both cubic feet and board feet based on the quadratic mean stand diameter and site index (Leak 1980). Thus, the yields by species are based on the percentage of a species in the total basal area. The cubic feet per square foot of basal area give the total cubic feet; similarly, the board feet per square foot give the board feet. Then the board feet divided by the board feet/cubic feet ratio gives the amount of cubic feet in the sawtimber yields. By subtracting this amount from the total yield, we can estimate the amount of cubic feet in pulp, cull, or extra sawtimber.

The computer programs described in this publication are available on request with the understanding that the U.S. Department of Agriculture cannot assure their accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program. For information, please write: Dr. Dale S. Solomon, USDA Building, University of Maine, Orono, ME, 04473.

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Table 3. — Sample run for SIMSAP, Version 2.0. Items in italics are entered by the user

SIMSAP

Please enter input file name:

SAP.CTL

Is input file <1> old or (2) new?

2

- | | |
|-------------------|-------------------|
| (1) HELP | (7) PRUNING |
| (2) NEW FILE | (8) RANDOM # |
| (3) TITLE | (9) # REPEAT RUNS |
| (4) INITIAL STAND | (10) DISPLAY FILE |
| (5) SITE INDEX | (11) OUTPUT |
| (6) WEEDING | <12> EXECUTE |

2

Enter title:

SAMPLE RUN OF SIMSAP

Enter percent composition of initial stand:

BE	YB	SM	RM	PB	WA	PC	STMAP	ASP	OTH	RMSP
8	12	16	5	16	2	18	2	3	8	10

Site index:

60

Is weeding desired?

Y

Enter the diameter at which to begin weeding (1.0 to 3.0):

2.5

Maximum number of acceptable stems:

3500

Minimum number of acceptable stems:

400

Number of crop trees released per acre:

400

Average number of competitors removed per crop tree:

2

Priority of removal from 1 to 6 (zero for not a crop tree):

BE	YB	SM	RM	PB	WA
0	5	6	1	2	3

(1) No pruning

<2> Prune YB and SM

<cr>

Random number:

987654321

of repeat runs:

1

- | | |
|-------------------|-------------------|
| (1) HELP | (7) PRUNING |
| (2) NEW FILE | (8) RANDOM # |
| (3) TITLE | (9) # REPEAT RUNS |
| (4) INITIAL STAND | (10) DISPLAY FILE |
| (5) SITE INDEX | (11) OUTPUT |
| (6) WEEDING | <12> EXECUTE |

11

INPUT DATA

SAMPLE RUN OF SIMSAP

Species comp:

BE	YB	SM	RM	PB	WA	PC	STMAP	ASP	OTH	RMSP
.08	.12	.16	.05	.16	.02	.18	.02	.03	.08	.10

Site index = 60.0

Weeding desired at d.b.h. 2.5

Acceptable stems	Crop trees	Competitors
min	released	removed
400.	400.	2.
max		
3500.		

Priority: BE YB SM RM PB WA
0. 5. 6. 1. 2. 3.

YB and SM will be pruned

Random number: 987654321

of repeat runs: 1

SAMPLE RUN OF SIMSAP

Number of yellow birch pruned = 47.4

Number of sugar maple pruned = 19.4

Weeding was applied at 2.5 d.b.h.

Crop trees of	BE	YB	SM	RM	PB	WA	ALL
	.0	75.4	41.0	45.9	185.0	26.4	373.6

Number cut in weeding = 747.3

Number left = 1541.9

2-INCH CLASS DROPPED

END OF SAPLING STAGE:

# TREES	BASAL AREA	AVG DBH	YEARS
769.1	85.8	4.5	38.0

NUMBER AND PERCENT OF TREES

COMMERCIAL SPECIES

POTENTIAL		BE	YB	SM	RM	PB	WA
QUALITY 1	#	0.7	26.5	41.0	7.0	48.9	6.0
(VENEER)	%	0.1	3.4	5.3	0.9	6.4	0.8
QUALITY 2	#	1.2	0.0	5.8	9.1	93.6	3.2
(SAWLOG)	%	0.2	0.0	0.8	1.2	12.2	0.4
QUALITY 3	#	13.0	57.2	21.3	20.7	127.8	6.6
(BULK)	%	1.7	7.4	2.8	2.7	16.6	0.9

NON-COMMERCIAL SPECIES

	RMSP	ASP	OTH	STMAP	PC
#	133.9	33.6	89.5	22.4	0.0
%	17.4	4.4	11.6	2.9	0.0

Do you want another run with this data file?

N

Do you want to use another data file?

<cr>

Stop - Program terminated.

Table 4. — Sample run of SIMTIM Version 2.0 showing the first of 6 thinnings. Items in italics are entered by the user

SIMTIM

Please enter input file name:

TIM.CTL

Is input file <1> old or (2) new?

2

- (1) HELP (7) THINNING
- (2) NEW FILE (8) ROTATION
- (3) TITLE (9) RANDOM #
- (4) SITE INDEX (10) DISPLAY FILE
- (5) INITIAL STAND (11) OUTPUT
- (6) INITIAL COMPOSITION <12>EXECUTE

2

Enter title:

SAMPLE RUN OF SIMTIM

Site index:

60

Average number of trees/acre:

1050

Enter the basal area:

91.0

Mean stand diameter:

4.0

Age of stand:

30

Species composition and quality class

	BE	YB	SM	RM	PBA	WA	CON	OTH
Class 1	7	23	22	1	5	1	0	0
Class 2	4	11	11	0	3	1	0	0
Class 3	1	4	4	0	1	0	0	1

(0) - No thinning

(1) - Thin when stand reaches A line

<2> - Thin at user-specified level above B line (in ft²)

<cr>

Please enter the amount of square feet above the B line to start thinning:

30

Do you wish to:

<1> thin to the B line for all diameters or

(2) thin to 80 ft² up to stand diameter 6 and then to the B line?

2

Species composition and quality class

	BE	YB	SM	RM	PBA	WA	CON	OTH
1 %	7.0	23.0	22.0	1.0	5.0	1.0	0.0	0.0
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2 %	4.0	11.0	11.0	0.0	3.0	1.0	0.0	0.0
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)

3 % 1.0 4.0 4.0 0.0 1.0 0.0 0.0 1.0
(17) (18) (19) (20) (21) (22) (23) (24)

Current species removal order:

< 24 20 17 23 18 19 21 22 16 12 9 15 13 14 10 11 8 4 1 7 5 6 2 3 >

Choose current species removal order:

<cr>

Please enter the thinning split number. Species that occur after this number in the species removal array will be thinned according to their proportion of the stand composition. 24 MEANS NO PROPORTIONAL THINNING WILL OCCUR.

<24>

17

Paper Birch removal:

(0) - paper birch and aspen are removed first in thinning after age 70

<1> - operator specified removal order

0

Beginning thinning diameter:

5.0

Rotation age:

200

Harvest diameter of the stand:

18.0

Report interval in years:

<1>

200

Random number:

987654321

- (1) HELP (7) THINNING
- (2) NEW FILE (8) ROTATION
- (3) TITLE (9) RANDOM #
- (4) SITE INDEX (10) DISPLAY FILE
- (5) INITIAL STAND (11) OUTPUT
- (6) INITIAL COMPOSITION <12> EXECUTE

<cr>

INPUT DATA

TEST OF SIMTIM

Site index = 60.0

Number of trees/acre = 1050.0

Basal area/acre = 91.0

Quadratic mean diameter = 4.0

Age of stand = 30.0

QUALITY

SPECIES

CLASS	BE	YB	SM	RM	PBA	WA	CON	OTH	TOTAL
1 %	7.0	23.0	22.0	1.0	5.0	1.0	0.0	0.0	59.0
FT2	6.4	20.9	20.0	0.9	4.6	0.9	0.0	0.0	53.7
2 %	4.0	11.0	11.0	0.0	3.0	1.0	0.0	0.0	30.0
FT2	3.6	10.0	10.0	0.0	2.7	0.9	0.0	0.0	27.3
3 %	1.0	4.0	4.0	0.0	1.0	0.0	0.0	1.0	11.0
FT2	0.9	3.6	3.6	0.0	0.9	0.0	0.0	0.9	10.0

Thin when stand reaches 30 ft² above the B line and mean stand diameter is at least 5.0 inches.

Quality-line thinning (thin to 80 ft²) will be used up to diameter 6 inches.

Order of species class removal by priority:

24 20 17 23 18 19 21 22 16 12 9 15
13 14 10 11 8 4 1 7 5 6 2 3

Thinning split number: 17

Model starts to remove paper birch and aspen first in thinnings after age 70

Rotation age: 200.

Harvest diameter: 18.0

Report interval: 200

Random number: 987654321

TEST OF SIMTIM

Thinning #1

Stand at 45 years

	Stand	A line	B line
Diameter	5.5		
# trees	635.5	635.5	355.6
Sq. ft.	104.0	103.9	58.1

Percent sawtimber = 0.

Thinning yields

Number of trees thinned = 147.2

BA thinned = 24.1

QUALITY CLASS	SPECIES								
	BE	YB	SM	RM	PBA	WA	CON	OTH	TOTAL
1 %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 %	3.8	2.7	0.0	0.0	4.3	1.3	0.0	0.0	12.0
FT2	4.0	2.8	0.0	0.0	4.4	1.3	0.0	0.0	12.5
FT3	57.0	39.7	0.0	0.0	63.2	18.7	0.0	0.0	178.6
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 %	1.0	3.9	3.6	0.0	1.4	0.0	0.0	1.2	11.1
FT2	1.0	4.0	3.8	0.0	1.5	0.0	0.0	1.3	11.6
FT3	14.3	57.6	54.1	0.0	21.1	0.0	0.0	17.9	164.9
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TEST OF SIMTIM

STAND AT HARVEST

Site index = 60.0

Number of trees/acre = 49.2

Basal area = 87.8

Quadratic mean diameter = 18.0

Age of stand = 122.

Thinning began at diameter 5.0

HARVEST YIELD

QUALITY CLASS	SPECIES								
	BE	YB	SM	RM	PBA	WA	CON	OTH	TOTAL
%	15.2	37.6	40.8	3.3	0.0	3.2	0.0	0.0	100.0
FT2	13.3	33.0	35.8	2.9	0.0	2.8	0.0	0.0	87.8
1 FT3	357.3	883.9	959.9	77.1	0.0	75.4	0.0	0.0	2353.6
BF	1501.9	3715.0	4034.4	324.0	0.0	316.8	0.0	0.0	9892.1
%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 FT3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 FT3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TOTAL YIELD FROM THINNINGS

QUALITY CLASS	SPECIES								
	BE	YB	SM	RM	PBA	WA	CON	OTH	TOTAL
FT2	15.0	40.4	41.6	3.3	17.3	3.2	0.0	0.0	120.8
1 FT3	340.6	900.0	937.4	74.8	342.9	73.1	0.0	0.0	2668.9
BF	1125.7	2883.8	3066.1	246.7	852.8	241.0	0.0	0.0	8416.0
FT2	4.0	12.0	11.6	0.0	4.4	1.3	0.0	0.0	33.3
2 FT3	57.0	177.7	173.8	0.0	63.2	18.7	0.0	0.0	490.5
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT2	1.0	4.0	3.8	0.0	1.5	0.0	0.0	1.3	11.6
3 FT3	14.3	57.6	54.1	0.0	21.1	0.0	0.0	17.9	164.9
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TOTAL YIELD

QUALITY CLASS	SPECIES								
	BE	YB	SM	RM	PBA	WA	CON	OTH	TOTAL
FT2	28.3	73.3	77.4	6.2	17.3	6.0	0.0	0.0	208.6
1 FT3	698.0	1783.9	1897.3	151.9	342.9	148.5	0.0	0.0	5022.5
BF	2627.6	6598.7	7100.5	570.6	852.8	557.8	0.0	0.0	18308.0
FT2	4.0	12.0	11.6	0.0	4.4	1.3	0.0	0.0	33.3
2 FT3	57.0	177.7	173.8	0.0	63.2	18.7	0.0	0.0	490.5
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FT2	1.0	4.0	3.8	0.0	1.5	0.0	0.0	1.3	11.6
3 FT3	14.3	57.6	54.1	0.0	21.1	0.0	0.0	17.9	164.9
BF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE TOTAL HARVEST PER ACRE (INCLUDING THINNINGS) IS:

BASAL AREA: 253.4
CUBIC FEET: 5677.9
BOARD FEET: 18308.0

Solomon, Dale S.; Hosmer, Richard A. 1987. **User's guide for the northern hardwood stand models: SIMSAP and SIMTIM.** Res. Pap. NE-606. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 13 p.

SIMSAP and SIMTIM are computer programs that have been developed to simulate the stand growth and development of natural and treated even-aged northern hardwood stands. SIMSAP begins with species distributions by quality classes in sapling stands after regeneration. SIMTIM, the poletimber-sawtimber-harvest phase, uses stocking guides based on quadratic mean stand diameter, number of trees, and basal area per acre of trees in the main crown canopy. Using available data, the connecting phases of the models have been tested to determine the effects of silvicultural treatments (or no treatment) on long-term stand response. The models are coded in FORTRAN 77 and are available on mainframe and IBM compatible microcomputers with a minimum of 256 K.

ODC. 181.65, 228.5, 228.82

Keywords: Growth model, Northern hardwoods, even-aged

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