United States Department of Agriculture

Forest Service

Pacific Northwest Research Station

General Technical Report PNW-GTR-619 November 2004

CalPro: A Spreadsheet Program for the Management of California Mixed-Conifer Stands

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Abstract

Liang, Jingjing; Buongiorno, Joseph; Monserud, Robert A. 2004. CalPro: a spreadsheet program for the management of California mixed-conifer stands. Gen. Tech. Rep. PNW-GTR-619. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p.

CalPro is an add-in program developed to work with Microsoft Excel to simulate the growth and management of uneven-aged mixed-conifer stands in California. Its built-in growth model was calibrated from 177 uneven-aged plots on industry and other private lands. Stands are described by the number of trees per acre in each of nineteen 2-inch diameter classes in two species groups, hardwoods and softwoods.

CalPro allows managers to predict stand development by year and for many decades from a specific initial state. Users can choose cutting regimes by specifying the interval between harvests (cutting cycle) and a target distribution of trees remaining after harvest. A target distribution can be a reverse-J-shaped distribution or any other desired distribution. Diameter-limit cuts can also be simulated. Tabulated and graphic results show diameter distributions, basal area, volumes, income, net present value, and indices of stand diversity by species and size.

This manual documents the program installation and activation, provides suggestions for working with Excel, and gives background information on CalPro's growth model. It offers a comprehensive tutorial in the form of two practical examples that explain how to start the program, enter simulation data, execute a simulation, compare simulations, and plot summary statistics.

Keywords: Mixed conifers, uneven-aged management, economics, ecology, CalPro, simulation, software, growth model, diversity.

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I. Introduction

Welcome to CalPro—a spreadsheet program to help with management decisions using uneven-aged systems in mixed-conifer forests. This paper provides background, instruction, and additional suggestions for using the CalPro program. The examples contain detailed instructions for each step. If you are new to CalPro, it will be useful to run these examples while reading the paper.

What Is CalPro?

CalPro is a computer program meant to predict the development of mixed-conifer stands in California. With this program, various management regimes can be considered, and their outcomes can be quickly predicted. Three relatives of CalPro (NorthPro, WestPro, and SouthPro) already exist for northern hardwoods in Wisconsin and Michigan (Liang et al. 2004), for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in the Pacific Northwest region of the United States (Ralston et al. 2003), and for loblolly pine (*Pinus taeda* L.) in the Southern United States (Schulte et al. 1998), respectively. We have used our experience with these programs to further simplify the data input and the program output to maximize CalPro's usefulness for practitioners.

Why Simulate This Type of Stand?

Mixed-conifer forests compose one of the largest vegetation types in California, covering 13 percent of the state's area (Barbour and Major 1977). The expansiveness of the mixed-conifer types and the amount of timber harvested from the west slopes of the Sierra Nevada Mountains emphasize the need for accurate growth-and-yield prediction methods applicable to mixed-conifer stands. Uneven-aged management, selecting single trees or small groups of trees at intervals of 5 to 20 years and encouraging natural regeneration, helps maintain a continuous tree cover with aesthetic and ecological benefits (DeBell and Franklin 1987). Some of the examples in this manual also suggest that effective uneven-aged management of mixed conifers can be profitable. CalPro helps foresters predict how a given forest stand might look in the future and what it could yield under uneven-aged management.

How Does CalPro Work?

CalPro predictions are based on a multispecies, site- and density-dependent matrix growth model for California,[1] an extension of earlier density-dependent matrix models (Lu and Buongiorno 1993). The data used to calibrate the growth model came from plots remeasured in two surveys in the 1980s and 1990s in forest stands in the Sierra Nevada Mountains (app. 1).

The equations built in CalPro predict growth, mortality, and the rate of ingrowth (recruitment) for hardwood and softwood species. The model equations are in appendix 2.

What Is in This Manual?

The next section explains how to install CalPro on your computer and provides a description of the input data, as well as instructions for loading and saving these data, running simulations, and saving the results. Two examples of applications are given. We included answers to some common questions. The manual assumes that you are familiar with the basics of Microsoft Excel.

2. Getting Started

System Requirements

You need the following hardware and software to operate CalPro:

- A computer (PC) with at least 16 megabytes of random access memory (RAM)
- Windows® 95, 98, 2000, Me, XP, or Windows NT™ 4[2]
- Microsoft Excel 5.0 to Excel 2002
- A free copy of the CalPro software downloaded from http://forest.wisc.edu/facstaff/buongiorno/index.htm or from the authors through jbuongio@wisc.edu.

Installing CalPro

To install the program for the first time:

1. Insert the diskette containing CalPro.xla into your computer, or download it from the Web site to your local disk and go to step 3.
2. Select the CalPro.xla icon and copy it onto your hard disk. For your convenience, you may save it in a new folder named CalPro, e.g., C:\CalPro\CalPro.xla.

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[1] Liang, J.J.; Buongiorno, J.; Monserud, R.A. Estimation and application of a growth and yield model for uneven-aged mixed conifer stands in California. Forest Ecology and Management. Manuscript in preparation. On file with: R. Monserud, Pacific Northwest Research Station, 620 SW Main St., Suite 400, Portland, OR 97205.

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

3. Open Microsoft Excel and START A NEW WORKBOOK.
4. Under the **Tools** menu, select **Add-ins**. In the add-ins dialogue box, select **Browse** and choose **CalPro.xla** from its location on your hard disk. Click **OK**.
5. Return to the **Tools** menu and notice that CalPro is now the last choice in the menu. Select **CalPro** and click **OK** in the title box.
6. The **CalPro** menu should now be in the Excel menu bar.

Until you uninstall it, CalPro will be a permanent option in the **Tools** menu of Excel. Clicking on the name **CalPro** in the **Tools** menu adds CalPro to the Excel menu and makes the input data worksheet (fig. 1) appear.

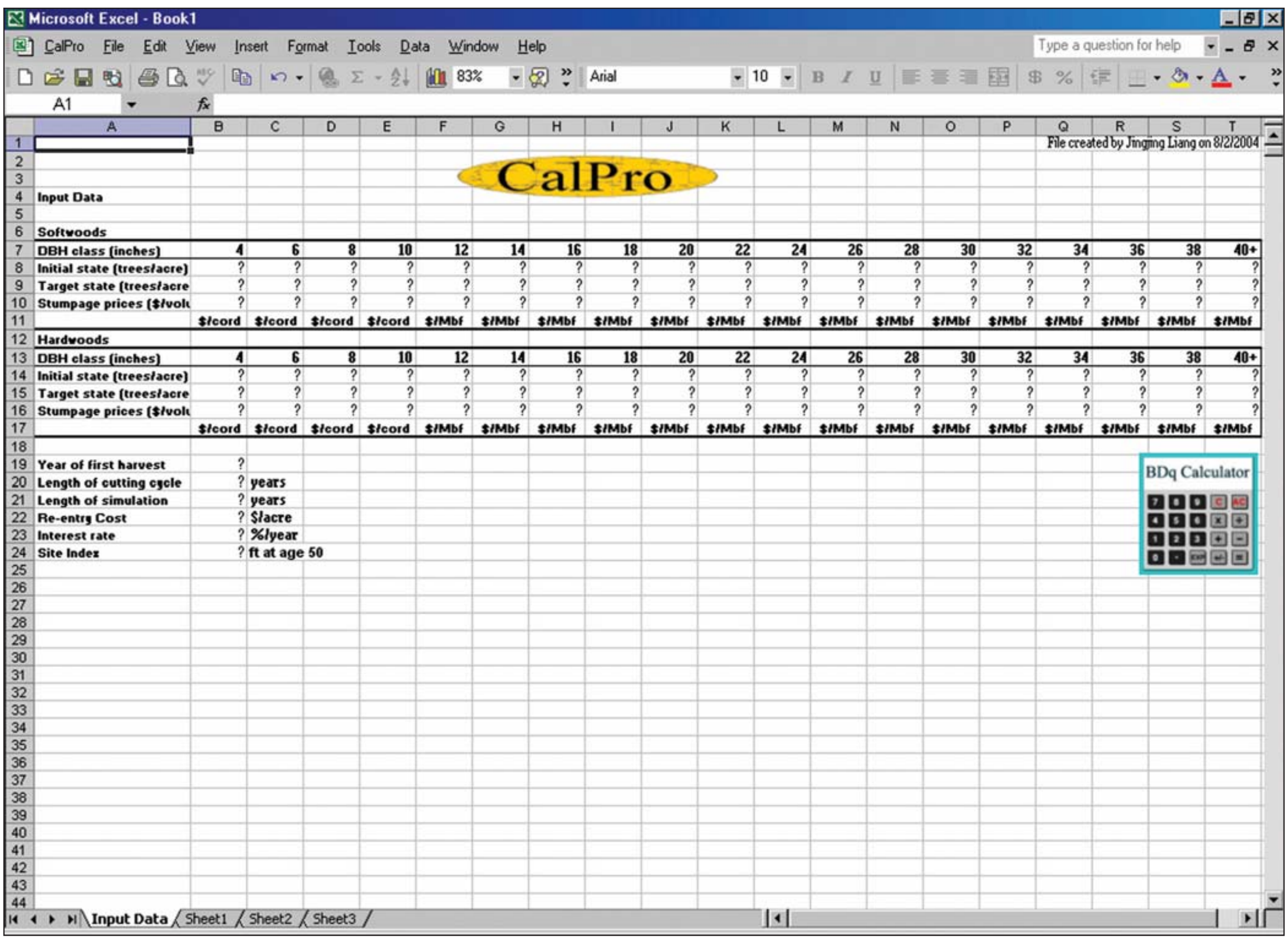


Figure 1—Input Data worksheet.

There are five sample workbooks at our Web site with the input data worksheets corresponding to the examples in section 4 of this paper. By copying the data from these worksheets into your input data worksheet you will be able to run these examples with CalPro.

Uninstalling CalPro

To remove the CalPro menu and uninstall the program:

1. Close all Excel windows.
2. Select the file CalPro.xla and delete it from your hard disk.
3. Open Microsoft Excel and start a new workbook.
4. Under the **Tools** menu, select **Add-ins**. Deselect **CalPro** to remove the title from the add-ins list.
5. Close the Excel window.

3. Using CalPro

CalPro Input

In the input data worksheet (fig. 1), each cell with a question mark requires a numeric entry. CalPro automatically converts numeric entries to one or two decimal places.

In figure 1, the two rows labeled "**initial state**" contain the initial number of trees per acre in the stand (at time zero), by species groups and by 2-in diameter classes. CalPro recognizes two species groups, hardwoods and softwoods (app. 1).

The two rows labeled "**target state**" contain the number of trees per acre, by species group and by diameter class that should remain after harvest. A target entry of zero instructs CalPro to harvest all trees in that species category and diameter class. When the number of trees in the stand exceeds the target value, the harvest is the difference between the available trees and the target; otherwise the harvest is zero. You can always prevent the removal of any tree by entering a very high target, e.g., 1,000.

The data in the rows labeled "**Stumpage prices**" are in dollars per cord (1 cord = 128 ft^3) for trees of pole size. They are in dollars per thousand board feet (MBF) for trees of sawtimber size.

CalPro measures time in years. All simulations start at time zero and last for the "**Length of simulation**." The "**Year of first harvest**" may be set at any nonnegative value. The "**Length of cutting cycle**," i.e., the interval between harvests, must be at least 1 year. To simulate stand growth without harvest, set the "**Year of first harvest**" to a value greater than the "**Length of simulation**."

The "**Re-entry Cost**" represents cost of doing a harvest, in dollars per acre, independent of the volume harvested. The cost of timber sale preparation and administration would be part of a typical re-entry cost.

The "**Site Index**" is measured by the average total height of the dominant and codominant trees at 50 years of age (Hanson et al. 2002). The site index should be between 30 and 99, the range of site-index values on the plots used to calibrate CalPro.

CalPro treats empty input data cells as errors and will prompt you to fix them. You can enter zeros for **Stumpage prices**, **Re-entry Cost**, and **Interest rate** if you do not want a financial analysis.

BDq Calculator

A BDq distribution is a tree distribution, by diameter class, defined by a stand basal area (B), a maximum and minimum tree diameter (D), and a q-ratio (q), the ratio of the number of trees in a given diameter class to the number of trees in the next larger class. You can use the BDq calculator to define either the target state or the initial state with a BDq distribution.

To use the BDq calculator, click on the **BDq calculator** icon in the input data worksheet. Use the arrow buttons to set the stand basal area (ft^2/ac), the q-ratio, the minimum and the maximum diameters (in); click the **Calculate** button (fig. 2).

The example in figure 2 shows the number of trees by diameter class that would give a basal area of 90 ft^2/ac with trees of diameters from 3 to 40 in and a q-ratio of 1.7. You can copy the resulting stand distribution to the input data worksheet as the initial distribution or as the target distribution for a species group by selecting the destination and clicking the **Copy** button on the BDq calculator (fig. 2).

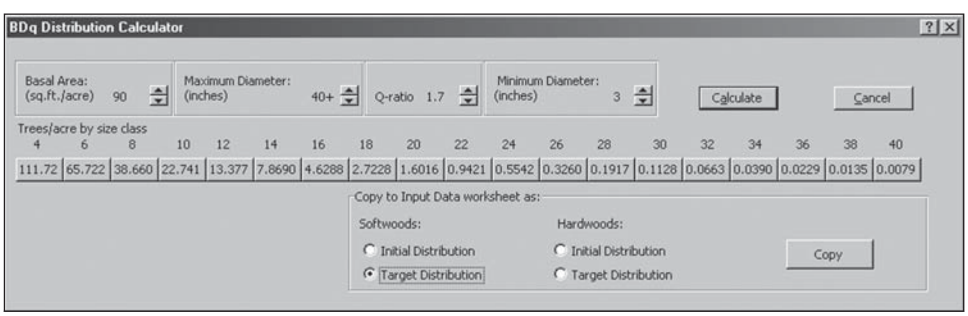


Figure 2—The BDq Distribution Calculator window.

Storing Data and Retrieving Stored Data

After entering data in the **Input Data** worksheet, you can save this worksheet for later use. You should save your work frequently to avoid losing data. It is advisable to save the work in a particular folder to facilitate locating the file in the future. To run several simulations, e.g., to examine the effects of changing some of the parameters, you may find it efficient to work with previously saved input data. To retrieve the data, choose the **File→Open** command in Excel to open your saved file or double click on the file icon.

Running Simulations

After completing the input data worksheet or retrieving a previously saved one, you are ready to run a simulation. To run CalPro, make sure that the CalPro menu is in the Excel menu bar. If not, click **CalPro** under the **Tools** menu to activate CalPro. You can then run the simulation by choosing **Run** in the **CalPro** menu.

Each CalPro simulation generates the following worksheets and charts:

- A **TreesPerAcre** worksheet: The number of trees by species and diameter class for each simulated year.
- A **Basal Area** worksheet: The basal area by species and diameter class, for each simulated year.
- A **Products** worksheet: The physical output and the financial return from the harvests throughout the simulation.
- A **Diversity** worksheet: Shannon's species diversity indices and size diversity indices for each year of the simulation.
- A **Diversity** chart: A plot of Shannon's indices of species and size diversity over time.
- A **Species BA** chart: A stacked area chart showing the development of stand basal area by species group over time.
- A **Size BA** chart: A stacked area chart showing the development of stand basal area by timber size over time.

To compare various management regimes, save the output worksheets immediately after running a simulation. Otherwise CalPro will overwrite the previous results every time you run a new simulation.

All the data in the output worksheets are protected and you cannot change them. To see how results change with different input data, change the input data worksheet and rerun the simulation.

Quitting CalPro

To finish working with CalPro, choose the command **Quit** under the **CalPro** menu. The **CalPro** menu will then disappear, but the current worksheets will stay in the Excel window until you close them.

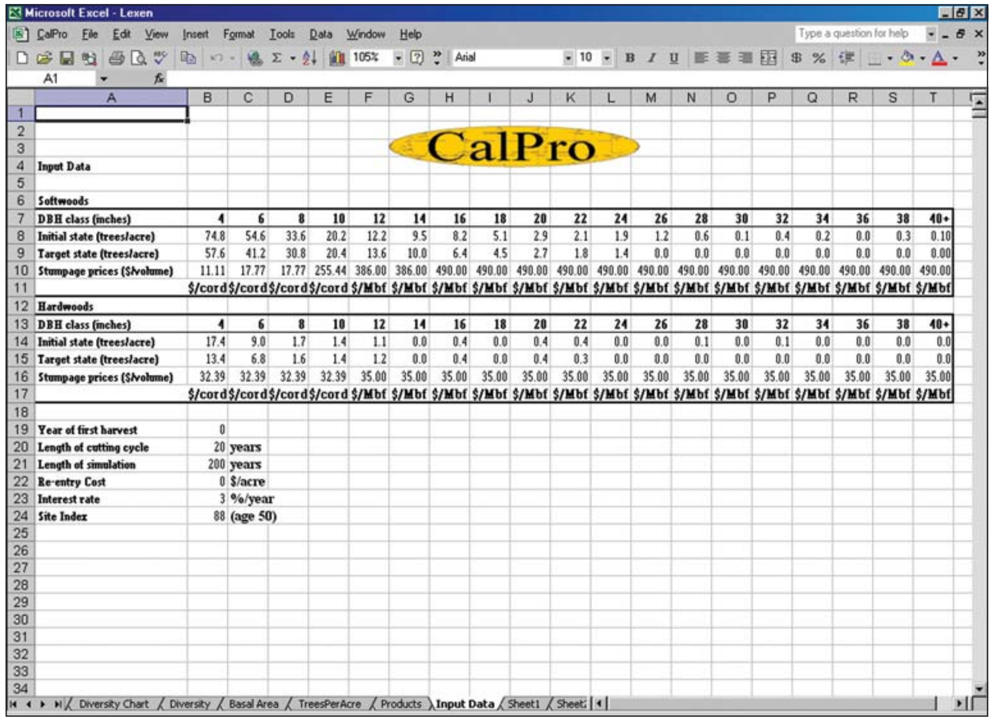
4. Examples

Simulating the Lexen Stocking Standard

Bert Lexen developed a stocking standard for ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) stands managed by selection (Alexander and Edminster 1976). Based on his studies of space requirements of ponderosa pines of different sizes, Lexen recommended a residual basal area of about 98 ft^2, distributed by diameter class as in table 1, for lands of site index from 75 to 100. One possible interpretation of this approach is reflected by the target stand distribution shown in figure 3. The objective of this example is to apply CalPro to simulate the effect of applying Lexen's stocking standard.

Table 1—Lexen's growing stock for selection forests of ponderosa pine

D.b.h. class	Trees	Basal area
Inches	*Number per acre*	*Square feet per acre*
2	105.4	2.29
4	71.0	6.20
6	48.0	9.50
8	32.4	11.31
10	21.8	11.89
12	14.8	11.62
14	10.0	10.69
16	6.8	9.49
18	4.5	7.99
20	3.1	6.72
22	2.1	5.44
24	1.4	4.40
Total	322.4	97.55



Input Data

Softwoods

DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
Initial state (trees/acre)	74.8	54.6	33.6	20.2	12.2	9.5	8.2	5.1	2.9	2.1	1.9	1.2	0.6	0.1	0.4	0.2	0.0	0.3	0.10
Target state (trees/acre)	57.6	41.2	30.8	20.4	13.6	10.0	6.4	4.5	2.7	1.8	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Stumpage prices ($/volume)	11.11	17.77	17.77	255.44	386.00	386.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00
	$/cord	$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf

Hardwoods

DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
Initial state (trees/acre)	17.4	9.0	1.7	1.4	1.1	0.0	0.4	0.0	0.4	0.4	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
Target state (trees/acre)	13.4	6.8	1.6	1.4	1.2	0.0	0.4	0.0	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stumpage prices ($/volume)	32.39	32.39	32.39	32.39	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	$/cord	$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf

Year of first harvest	0	
Length of cutting cycle	20	years
Length of simulation	200	years
Re-entry Cost	0	$/acre
Interest rate	3	%/year
Site Index	88	(age 50)

Figure 3—Input data worksheet to simulate Lexen regime.

Input data—

The initial stand state for this example is in figure 3. It corresponds to the average distribution on the 21 plots (of 205 total used in calibrating CalPro) that were dominated by ponderosa pine trees. Trees in each species group were assembled into nineteen 2-in diameter classes ranging from 3 to 39+ in. Each class is denoted by its midpoint diameter. For example, the 4-in class includes trees with a diameter at breast height (d.b.h.) from 3 to 5 in. The 40+ in diameter class includes trees 39 in and larger in d.b.h. Enter these data into the **Initial state** rows of the input data worksheet, softwood data into cells B8 through T8 and hardwood data into cells B14 through T14. In this example, you do not use the BDq calculator.

The target stand state is the proposed number of trees per acre in each diameter class and species group after each harvest. We divided Lexen's desired number of trees per acre by species in proportion to the number of trees per acre in the initial stand state (88 percent for softwoods and 12 percent for hardwoods). Enter this **Target state** into cells B9 through T9 for softwoods and B15 through T15 for hardwoods.

Enter the **Stumpage prices** in cells B10 through T10 for softwoods and B16 through T16 for hardwoods. Enter the Re-entry Cost into cell B26, assumed to be zero in the absence of timber sale preparation and administration.

Enter into cell B23 the real **Interest rate** of 3 percent per year, which is the projected return on the Treasury bonds in the Social Security trust fund (USGPO 2004).

Next, enter in cell B19 the **Year of first harvest**, assumed here to be zero, the beginning of the first year of the simulation.

Set the **Length of cutting cycle** to 20 years in B20 and set the **Length of simulation** in B21 to 200 to allow for 10 harvests.

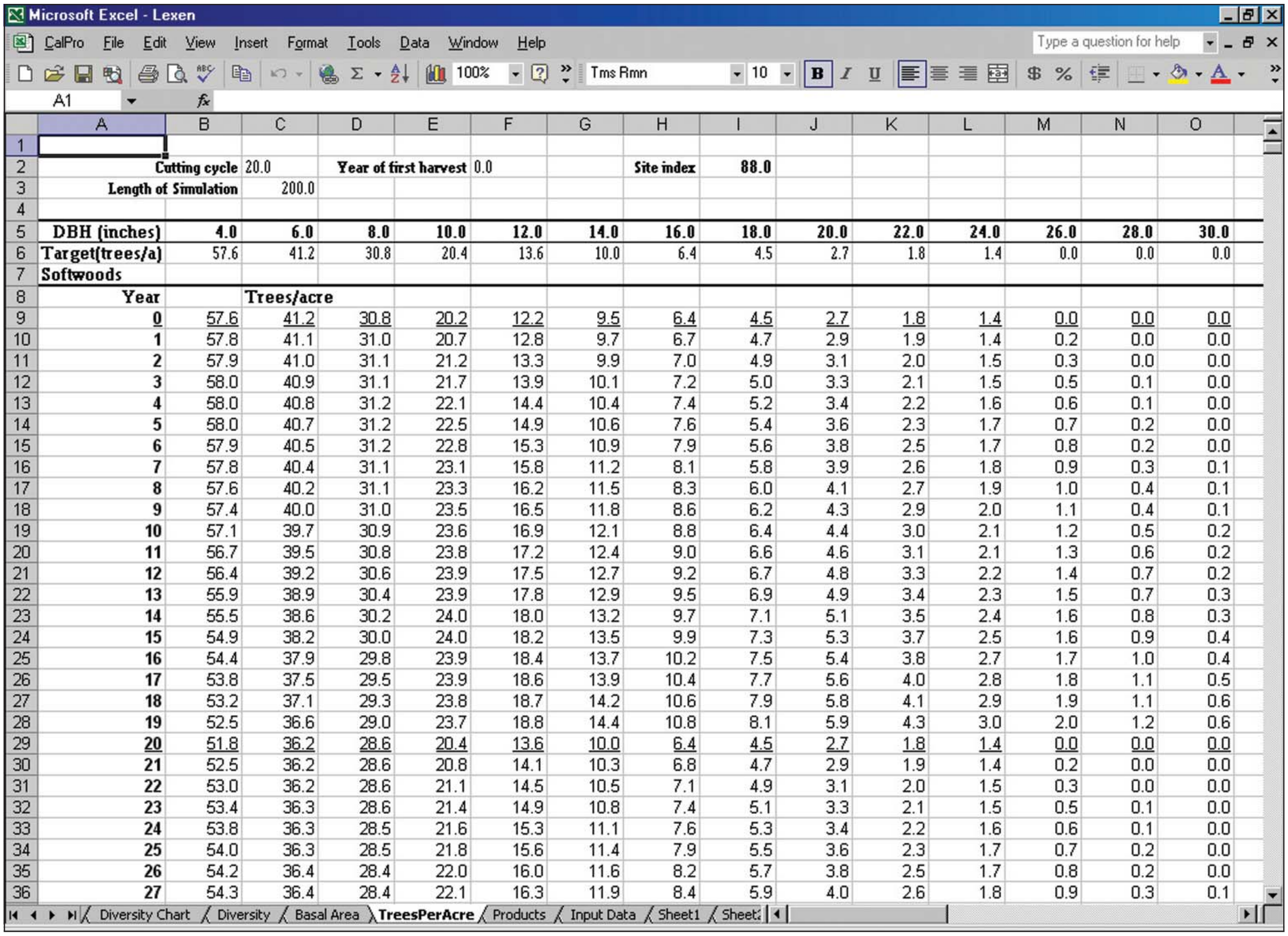
Last, in cell B24, enter a **Site index** of 88, the average site index for the 21 California plots dominated by ponderosa pine trees.

Simulation output—
The simulation outcomes are displayed in tables and charts. They are located in the same workbook as the input data worksheet.

TreesPerAcre worksheet—This worksheet (fig. 4) shows the number of trees per acre, by species and tree diameter class, for each year of simulation under the Lexen stocking standard and a 20-year cutting cycle. Scrolling to the right reveals the trees-per-acre distribution for hardwood species. The underlined numbers represent the year of harvest and the number of trees per acre just after the harvest.

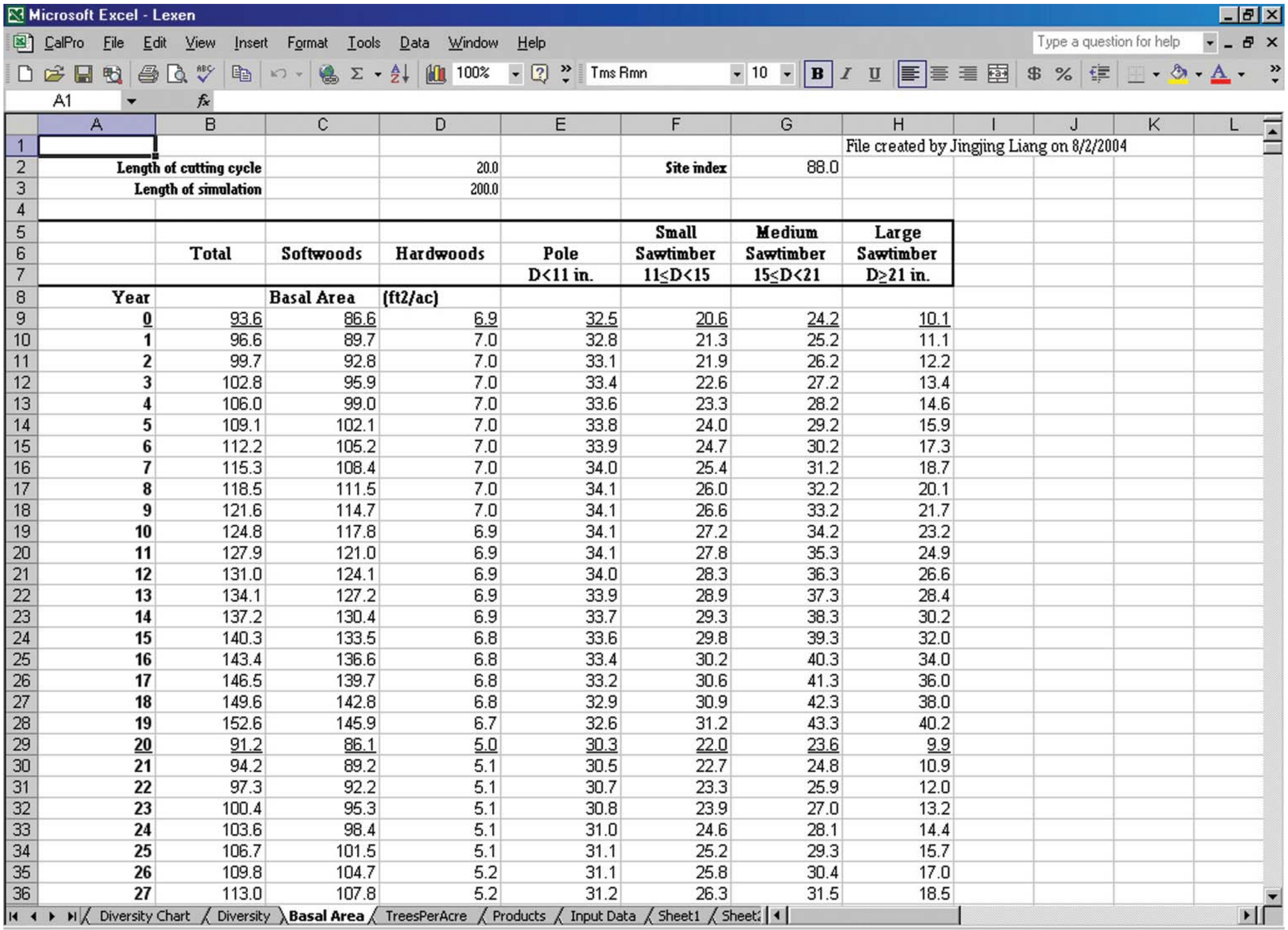
Basal area worksheet—This worksheet (fig. 5) shows, for each simulated year, the total stand basal area, the stand basal area by species group, and the stand basal area by timber size category: poles (trees from 5 to 11 in d.b.h.), small sawtimber (trees from 11 to 15 in d.b.h.), medium sawtimber (trees from 15 to 21 in d.b.h.), and large sawtimber (trees 21 in d.b.h. and larger). Underlined numbers show the year of harvest and the basal areas just after harvest.

Products worksheet—The upper part of the products worksheet (fig. 6) shows data for each harvest in terms of basal area cut, gross income, total net present value (NPV), the pole and sawtimber volumes cut for each species group, and the annual production in basal area and volume cut. The volumes are computed from equations linking tree volume to tree diameter, stand basal area, and site index (app. 2). The lower part is a copy of the input data for reference only.



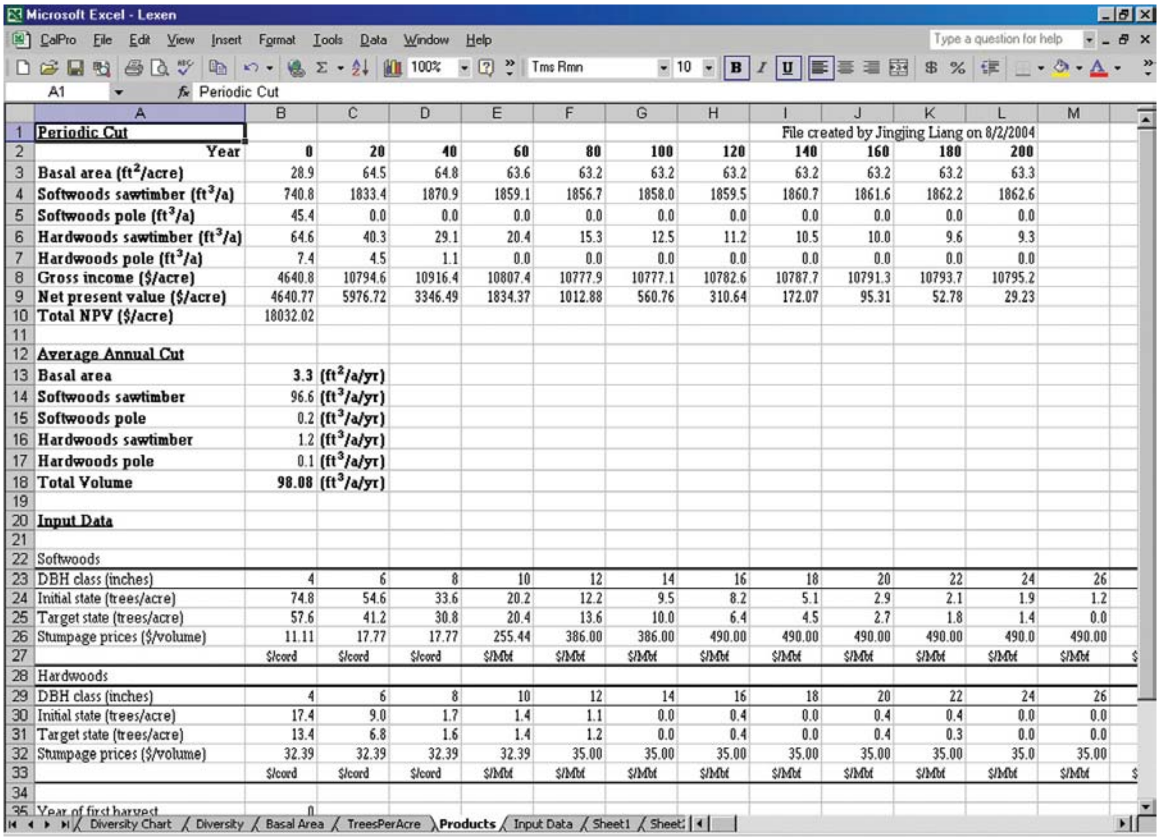
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1															
2	Cutting cycle	20.0		Year of first harvest	0.0		Site index		88.0						
3	Length of Simulation		200.0												
4															
5	**DBH (inches)**	**4.0**	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**16.0**	**18.0**	**20.0**	**22.0**	**24.0**	**26.0**	**28.0**	**30.0**
6	**Target(trees/a)**	57.6	41.2	30.8	20.4	13.6	10.0	6.4	4.5	2.7	1.8	1.4	0.0	0.0	0.0
7	**Softwoods**														
8	**Year**		**Trees/acre**												
9	**0**	57.6	41.2	30.8	20.2	12.2	9.5	6.4	4.5	2.7	1.8	1.4	0.0	0.0	0.0
10	**1**	57.8	41.1	31.0	20.7	12.8	9.7	6.7	4.7	2.9	1.9	1.4	0.2	0.0	0.0
11	**2**	57.9	41.0	31.1	21.2	13.3	9.9	7.0	4.9	3.1	2.0	1.5	0.3	0.0	0.0
12	**3**	58.0	40.9	31.1	21.7	13.9	10.1	7.2	5.0	3.3	2.1	1.5	0.5	0.1	0.0
13	**4**	58.0	40.8	31.2	22.1	14.4	10.4	7.4	5.2	3.4	2.2	1.6	0.6	0.1	0.0
14	**5**	58.0	40.7	31.2	22.5	14.9	10.6	7.6	5.4	3.6	2.3	1.7	0.7	0.2	0.0
15	**6**	57.9	40.5	31.2	22.8	15.3	10.9	7.9	5.6	3.8	2.5	1.7	0.8	0.2	0.0
16	**7**	57.8	40.4	31.1	23.1	15.8	11.2	8.1	5.8	3.9	2.6	1.8	0.9	0.3	0.1
17	**8**	57.6	40.2	31.1	23.3	16.2	11.5	8.3	6.0	4.1	2.7	1.9	1.0	0.4	0.1
18	**9**	57.4	40.0	31.0	23.5	16.5	11.8	8.6	6.2	4.3	2.9	2.0	1.1	0.4	0.1
19	**10**	57.1	39.7	30.9	23.6	16.9	12.1	8.8	6.4	4.4	3.0	2.1	1.2	0.5	0.2
20	**11**	56.7	39.5	30.8	23.8	17.2	12.4	9.0	6.6	4.6	3.1	2.1	1.3	0.6	0.2
21	**12**	56.4	39.2	30.6	23.9	17.5	12.7	9.2	6.7	4.8	3.3	2.2	1.4	0.7	0.2
22	**13**	55.9	38.9	30.4	23.9	17.8	12.9	9.5	6.9	4.9	3.4	2.3	1.5	0.7	0.3
23	**14**	55.5	38.6	30.2	24.0	18.0	13.2	9.7	7.1	5.1	3.5	2.4	1.6	0.8	0.3
24	**15**	54.9	38.2	30.0	24.0	18.2	13.5	9.9	7.3	5.3	3.7	2.5	1.6	0.9	0.4
25	**16**	54.4	37.9	29.8	23.9	18.4	13.7	10.2	7.5	5.4	3.8	2.7	1.7	1.0	0.4
26	**17**	53.8	37.5	29.5	23.9	18.6	13.9	10.4	7.7	5.6	4.0	2.8	1.8	1.1	0.5
27	**18**	53.2	37.1	29.3	23.8	18.7	14.2	10.6	7.9	5.8	4.1	2.9	1.9	1.1	0.6
28	**19**	52.5	36.6	29.0	23.7	18.8	14.4	10.8	8.1	5.9	4.3	3.0	2.0	1.2	0.6
29	**20**	51.8	36.2	28.6	20.4	13.6	10.0	6.4	4.5	2.7	1.8	1.4	0.0	0.0	0.0
30	**21**	52.5	36.2	28.6	20.8	14.1	10.3	6.8	4.7	2.9	1.9	1.4	0.2	0.0	0.0
31	**22**	53.0	36.2	28.6	21.1	14.5	10.5	7.1	4.9	3.1	2.0	1.5	0.3	0.0	0.0
32	**23**	53.4	36.3	28.6	21.4	14.9	10.8	7.4	5.1	3.3	2.1	1.5	0.5	0.1	0.0
33	**24**	53.8	36.3	28.5	21.6	15.3	11.1	7.6	5.3	3.4	2.2	1.6	0.6	0.1	0.0
34	**25**	54.0	36.3	28.5	21.8	15.6	11.4	7.9	5.5	3.6	2.3	1.7	0.7	0.2	0.0
35	**26**	54.2	36.4	28.4	22.0	16.0	11.6	8.2	5.7	3.8	2.5	1.7	0.8	0.2	0.0
36	**27**	54.3	36.4	28.4	22.1	16.3	11.9	8.4	5.9	4.0	2.6	1.8	0.9	0.3	0.1

Figure 4—TreesPerAcre worksheet.



Year	Total	Softwoods	Hardwoods	Pole D<11 in.	Small Sawtimber 11≤D<15	Medium Sawtimber 15≤D<21	Large Sawtimber D≥21 in.
		Basal Area	(ft2/ac)				
0	93.6	86.6	6.9	32.5	20.6	24.2	10.1
1	96.6	89.7	7.0	32.8	21.3	25.2	11.1
2	99.7	92.8	7.0	33.1	21.9	26.2	12.2
3	102.8	95.9	7.0	33.4	22.6	27.2	13.4
4	106.0	99.0	7.0	33.6	23.3	28.2	14.6
5	109.1	102.1	7.0	33.8	24.0	29.2	15.9
6	112.2	105.2	7.0	33.9	24.7	30.2	17.3
7	115.3	108.4	7.0	34.0	25.4	31.2	18.7
8	118.5	111.5	7.0	34.1	26.0	32.2	20.1
9	121.6	114.7	7.0	34.1	26.6	33.2	21.7
10	124.8	117.8	6.9	34.1	27.2	34.2	23.2
11	127.9	121.0	6.9	34.1	27.8	35.3	24.9
12	131.0	124.1	6.9	34.0	28.3	36.3	26.6
13	134.1	127.2	6.9	33.9	28.9	37.3	28.4
14	137.2	130.4	6.9	33.7	29.3	38.3	30.2
15	140.3	133.5	6.8	33.6	29.8	39.3	32.0
16	143.4	136.6	6.8	33.4	30.2	40.3	34.0
17	146.5	139.7	6.8	33.2	30.6	41.3	36.0
18	149.6	142.8	6.8	32.9	30.9	42.3	38.0
19	152.6	145.9	6.7	32.6	31.2	43.3	40.2
20	91.2	86.1	5.0	30.3	22.0	23.6	9.9
21	94.2	89.2	5.1	30.5	22.7	24.8	10.9
22	97.3	92.2	5.1	30.7	23.3	25.9	12.0
23	100.4	95.3	5.1	30.8	23.9	27.0	13.2
24	103.6	98.4	5.1	31.0	24.6	28.1	14.4
25	106.7	101.5	5.1	31.1	25.2	29.3	15.7
26	109.8	104.7	5.2	31.1	25.8	30.4	17.0
27	113.0	107.8	5.2	31.2	26.3	31.5	18.5

Figure 5—Basal Area worksheet.

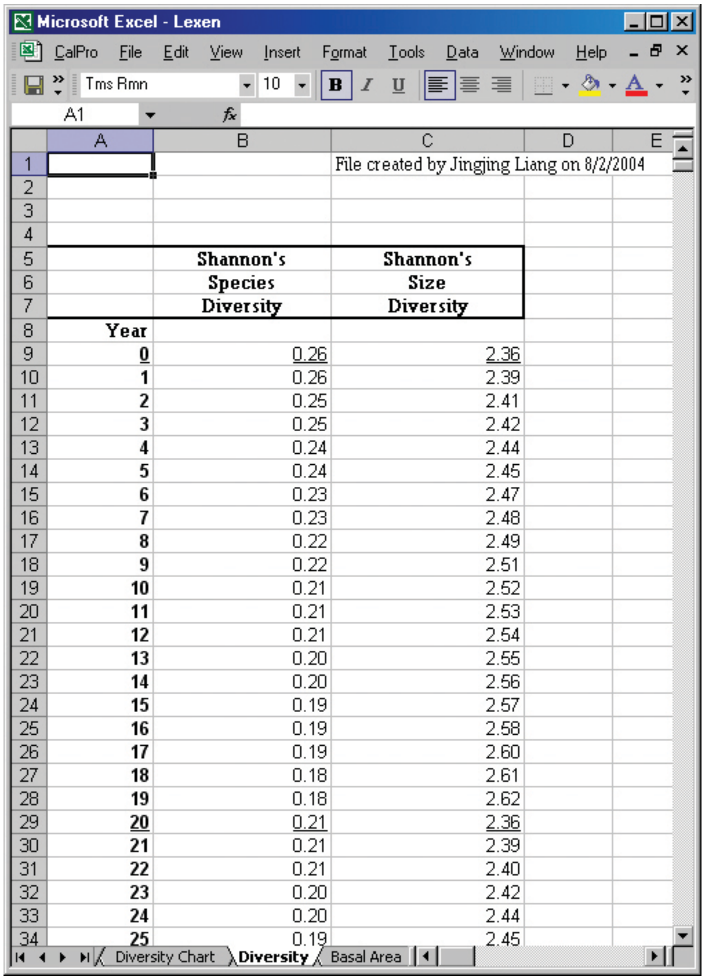


	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Periodic Cut								File created by Jingjing Liang on 8/2/2004				
2	Year	0	20	40	60	80	100	120	140	160	180	200	
3	Basal area (ft^2/acre)	28.9	64.5	64.8	63.6	63.2	63.2	63.2	63.2	63.2	63.2	63.3	
4	Softwoods sawtimber (ft^3/a)	740.8	1833.4	1870.9	1859.1	1856.7	1858.0	1859.5	1860.7	1861.6	1862.2	1862.6	
5	Softwoods pole (ft^3/a)	45.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	Hardwoods sawtimber (ft^3/a)	64.6	40.3	29.1	20.4	15.3	12.5	11.2	10.5	10.0	9.6	9.3	
7	Hardwoods pole (ft^3/a)	7.4	4.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	Gross income ($/acre)	4640.8	10794.6	10916.4	10807.4	10777.9	10777.1	10782.6	10787.7	10791.3	10793.7	10795.2	
9	Net present value ($/acre)	4640.77	5976.72	3346.49	1834.37	1012.88	560.76	310.64	172.07	95.31	52.78	29.23	
10	Total NPV ($/acre)	18032.02											
11													
12	Average Annual Cut												
13	Basal area	3.3	(ft^2/a/yr)										
14	Softwoods sawtimber	96.6	(ft^3/a/yr)										
15	Softwoods pole	0.2	(ft^3/a/yr)										
16	Hardwoods sawtimber	1.2	(ft^3/a/yr)										
17	Hardwoods pole	0.1	(ft^3/a/yr)										
18	Total Volume	98.08	(ft^3/a/yr)										
19													
20	Input Data												
21													
22	Softwoods												
23	DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26
24	Initial state (trees/acre)	74.8	54.6	33.6	20.2	12.2	9.5	8.2	5.1	2.9	2.1	1.9	1.2
25	Target state (trees/acre)	57.6	41.2	30.8	20.4	13.6	10.0	6.4	4.5	2.7	1.8	1.4	0.0
26	Stumpage prices ($/volume)	11.11	17.77	17.77	255.44	386.00	386.00	490.00	490.00	490.00	490.00	490.0	490.00
27		$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf
28	Hardwoods												
29	DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26
30	Initial state (trees/acre)	17.4	9.0	1.7	1.4	1.1	0.0	0.4	0.0	0.4	0.4	0.0	0.0
31	Target state (trees/acre)	13.4	6.8	1.6	1.4	1.2	0.0	0.4	0.0	0.4	0.3	0.0	0.0
32	Stumpage prices ($/volume)	32.39	32.39	32.39	32.39	35.00	35.00	35.00	35.00	35.00	35.00	35.0	35.00
33		$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf
34													
35	Year of first harvest	0											

Figure 6—Products worksheet.

The results show that with this particular initial stand state and with a 20-year cutting cycle, the Lexen regime would produce a nearly constant periodic production beginning in the 60th year. The average yield over 200 years would be 104.90 ft^3•ac^{-1}•yr^{-1}, for a net present value of $13,506/ac. This is the value of the land and initial trees under this management. It suggests that Lexen's regime, with this cutting cycle, would not be economically efficient. Because the value of the initial trees was $14,072/ac (this value is easily calculated from the data in the lower part of the products worksheet), the present value of the return from land and initial trees would be less than the initial investment in trees alone.

Diversity worksheet—The diversity worksheet (fig. 7) shows Shannon's indices of species group diversity and tree size diversity for each simulated year (see app. 3 for the definitions of Shannon's diversity). The underlined data show the year of harvest and the values of the diversity indices just after harvest.



File created by Jingjing Liang on 8/2/2004

	A	B	C
5		Shannon's Species Diversity	Shannon's Size Diversity
8	Year		
9	0	0.26	2.36
10	1	0.26	2.39
11	2	0.25	2.41
12	3	0.25	2.42
13	4	0.24	2.44
14	5	0.24	2.45
15	6	0.23	2.47
16	7	0.23	2.48
17	8	0.22	2.49
18	9	0.22	2.51
19	10	0.21	2.52
20	11	0.21	2.53
21	12	0.21	2.54
22	13	0.20	2.55
23	14	0.20	2.56
24	15	0.19	2.57
25	16	0.19	2.58
26	17	0.19	2.60
27	18	0.18	2.61
28	19	0.18	2.62
29	20	0.21	2.36
30	21	0.21	2.39
31	22	0.21	2.40
32	23	0.20	2.42
33	24	0.20	2.44
34	25	0.19	2.45

Figure 7—Diversity worksheet.

Diversity chart—The diversity chart (fig. 8) displays the evolution of Shannon’s indices over time. The results show that the Lexen regime with a 20-year cutting cycle would lead to a sharp decrease of size diversity and increase of species diversity right after each harvest. Both diversity indices would recover to about their initial level by the time of the next harvest.

Species basal area chart—This chart (fig. 9) shows the development of basal area by species throughout the simulation period. The chart suggests that, with a 20-year cutting cycle, the Lexen regime would lead to a 50-percent decrease in the basal area of softwoods after each harvest, but to little change in the basal area of

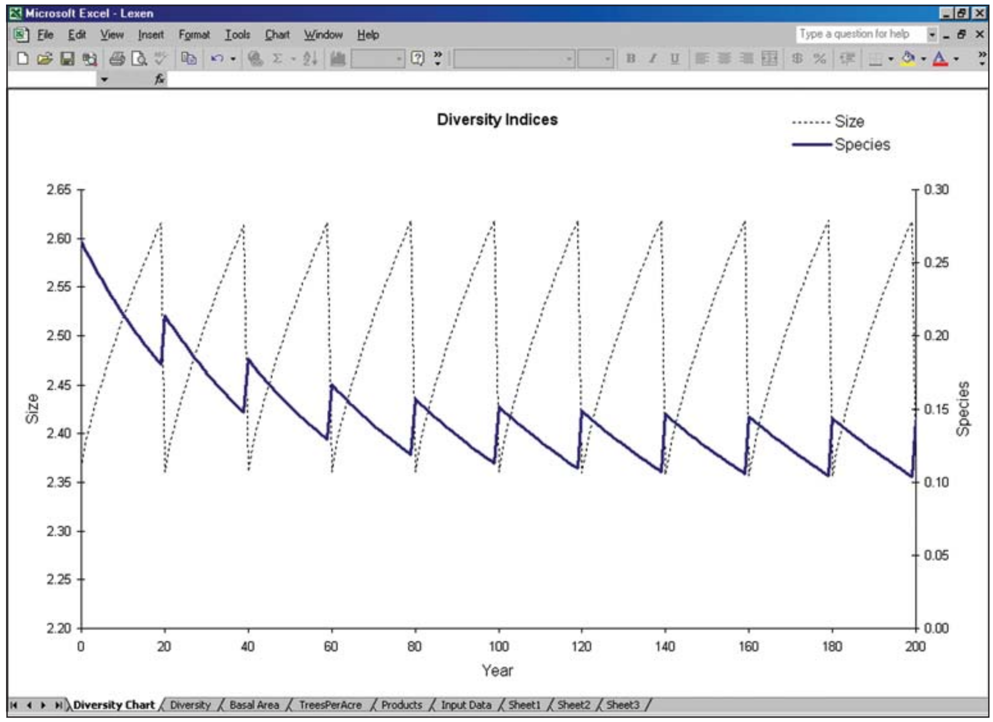


Figure 8—Diversity chart.

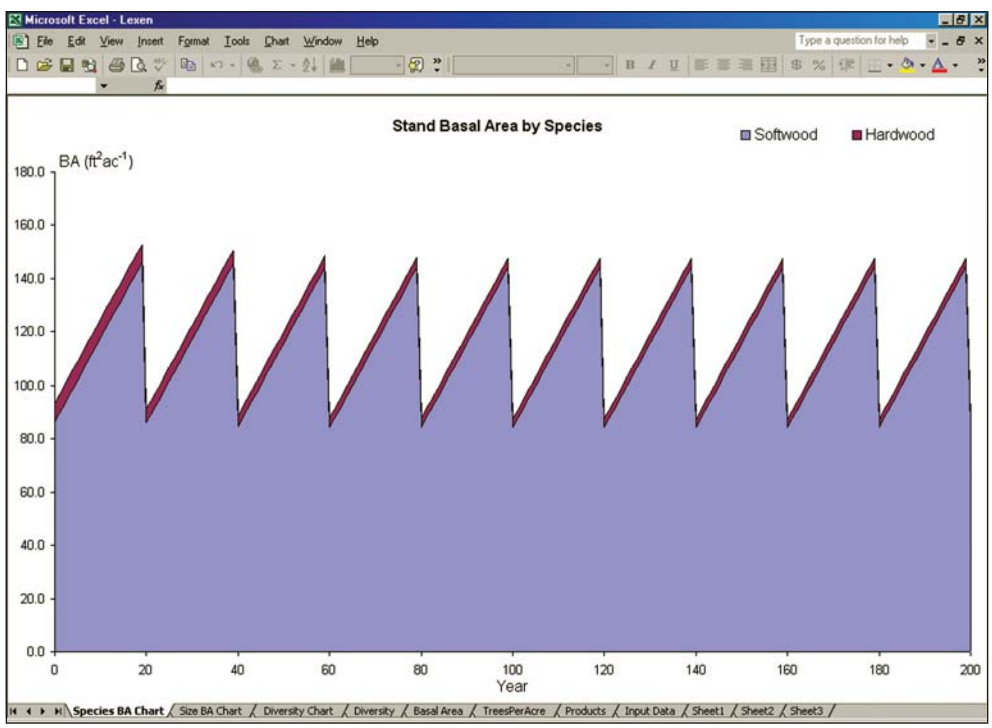


Figure 9—Species BA chart.

hardwoods. The basal area of softwoods would recover almost totally in 20 years, while the hardwood component remains essentially constant.

Timber size basal area chart—This chart (fig. 10) shows the development of basal area by timber size throughout the simulation of the Lexen regime. It excludes the basal area of trees smaller than poles, which have a minimum diameter of 5 in. The results suggest that the basal area of poles would gradually decrease over the first 80 years and then stabilize. The basal area of sawtimber—large, medium, and small—is reduced heavily in each 20-year cutting cycle, with each cycle essentially the same after about 80 years.

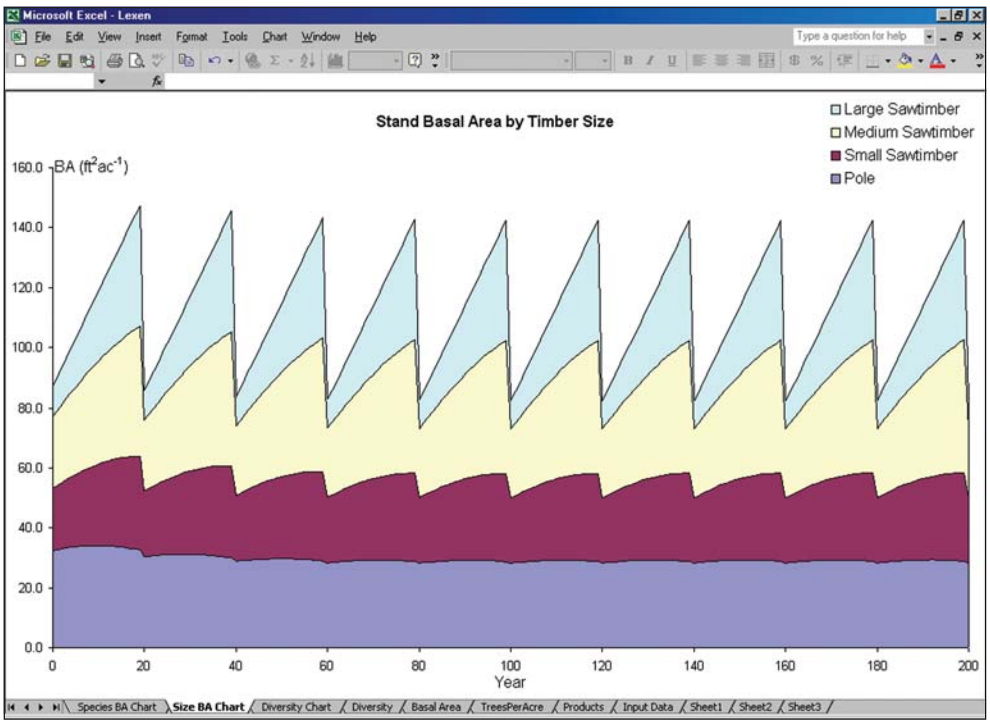


Figure 10—Size BA chart.

Simulating BDq and Diameter-Limit Management Regimes

In this example, we performed a series of simulations on two kinds of cutting regimes: basal-area-diameter-q-ratio (BDq) selection and diameter-limit cut. We then compared the results in terms of economic returns, productivity, tree diversity, and stand structure.

Simulation parameters—
The simulations were for 200 years with cutting cycles of 20 years. The initial stand state was the average distribution of the 205 plots used in calibrating the growth equations of CalPro. The average site index was 88 ft. Softwood trees composed 88 percent of the stand initial basal area, and hardwood trees composed 12 percent. The interest rate was set at 3 percent per year, in real terms (net of inflation). The prices used are in table 2.

For the BDq regimes, the residual stand basal area was set at 91 ft^2/ac, 74 ft^2/ac, or 61 ft^2/ac, corresponding to a light, medium, or heavy selection. The q-ratio was 1.40, the average value on the 205 plots.

Figure 11 shows the BDq calculator set to produce the target state for softwood trees according to a light selection. Setting the basal area to 80 reflects the fact that 88 percent of the initial stand is composed of softwood trees ($91\ ft^2 \times .88 = 80\ ft^2$). Set the q-ratio to 1.40, the maximum diameter limit to 40+, and the minimum diameter limit to 3. Click on the **Calculate** button. The BDq calculator produces the number of trees by size class.

To copy the distribution to the input data worksheet, select the option box corresponding to **Softwood Target Distribution** and click on the **Copy** button.

Repeat these steps for the **Hardwood Target Distribution**, using a basal area of 11 ft^2.

The diameter limits were set at:

10 in (cut all sawtimber trees), or

16 in (cut medium and large sawtimber trees), or

22 in (cut only large sawtimber trees).

Figures 12 and 13 show the input data worksheet for the light BDq selection regime and the 10-in diameter-limit cutting regime, respectively. The two spreadsheets differ only by the number of trees in the target states.

Running simulations—
To run a series of simulations, load the input data for the first management regime, run the simulation, save your outcome, and proceed to load and run the second management regime.

Upon running a simulation, CalPro will replace any old tables and charts with new ones. For this reason, you should save the workbook after each simulation. You can then compare the data on NVP, basal area, number of trees, diversity of species and size, and volume production for different regimes. To that end, comparative charts and tables can be built with Excel from the CalPro output worksheets.

Table 2—Target distribution for BDq selection regimes

Species	Timber size	D.b.h.	Stumpage price[a]		BDq selection		
					Light	Medium	Heavy
		Inches	*$/cord*[b]	*$/MBF*[c]	*– – – – Trees per acre – – – –*		
Softwoods		4	11.11		37.3	30.3	25.2
	Pole	6	17.77		26.7	21.7	18.0
		8	17.77		19.0	15.5	12.9
	Sawtimber	10		255.44	13.6	11.1	9.2
		12		386.00	9.7	7.9	6.6
		14		386.00	6.9	5.6	4.7
		16		490.00	5.0	4.0	3.3
		18		490.00	3.5	2.9	2.4
		20		490.00	2.5	2.1	1.7
		22		490.00	1.8	1.5	1.2
		24		490.00	1.3	1.0	.9
		26		490.00	.9	.7	.6
		28		490.00	.7	.5	.4
		30		490.00	.5	.4	.3
		32		490.00	.3	.3	.2
		34		490.00	.2	.2	.2
		36		490.00	.2	.1	.1
		38		490.00	.1	.1	.1
		40+		490.00	.1	.1	.1
Hardwoods		4	32.39		5.1	4.2	3.3
	Pole	6	32.39		3.7	3.0	2.3
		8	32.39		2.6	2.1	1.7
	Sawtimber	10		32.39	1.9	1.5	1.2
		12		35.00	1.3	1.1	.9
		14		35.00	1.0	.8	.6
		16		35.00	.7	.6	.4
		18		35.00	.5	.4	.3
		20		35.00	.3	.3	.2
		22		35.00	.2	.2	.2
		24		35.00	.2	.1	.1
		26		35.00	.1	.1	.1
		28		35.00	.1	.1	.1
		30		35.00	.1	.1	0
		32		35.00	0	0	0
		34		35.00	0	0	0
		36		35.00	0	0	0
		38		35.00	0	0	0
		40+		35.00	0	0	0

[a] Unit values are adapted from California State Board of Equalization (2003), Harvest values schedule, effective July 1, 2003, through December 31, 2003.

[b] 1 cord = 128 ft^3.

[c] MBF = 1,000 board feet.

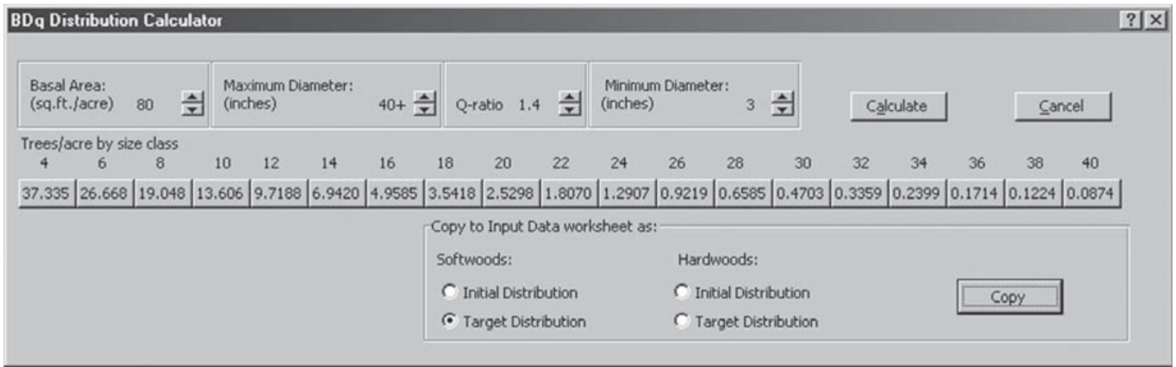
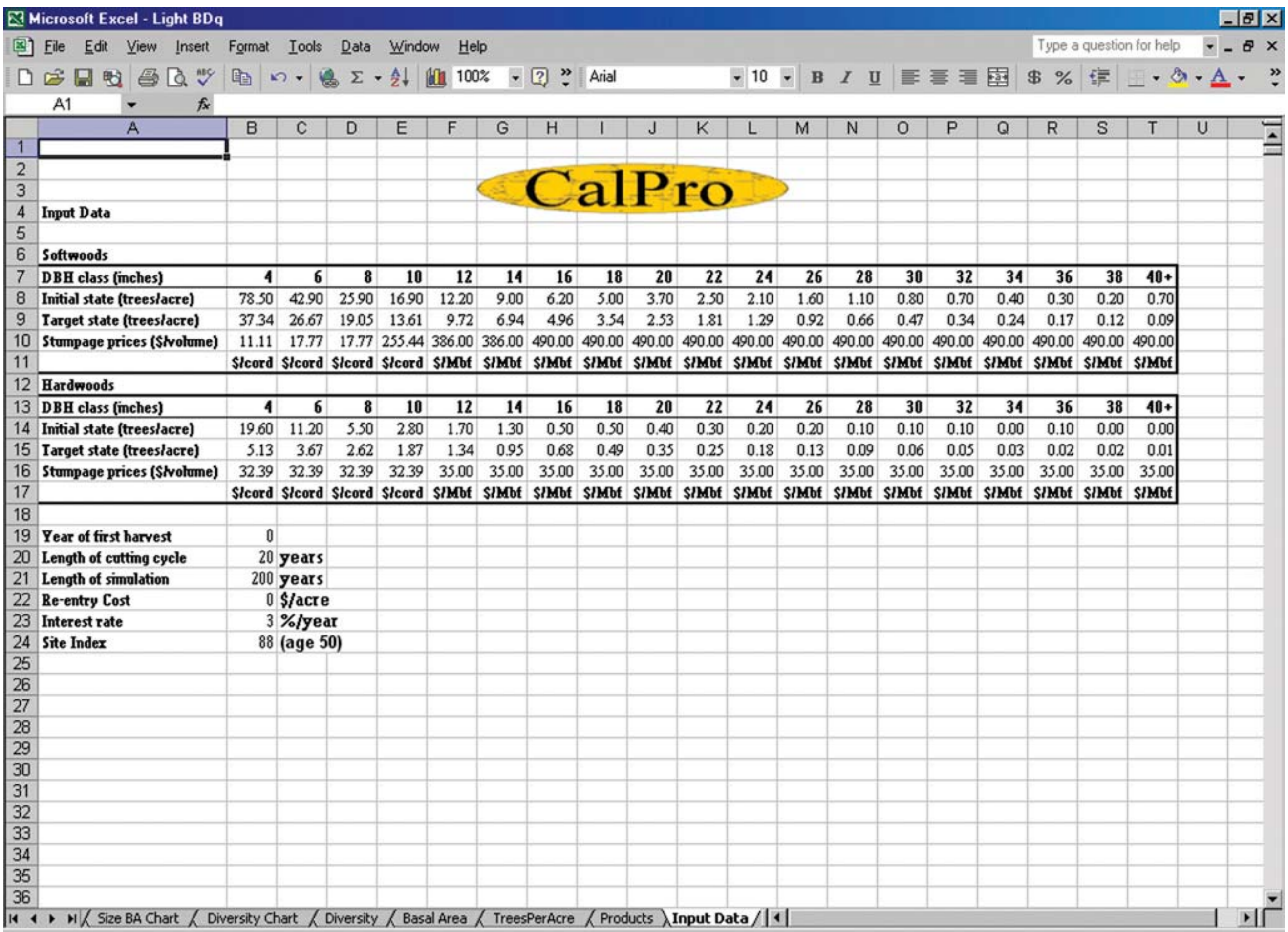
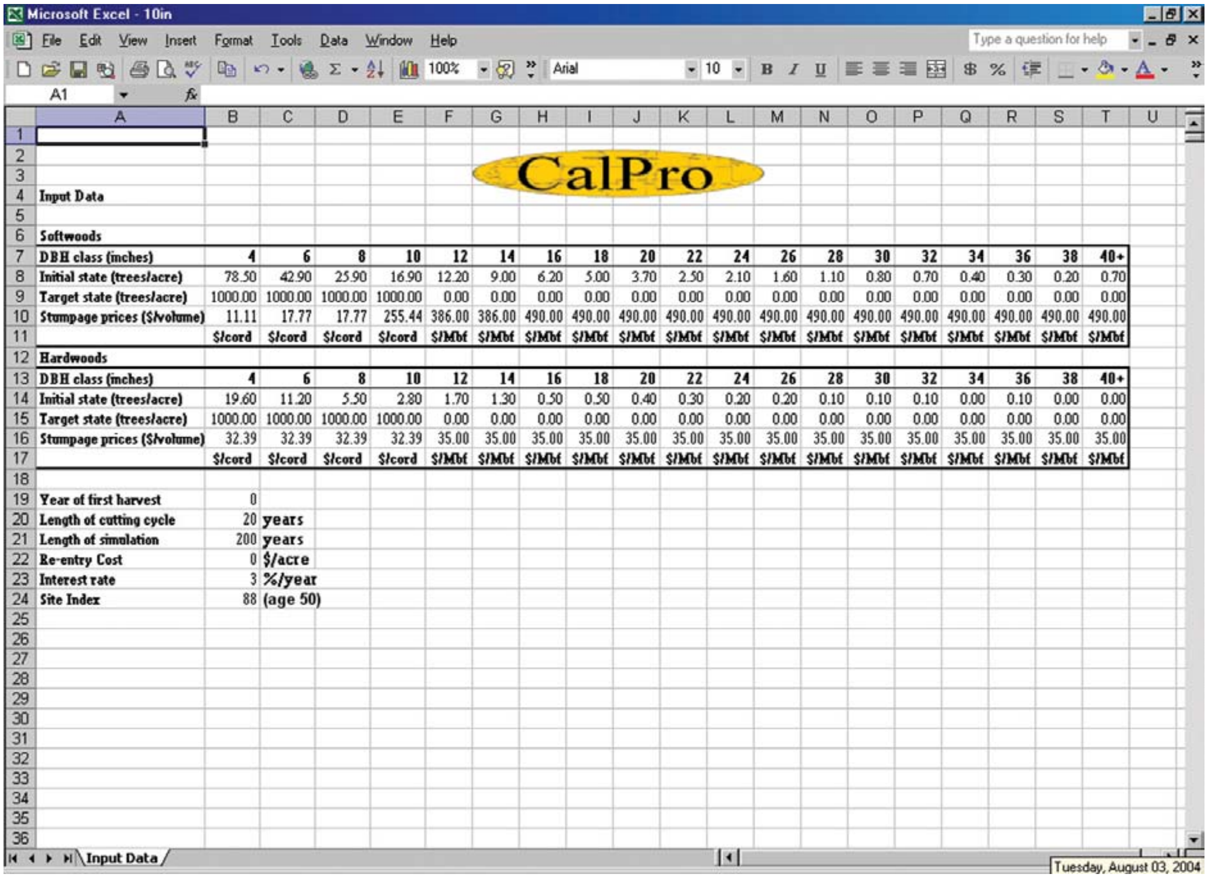


Figure 11—BDq Distribution calculation dialog box.



Input Data																			
Softwoods																			
DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
Initial state (trees/acre)	78.50	42.90	25.90	16.90	12.20	9.00	6.20	5.00	3.70	2.50	2.10	1.60	1.10	0.80	0.70	0.40	0.30	0.20	0.70
Target state (trees/acre)	37.34	26.67	19.05	13.61	9.72	6.94	4.96	3.54	2.53	1.81	1.29	0.92	0.66	0.47	0.34	0.24	0.17	0.12	0.09
Stumpage prices ($/volume)	11.11	17.77	17.77	255.44	386.00	386.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00
	$/cord	$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf
Hardwoods																			
DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
Initial state (trees/acre)	19.60	11.20	5.50	2.80	1.70	1.30	0.50	0.50	0.40	0.30	0.20	0.20	0.10	0.10	0.10	0.00	0.10	0.00	0.00
Target state (trees/acre)	5.13	3.67	2.62	1.87	1.34	0.95	0.68	0.49	0.35	0.25	0.18	0.13	0.09	0.06	0.05	0.03	0.02	0.02	0.01
Stumpage prices ($/volume)	32.39	32.39	32.39	32.39	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	$/cord	$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf
Year of first harvest	0																		
Length of cutting cycle	20	years																	
Length of simulation	200	years																	
Re-entry Cost	0	$/acre																	
Interest rate	3	%/year																	
Site Index	88	(age 50)																	

Figure 12—Input data worksheet for light BDq selection.


Input Data

Softwoods

DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
Initial state (trees/acre)	78.50	42.90	25.90	16.90	12.20	9.00	6.20	5.00	3.70	2.50	2.10	1.60	1.10	0.80	0.70	0.40	0.30	0.20	0.70
Target state (trees/acre)	1000.00	1000.00	1000.00	1000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stumpage prices ($/volume)	11.11	17.77	17.77	255.44	386.00	386.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00	490.00
	$/cord	$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf

Hardwoods

DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
Initial state (trees/acre)	19.60	11.20	5.50	2.80	1.70	1.30	0.50	0.50	0.40	0.30	0.20	0.20	0.10	0.10	0.10	0.00	0.10	0.00	0.00
Target state (trees/acre)	1000.00	1000.00	1000.00	1000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stumpage prices ($/volume)	32.39	32.39	32.39	32.39	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
	$/cord	$/cord	$/cord	$/cord	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf	$/Mbf

Year of first harvest	0	
Length of cutting cycle	20	years
Length of simulation	200	years
Re-entry Cost	0	$/acre
Interest rate	3	%/year
Site Index	88	(age 50)

Figure 13—Input data worksheet for 10-in diameter-limit regime.

Simulation results—

For all six cutting regimes except the 22-in diameter-limit cut, after 200 years, the stand basal area reached a near-homeostasis, where growth over a cutting cycle generally replaced the harvest. For example, figure 14 shows how basal area by tree size developed with the light BDq selection. The figure was generated by CalPro (**Size BA chart**).

Figures 15 and 16 show comparative statistics on diversity and productivity assembled from six simulation runs. Figure 15 shows that the three BDq selections generated higher species and size diversity than the diameter-limits cuts. The data were obtained from the diversity worksheet produced by CalPro.

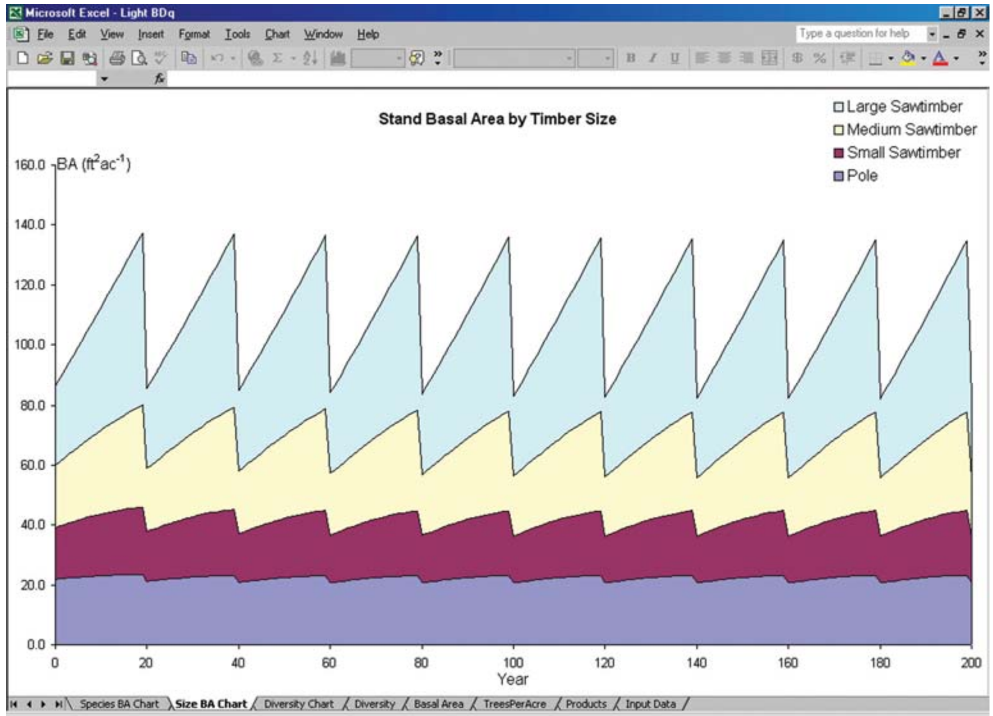


Figure 14—Development of stand basal area by timber size, under light selection.

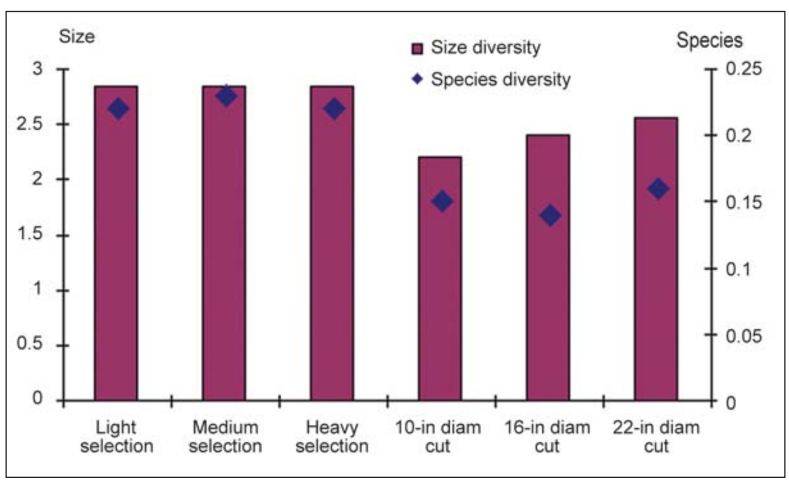


Figure 15—Effect of management regime on tree diversity after 200 years.

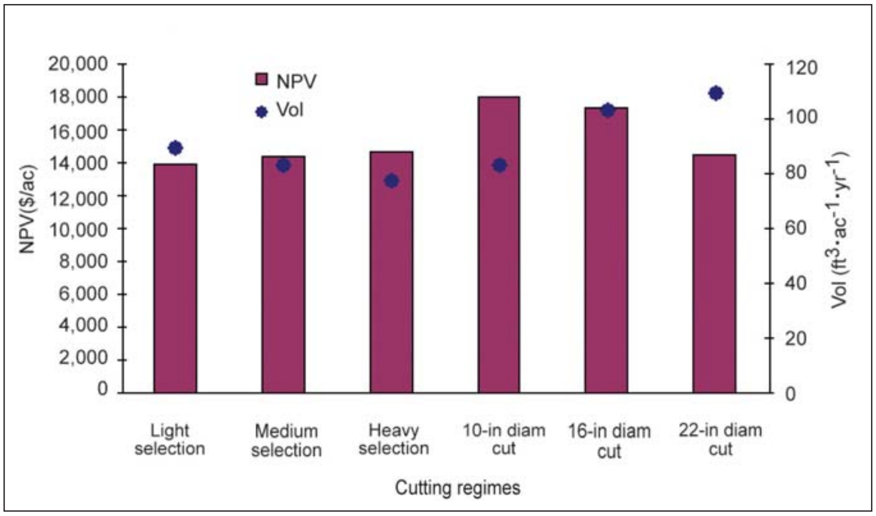


Figure 16—Net present value (NPV) and volume yield of different cutting regimes.

Figure 16 shows the NPV and yearly production of the different cutting regimes over 200 years, with a 20-year cutting cycle. We built these figures from the results in the Products worksheets of CalPro. The 10-in diameter-limit cut yielded the highest NVP, whereas the 22-in diameter-limit cut gave the highest annual production.

5. Troubleshooting CalPro

Why can't I open CalPro?

Make sure you have the latest copy of CalPro (2004). It should be 535KB in size, and the file type should be Microsoft Excel Add-in.

How can I download CalPro from your Web site?

Visit our Web site: http://forest.wisc.edu/facstaff/buongiorno/index.htm.You will find an icon of CalPro on the index page. Click on the icon, and you will be directed to our Products page where you can see the links for the CalPro program and some example worksheets. Right click on the link and save CalPro.xla to your local disk.

CalPro does not insert a new input data worksheet. What can I do?

Before inserting a new input data worksheet, CalPro checks to see if there is a worksheet named **Input Data** already open. If there is one, CalPro will not generate a new Input Data worksheet. To get a new input data worksheet, close all Excel windows and reopen CalPro.

Why is there no BDq calculator in the example worksheets?

The example workbooks contain only the input data. After you have installed CalPro, the BDq calculator icon will appear in the new input data worksheet. At that point, you can copy data from the example workbooks into the input data worksheet.

Why is the BDq calculator not working?

CalPro must be open to use the BDq calculator. To use the BDq calculator on a previously saved input data worksheet, **CalPro** must be in the Excel menu bar.

Why can't I copy all the content from the example worksheet to the input data worksheet?

All the cells of the input data worksheet are protected except those that need entries (marked with ? marks). Copy only the data from the example worksheet and paste them to the corresponding locations in the input data worksheet.

For further assistance, or to send us your comments, please visit our Web site at http://forest.wisc.edu/facstaff/buongiorno/index.htm, or contact us through jbuongio@wisc.edu.

Acknowledgments

The research leading to this paper was supported, in part, by the USDA Forest Service, Pacific Northwest Research Station, by USDA-CSREES grant 2001-35108-10673, and by the School of Natural Resources, University of Wisconsin, Madison. We thank Jeremy Fried for his participation in the research leading to the growth-and-yield model underlying CalPro. The authors take sole responsibility for any error or omission.

Metric Equivalents

When you know:	**Multiply by:**	**To find:**
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	.305	Meters (m)
Square feet (ft^2)	.093	Square meters (m^2)
Square feet per acre (ft^2/ac)	.2296	Square meters per hectare (m^2/ha)
Cubic feet (ft^3)	.0283	Cubic meters (m^3)

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Appendix 1—CalPro Data

The data to calibrate the model used by CalPro came from 205 permanent plots measured during the last two Forest Inventory and Analysis (2000) surveys conducted by the Portland Inventory and Economics Program of the Pacific Northwest Research Station. The surveys were conducted in the 1980s and 1990s in forests in the Sierra Nevada Mountains; national forests and parks were not included in the sample.

The plots were in the mixed-conifer forest type and in uneven-aged stands (fewer than 70 percent of the trees differed by less than 30 years in age [Hiserote and Waddell 2003]). Most of the plots were in northern California (fig. 17). About 70 percent of the plots were on industry lands, and 25 percent belonged to other private owners.

Trees were grouped as softwoods and hardwoods, and into nineteen 2-in diameter classes, from 3 to 5 in up to 40 in and above. White fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.), a shade-tolerant conifer, was the most abundant softwood on the plots (table 3). The moderately shade-tolerant California black oak (*Quercus kelloggii* Newberry) and canyon live oak (*Quercus chrysolepis* Liebm.) were the most abundant hardwoods. Most plots were on lands with site indexes between 50 and 80 ft.

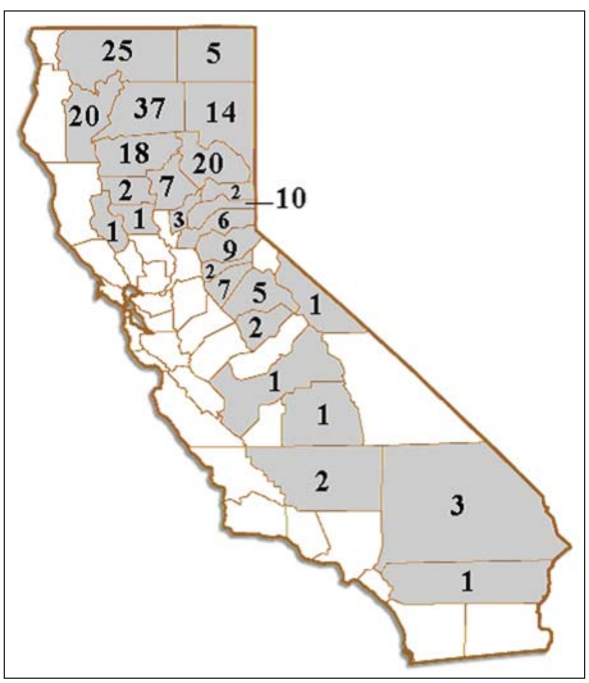

Figure 17—Number of plots (205 total) per county used to calibrate CalPro.

Table 3—Average number of trees per acre by species on the plots used to calibrate CalPro

Scientific name[a]	Common name	First inventory	Second inventory
Softwood:			
Abies concolor	White fir	61.76	66.33
Libocedrus decurrens	Incense-cedar	44.17	51.97
Pseudotsuga menziesii	Douglas-fir	43.15	49.21
Pinus ponderosa	Ponderosa pine	28.92	29.85
Pinus lambertiana	Sugar pine	9.93	10.94
Pinus jeffreyii	Jeffrey pine	5.00	5.85
Abies magnifica	California red fir	3.40	5.29
Pinus contorta	Lodgepole pine	1.08	.91
Juniperus occidentalis	Western juniper	.35	.35
Taxus brevifolia	Pacific yew	.44	.28
Pinus monticola	Western white pine	.28	.28
Pinus coulteri	Coulter pine	.22	.22
Pinus attenuata	Knobcone pine	.26	.14
Sequoia gigantea	Giant sequoia	.13	.13
Torreya californica	California-nutmeg	.09	.09
Pinus sabiniana	Gray pine	.02	.02
Pinus albicaulis	Whitebark pine	.01	.01
Pseudotsuga macrocarpa	Bigcone Douglas-fir	.01	.01
Abies magnifica v. *shastensis*	Shasta red fir	0	0
Total		199.23	221.87
Hardwood:			
Quercus kelloggii	California black oak	18.70	18.21
Quercus chrysolepis	Canyon live oak	11.10	12.44
Acer macrophyllum	Bigleaf maple	2.61	5.04
Lithocarpus densiflorus	Tanoak	3.12	4.68
Arbutus menziesii	Pacific madrone	1.41	2.66
Umbellularia californica	California-laurel	1.17	1.74
Cornus nuttallii	Pacific dogwood	0	1.64
Quercus wislizeni	Interior live oak	.60	1.56
Alnus rhombifolia	White alder	.70	.80
Alnus rubra	Red alder	.25	.37
Castanopsis chrysophylla	Golden chinkapin	.21	.21
Quercus garryana	Oregon white oak	.12	.12
Salix spp.	Willow	.05	.05
Quercus lobata	California white oak	.02	.02
Populus tremuloides	Quaking aspen	.04	0
Total		40.11	49.54

[a] Nomenclature per Little (1979).

Appendix 2—Growth-and-Yield Model

The growth model used in WestPro (Ralston et al. 2003) has the following form (Liang et al. 2004):

$$\mathbf{y}_{t+1} = \mathbf{G}(\mathbf{y}_t - \mathbf{h}_t) + \mathbf{R}, \quad (1)$$

where $\mathbf{y}_t = [y_{ijt}]$ is a column vector representing the number of live trees per acre of species group i (i = 1,2), diameter class j (j = 1,2,…,19) at time t. The harvest column vector $\mathbf{h}_t = [h_{ijt}]$ represents the number of trees of species i, diameter class j that are cut at time t. **G**, the state-dependent growth matrix, describes how uncut trees grow or die between t and t+1 year. The state-dependent vector **R** represents the number of trees recruited in the smallest diameter class of each species group, between t and t+1. **G** and **R** are defined as:

$$\mathbf{G} = \begin{bmatrix} \mathbf{G}_1 & \\ & \mathbf{G}_2 \end{bmatrix}, \mathbf{G}_i = \begin{bmatrix} a_{i1} & & & & \\ b_{i1} & a_{i2} & & & \\ & \ddots & \ddots & & \\ & & b_{i,17} & a_{i,18} & \\ & & & b_{i,18} & a_{i,19} \end{bmatrix},$$

$$\mathbf{R} = \begin{bmatrix} \mathbf{R}_1 \\ \mathbf{R}_2 \end{bmatrix}, \qquad \mathbf{R}_i = \begin{bmatrix} R_i \\ 0 \\ \vdots \\ 0 \end{bmatrix},$$

where a_{ij} is the probability that a tree of species i and diameter class j stays alive and in the same diameter class between t and t+1, b_{ij} is the probability that it stays alive and grows up to diameter class j+1, and R_i is the number of trees of species i recruited in the smallest diameter class between t and t+1.

The staying rate, a_{ij}, is related to the upgrowth rate, b_{ij}, and the mortality rate, m_{ij}, by:

$$a_{ij} = 1 - b_{ij} - m_{ij}.$$

The expected annual upgrowth rate was calculated as:

$$b_{ij} = \frac{1}{d} g_{ij},$$

where d = 2 in is the width of each diameter class, and g_{ij} is the expected annual diameter growth of a tree of species i and diameter class j. The equation of the expected annual diameter growth, for softwoods is:

$$b_{1j} = \exp(-7.07 + 2.99\ln D_j - 0.52(1nD_j)^2 - 0.261nB + 0.581nS)$$

and for hardwoods:

$$b_{2j} = \exp(5.69 + 0.641nD_j - 0.11(1nD_j)^2 - 0.011nB + 0.481nS) ,$$

where D_j is the average tree diameter in diameter class j, B is the stand basal area, S is the site index, and ln(x) is the natural logarithm of x.

The expected annual mortality rate is given by:

$$m_{ij} = \frac{1}{\overline{T}} M_{ij} ,$$

where M_{ij} is the expected mortality rate between two inventories, and $\overline{T} = 10.88$ yr is the average time between inventories in the sample. The equation of M_{ij} for softwoods is:

$$M_{1j} = \Phi\ (-0.148D_j + 0.0026D_j^2 + 0.005B + 0.238\overline{T} - 3.141) ,$$

and for hardwoods:

$$M_{2j} = \Phi\ (-0.138D_j + 0.002D_j^2 + 0.357\overline{T} - 3.268) ,$$

where Φ is the standard normal cumulative distribution.

The equation for the expected annual recruitment per acre is:

$$R_i = \Phi\ (\beta_i x_i / \sigma_i)\ \beta_i x_i + \sigma_i \phi(\beta_i x_i / \sigma_i) \ ,$$

where ϕ is the standard normal density function, and for softwoods:

$$\beta_1 x_1 = -0.035B + 0.018N + 4.266 \text{ and } \sigma_1 = 5.703,$$

whereas for hardwoods:

$$\beta_2 x_2 = -0.023B + 0.058N - 7.379 \text{ and } \sigma_2 = 8.69.$$

The expected volume of individual trees, in cubic feet, is calculated with the following equations. For softwoods:

$$v_{1j} = \exp(2.71 \ln D_j + 0.026 \ln B + 0.209 \ln S - 5.079)$$

and for hardwoods:

$$v_{2j} = \exp(2.518 \ln D_j + 0.139 \ln B + 0.283 \ln S - 5.371).$$

For poletimber, the cubic-foot volume is converted to cords (1 cord = 128 ft^3). For sawtimber, the cubic-foot volume is converted to thousand board feet Scribner log rule, with the conversion factors in table 4 (Schmidt 1998).

Table 4—Scribner rule conversion factors

D.b.h.	Softwoods	Hardwoods
Inches	*Thousand board feet per cubic foot*	
9.0-10.9	0.783	—
11.0-12.9	.829	0.832
13.0-14.9	.858	.861
15.0-16.9	.878	.883
17.0-18.9	.895	.900
19.0-20.9	.908	.913
21.0-22.9	.917	.924
23.0-24.9	.924	.933
25.0-26.9	.930	.940
27.0-28.9	.932	.945
29.0+	.936	.954

Appendix 3—Definition of Diversity of Tree Species and Size

CalPro uses Shannon's index to measure the stand diversity in terms of tree species (how well trees are distributed across species class) and timber size classes. CalPro measures the presence of trees in a class by their basal area, which gives more weight to larger trees.

The tree species diversity is defined in CalPro as:

$$H_{species} = -\sum_{i=1}^{m} \frac{y_i}{y} \ln\left(\frac{y_i}{y}\right),$$

where y_i is the basal area of trees of species *i* per acre, *y* is total basal area, and 1n (x) is the natural logarithm of x. In CalPro, *m* = 2 (softwood and hardwood). The tree species diversity reaches a maximum value of ln(2) = 0.69, when basal area is equally distributed in both species groups, and a minimum value of zero when all trees are in the same species group.

Similarly, tree size diversity is:

$$H_{size} = -\sum_{j=1}^{n} \frac{y_j}{y} \ln\left(\frac{y_j}{y}\right),$$

where, again, y_j is the basal area of trees in diameter class *j* per acre, *y* is total basal area, and 1n (x) is the natural logarithm of x. In CalPro, *n* = 19 diameter classes. The tree size diversity reaches a maximum ln(19) = 2.94 when basal area is equally distributed in all 19 diameter classes, and a minimum of zero when all trees are in a single diameter class.

Glossary

BA chart—A CalPro-generated chart showing, for a selected range of years, the per-acre basal area of softwoods, hardwoods, and the whole stand.

BDq distribution—A tree distribution, by diameter class, defined by a stand basal area (B), a maximum and minimum tree diameter (D), and a q-ratio (q), the ratio of the number of trees in a given diameter class to the number of trees in the next larger class.

cutting cycle—The number of years between successive harvests. For two-cut silvicultural systems, this is also equal to the number of years between successive harvests.

diameter class—One of nineteen 2-in diameter at breast height (d.b.h.) categories used by CalPro to classify trees by size. Diameter classes range from 4 to 40+ in, with each class denoted by its midpoint diameter. Diameter class 4 is for trees with diameters from 3 to less than 5 in. The 40+ in class is for all trees 39 in in diameter and larger.

diversity chart—A CalPro-generated chart showing changes in the Shannon index of species or size diversity over a selected range of years.

hardwood—See **species groups**.

initial stand state—The number of live trees per acre, by species and size, at the start of a simulation.

input data worksheet—A worksheet to enter the data for running a CalPro simulation.

Microsoft Excel add-in—A command, function, or software program that runs within Microsoft Excel and adds special capabilities. CalPro is an add-in.

net present value (NPV)—The net revenue discounted to the present.

pole-size trees—Trees suitable for the production of poletimber but too small to produce saw logs. In CalPro, these include trees from 5 to less than 11 in.

preharvest stand state—The number of live trees per acre, by species and size, immediately before a harvest.

products worksheet—A CalPro output worksheet that shows, for each harvest, the basal area cut, the volume of poles and sawtimber removed by species group, the gross income generated, and the NPV of the harvest, as well as the total NPV of the stand and its mean annual production in terms of basal area cut and volumes harvested, on a per-acre basis.

re-entry costs—Costs per acre associated with each harvest that are not reflected in the stumpage prices. These may include, e.g., the added expense of marking the stand for single-tree selection or controlling hardwood competition.

sawtimber—Trees suitable for the production of saw logs. CalPro's marking guides recognize three classes of sawtimber trees:

(1) Small sawtimber**—**Trees with d.b.h. of 11 to less than 15 in.

(2) Medium sawtimber**—**Trees with d.b.h. of 15 to less than 21 in.

(3) Large sawtimber**—**Trees with d.b.h. of 21 in or larger.

Setup File worksheet—A worksheet to store CalPro setup files. It is typically hidden.

Setup Files—Collections of related input data that are stored together on a Setup File worksheet. Setup Files may contain data for initial stand states, target stand states, cutting cycle parameters, stumpage prices, or fixed costs, and may be used in varying combinations as input for CalPro simulations.

site index—The average height of a stand's dominant and codominant trees at age 50 years.

size diversity—The diversity of tree diameter classes as measured by the Shannon index. With 19 diameter classes, size diversity reaches its maximum value of 2.94 when the basal area or number of trees is distributed evenly among the diameter classes.

softwood —See **species groups**.

species diversity—The diversity of species groups as measured by the Shannon index. With two species classes, species diversity reaches its maximum value of 0.69 when the basal area or number of trees is distributed evenly among the species groups.

species groups—The two categories used by CalPro to classify trees by species.

***softwoods*—**Wood from Gymnospermae, mostly coniferous species such as pine or fir.

***hardwoods*—**Wood from Angiospermae, mostly broad-leaved dicotyledonous species.

stumpage prices—Prices paid to a landowner for standing timber.

target stand state—The desired number of live trees per acre in each species group and diameter class after a harvest.

total net present value—The sum of all discounted revenues minus the sum of all discounted costs.

workbook—The workbook is the normal document or file type in Microsoft Excel. A workbook is the electronic equivalent of a three-ring binder. Inside workbooks you will find sheets, such as worksheets and chart sheets.

worksheet—Most of the work you do in Excel will be on a worksheet. A worksheet is a grid of rows and columns. Each cell is the intersection of a row and a column and has a unique address, or reference.

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