kup

United States Department of Agriculture

Forest Service

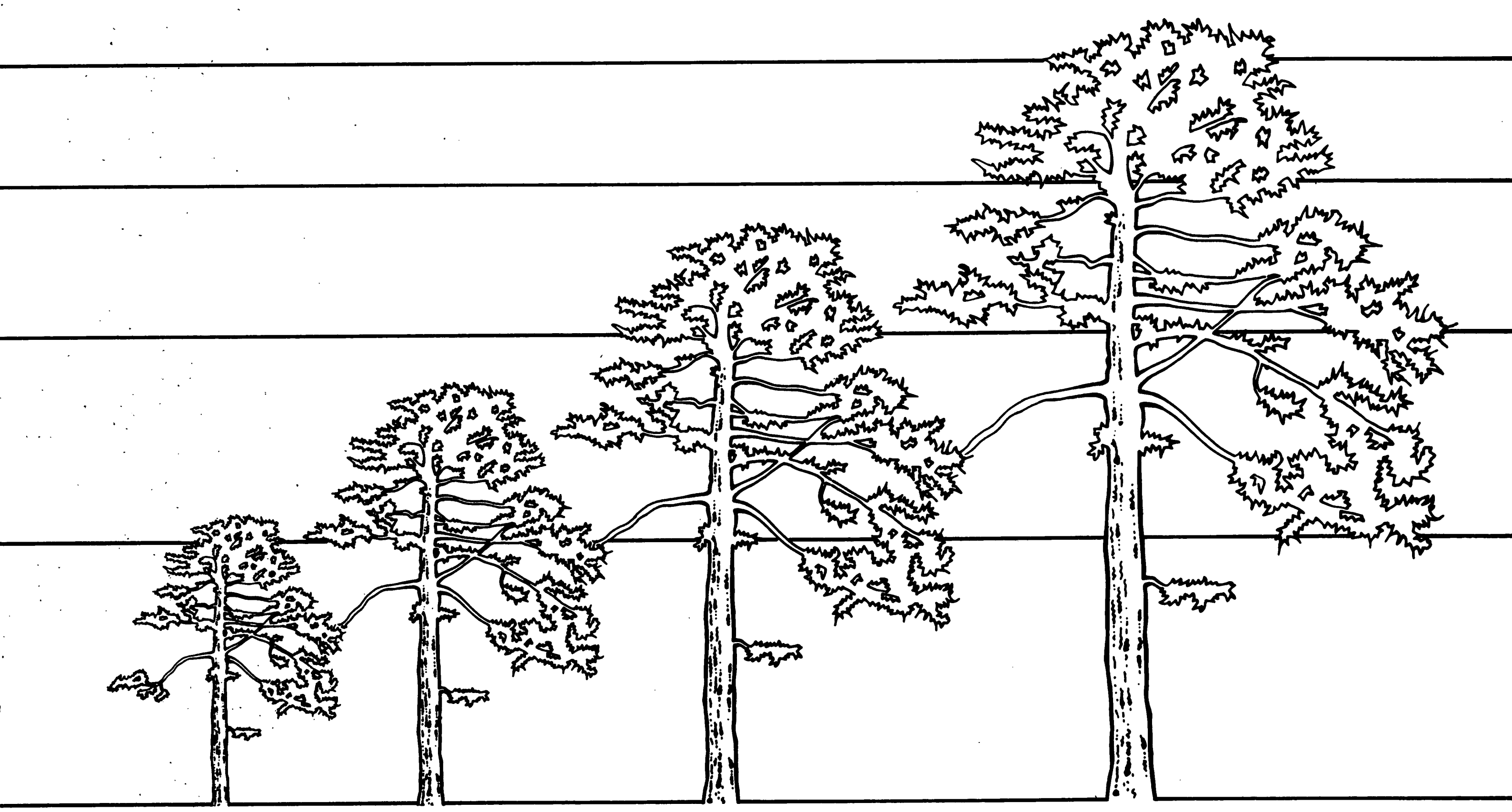
North Central Forest Experiment Station

Research Paper NC-252

1964

STEMS: A Nontechnical Description for Foresters

Cynthia L. Miner and Nancy R. Walters



CONTENTS

North Central Forest Experiment Station
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108
Manuscript approved for publication April 4, 1984
December 1984

STEMS: A NONTECHNICAL DESCRIPTION FOR FORESTERS

Cynthia L. Miner, *Forester,*
and **Nancy R. Walters,** *Forester*

Forest managers have long wished for a view of tomorrow's forests that reflects today's decisions. For the past 20 years researchers have been developing computer models of future stands by using past forest changes and mathematics as building blocks. In 1975, research was begun at the North Central Forest Experiment Station to model forest changes. The result of this research is the Stand and Tree Evaluation and Modeling System (STEMS).

The future of a forest depends on the birth, growth, and death of trees. STEMS simulates the life cycle and management of trees native to the Lake States (Michigan, Minnesota, and Wisconsin), and Central States (Indiana, Illinois, and Missouri). Individual trees, any of 95 species in the Central States and 47 species in the Lake States, are "grown" and "managed" in stands of any age or species combination.

STEMS consists of two linked programs (fig. 1): the Tree Growth Projection System (TGPS), the essential part of STEMS that simulates tree growth, mortality, timber management, and regeneration; and Table (TABL), an optional program that produces detailed summaries from TGPS.

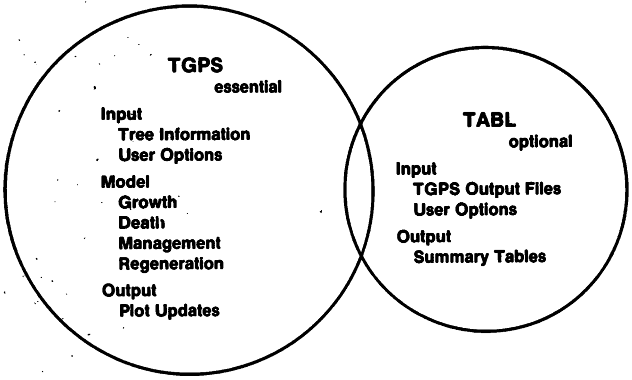


Figure 1.—*TGPS and TABL, the two linked programs of STEMS.*

TGPS contains most of the building blocks for modeling a forest; however, it is the STEMS user who determines the model's final outcome by providing initial tree information and choosing options available in STEMS. Although knowing how to program computers enhances STEM's flexibility, even novice computer users can tailor stand growth, management, and output to fit their needs.

Because STEMS does not integrate forest management factors such as tree spacing, slope, understory vegetation, catastrophes, and forest use, it cannot be used to produce "cookbook" prescriptions. But STEMS can update past inventories, project future yields, and help evaluate alternatives for timber management. When combined with a forester's skills and subjective judgments, STEMS becomes a valuable management tool.

INPUT

To simulate growth and management, STEMS needs two types of information from the user: (1) a tree list representing a valid sample of a homogeneous area to be examined and (2) selections from STEMS computer options.

Tree Lists

Lists can be created for hypothetical forest stands or drawn from field inventory data cards taken from variable or fixed-radius plots. To obtain accurate growth projections, the list must be a valid representation of the plot, whether the plot represents part of a stand, all of a stand, or a group of stands.

A tree list must be in a format that STEMS can read. You either type the list in this format onto a computer file or call another computer program, TREEGEN, to arrange your list in the required format (fig. 2).

PROP/PLOT=HAWK12C   AGE= 55 SITE= 45 YEAR=1985

TREE NUMB	SPECIES	DBH	CROWN RATIO	EXPANS FACTOR	STATUS	"STEMS" SPGP	TREE CLASS
1	241.	11.2	6.0	6.5	1	8	20
2	543.	3.6	3.0	9.9	1	11	20
3	543.	7.0	3.0	6.8	1	11	20
4	543.	4.6	2.0	9.9	1	11	20
5	241.	8.7	6.0	2.2	1	8	20
6	94.	10.5	6.0	7.6	1	4	20
7	543.	8.0	3.0	2.2	1	11	20
8	543.	7.3	3.0	9.1	1	11	40
9	543.	9.9	3.0	7.6	1	11	20
10	543.	10.2	2.0	7.0	1	11	20
11	241.	9.4	7.0	8.9	1	8	20
12	543.	10.8	3.0	6.6	1	11	20
13	241.	10.2	6.0	8.1	1	8	20
14	972.	9.2	3.0	10.0	1	15	20
15	972.	11.0	3.0	7.0	1	15	20
16	12.	8.6	7.0	3.3	1	5	20
17	741.	12.1	2.0	5.4	1	25	20

Figure 2.—*Tree list for plot 12C in format used by STEMS.*

Plot data needed by STEMS include: present age, year when measured, and site index, as well as property and plot identification.

Information needed for each tree includes:

1. species code
2. d.b.h.—diameter at breast height
3. crown ratio—fraction of total tree height in live crown (optional)
4. tree expansion factor—number of trees per acre that each tree in the list represents[1]
5. tree status—live or dead
6. STEMS SPGP—species group assigned by STEMS, i.e. northern hardwood
7. tree class—acceptable, rough, short sawtimber, rotten, or wildlife.

If detailed tree information is not available, TREEGEN can generate the tree list from plot averages. For this, you specify plot species groups, number of trees per acre, and information about the distribution of trees by diameter class.

User Options

After the tree list is generated and entered into STEMS, you choose from several options that determine the characteristics of growth projection, management, and output. For example, you choose the length of your projection period by using the CYCLE and the YEAR options. The YEAR option determines the interval at which STEMS will stop to both show the growth of a plot and, if you choose, to manage the plot. The CYCLE option sets the number of these intervals. In figure 3, five output cycles of 10 years per cycle create a 50-year projection period. Two other option examples are:

1. Whether or not TABL will be used. Instructions are given for TGPS to create a standard output file to be used by TABL for producing printed detailed summaries (fig. 3, STAN). If this option is not taken, information will not be stored to run TABL.
2. Whether or not to apply management, and if so, when: before, after, in the middle of each cycle, or at year(s) you set for cutting (fig. 3, MANA).

Interactive and Batch Versions

Two versions of STEMS can be used, interactive and batch. The interactive version is typically used for modeling a few stands to prepare for a batch run or to compare the effects of different prescriptions or marking rules. This version allows you to make choices throughout the run. Here, not only are the user options initially presented, but they later reappear at the beginning of each growth cycle. You, therefore, have more than one opportunity to change these options and shape the STEMS run.

---

[1]*For variable-radius plots, the following equation is used to calculate the expansion factor;*

$$BAF/.005454n[1/D^2]$$

where: BAF = basal area factor
n = number of sample points
D = individual tree diameter

```
(CYCL)    5.  NUMBER OF OUTPUT CYCLES.
(YEAR)   10.  NUMBER OF YEARS/CYCLE.
(STAN)    1.  STANDARD OUTPUT FILE FOR PROGRAM TABL, 0=NOT USED, 1=USED
(MANA)    3.  MANAGEMENT OPTION, 1=FIRST YEAR,2=MID-POINT,3=LAST YEAR,4=USER SFT.
```

Figure 3.—*User option examples.*

The batch version is used when you want to process many plots quickly. You choose all the options before the run begins, and the plots are processed successively and continuously. Unlike the interactive version, you cannot make changes or experiment.

GROWTH PROJECTIONS

Once you enter the tree list and select the initial options, STEMS begins annually projecting the stand growth. For each tree on the list it simulates potential tree growth, tree growth modifiers, and tree mortality based on biological principles (Belcher *et al.* 1982) (fig. 4). At the end of each growth cycle, the system updates and reports plot conditions in terms of basal area, number of trees per acre, average d.b.h., and volume, as shown for plot 12C in figure 5.

STAND GROWTH = POTENTIAL TREE GROWTH + TREE GROWTH MODIFIER + TREE MORTALITY

Figure 4.—*Components in STEMS growth projections.*

Potential Tree Growth

Growth is first projected by calculating the potential growth for each tree on the list as if it were freely growing without competition from neighboring trees.

SUMMARY OF INITIAL CONDITIONS.
+++
SHORT REPORT FOR PLOT=12C YEAR= 1985 CYCLE= 0 SITE INDEX= 45 AGE= 55

SPECIES GP.	#TREES	#DEAD TREES	#CUT TREES	#LIVE TREES	#LIVE TREE/AC	BA/ ACRE	AVG DBH	VOLUME IN CUBIC FEET.
WH. SPRUCE	1	0	0	1	7.6	4.6	10.5	95.20
BALSAM FIR	1	0	0	1	3.3	1.3	8.6	22.65
N.WH.CEDAR	4	0	0	4	25.7	14.2	10.0	215.04
BLK.GR.ASH	8	0	0	8	59.1	19.3	7.3	268.15
ELM	2	0	0	2	17.0	9.2	9.9	154.87
QUAK.ASPEN	1	0	0	1	5.4	4.3	12.1	84.88
TOTAL	17	0	0	17	118.1	53.0	8.7	840.81

SUMMARY FOR END OF CYCLE.
+++
SHORT REPORT FOR PLOT=12C YEAR= 2025 CYCLE= 4 SITE INDEX= 45 AGE= 95

SPECIES GP.	#TREES	#DEAD TREES	#CUT TREES	#LIVE TREES	#LIVE TREE/AC	BA/ ACRE	AVG DBH	VOLUME IN CUBIC FEET.
WH. SPRUCE	1	0	0	1	7.6	10.9	16.2	290.85
BALSAM FIR	1	0	0	1	3.3	4.6	16.0	120.74
N.WH.CEDAR	4	1	0	3	19.2	26.9	16.0	472.44
BLK.GR.ASH	8	1	0	7	49.2	35.6	11.0	599.79
ELM	2	1	0	1	10.0	11.5	14.5	212.76
QUAK.ASPEN	1	1	0	0	0	0	0	0
TOTAL	17	4	0	13	89.3	89.5	13.1	1696.59

Figure 5.—*Reports before and after STEMS "grows" plot 12C.*

The potential diameter growth is calculated with tree crown ratio, initial d.b.h., species, and site index. Diameter is used as the basic tree measurement for growth projection because it reflects the entire tree's growth and is easily obtained.

The tree crown, as the site of photosynthesis, influences current growth. Field-measured crown ratios give the most accurate growth projections. However, if you have not measured crown ratio for your plot, STEMS will produce its own estimates of crown ratio based on d.b.h. and basal area.

Growth Modifier

To make projections realistic for trees that grow in forests and not in the open, the estimated potential growth is modified by considering each tree as a member of a plant community that shares sunlight, water, and nutrients.

A modifying factor is calculated using plot basal area, average plot diameter, and tree diameter. This factor is combined with potential growth to predict the "realized" diameter growth for each tree entry and the trees it represents.

Tree Mortality

To estimate change in a forest, both the growth and death of each tree in the plot need to be predicted. Trees usually die when they become unable to compete for sunlight, water, and nutrients. STEMS predicts this competition-related mortality. Occasionally catastrophes, including diseases, insects, and winds, cause many trees or an entire stand to die in a short time. STEMS does not predict this mortality.

The probability that a tree will die in a given year is calculated using the tree's current d.b.h. and a measure of its vigor. In the Lake States, this vigor is measured by annual diameter growth rate; and in the Central States it is measured by the basal area of trees larger than the sample tree. You have two options for assigning this mortality function to a tree: probabilistic and deterministic mortality (appendix).

TIMBER MANAGEMENT

TGPS projects tree growth and mortality for each year of the projection period. The interactive system stops at each cycle and if you decide to "manage" the plot, silvicultural prescriptions are made. Plots prescribed for harvests and thinnings are "marked" and "cut". Harvested plots are then regenerated. If you decide not to use the management option, STEMS "grows" the plot through the projection period without management (fig. 6).

Plots are "managed" with silvicultural prescriptions selected on the basis of cover type. Plot cover type is determined from the species or group of species with the greatest basal area. For each cover type, STEMS uses a management key based on silvicultural guides published by the North Central Forest Experiment Station.

STEMS uses assumptions that greatly simplify the integration of complex forest factors (i.e., soil, insects, disease, competing vegetation, and land use). For example, STEMS assumes that: trees are uniformly spaced and that shrubs and herbs are unimportant to tree growth and mortality. Other assumptions are made for each cover type. Thus STEMS management prescriptions can only be used as guidelines. Although you can manipulate prescriptions to reflect stand conditions, you will probably need to modify and adjust these prescriptions before actually applying them to your stands.

Cut prescriptions are put into "action" with marking rules. After management, STEMS produces an updated summary of the plot that includes number of live, cut, and dead trees in the plot; live trees per acre; basal area per acre; d.b.h.; and volume (fig. 7). Volume can be calculated in board feet, cords, cubic feet in saw logs, cubic feet, or biomass in cubic feet.

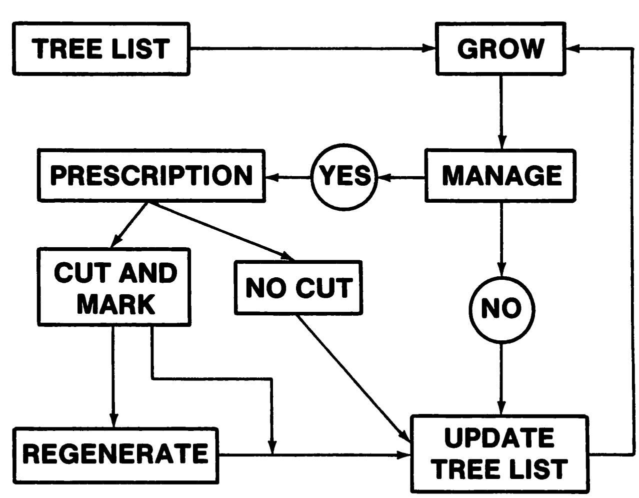


Figure 6.—*STEMS management.*

```
==== MANAGEMENT ====                                    YEAR=2025
                                                        MANAGEMENT GUIDE
COVERTYPE: B.ASH-ELM-MAPLE                              LOWLAND HDWD.
ACTION: CLEARCUT                                        SI = 45
                                                        AGE = 95
                                                        TREES/AC = 89

NUMBER OF TREES CUT=  89.3  BASAL AREA CUT=  89.5 SQUARE FEET/AC.
VOLUME CUT=    1696.6 CUBIC FEET.


PLOT CONDITIONS AFTER MANAGEMENT.
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
SHORT REPORT FOR PLOT=12C  YEAR= 2025  CYCLE=  4  SITE INDEX=  45  AGE=  0
```

SPECIES GP.	#TREES	#DEAD TREES	#CUT TREES	#LIVE TREES	#LIVE TREE/AC	BA/ ACRE	AVG DBH	VOLUME IN CUBIC FEET.
WH. SPRUCE	1	0	1	0	0	0	0	0
BALSAM FIR	1	0	1	0	0	0	0	0
N.WH.CEDAR	4	1	3	0	0	0	0	0
BLK.GR.ASH	8	1	7	0	0	0	0	0
ELM	2	1	1	0	0	0	0	0
QUAK.ASPEN	1	1	0	0	0	0	0	0
TOTAL	17	4	13	0	0	0	0	0

Figure 7.—*Update after a clearcut for plot 12C.*

Prescription Standards

STEMS makes management prescriptions for the following forest types:

Lake States

Jack pine	Tamarack
Red pine	Oak-hickory
White pine	Aspen
Spruce-fir	Paper birch
Black spruce	Lowland hardwoods
Mixed swamp conifers	Northern hardwoods
Northern white-cedar	Understocked

Central States

Elm-ash-cottonwood	Shortleaf pine
Pin oak	Northern hardwood
Oak-hickory	Eastern redcedar

The prescriptions come from management keys that are like roads with a series of intersections. At each intersection, STEMS decides which way to turn (or how to manage your plot) by comparing the plot's characteristics with values given by the management key. These values are called critical values. In figure 8, the critical values for jack pine are 60 feet for site index and 65 and 50 years for age.

To understand management-by-key, imagine you are managing this plot:

Cover Type - Lake States Lowland Hardwood
Site Index - 60
Age - 75
Basal Area - 80 square feet per acre

Without your intervention, STEMS assigns the Lake States lowland hardwood management key based on the species composition of the plot. Using this key, a prescription is obtained by first comparing

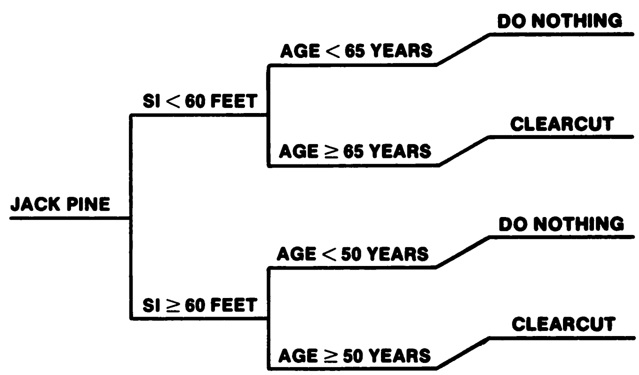


Figure 8.—*Jack pine management key.*

the plot site index of 60 with the value at the first intersection, 55 (fig. 9). Because the site index is greater than 55, the lower path is taken. Next, the plot age of 75 years is compared with the value at the next intersection, 90 years. The top route is selected because the plot age is less than 90. Finally, the plot basal area of 80 square feet per acre is less than 110, so the prescription is "do nothing".

Using the "management-by-key" method, STEMS automatically manages your plot according to its built-in prescriptions.

If you choose to "manage" the plot differently than the keys do, the interactive version of STEMS can be modified to alter its management prescriptions. You can change prescriptions in two ways:

1. Use a different key for a different cover type instead of accepting the assigned management key for your cover type, or
2. change the critical values within the assigned key. To make the key more general, the critical values are replaced with symbols that indicate they may be changed (fig.10).

As an example of this first method, suppose your plot is part of a stand that has been underplanted with spruce, and your stand objective is conifer conversion. You decide the lowland hardwood key is inappropriate. Before the management subsystem begins, you are given the option to accept the use of the lowland hardwood key or choose an alternative. In this instance you would select the spruce-fir key because it would probably give the most suitable prescription for your underplanted stand.

Consider the second method: assume that the best cover type for your plot is lowland hardwood, but you would like to see a different treatment prescribed than offered by the lowland hardwood key. For example, you would like to know how a shelterwood cut

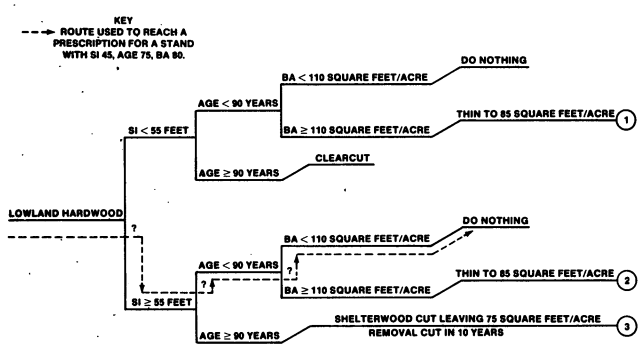


Figure 9.—*Example of how a Lake States lowland hardwood key is used by STEMS.*

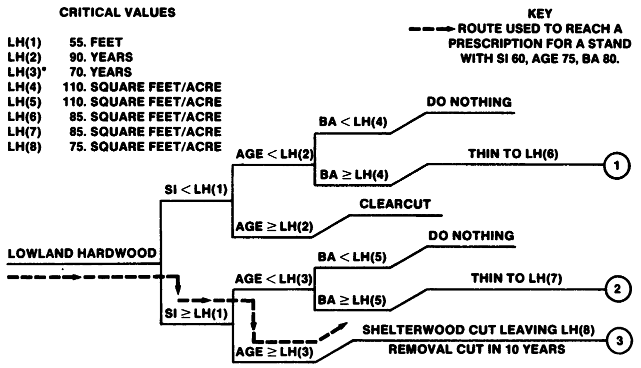


Figure 10.—*Modified Lake States lowland hardwood key.*

would affect your plot. To obtain a different prescription, you modify the Lake States lowland hardwood key (fig. 10). In this example, you could change the critical value LH(3) from 90 to 70 years. Comparing the plot site index 60 with the critical value of 55 (LH(1)), you again take the lower path. Next, the stand's age (75) is greater than 70 so this time the lower path is selected and the prescription is "shelterwood cut". This critical value is changed with an option that asks the user if critical values are to be changed and what the changes are (fig. 11).

Because of the ability to change critical values, many other lowland hardwood prescriptions can be produced with this key. Flexibility, however, is limited because the structure of these keys cannot be changed. This means intersections are not added and other stand characteristics cannot be substituted. For instance, if a Lake States lowland hardwood silvicultural guideline recommends different prescriptions for three ranges of site index, this key in figure 10 cannot be used. Neither can a guideline be used that makes a prescription based on average diameter. In these cases, a new key must be constructed and programmed from the silvicultural guidelines.

Marking

When a cut is prescribed for a plot, STEMS "marks" and "cuts" the trees. For a clearcut prescription, all trees are cut. For thinnings and shelterwood cuts, STEMS simulates marking rules. Unlike the critical values, the marking rules cannot be changed during the STEMS interactive version run. However, with minimal programming ability, they can be changed before the run begins.

For each management key, different marking rules rank trees to be cut. One example of marking rules for thinning a Lake States lowland hardwood stand is to mark in the following order:

(1) low-quality trees,

```
THE CURRENT CRITICAL VALUES ARE:
INDEX     1        2        3        4        5        6        7        8
VALUE    55.0     90.0     90.0    100.0    110.0    85.00    85.00    75.00


ENTER THE INDEX AND VALUE FOR THE CRITICAL VALUE WHICH YOU WISH TO CHANGE.
PRESS (CR) WHEN ALL THE CHANGES ARE MADE.

ENTER INDEX AND VALUE:

? 3 70


THE CURRENT CRITICAL VALUES ARE:
INDEX     1        2        3        4        5        6        7        8
VALUE    55.0     90.0     70.0    100.0    110.0    85.00    85.00    75.00
```

Figure 11.—*Changing critical values for management.*

(2) elms from above (with the largest diameters cut first),
(3) specified undesirable species from below (cut the smallest diameter trees first),
(4) specified desirable species from below.

These rules follow in order until the cutting limit, set by the prescription, is obtained. If the prescription was to thin to 90 BA and this limit was obtained after going through step 1 and halfway into step 2, the remainder of the marking rule steps would not be used.

The Lake States management keys, their objectives and assumptions; marking rules; and further STEMS timber management information can be found in *Simulating Timber Management in Lake State Forests*, Brand (1981). For Central States management information, contact the North Central Forest Experiment Station.

REGENERATION

STEMS simulates regeneration that occurs immediately after a plot has been cut. The system does not consider regeneration that grows under a stand each year or that fills in openings created by natural death or thinnings. These types of regeneration will be incorporated into STEMS in the future.

A cut is regenerated by STEMS when it places new trees on a tree list. This happens after TGPS has made a clearcut, shelterwood cut, or strip clearcut. By default, the age at which the regenerated plot enters the growth projection program is 15 years, but you can change this to any age.

The regenerated plot is characterized by the following critical values: species group, number of trees per acre, average d.b.h., and standard deviation (fig. 12). You can supply these regeneration values or, for most species, STEMS will use its default values.

Default values are based on a series of regeneration plots located in Lake and Central States national forests. Because the STEMS regeneration data base is not extensive, these values are only starting points. From them, STEMS will provide a general picture of the type of stand that will come back after a harvest. If you have a better idea of your plot's characteristics, you can enter them in lieu of STEMS's default values.

The default characteristics of the regenerated plot are based on the cover type of the harvested plot, the type of cut used, and cover type characteristics that include basal area and site index. In figure 13, the

```
THE REGENERATION CRITICAL VALUES SELECTED ARE:     NUMBER OF SPECIES GROUPS= 2
SP.GP.#   #TREES/AC   AVG DBH   STD.DEV.
   5.       800.0       2.0        .2
   4.       400.0       1.0        .1


PRESS (CR) TO ACCEPT THESE VALUES OR 1 TO RE-ENTER THEM.
```

Figure 12.—*Regeneration critical values.*

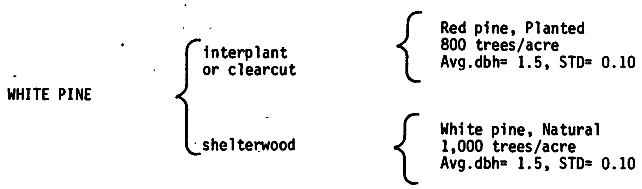


Figure 13.—*White pine regeneration as determined by previous management.*

white pine regeneration values are determined by previous management. If the plot had been interplanted or clearcut, a red pine plantation would result with 800 trees/acre and an average d.b.h. of 1.5 inches at 15 years of age. Had the plot been shelterwood cut, the regenerated plot would be a 15-year-old natural white pine plot with 1,000 trees per acre and an average d.b.h. of 1.5 inches.

OUTPUT

The output from STEMS summarizes growth projections, management, and regeneration in written tables. Summaries can be obtained from both TGPS and TABL. In the interactive version, brief TGPS summaries, produced at the beginning of each growth cycle, report stand conditions and volume for the plot (figs. 5 and 14). After STEMS presents the summary tables, you can change the user options such as the number and length of growth cycles, when to manage, and units for volume(fig. 3). When the batch version is used, however, no output is produced by TGPS and changes cannot be made.

TABL is only one of many ways STEMS can be used to summarize data. It is offered as a default summary program or a place to start when designing a summary program. TABL was made separate from

SHORT REPORT FOR PLOT= 12C YEAR=1985 CYCLE= 1 COVERTYPE= 71
MANAGEMENT GUIDE= 0 SITE INDEX= 45 AGE=55

SPECIES GP.	#TREES	#DEAD TREES	#CUT TREES	#LIVE TREES	#LIVE TREE/AC	BA/ ACRE	AVG DBH	VOLUME IN CUBIC FEET.
WH. SPRUCE	1	0	0	1	7.6	4.6	10.5	95.20
BALSAM FIR	1	0	0	1	3.3	1.3	8.6	23.53
N.WH.CEDAR	4	0	0	4	25.7	14.2	10.0	215.04
BLK.GR.ASH	8	0	0	8	59.1	19.3	7.3	268.15
ELM	2	0	0	2	17.0	9.2	9.9	148.95
QUAK.ASPEN	1	0	0	1	5.4	4.3	12.1	84.88
TOTAL	17	0	0	17	118.1	53.0	8.7	835.76

NUMBER OF LIVE TREES/AC BY DIAMETER CLASS.

	0---2	---4	---6	---8	---10	---12	---14	---16	---18	---20	---22	---24
WH.SPRUCE	0.	0.	0.	0.	0.	8.	0.	0.	0.	0.	0.	0.
BALSAM FIR	0.	0.	0.	0.	3.	0.	0.	0.	0.	0.	0.	0.
N.WH.CEDAR	0.	0.	0.	0.	11.	15.	0.	0.	0.	0.	0.	0.
BLK.GR.ASH	0.	10.	10.	16.	10.	14.	0.	0.	0.	0.	0.	0.
ELM	0.	0.	0.	0.	10.	7.	0.	0.	0.	0.	0.	0.
QUAK.ASPEN	0.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.	0.
TOTAL	0.	10.	10.	16.	34.	43.	5.	0.	0.	0.	0.	0.

VOLUME OF LIVE TREES/AC BY DIAMETER CLASS.

	0---2	---4	---6	---8	---10	---12	---14	---16	---18	---20	---22	---24
WH.SPRUCE	0.	0.	0.	0.	0.	95.	0.	0.	0.	0.	0.	0.
BALSAM FIR	0.	0.	0.	0.	24.	0.	0.	0.	0.	0.	0.	0.
N.WH.CEDAR	0.	0.	0.	0.	76.	139.	0.	0.	0.	0.	0.	0.
BLK.GR.ASH	0.	0.	0.	32.	86.	150.	0.	0.	0.	0.	0.	0.
ELM	0.	0.	0.	0.	72.	77.	0.	0.	0.	0.	0.	0.
QUAK.ASPEN	0.	0.	0.	0.	0.	0.	85.	0.	0.	0.	0.	0.
TOTAL	0.	0.	0.	32.	258.	461.	85.	0.	0.	0.	0.	0.

Figure 14.—*Brief TGPS summary.*

TGPS so, with some background in computer programming, you can create your own summary FORTRAN program and use it with STEMS. This is done with a "dummy" routine called OUTUR (Belcher 1981). For example, you can program OUTUR to produce a graphics plot of diameter distribution of northern hardwoods at 10-year intervals.

TABL makes final, detailed summaries of STEMS runs in both the interactive and batch versions. With user options, presented initially in the TABL run, you decide the type of table STEMS will produce. You can choose any or all of the following four types of tables (fig. 15):

1.—Single plot summaries for one growth cycle
2.—Single plot summaries for all growth cycles
3.—Cycle summaries for all plots and one cycle
4.—Grand summaries for all plots and all cycles

Two of the options you specify in formulating TABL are diameter class limits and units of volume i.e., no volume, biomass in cubic feet, cubic feet, board feet, cubic feet in saw logs, and cords.

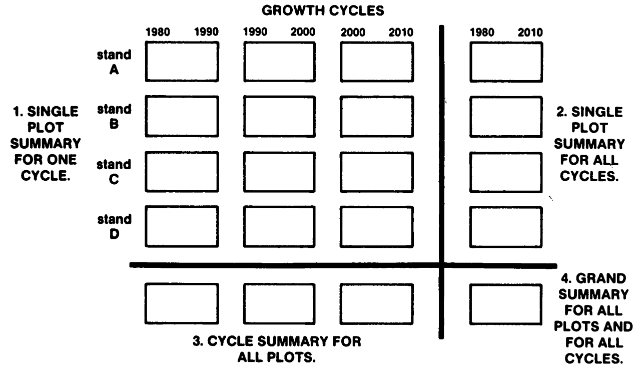


Figure 15.—*Four types of TABL summaries.*

Each TABL summary is divided into three sections (fig. 16) The first section identifies the plot and provides information such as cover type, initial age, site index, current age, and average stand diameter. The second section categorizes the number of trees per acre and basal area of the stand into species groups and user-specified diameter class. The final section shows volume of growth components. This summarizes initial volume, growth that remained in

```
                                                                  PROPERTY          HAWK   PLOT  12C
  1. PLOT SUMMARY TABLE FOR CYCLE  2 OF    4
COVERTYPE        B.ASH-ELM-MA    PLOT SITE INDEX                  45       PLOT AREA EXPANSION FACTOR   1.
INITIAL YEAR             2005    CURRENT YEAR                   2025       ALL VALUES ARE ON A PER ACRE BASIS.
INITIAL AGE                75    CURRENT AGE                      95       ALL VOLUMES ARE IN CORDS(79 CU.FT.)
PROBABILISTIC MORTALITY USED.    AVERAGE STAND DIAMETER (INCHES)  13.1     INGROWTH DIAMETER: TREES AND BA= 5.0 INCHES.
MEAN ANNUAL INCREMENT ***** CORDS(79 CU.FT.) PER ACRE PER YEAR.
                                                                           INGROWTH DIAMETER: VOLUMES     = 5.0 INCHES.
MANAGEMENT ACTION IN YEAR 2005 WAS: DO NOTHING
```

2. NUMBER OF TREES AND BASAL AREA INFORMATION.

SPECIES GROUP	DIAMETER CLASS	...INITIAL.. TREES	BA	...NON-ING... TREES	BA	..INGROWTH.. TREES	BA	..MORTALITY. TREES	BA	..REMOVALS.. TREES	BA	...CURRENT.. TREES	BA	GROWTH (BA)
WH. SPRUCE	0.0- 5.0	0	0	0	0	0	0	0	0	0	0	0	0	
	5.0-11.0	0	0	0	0	0	0	0	0	0	0	0	0	
	11.0- +	8.	8.0	8.	10.9	0	0	0	0	0	0	8.	10.9	2.9
	TOTAL	8.	8.0	8.	10.9	0	0	0	0	0	0	8.	10.9	2.9

##

3. VOLUME BY COMPONENTS OF GROWTH. CORDS(79 CU.FT.)

SPECIES GROUP	DIAMETER CLASS	INITIAL VOLUME	GROWTH ON NON-ING	INGROWTH	GROWTH ON INGROWTH	OTHER GROWTH	GROSS GROWTH	MORTALITY	NET GROWTH	REMOVALS	NET INC. INVENTORY	CURRENT VOLUME
WH. SPRUCE	0.0- 5.0	0	0	0	0	0	0	0	0	0	0	0
	5.0-11.0	0	0	0	0	0	0	0	0	0	0	0
	11.0- +	3408.2	6.3	0	0	0	6.3	0	6.3	0	6.3	3414.5
	TOTAL	3408.2	6.3	0	0	0	6.3	0	6.3	0	6.3	3414.5

Figure 16.—*Three sections of TABL cycle summary for one species of plot 12C.*

one diameter class (NON-ING), growth from one diameter class to another in the period represented by the table (INGROWTH), other growth, gross growth, mortality, net growth, removals, net increase in inventory, and current volume.

APPLICATIONS

As a mainframe computer system, STEMS has the capacity to evaluate large numbers of plots successively; therefore, statewide and regionwide analyses can be quickly made at reasonable costs. The system's flexibility allows you to tailor output to fit your needs. STEMS is used for forest planning, management, education, and research.

For example, natural resource planning in Wisconsin by State and regional public agencies, as well as by private companies and organizations, has been done on the basis of a 1980 Wisconsin timber update that implemented STEMS. This inventory was conducted by foresters at the North Central Forest Experiment Station who first used aerial photographs to determine if permanent plots had or had not been disturbed since the last inventory in 1968. Then, on the basis of the 1968 inventory, STEMS updated the forest growth on the undisturbed plots while field crews inventoried the disturbed plots.

Similar inventories have been done for national, state, and private industry forests in the Lake States. One timber company uses STEMS data to help calculate yearly capital gains during years when field inventories are not conducted and to analyze alternative management schemes for long-range planning.

The management routine's wide range of alternatives, combined with the growth routine, allows planners to compare future stands shaped by different silvicultural treatments. Timber yields can be predicted with management at various intensities or without management.

In addition to being a planning and management tool, STEMS provides realistic and dynamic means for educators to teach forest growth and management to students. Also, researchers can use STEMS to simulate forest growth experiments, many of which would be impractical or impossible to conduct in the field.

SUMMARY

As a growth and yield model, STEMS simulates tree growth annually. Plot growth is based on potential tree growth, a growth modifier, and mortality. A management routine selects plot prescriptions based on cover type and silvicultural guides. Plots are "marked" for cut prescriptions; and after harvest cuts, plots are "regenerated".

The STEMS user supplies the system with a tree list representing an actual or hypothetical plot. He or she chooses options that tailor the STEMS run. STEMS output is used to update forest inventories, project yields, and evaluate silvicultural responses to alternative prescriptions. The system is a valuable tool for forest planning, management, education, and research.

LITERATURE CITED

Belcher, David M. The user's guide to STEMS (Stand and Tree Evaluation and Modeling System). Gen. Tech. Rep. NC-70. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981. 49 p.

Belcher, D. M.; Holdaway, M. R.; Brand, G. J. A description of STEMS—the Stand and Tree Evaluation and Modeling System. Gen. Tech. Rep. NC-79. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1982. 18 p.

Brand, Gary J. Simulating timber management in Lake States forests. Gen. Tech. Rep. NC-69. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981. 25 p.

APPENDIX

MORTALITY

Probabilistic (Lumpy) Mortality: A tree and all trees per acre it represents live or die as a group. (Lumps of mortality occur periodically (fig. 17)).

Deterministic (Smooth) Mortality: A tree's per acre expansion factor is annually reduced in proportion to the mortality rate. (Small amounts of mortality occur annually, smoothing out stand growth over time (fig. 17)).

Example: Consider the situation where a tree list includes a tree with a 7 inch d.b.h. and a per acre expansion factor of 10 (i.e., it represents ten 7-inch trees per acre). If the probability of mortality for the tree was 0.10 in a given year, then:

A. With probabilistic mortality, there is a 1 in 10 chance that all ten 7-inch d.b.h. trees will die that year. If the 1 in 10 chance occurs, all 10 trees per acre are classified as dead for that year (fig. 18).

B. With deterministic mortality, the tree expansion factor is reduced to 90 percent of its original value. There would be nine 7-inch live trees and one 7-inch dead tree (fig. 18).

Probabilistic vs. Deterministic Mortality

Because probabilistic mortality uses fewer calculations, it costs less to use than deterministic mortality. When the probabilistic mortality method "kills" trees in lumps, growth computations for the remaining projection period are unnecessary for the 'dead' tree list entry. When deterministic mortality is applied, however, each tree on the list is retained, and the tree expansion factor is diminished by fractions.

For small amounts of data, deterministic mortality better imitates nature by its smooth reduction of growth than does probabilistic mortality. For large amounts of data, however, with many plots and long projection periods, such as found in statewide inventories, the "lumpiness" of probabilistic mortality is averaged, resulting in a realistic mortality prediction.

AFTERWORD

STEMS is continually being refined and expanded to better simulate the natural world and to meet its users' needs. One expansion is a microcomputer version, TWIGS. This program, unlike STEMS, cannot evaluate the growth and management of many stands successively. TWIGS, however, is ideal for stand by stand analyses. It also examines the costs and revenues of stand management.

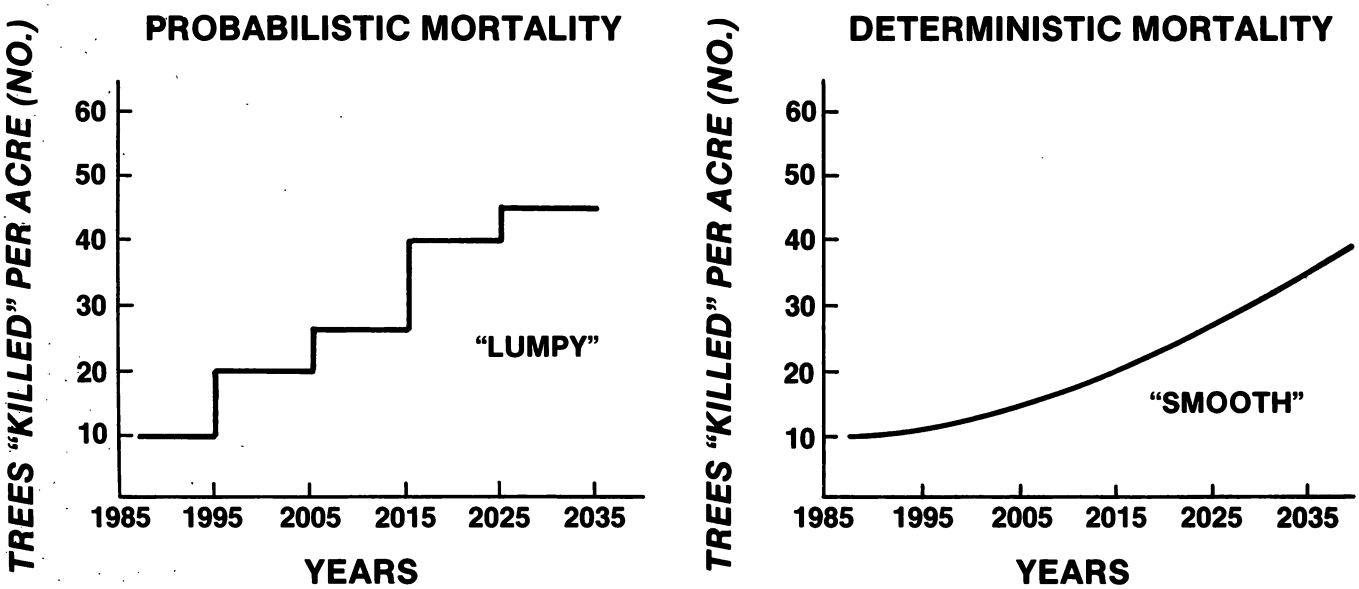


Figure 17.—*"Lumpy" and "smooth" mortality.*

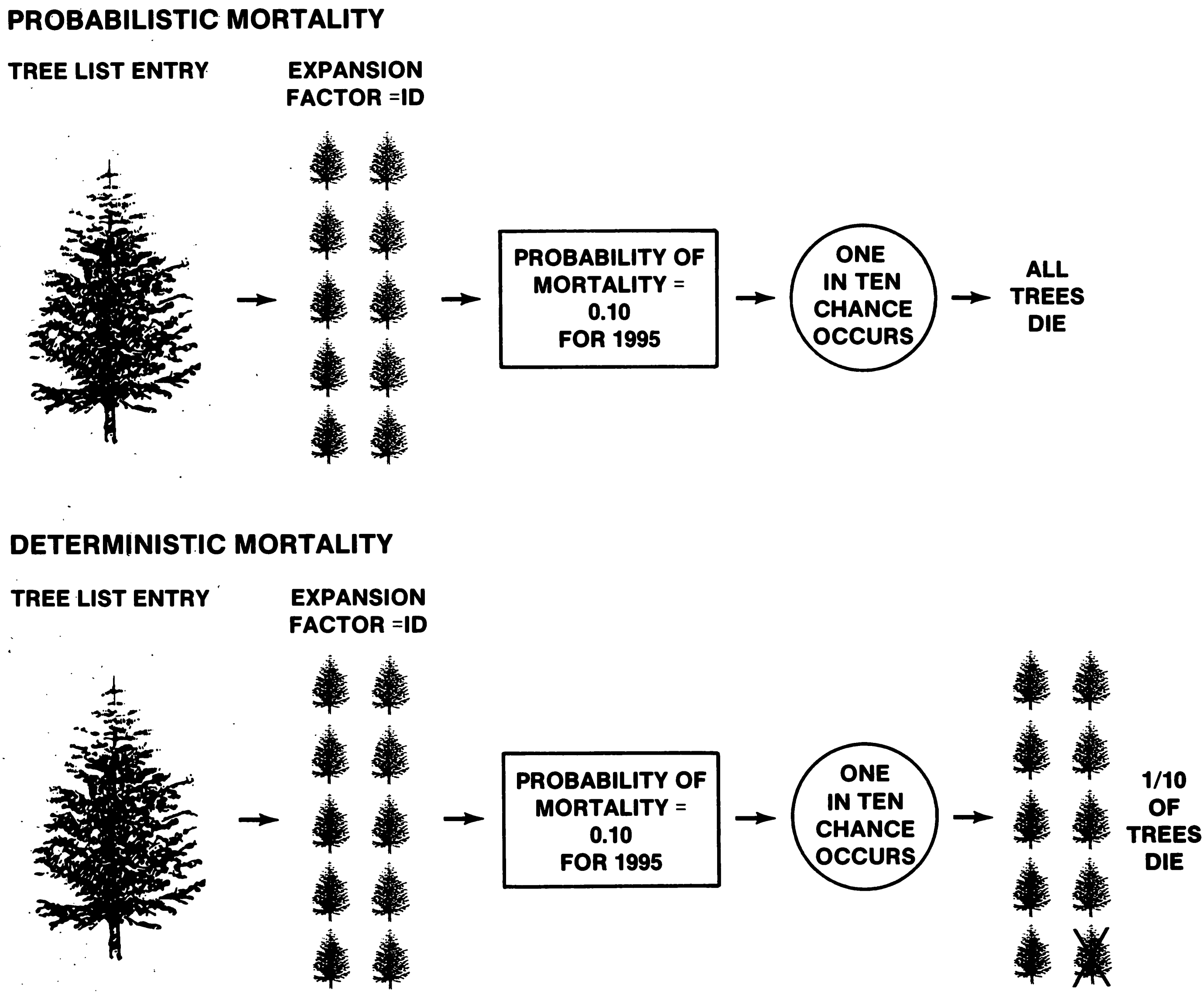


Figure 18.—*Example of probabilistic and deterministic mortality.*

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984—767-147/10063

Miner, Cynthia L.; Walters, Nancy R.
STEMS: A nontechnical description for foresters. Res. Pap. NC-252. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1984. 12 p.

Explains how STEMS simulates tree growth, mortality, management, and regeneration. Discusses input—including user options and tree lists—output, and applications.

KEY WORDS: Simulation, growth projections, forest modeling, timber management, FORTRAN, individual tree.