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# Planning with PSME: A Growth Model for Young Douglas-fir and Hardwood Stands in Southwestern Oregon

Timothy B. Harrington  
John C. Tappeiner II  
Thomas F. Hughes  
Arlene S. Hester

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Planning with PSME

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# Introduction

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In southwestern Oregon, growth of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*] has been shown to be inversely related to the level of associated hardwood cover (Hughes *et al.* 1990, Harrington *et al.*, in press). Because the stocking and size of tanoak [*Lithocarpus densiflorus* (Hook. and Arn.) Rehd.] or Pacific madrone (*Arbutus menziesii* Pursh) in a pre-harvest stand determine their post-harvest rates of cover development, future levels of hardwood competition can be estimated for planted Douglas-fir (Tappeiner *et al.* 1984). Such information may be used to set priorities and schedules for vegetation management of Douglas-fir plantations.

Computerized growth models have proved to be powerful and flexible tools for forecasting the development of young forest stands under different types of competition. In the Pacific Northwest, simulators of individual-tree growth of young conifers are being developed (Powers *et al.* 1989, Opalach *et al.* 1990) with the objective of providing stand-table information for input into older stand models such as DFSIM and ORGANON.

The computer model presented here was developed to provide a simple technique for predicting and comparing general stand characteristics of plantation-grown Douglas-fir under various levels of hardwood competition. Plantation Simulator-Mixed Evergreen (PSME), Version 1.0, provides estimates of 10-year development of stands composed of Douglas-fir seedlings growing with a hardwood species (tanoak, Pacific madrone, or chinkapin [*Castanopsis chrysophylla* (Dougl.) A. DC.] and understory vegeta-

tion (herbs and shrubs). PSME is based on data from three studies in the Forestry Intensified Research (FIR) program in which tanoak or madrone crown coverage in 2-, 3-, or 4-year-old Douglas-fir plantations was reduced to different levels with herbicides, and subsequent growth responses of the stands from 1983 to 1989 were monitored (Hughes *et al.* 1990, Harrington *et al.*, in press). The competitive effects of chinkapin cover on Douglas-fir growth were not evaluated, but because chinkapin is similar to tanoak in canopy structure and growth form, it is assumed here to have the same rate of cover growth and same competitive effect on Douglas-fir growth.

PSME requires values for either pre-harvest basal area and stem density or post-harvest (*i.e.*, sprout-origin) cover of the dominant hardwood species associated with planted Douglas-fir. The model also requires values for total herb and shrub cover and for the average height, stem diameter, crown width, and density of Douglas-fir seedlings. The output is an estimation of average stand parameters for ages 3 to 10 years and of Douglas-fir height and stem diameter distributions at 10 years, along with graphic displays of height, cover, and Douglas-fir diameter plotted against stand age. The model automatically writes parameter predictions to two files: 1) a text file that provides a visual record of model simulations, and 2) a computer-readable ASCII file that facilitates using the model predictions as input for other Douglas-fir growth simulators.

The BASIC computer code is not included in this user manual, but model users have access to the code from the computer disk that is included.

## Model Behavior and Guidelines

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Appropriate use of PSME to predict development of young stands requires an understanding of the principles upon which the model is based. This section discusses basic aspects of the model behavior and provides general guidelines.

### Prediction of Development of Young Stands

Because current-year growth of Douglas-fir is inversely related to the amount of hardwood cover in the previous year (see the section "Douglas-fir Param-

eters," p. 4), the rate at which hardwood cover develops is a principal factor affecting the Douglas-fir growth trajectory. We recommend that three or more simulations of PSME be run for each Douglas-fir plantation that is being considered for a vegetation-management treatment. For example, current values for initial hardwood parameters (*i.e.*, pre-harvest or post-harvest variables) could be varied by 0, 50, and 100 percent so that differences in the predicted 10-year sizes and size distributions of Douglas-fir can be evaluated. In each series of simulations, the potential for hardwood recovery should be varied according to the amount expected 1 year after a given treatment.

In PSME simulations, high pre-harvest values for hardwood stem density produce larger values for 3rd-year hardwood cover than do high values for basal area (Figure 1), although maximum values for 3rd-year hardwood cover occur when both stem density and basal area are high. From a given level of 3rd-year hardwood cover, PSME predicts that tanoak (or chinkapin) has more rapid cover development than madrone (Figure 2), which may explain its greater competitive effect on Douglas-fir growth (Harrington *et al.*, in press).

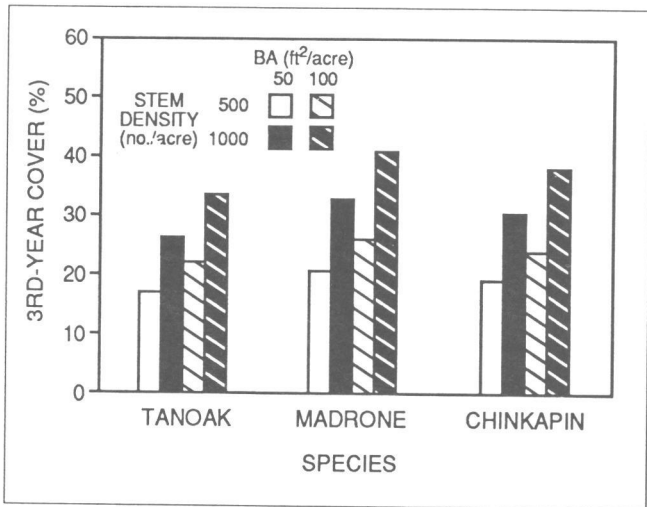


Figure 1. Cover of 3-year-old stands of tanoak, madrone, and chinkapin predicted with pre-harvest basal area (BA) at 50 and 100 ft² per acre and with stem density at 500 and 1,000 stems per acre.

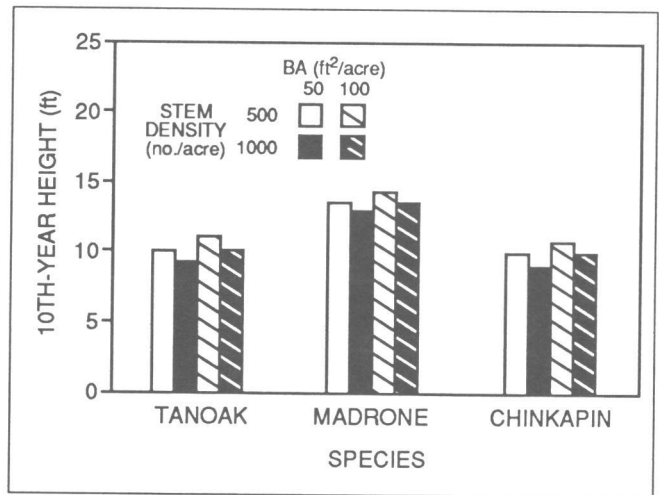


Figure 3. Height of 10-year-old stands of tanoak, madrone, and chinkapin predicted with pre-harvest basal area (BA) at 50 and 100 ft² per acre and with stem density at 500 and 1,000 stems per acre.

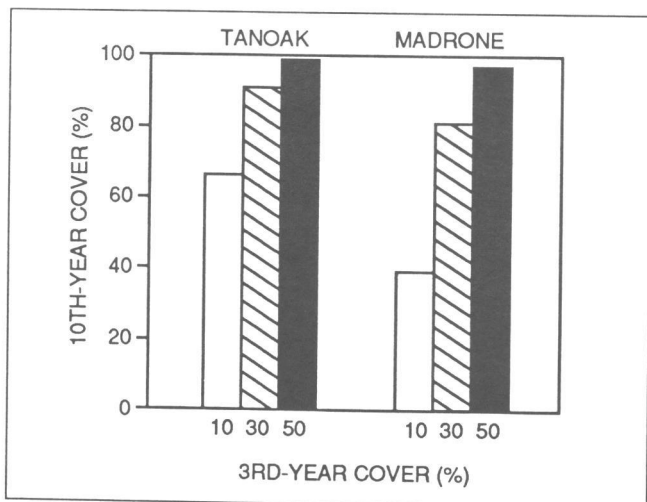


Figure 2. Cover of 10-year-old stands of tanoak and madrone predicted with 10-percent, 30-percent, and 50-percent cover in the 3rd year.

Post-harvest height development of hardwood sprout clumps is directly related to the size of the parent tree before harvest (Tappeiner *et al.* 1984). However, PSME simulations show that varying the pre-harvest hardwood basal area (50 or 100 ft²/acre) and stem density (500 or 1,000 stems/acre) results in only minor differences in average height 10 years after harvest (Figure 3). The average height of madrone is almost 40 percent greater than that predicted for tanoak or chinkapin.

In PSME, the predicted average growth of Douglas-fir in the current year is proportional to the average size in the previous year; thus the predicted growth trajectories for stands having different average sizes will diverge with time.

PSME predicts that hardwood cover limits herb and shrub cover such that they reach maximum development in the model when hardwood cover is zero. Large increases in Douglas-fir growth are predicted after the removal of hardwoods, especially when herbs and shrubs are suppressed. If hardwoods are not removed, suppression of herbs and shrubs does not affect the prediction of Douglas-fir growth.

The following are general guidelines to be considered when making estimations of young stand development with PSME:

- For rough estimates of the effect of manual cutting of hardwoods or of other treatments on the growth of associated Douglas-fir, a stand should

be inventoried one growing season after treatment (see the section "Data Collection," p. 5 ).

- Effective site preparation and planting of large Douglas-fir stock can produce larger seedlings at later stand-age (Iverson and Newton 1980, Howard and Newton 1984) and should be considered when planning with PSME because the average size of the seedlings strongly influences their growth trajectory.
- Pre-harvest stands with high hardwood stem density or high stem density and basal area will have rapid development of cover after harvest that will be highly competitive with associated Douglas-fir seedlings.
- Because of a more rapid rate of cover development and higher leaf-area index (Harrington *et al.* 1984), stands dominated by tanoak, and perhaps chinkapin, should have higher priority for vegetation management treatment than stands dominated by madrone.
- Average height development of hardwoods is not strongly influenced by pre-harvest levels of basal area and stem density (Figure 3), but height development of individual hardwood sprout clumps is directly related to parent-tree size (Tappeiner *et al.* 1984); thus, large hardwood trees should be noted before harvest so that the planting arrangement and subsequent management of individual Douglas-fir seedlings can be adjusted.
- Herb and shrub cover reaches its maximum after hardwood removal and can have substantial competitive effect on Douglas-fir growth; therefore, treatments for minimizing hardwood cover should be accompanied by subsequent control of herbs and shrub to be most effective.
- Suppression of herbs and shrub probably will not increase Douglas-fir growth if a significant amount of hardwood cover remains.

## Description of Growth Equations

The following is a brief description of the equations used for predicting the stand-growth parameters. Derivations for some of the equations and associated values for the regression coefficients are given in Harrington *et al.* (in press).

## Hardwood parameters

When pre-harvest basal area and stem-density are entered in PSME, plantation age is initialized at 3 years, and 3rd-year cover is estimated with the following equations.

The mean basal area per single- or multi-stemmed hardwood tree is calculated as:

$$AVGBA = BA + (n + STEMNOB_0)$$

where

AVGBA = average basal area (ft<sup>2</sup>) at breast height (4.5 ft) per single- or multi-stemmed tree,

BA = hardwood stand basal area (ft<sup>2</sup>/acre),

$n$  = hardwood stem density (no. stems/acre), and

STEMNOB<sub>0</sub><sub>*i*</sub> = stem number: the average number of stems of dbh ≥ 1 inch per tree (single or multi-stemmed) for hardwood species *i*.

The following values for STEMNOB<sub>0</sub><sub>*i*</sub> were determined from a random sample of sprout clumps in which parent-tree stumps were counted only if their estimated dbh was ≥ 1 inch (T.B. Harrington and J.C. Tappeiner, unpublished data):

tanoak      1.5975       $n = 236$

madrone    1.3263       $n = 95$

chinkapin   1.2857       $n = 35$

The crown width of a 3-year-old sprout clump originating from a hardwood tree having the determined mean basal area is calculated with the model form (T.B. Harrington and J.C. Tappeiner, unpublished data):

$$CW_3 = b_0 * AVGBA^{b_1} * AGE^{b_2}$$

where

CW<sub>3</sub> = predicted crown width (ft) of the mean sprout clump at age 3 years,

$b_0, b_1, b_2$  = regression coefficients, and

AGE = 3 years after parent trees are burned or cut.

The crown width of the mean sprout clump is converted to the percentage of cover per acre that it would represent, and this value is multiplied by the number of hardwood trees per acre ( $n + STEMNOB_0$ ) to produce an estimate of 3rd-year cover.

Hardwood height is predicted as:

$$HT_t = b_0 * AVGBA^{b_1} * AGE^{b_2}$$

where

$HT_t$  = predicted height (ft) of the mean sprout clump at age  $t$ .

If post-harvest cover is entered in PSME, hardwood height is predicted with these values for AVGBA (ft<sup>2</sup>) (T.B. Harrington and J.C. Tappeiner, unpublished data):

tanoak	0.2452	$n = 513$
madrone	0.4974	$n = 341$
chinkapin	0.1801	$n = 54$

Increment in hardwood cover is predicted with an equation derived from a monomolecular model form (Harrington *et al.*, in press). This model assumes that the intrinsic rate of hardwood cover growth,  $k = [b_0 + b_1 * (PCOVER_{t-1})^2]$ , increases linearly with the square of previous-year cover:

$$COVG_t = [b_0 + b_1 * (PCOVER_{t-1})^2] * (100 - PCOVER_{t-1})$$

where

$COVG_t$  = increment in hardwood cover at age  $t$ , and

$PCOVER_{t-1}$  = predicted hardwood cover at age  $t-1$ .

## Herb + shrub parameters

Increment in herb and shrub cover is predicted with a model form similar to that for hardwood cover. This model assumes that the intrinsic rate of growth of the herb + shrub cover,  $k = [b_0 - b_1 * (PCOVER_{t-1})]$ , declines linearly with increasing amounts of previous-year hardwood cover:

$$COVG_{h,t} = [b_0 - b_1 * (PCOVER_{t-1})] * (100 - PCOVER_{h,t-1})$$

where

$COVG_{h,t}$  = increment in herb + shrub cover at age  $t$ , and

$PCOVER_{h,t-1}$  = predicted herb + shrub cover at age  $t-1$ .

## Douglas-fir parameters

Douglas-fir parameters are predicted by means of a modified exponential function that is the product

of two types of equations. The first type—see equations [1a] and [2a]—defines potential growth as a constant or gradually declining proportion of previous-year tree size, *i.e.*, Douglas-fir trees are approaching exponential rates of growth. In the absence of competition (hardwood cover 0% and herbs + shrubs suppressed), models [1] and [2] predict that Douglas-fir growth will equal potential growth, *i.e.*, equations [1b] or [2b] = 1.

$$G_t = [a * PG_{avg,i} + b * (SIZE_{t-1})] \quad [1]a$$

$$* \exp(-c * PCOVER_{t-1} - d * HERB) \quad b$$

$$G_t = [a * PG_{avg,i} * (SIZE_{t-1})^b] \quad [2]a$$

$$* \exp(-c * PCOVER_{t-1} - d * HERB) \quad b$$

where

$G_t$  = increment in Douglas-fir size at age  $t$ ,

$a, b, c, d$  = regression coefficients,

$PG_{avg,i}$  = the average annual rate of growth for a Douglas-fir parameter in the absence of competing vegetation at site  $i$ ,

$SIZE_{t-1}$  = Douglas-fir size at age  $t-1$ , and

$HERB$  = the indicator variable for herb + shrub suppression. (If hardwood cover = 0% and herbs + shrubs are not suppressed,  $HERB = 1$ ; otherwise,  $HERB = 0$ .)

Model form [1] was found to be the best descriptor of height growth (Harrington *et al.*, in press). In the development of diameter-growth and cover-growth models, the potential growth function given in [2a] was the best descriptor. PSME predicts increment in diameter squared with model form [2], and then converts cumulative values of diameter squared to diameter. For predicting Douglas-fir cover development, PSME converts values for density and average crown width into initial percentage values for cover per acre.

When the indicator variable,  $HERB$ , denotes 0-percent hardwood cover and no suppression of herb + shrub vegetation, herb + shrub cover reaches maximum development and competitive effect (Hughes *et al.* 1990, Harrington *et al.*, in press). Increases in Douglas-fir growth after suppression of herbs and shrubs were detected only in the absence of hardwoods (Harrington *et al.*, in press).

Weibull functions were used to predict the proportion of Douglas-fir saplings represented in each of six size classes for height and stem diameter. In the research upon which PSME was based, hardwood competition was found to cause positive skewing in size distributions of Douglas-fir (Harrington *et al.*, in press).

## Data Collection

### Pre-harvest data

Measurements of hardwood basal area and stem density that are to be used as input for PSME can be taken during pre-harvest timber cruises or stand examinations. We suggest using either variable-radius or fixed-area plots for estimating hardwood basal area and stem density.

Since tanoak, Pacific madrone, and chinkapin are often multi-stemmed, PSME contains for each species the value STEMNOBO (average number of stems per tree) for estimating hardwood stem density (see the section "Hardwood Parameters," p. 3). This enables the user to inventory only the number of stems per plot rather than the number of stems per tree in each plot. The latter count may be used to make predictions from pre-harvest variables more site-specific (see the section "Modification: Hardwood Constants," p. 10).

The following instructions are based on the principles of variable-plot sampling that are described in detail by Bell and Dilworth (1989).

1) Use a wedge prism with a small (10-15) basal-area factor (BAF) to determine which stems are to be included in the given variable-radius plot. With the prism located immediately over the sample point, sight each surrounding hardwood stem through the prism at breast height (4.5 ft), starting from a northerly direction. Count a given stem if the two images it produces overlap or touch.

2) Because PSME simulates stand development with only one hardwood species—tanoak, Pacific madrone, or chinkapin—determine which species occupies more than 66 percent of the hardwood basal area in a given stand. Group stem counts from the variable-plot (prism) sample by species.

3) Measure the diameter at breast height (4.5 ft) of each counted stem to the nearest inch.

4) When a representative number of sample points have been measured in this way for a given

site, perform the following calculations to determine hardwood basal area:

$$\bar{n}_i = (\sum \text{COUNT}_{i,j})/N$$

$$\bar{n}_{all} = (\sum \text{COUNT}_{all,j})/N$$

$$\text{BA}_i = \text{BAF} \times \bar{n}_i$$

$$\text{BA}_{all} = \text{BAF} \times \bar{n}_{all}$$

$$\text{BA}\%_i = 100\% \times \text{BA}_i/\text{BA}_{all}$$

where

$\bar{n}_i$  = average number of stems counted for species  $i$ ,

$\text{COUNT}_{i,j}$  = number of stems of species  $i$  counted at sample point  $j$ ,

$N$  = number of sample points,

$\bar{n}_{all}$  = average number of hardwood stems counted for all species,

$\text{COUNT}_{all,j}$  = number of hardwood stems counted at sample point  $j$ ,

$\text{BA}_i$  = basal area (ft<sup>2</sup>/acre) of species  $i$ ,

$\text{BA}_{all}$  = total basal area (ft<sup>2</sup>/acre) of hardwoods, and

$\text{BA}\%_i$  = percentage of the hardwood basal area in species  $i$ .

5) Determine which species occupies more than 66 percent of the total hardwood basal area. For PSME, assume that  $\text{BA}_{all}$  is the estimated basal area for the dominant hardwood species.

6) Perform the following calculations to determine stem density for the dominant hardwood species.

$$\bar{n}_k = (\sum \text{COUNT}_{k,j})/N$$

$$\text{STF}_k = \text{BAF} / \{\pi * [k/(2 \times 12)]^2\}$$

$$n_k = \bar{n}_k * \text{STF}_k$$

$$n_{total} = \sum n_k$$

where

$k$  = an integer value for dbh (in.),

$\bar{n}_k$  = average number of counted stems of dbh  $k$ ,

$\text{COUNT}_{k,j}$  = total number of counted stems of dbh  $k$  at sample point  $j$ ,

$\text{STF}_k$  = stand table factor for a tree of dbh  $k$ ,



$n_k$  = number of stems per acre of dbh  $k$ ,  
and

$n_{\text{total}}$  = stem density (no. stems/acre).

## Post-harvest data

Data from regeneration surveys can be used with PSME to estimate subsequent plantation development. We recommend the following procedures for estimating the post-harvest data required to run PSME; however, estimates can be obtained by other plantation-survey methods.

1) From a given sample point, mark the boundaries of a circular plot with a radius of 8.33 feet (1/200 acre).

2) Visually estimate the cover (to nearest 5 percent, not to exceed 100 percent) for each hardwood species. Group hardwood cover by species so that the dominant species (cover >66 percent) in a given stand can be determined.

3) Visually estimate the total cover for herb + shrub species to the nearest 5 percent, not to exceed 100 percent.

4) Locate the Douglas-fir seedling nearest the plot center; position a height pole at stem base on the uphill side of the seedling; measure the total height of the tallest living shoot to the nearest 0.1 foot.

5) With calipers, measure stem diameter 6 inches above the ground to the nearest 0.1 inch. If stem deformities occur at that point (e.g., swelling associated with a lateral branch), move the point of measurement slightly.

6) Determine crown width at its maximum point (i.e., near the base) by averaging two measurements (to the nearest 0.1 ft) taken at right angles to each other.

7) Count the number of Douglas-fir seedlings having a mainstem within the plot boundary.

8) When a representative number of sample points have been measured for a given site, perform the following calculations to determine the dominant hardwood species.

$$\overline{\text{COV}}_i = (\sum \text{COV}_{i,j})/N$$

$$\overline{\text{COV}}_{\text{all}} = (\sum \text{COV}_{\text{all},j})/N$$

$$\text{COV}\%_i = 100\% \times \overline{\text{COV}}_i / \overline{\text{COV}}_{\text{all}}$$

where

$\overline{\text{COV}}_i$  = average cover (%) for species  $i$ ,

$\text{COV}_{i,j}$  = cover (%) for species  $i$  at sample point  $j$ ,

$\overline{\text{COV}}_{\text{all}}$  = average cover (%) for hardwoods,

$\text{COV}_{\text{all},j}$  = total cover (%) for hardwoods at sample point  $j$ , and

$\text{COV}\%_i$  = percentage of the hardwood cover in species  $i$ .

9) Determine which species occupies more than 66 percent of the total hardwood cover. For PSME, assume that  $\overline{\text{COV}}_{\text{all}}$  is the estimated cover value for the dominant hardwood species.

10) Calculate the following stand averages for input values for PSME:

$$\overline{\text{COV}}_h = (\sum \text{COV}_{h,j})/N$$

$$\overline{\text{HT}} = (\sum \text{HT}_j)/N$$

$$\overline{\text{DIAM}} = (\sum \text{DIAM}_j)/N$$

$$\overline{\text{CW}} = (\sum \text{CW}_j)/N$$

$$\bar{n}_{\text{fir}} = 200 \times (\sum \text{COUNT}_{\text{fir},j})/N$$

where

$\overline{\text{COV}}_h$  = average cover (%) for herbs + shrubs,

$\text{COV}_{h,j}$  = cover (%) for herbs + shrubs at sample point  $j$ ,

$\overline{\text{HT}}$  = average Douglas-fir height (ft),

$\text{HT}_j$  = Douglas-fir height (ft) at sample point  $j$ ,

$\overline{\text{DIAM}}$  = average Douglas-fir stem diameter (in.),

$\text{DIAM}_j$  = Douglas-fir stem diameter (in.) at sample point  $j$ ,

$\overline{\text{CW}}$  = average Douglas-fir crown width (ft),

$\text{CW}_j$  = Douglas-fir crown width (ft) at sample point  $j$ ,

$\bar{n}_{\text{fir}}$  = average Douglas-fir density (no./acre), and

$\text{COUNT}_{\text{fir},j}$  = number of Douglas-fir within the plot at sample point  $j$ .

# Software Installation

Designations used in this publication:

<Ctrl> A computer key labeled "Ctrl"

<cr> The carriage return or <Enter> key

In-line prompts for user input are in **boldface** type.

Other prompts and program output are screened.

PSME is written in GW-BASIC 3.1. With a BASIC interpreter, such as GW-BASIC.EXE, BASICA.EXE, or BASIC.EXE, the program will run on any IBM-compatible microcomputer. A hard disk is not required. All graphic output in the computer screens is produced with the extended ASCII character set (see the MS-DOS user manual). Information on the screen can be sent directly to a printer connected to the computer for hard copy. However, a printer that emulates an IBM graphics printer is required for exact reproduction of the screens.

The steps that follow describe how to install and run PSME. Either lower- or upper-case letters can be used to enter commands or values.

## Hard Disk

1) At the DOS prompt, make a subdirectory for PSME by entering the command MD PSME <cr>. Change to this subdirectory by entering CD PSME <cr>.

2) Insert the disk containing the file PSME.BAS into the A: floppy-disk drive and type COPY A:\* C: <cr>. This copies the program to the PSME subdirectory on hard disk C:.

3) To load and execute PSME, type GWBASIC PSME <cr>, BASIC PSME <cr>, or BASICA PSME <cr>, depending on the name of the BASIC interpreter. (Consult your user manual to determine the name of the BASIC interpreter that is resident on your computer.) The computer should now display the title screen for PSME (Figure 4).

4) To terminate the program, hold down <Ctrl> and strike <Break>. To restart after terminating, type RUN <cr>.

5) To return to DOS, first terminate the program as described above. The computer displays the BASIC prompt: Ok. Type SYSTEM <cr>.

## Floppy Disk

1) Insert the disk containing the BASIC interpreter into the A: drive. Type A: <cr>. Invoke the BASIC interpreter by typing either GW-BASIC <cr>, BASICA <cr>, or BASIC <cr>, depending on the version of BASIC. (Consult your user manual to determine the name of the BASIC interpreter that is resident on your computer). The computer loads the BASIC interpreter and responds with the prompt: **Ok**.

2) Insert the disk containing the file PSME.BAS into the B: drive and type, with the quotation marks, LOAD "B:PSME" <cr>. The computer displays the BASIC system prompt: **Ok**. Type RUN <cr>. The computer should now display the title screen for PSME (Figure 4).

3) To terminate the program, hold down <Ctrl> and strike <Break>. To restart the program, type RUN <cr>.

4) To return to DOS, terminate the program as previously described. The computer displays the BASIC prompt: **Ok**. Type SYSTEM <cr>.

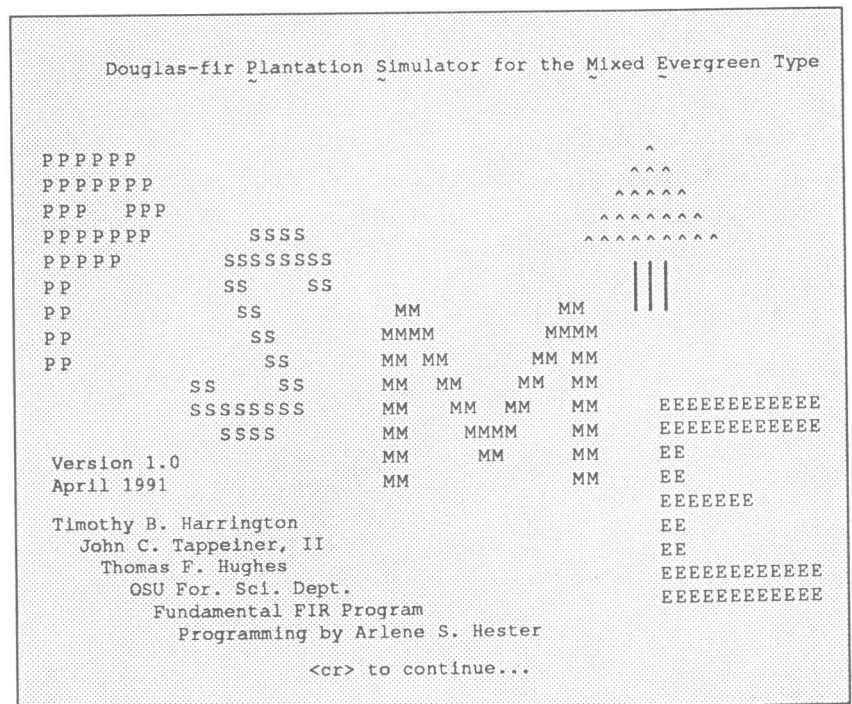


Figure 4. The title screen for PSME.

# Input Data

Figure 5 is a generalized flowchart of the sequences of operations in PSME. (Techniques for measuring the variables are described in the section "Data Collection," p. 5.) In a series of prompt statements, PSME requests the values required to run the program. Either capital or lower-case letters are accepted.

*Each value entered must be followed by <cr>. The default value is entered by <cr> alone. Default values appear in parentheses at the end of each prompt statement.*

Individual or groups of prompt statements are followed by the request, **Continue (Y)?** Answer N to enter a new value, Y or <cr> to continue the program.

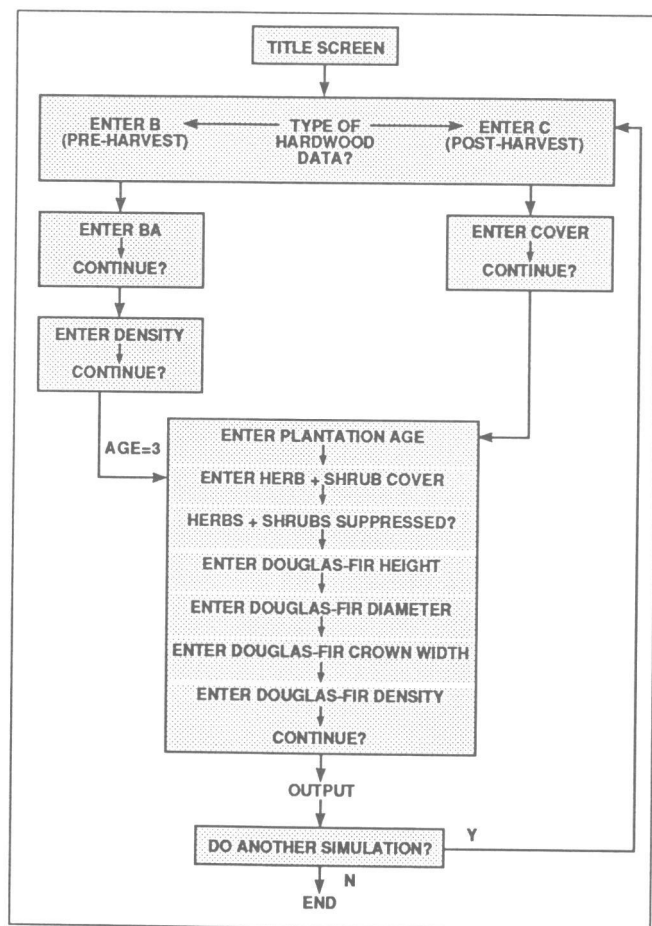


Figure 5. Flowchart of the sequence of input and output operations in PSME.

## Hardwood Data

The program is initialized by entering values for either of two types of hardwood competition, pre-harvest basal area or post-harvest cover. The screen displays:

Are you going to enter pre-harvest hardwood basal area (B) or post-harvest hardwood cover (C)?

Enter B or C, followed by <cr>.

If B is selected, values for basal area and stem density of the pre-harvest hardwood stand are requested, and plantation age is set to 3 years.

### PRE-HARVEST HARDWOOD BASAL AREA

Enter basal area for ONE species:

tanoak (30 sq. ft./acre)

madrone (30 sq. ft./acre)

chinkapin (30 sq. ft./acre)

Enter the basal area (BA) in square feet per acre for the dominant hardwood species (tanoak, madrone, or chinkapin) in the pre-harvest stand. (See the section "Data Collection," p. 5 for criteria for determining the dominant species if more than one is present.) Use the down arrow key to move the cursor for input of madrone or chinkapin data. Limits for the input value are 0 to 200. (Note defaults in parentheses.)

The next screen asks for stem density. (Tanoak has been selected in the example.)

### PRE-HARVEST HARDWOOD DENSITY

Enter density for tanoak (500 stems/acre)

Enter number of stems per acre for the dominant hardwood species (tanoak, madrone, or chinkapin) in the pre-harvest stand. Limits are 0 to 3,000.

If C is selected, the percentage of cover of the post-harvest (i.e., sprout-origin) hardwood stand is requested.

### POST-HARVEST HARDWOOD COVER

Enter cover (%) for ONE species:

tanoak (25%) %

madrone (25%) %

chinkapin (25%) %

Enter the percentage of cover for the single hardwood species in the post-harvest (i.e., sprout-origin) stand. Use the down arrow key to move the

cursor for input of madrone or chinkapin data. Limits for the input values are 0 to 100.

## Douglas-fir and Herb + Shrub Data

Because the data upon which PSME is based were collected one growing season after the various levels of hardwood cover were established, we recommend that input for Douglas-fir size reflect the 1st-year growth response expected after vegetation-management treatment. We observed that 1 year after complete removal of hardwoods and herbs + shrubs, stem diameter of Douglas-fir exceeded that for trees growing among untreated vegetation by 25 percent; however, there was no such response in height growth (Harrington 1989; Hughes *et al.* 1990).

For responses to the following requests for input, enter values that are appropriate for the specific Douglas-fir plantation being considered for vegetation-management treatment. If pre-harvest hardwood variables have been entered, use values for the Douglas-fir variables that correspond to those for a 3-year-old plantation.

Douglas-fir plantation age (3 yr)?

Enter the number of growing seasons since the Douglas-fir seedlings were planted. PSME will round non-integer values for plantation age to the nearest whole number. Limits for the input value are 3 to 9.

Although age is not a driving variable in the equations for PSME (see the section "Description of Growth Equations," p. 3), it is important that the model not be used to make growth predictions beyond plantation-age 10 years. In developing PSME, we assumed that exponential increases in Douglas-fir size occur during early stand development. Such growth accelerations, however, are sustained only briefly and generally are followed by constant or gradually declining rates of tree growth.

Herb + shrub+ cover (15 %)?

Enter the percentage of total cover for herb and shrub species. Limits for the input value are 0 to 100. (The value entered for herb + shrub cover does not affect the predicted rate of Douglas-fir growth.)

Have herbs & shrubs been suppressed (N)?

Enter Y for "yes" if herb and shrub cover has been reduced significantly as a result of a vegetation management treatment; otherwise enter N or <cr>. The response to this question does not affect predictions of Douglas-fir growth unless either pre-harvest basal area and stem density or post-harvest cover of hardwoods is zero. (For more explanation, see the section "Douglas-fir Parameters," p. 4.)

Douglas-fir height (1.5 ft)?

Enter the average height (ft) of Douglas-fir in the plantation. Limits for the input value are 0.1 to 16.

Douglas-fir stem diameter (0.3 in)?

Enter the average stem diameter (inches at 6-in. height) of Douglas-fir in the plantation. Limits for the input value are 0.1 to 4.

Douglas-fir crown width (0.8 ft)?

Enter the average crown width (ft) of Douglas-fir in the plantation. Limits for the input value are 0.1 to 10.

Douglas-fir density (436 trees/acre)?

Enter the number of Douglas-fir seedlings per acre. The default value (in parentheses) corresponds to a square spacing of 10 ft × 10 ft. Limits for the input value are 0.1 to 600.

Statements such as the following then appear, listing the current input values for Douglas-fir and herb + shrub parameters. (In this example, default values were selected.)

Douglas-fir plantation age = 3 yrs  
Herb + shrub cover = 15 %  
Herb & shrubs suppressed? N  
Douglas-fir height = 1.5 ft  
Douglas-fir diameter = .3 in  
Douglas-fir crown width = .8 ft  
Douglas-fir density = 435.6 trees/acre



## Modification: Site Qualities

The Douglas-fir parameter,  $PG_{avg,i}$ , is the average annual rate of growth during 1983-1989 at site  $i$  following complete removal of hardwoods and suppression of herbs and shrubs (see the section "Douglas-fir Parameters," p. 4). This parameter was included in the Douglas-fir growth models to account for differences in site quality among the three study sites. Its incorporation allowed potential differences in the competitive effects of tanoak and madrone to be estimated after adjustments were made for inherent differences in site quality. The following values for  $PG_{avg}$  (averaged across the three sites) are used in PSME.

Height (in./yr)	18.5577	$n = 270$
Diameter <sup>2</sup> (in. <sup>2</sup> /yr)	1.2503	$n = 270$
Cover (%/yr)	4.8457	$n = 270$

These values are also given on line 420 in the BASIC code for PSME.

The following commands can be used to edit  $PG_{avg}$ , making PSME adaptable to different site qualities:

Terminate the program by holding down <Ctrl> and striking <Break>. The program responds with the BASIC prompt, **Ok**.

Type EDIT 420 <cr>. The program gives a listing of line 420 in the following order: average growth rate for Douglas-fir height (in./yr), diameter-squared (in.<sup>2</sup>/yr), and cover (%/yr).

```
420 MAXHRATE=18.5577:MAXDRATE
    =1.2503:MAXCRATE=4.8457
```

Use the arrow keys to move the cursor to the appropriate location on line 420, change values for MAXHRATE, MAXDRATE, or MAXCRATE as desired, and follow changes with <cr>. Average rates of potential growth for Douglas-fir can be estimated for a given site from measurements of nearby progeny test sites or experimental areas in which competing vegetation has been removed.

Run the program with the new values for  $PG_{avg}$  by typing RUN <cr>. (If you type SYSTEM <cr>, the program will return you to DOS without saving the new values for  $PG_{avg}$ .)

If you wish to save a new version of PSME with the edited values for  $PG_{avg}$ , type SAVE "PSME" <cr>, including quotation marks, after the BASIC prompt, **Ok**. The new version of PSME can be given other file

names, such as "PSME1", by substituting the desired text within the quotation marks.

## Modification: Hardwood Constants

PSME divides pre-harvest stem density of hardwoods by  $STEMNOB_0$  (average no. stems/tree) to predict the number of hardwood trees per acre (see the section "Hardwood Parameters," p. 3). Predictions of 3rd-year hardwood cover generated from pre-harvest data can be improved by estimating site-specific values for  $STEMNOB_0$  and including these in the BASIC code for PSME as follows:

1) At each sample point in the pre-harvest inventory (see the section "Data Collection," p. 5), record, by species, three to five counts of the number of stems per tree. Count only the stems having a dbh  $\geq 1$  inch. If both single- and multi-stemmed trees are present, include both in the sample. Average the counts of stems per tree for the dominant hardwood species to provide a site-specific estimate of  $STEMNOB_0$ .

2) While in PSME, terminate the program by holding down <Ctrl> and striking <Break>. The program responds with the BASIC prompt, **Ok**.

3) Type EDIT 380 <cr>. The program will give the following listing of line 380:

```
380 STEMNOB0 (1)=1.5975:STEMNOB0 (2)
    =1.3263:STEMNOB0 (3)=1.2857
```

4) Change the values to your estimate of  $STEMNOB_0$  by using the arrow keys to move the cursor to the appropriate location on line 380,

```
tanoak    = STEMNOB0(1)
madrone   = STEMNOB0(2)
chinkapin = STEMNOB0(3)
```

5) Run the program with the new values for  $STEMNOB_0$  by typing RUN <cr>. (If you type SYSTEM <cr>, the program will return you to DOS without saving the new values for  $STEMNOB_0$ .)

6) If you wish to save a new version of PSME with the edited values for  $STEMNOB_0$ , type SAVE "PSME" <cr>, including the quotation marks, after the BASIC prompt, **Ok**.



# Output Data

After PSME has calculated the table of growth predictions for a given simulation, the user may start a new stand simulation or review any screen output. At the bottom of each output screen is a menu for selecting the kind of output desired (e.g., see Figure 6).

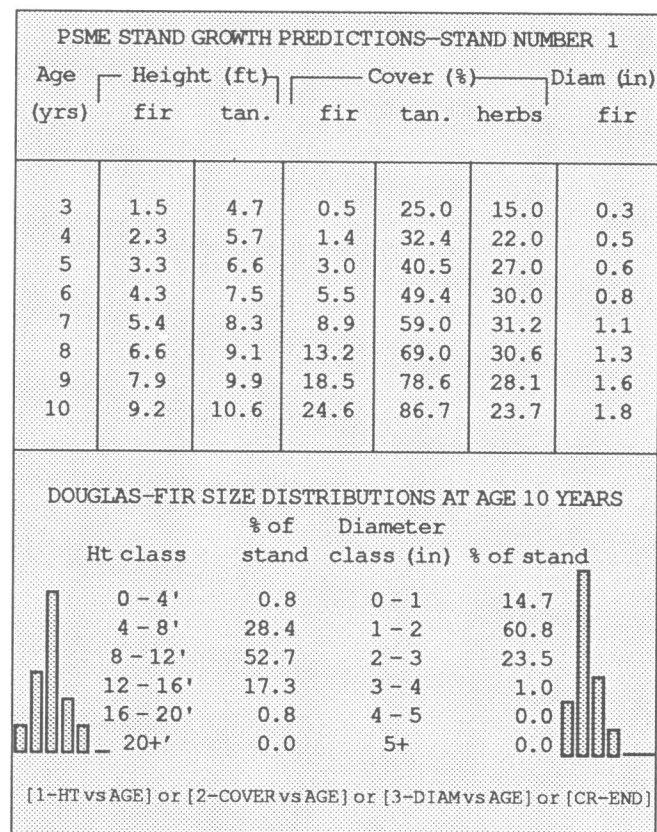


Figure 6. Output screen showing a table of stand growth predictions and information on Douglas-fir size distributions.

## Stand Growth Predictions

The first line in the table of stand-growth predictions (Figure 6) gives the initial values entered for Douglas-fir, hardwood, and herb + shrub variables at the initial plantation age. In the example, post-harvest tanoak cover was initialized at 25 percent, and default values were selected for the remaining variables. PSME calculates Douglas-fir cover by multiplying the density value by the cover value for a tree of average crown width. Hardwood height, not an input variable, is predicted by the method described in the section "Hardwood Parameters," p. 3.

As annual increments are predicted for each variable, cumulative values are displayed in successive lines of the table until the plantation age is 10 years.

If pre-harvest hardwood data have been entered, plantation age is set at 3 years and initial hardwood cover is predicted as described in the section "Hardwood Parameters," p. 3. To distinguish simulations when repeat runs of PSME are performed, the program displays a stand number at the top of each output screen. In the first run, the stand number is 1; successive runs are numbered consecutively.

## Douglas-fir Size Distributions

Below the table of growth predictions are histograms and percentage values showing the size distributions of Douglas-fir saplings at stand age 10 years (Figure 6). This information can be used to determine the percentage of Douglas-fir saplings in a given stand that have or have not high potential for becoming crop trees. In Figure 6, for example, the percentage of trees in height class 1 (0-4 ft) gives a measure of the proportion of the stand that has high probability of mortality from stand competition.

In addition, size-distribution data from the output file, PSME.DAT (see the section "Summary Files," p. 12), can be read by a computer, and, with additional programming, a list of individual trees can be created for export to programs such as SYSTUM-I (Powers *et al.* 1989), enabling a user to project stand development after the first 10 years. See Harrington *et al.* (in press) for details.

## Plots of Stand Development

PSME produces graphic output of the development of stand parameters through plantation age 10 years. (As noted previously, screen information from PSME can be sent directly to a printer by holding down <Shift> and striking <PrtSc>. A printer that emulates an IBM graphics printer is required for exact depictions of the screens.) Because ASCII characters are used in the display of graphs, resolution is limited to the width of an individual character. An asterisk (\*) is plotted if two or more observations are located in the same position on a given graph.

The first graph produced by PSME is a display of height values for Douglas-fir and the given hardwood species plotted against plantation age (Figure 7A). The maximum height that can be plotted is 20 feet. If predicted height exceeds this, "(values > 20)" is displayed in the upper right margin of the graph. (If 3rd-year hardwood cover has been set at zero, hardwood height will not be shown.)

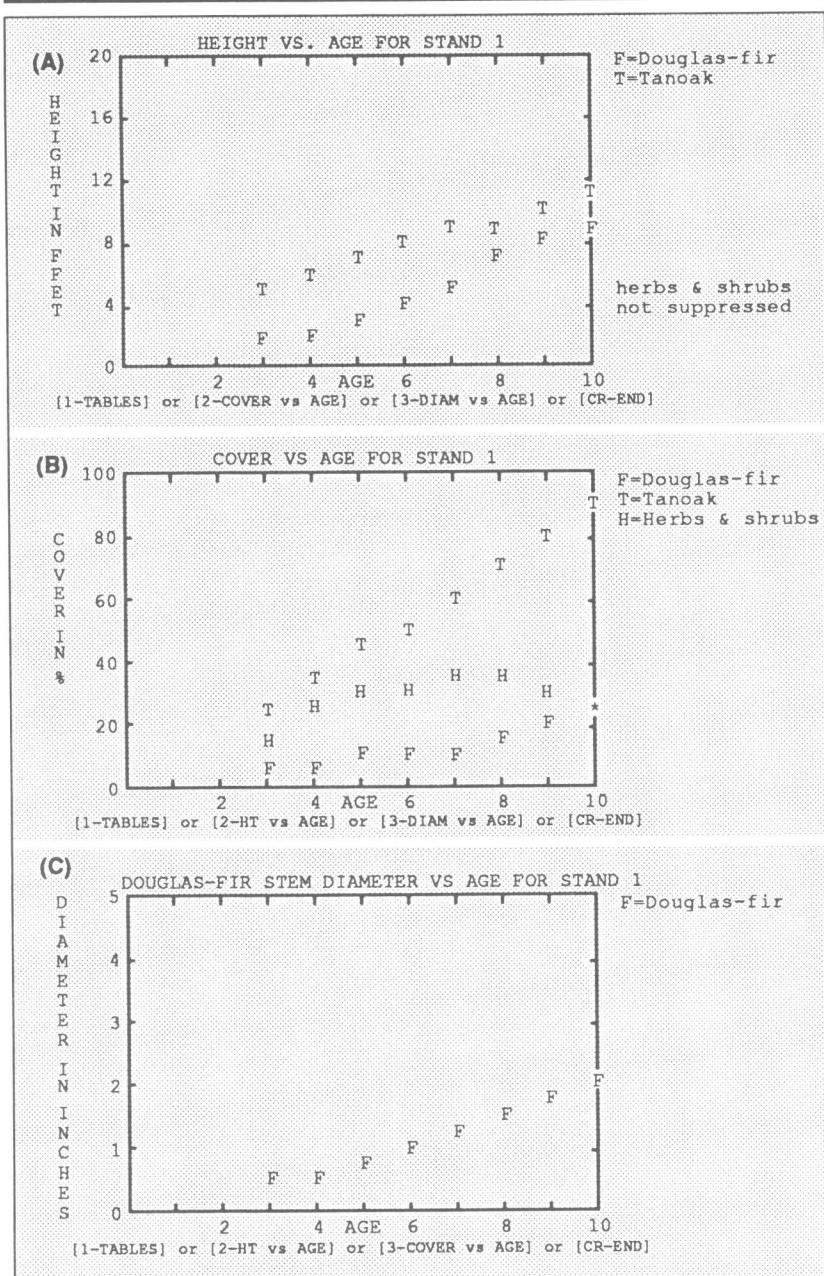


Figure 7. Output screens showing plots against stand age of the parameters (A) hardwood and Douglas-fir height; (B) hardwood, herb + shrub, and Douglas-fir cover (asterisk indicates two observations at same point; and (C) Douglas-fir stem diameter.

Also displayed in the right margin of the graph are the level of herb and shrub suppression and the pre-harvest basal area and stem density of the hardwood stand. (If post-harvest cover has been entered, pre-harvest information is not displayed.)

Percentage of crown cover of the given hardwood, herbs and shrubs, and Douglas-fir are plotted against plantation age in the second graph

(Figure 7B). (If 3rd-year hardwood cover was set at zero, hardwood cover is not plotted.)

The third graph gives Douglas-fir stem diameter plotted against plantation age (Figure 7C). The maximum diameter that can be plotted is 5 inches; if the predicted diameter exceeds this, "(values > 5)" is displayed in the upper right margin of the graph.

The user may start a new stand simulation or end the current series of simulations by striking <cr> to produce the following prompt:

Do you want to do another simulation (N)?

Answer Y to return the program to the point for entering the type of hardwood data. Answer N to return to the BASIC prompt, Ok; then type SYSTEM <cr> to return to DOS.

## Summary Files

As PSME calculates the table of growth predictions for a given simulation, the model automatically writes or appends two ASCII files, PSME.OUT and PSME.DAT, to the floppy- or hard-disk drive being accessed. As shown in Figure 8, PSME.OUT provides a readable summary of a given series of model simulations, including the input value for each parameter and the table of growth predictions. Note that information for successive simulations (*i.e.*, stands) is separated by a blank line.

PSME.DAT contains all of the information of PSME.OUT written in computer-readable FORTRAN data formats (Figure 9). Thus, PSME output can be

read easily by statistical packages such as SAS® or SYSTAT®, facilitating additional analyses. For a given simulation, size-distribution data for Douglas-fir height and diameter is provided in PSME.DAT only when stand age is 10 years.

Because terminating and re-invoking PSME causes the model to write over existing PSME.OUT and PSME.DAT files, the user must rename or print these files to retain a record of simulation results.

STAND NUMBER=						1
HARDWOOD SPECIES=						tan.
PRE-HARVEST BA=						.
PRE-HARVEST DENSITY=						.
DOUGLAS-FIR CROWN WIDTH=						.8
DOUGLAS-FIR DENSITY=						435.6
HERBS/SHRUBS NOT SUPPRESSED						
PSME STAND GROWTH PREDICTIONS--STAND NUMBER						1
HEIGHT						COVER
AGE	FIR	HARDWOOD	FIR	HARDWOOD	HERB	FIR
3	1.5	4.7	0.5	25.0	15.0	0.3
4	2.3	5.7	1.4	32.4	22.0	0.5
5	3.3	6.6	3.0	40.5	27.0	0.6
6	4.3	7.5	5.5	49.4	30.0	0.8
7	5.4	8.3	8.9	59.0	31.2	1.1
8	6.6	9.1	13.2	69.0	30.6	1.3
9	7.9	9.9	18.5	78.6	28.1	1.6
10	9.2	10.6	24.6	86.7	23.7	1.8
DOUGLAS-FIR SIZE DISTRIBUTIONS AT AGE 10 YEARS						
HT CLASS		%	DIA CLASS		%	
0 - 4'		0.8	0 - 1"		14.7	
4 - 8'		28.4	1 - 2"		60.8	
8 -12'		52.7	2 - 3"		23.5	
12-16'		17.3	3 - 4"		1.0	
16-20'		0.8	4 - 5"		0.0	
20+'		0.0	5+"		0.0	
STAND NUMBER=						2
HARDWOOD SPECIES=						mad.
PRE-HARVEST BA=						30
PRE-HARVEST DENSITY=						500
DOUGLAS-FIR CROWN WIDTH=						.8
DOUGLAS-FIR DENSITY=						435.6
HERBS/SHRUBS NOT SUPPRESSED						
PSME STAND GROWTH PREDICTIONS--STAND NUMBER						2
HEIGHT						COVER
AGE	FIR	HARDWOOD	FIR	HARDWOOD	HERB	FIR
3	1.5	5.7	0.5	17.5	15.0	0.3
4	2.4	7.0	1.5	21.1	23.8	0.5
5	3.5	8.1	3.2	25.2	30.9	0.7
6	4.8	9.2	6.0	29.8	36.6	1.0
7	6.3	10.2	10.0	35.0	41.0	1.3
8	8.0	11.2	15.3	40.9	44.3	1.7
9	10.0	12.2	22.0	47.7	46.5	2.1
10	12.2	13.1	30.1	55.2	47.7	2.5
DOUGLAS-FIR SIZE DISTRIBUTIONS AT AGE 10 YEARS						
HT CLASS		%	DIA CLASS		%	
0 - 4'		0.0	0 - 1"		4.0	
4 - 8'		5.9	1 - 2"		33.9	
8 -12'		31.0	2 - 3"		47.8	
12-16'		44.5	3 - 4"		13.7	
16-20'		17.3	4 - 5"		0.5	
20+'		1.3	5+"		0.0	

Figure 8. Example of a summary file produced by PSME.OUT.

Variable	Units	Format
Stand number	No.	I7
Hardwood species ("tan.", "mad.", or "chi.")	--	A7
Pre-harvest hardwood basal area	ft <sup>2</sup>	F7.1
Pre-harvest hardwood stem density	No./acre	F7.1
Douglas-fir crown width	ft	F7.1
Douglas-fir density	No./acre	F7.1
Herb + shrubs suppressed? ("YES" or "NO")	---	A7
Stand age	(yr)	I7 /
Douglas-fir height	(ft)	F7.1
Hardwood height	(ft)	F7.1
Douglas-fir cover	(%)	F7.1
Hardwood cover	(%)	F7.1
Herb + shrub cover	(%)	F7.1
Douglas-fir diameter	(in.)	F7.1
" height class 1	(%)	F7.1
" height class 2	(%)	F7.1 /
" height class 3	(%)	F7.1
" height class 4	(%)	F7.1
" height class 5	(%)	F7.1
" height class 6	(%)	F7.1
" diameter class 1	(%)	F7.1
" diameter class 2	(%)	F7.1
" diameter class 3	(%)	F7.1
" diameter class 4	(%)	F7.1 /
" diameter class 5	(%)	F7.1
" diameter class 6	(%)	F7.1

Figure 9. FORTRAN data formats for reading PSME.DAT.

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Harrington, T.B., J.C. Tappeiner II, T.F. Hughes, and A.S. Hester. 1991. PLANNING WITH PSME: A GROWTH MODEL FOR YOUNG DOUGLAS-FIR AND HARDWOOD STANDS IN SOUTHWESTERN OREGON. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 21. 14 p.

PSME (Plantation Simulator-Mixed Evergreen) is a computerized growth model for predicting development of Douglas-fir plantations under specific initial levels of competition from tanoak [*Lithocarpus densiflorus* (Hook. and Arn.) Rehd.], Pacific madrone (*Arbutus menziesii* Pursh), and chinkapin [*Castanopsis chrysophylla* (Dougl.) A. DC.] and from herb + shrub vegetation in southwestern Oregon. It uses values for cover of competing vegetation and average size of Douglas-fir seedlings at stand-age 3 years, or for pre-harvest stand information on hardwood basal area and stem density, to provide tabular and graphical output of the development of the Douglas-fir, hardwood, and herb + shrub components through stand-age 10 years. It also predicts frequency distributions of Douglas-fir height and stem diameter at 10 years. PSME can be run on any IBM-compatible microcomputer (hard disk not necessary) with a copy of a BASIC interpreter, such as GW-BASIC. This user's manual provides software for PSME, information on model installation and application, and techniques for collecting input data.

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