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WestPro: A Computer Program for Simulating Uneven-Aged Douglas-fir Stand Growth and Yield in the Pacific Northwest

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Abstract

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WestPro is an add-in program designed to work with Microsoft Excel to simulate the growth of uneven-aged Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands in the Pacific Northwest region of the United States. Given the initial stand state, defined as the number of softwood and hardwood trees per acre by diameter class, WestPro predicts the future stand state for each year of a predetermined time horizon. Management regimes are defined by a target stand distribution and a cutting cycle. Performance indicators include diversity of tree size and species, timber yield, and net present value of harvest over the given horizon.

This paper contains background information on the WestPro program and instructions and suggestions for its application. By working the examples found in the text, the user will learn how to simulate the growth of a given initial stand and to predict how different management regimes may affect stand structure, yield, and diversity. Limitations of the model also are discussed.

Keywords: Douglas-fir, *Pseudotsuga menziesii*, uneven-aged, management, economics, ecology, WestPro, simulation, software, growth model, diversity.

Contents

1. Introduction and Background Information

Before Beginning

This paper provides background, instructions for using WestPro, and additional suggestions for application of the program. The instructions go through each step of the examples (located in boxes throughout the manual). If you are new to WestPro, it will be useful to run these examples while reading the paper.

This section describes WestPro's purpose and background, section 2 shows how to install the program and use the WestPro menu, section 3 offers instructions for performing basic, single-stand simulations, section 4 discusses how to store and retrieve data, and section 5 provides instructions on using the more advanced features of the program. Users who are unfamiliar with Microsoft Excel may also want to consult the *Microsoft Excel User's Guide* for additional help.

What is WestPro?

WestPro is a computer program designed to simulate the growth of uneven-aged Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands over time. With this program, different management regimes can be considered, and their outcomes can be predicted quickly. WestPro is a useful tool for suggesting which management should be implemented. Similar programs, such as SouthPro for loblolly pine (*Pinus taeda* L.) in the Southern United States (Schulte et al. 1998), and NorthPro for hardwood stands in the Lake States (Kolbe 1998), have already been developed. The WestPro software was designed and calibrated for uneven-aged Douglas-fir stands in the Pacific Northwest region of the United States.

Why Simulate This Type of Stand?

Timber production is a primary goal for a large portion of Douglas-fir stands, but at the same time, concerns about sustainability and negative biological impacts are being raised as a result of the visible adverse effects of current management practices (Curtis and Carey 1996, Curtis and Marshall 1993). Because interest in silvicultural alternatives to even-age management of Pacific Northwest forests is increasing, better information is needed on the effects of these alternatives (Emmingham 1998). WestPro is meant to add to the "toolkit" of foresters a method for predicting how a given stand might look in the future, and what it might yield under uneven-age management.

How Does WestPro Work?

The WestPro program uses a density-dependent matrix model calculated from data for 66 uneven-aged Douglas-fir plots. The plots were in western Oregon and western Washington and were measured by the Forest Inventory and Analysis Program of the USDA Forest Service, Pacific Northwest Research Station (PNW-FIA). Each plot was measured twice over an interval of approximately 10½ years. Simulations with the WestPro model have produced, without apparent bias, results replicating the growth on the observed plots, and long-term projections consistent with prior knowledge of uneven-aged Douglas-fir stands (Ralston et al., in press).

The matrix model built in WestPro predicts growth, mortality, and the rate of regeneration for softwoods and hardwoods as a function of basal area, site index, and individual tree size when those variables are statistically significant. For details regarding the model data, form, and parameters, see appendices A and B.

2. Getting Started

Installing the WestPro Software

WestPro is an add-in program that works with Microsoft Excel for Windows.[1] You will need at least 16 megabytes of random access memory (RAM) to run WestPro. This program works for most versions of Windows (from Windows 3.1 through Windows XP) and Excel (from Excel 5.0 to Excel 2000).

[1] 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.

To install the software, follow these steps:

- Insert the diskette or compact disk (CD) containing the WestPro Microsoft Excel add-in.
- Open Microsoft Excel and start a new workbook.
- Under the **Tools** menu, select **Add-ins**. Once the add-ins dialog box appears, select **Browse** and choose the WestPro add-in (**WestPro.xla**) from the drive containing the diskette or CD. Click **OK**.
- The window that appears asks if you would like to copy WestPro to the add-ins folder on your hard drive. Click **OK**.
- The WestPro program will appear in the list of the add-ins dialog box. Be sure the box corresponding to the WestPro add-in is checked and click **OK**.
- Return to the **Tools** menu and notice that WestPro is now the last choice in the menu. Select **WestPro** and click **OK** in the title box. A new box will appear, asking you if you want the Input Data worksheet inserted. Click **Yes** to insert the new worksheet.
- The WestPro menu appears before the File menu of the Excel menu bar.

While WestPro is running, all Excel functions are still available. Once WestPro is installed, it will remain an option under the Tools menu every time Excel is opened. To uninstall WestPro, you must uncheck the corresponding box in the Add-ins list and quit Excel.

The WestPro Menu

The WestPro menu, in the upper left corner of the Excel menu bar, has seven options (fig. 1). To stop the WestPro program and remove the menu, click the last option, **Quit**. After you have quit the program, any worksheets you have added with WestPro will still be present, but no WestPro function can be carried out without again starting WestPro under the Tools menu.

The other six menu items are WestPro functions. Five have submenus, and under these you will find additional functions. Figure 1 shows the WestPro menu and one of the submenus.

While the program is running, the WestPro menu is present in all the workbooks open in Excel. Thus, you can work with several simulations, in different workbooks, at the same time.

3. A Basic WestPro Simulation

Use the Input Data worksheet (fig. 2) to enter data about the stand you want to simulate and the management you will use. WestPro is for uneven-aged Douglas-fir forests, and recognizes two species groups, softwoods and hardwoods.

The Input Data Worksheet

The initial distribution refers to the number of trees per acre, by species group, by 2-inch diameter classes (fig. 2). For example, the diameter class labeled “4” includes all trees with diameters greater than or equal to 3 inches and less than 5 inches.

The target distribution refers to the number of trees per acre, by species group, and by size class that should remain after harvest (fig. 2). A target of zero instructs WestPro to harvest all trees in that size class; you can prevent the removal of any tree by entering a very high target, say 1,000. When there are more available trees than the target value, then the harvest is the difference between the available trees and the target.

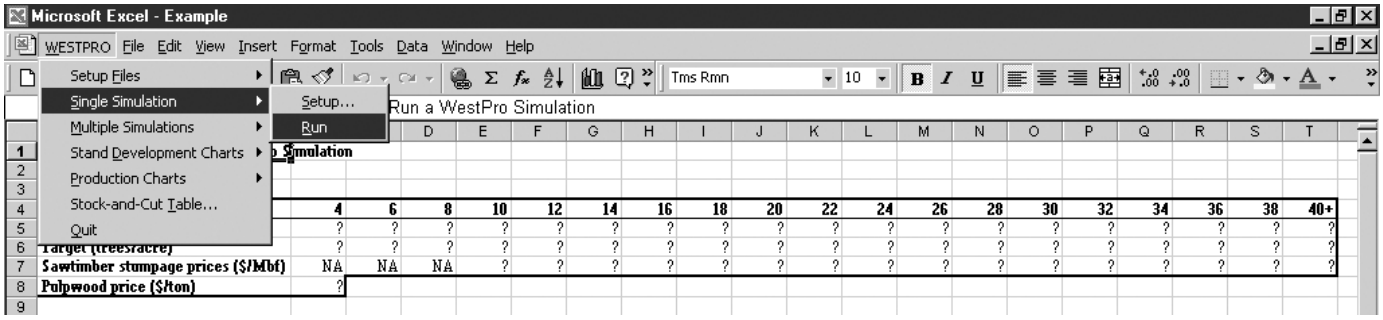


Figure 1—The WestPro menu.

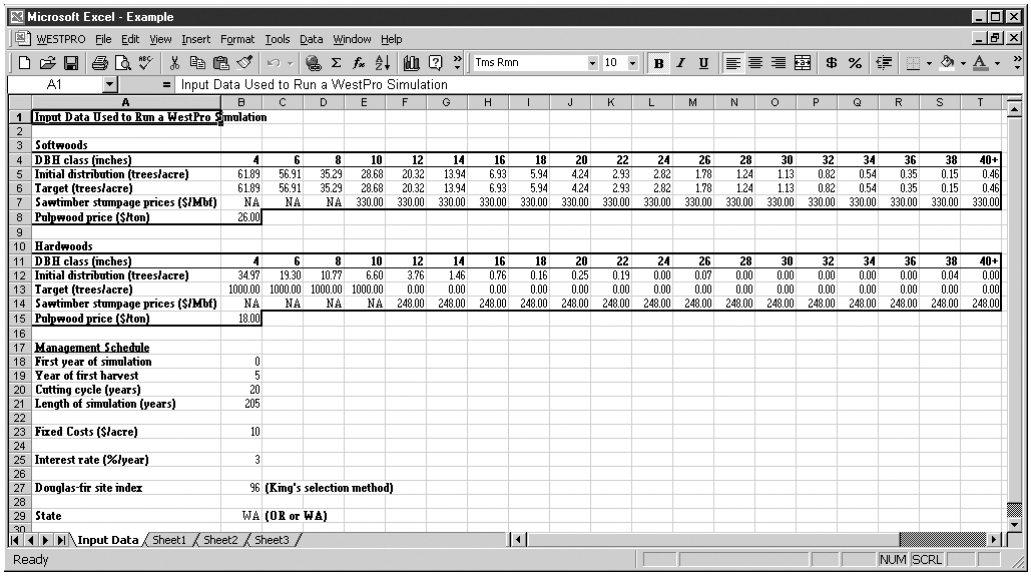


Figure 2—The Input Data worksheet, containing the data to run example 1.

Stumpage prices for sawtimber are by unit of volume and by size class, whereas for pulpwood they are by weight only. The management schedule data include the first year of the simulation, the year of the first harvest, the cutting cycle (interval between harvests), and the length of the simulation. The cutting cycle must be at least 2 years, even if there is no harvest.

Other input data include the fixed costs (costs of re-entry at each harvest, independent of the harvest), the interest rate, the site index (King 1966), and the state (OR or WA).

When you run a simulation, WestPro considers any empty input data cell an error and will prompt you to fix it. You can enter zero for price, fixed cost, and interest rate if you are not interested in financial information.

Example 1: A Single Simulation

Manually enter or copy the data in figure 2 into the Input Data worksheet on your computer. To copy the data, open the Excel workbook named “Data for Example 1” located on the WestPro diskette or CD. Copy and paste ranges B5:T8, B12:T15, and B18:B29 from the Data for Example 1 worksheet to the same location in your blank Input Data worksheet.

In this example, the initial distribution corresponds to the average diameter distribution of the plots in western Washington used to develop the WestPro model. The target distribution for softwoods is the same as the initial distribution, whereas the target distribution for hardwoods results in the removal of all trees larger than 11 inches in diameter. The sawtimber and pulpwood prices were typical for the region in 1999 (Warren 2001). To perform a single simulation, select **WestPro→Single Simulation→Run**. The results of the simulation are stored in two new worksheets, Stand Development and Production.

The Stand Development Worksheet

The Stand Development worksheet gives the expected number of trees per acre by diameter class and species group for each successive year. Figure 3 shows the part of the Stand Development worksheet containing the diameter distribution of softwoods, for the first 27 years from example 1.

Microsoft Excel - Example

WestPro File Edit View Insert Format Tools Data Window Help

A1 = WestPro diameter distribution predictions for SOFTWOODS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	WestPro diameter distribution predictions for SOFTWOODS																			
2											Cutting cycle	20 years						Site index	96	
3											Year of first harvest	5						State	WA	
4	Species						SOFTWOODS (trees/a)													
5	DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
6	Target (trees/a)	61.89	56.91	35.29	28.68	20.32	13.94	6.93	5.94	4.24	2.93	2.82	1.78	1.24	1.13	0.82	0.54	0.35	0.15	0.46
7	Year																			
8	0	61.89	56.91	35.29	28.68	20.32	13.94	6.93	5.94	4.24	2.93	2.82	1.78	1.24	1.13	0.82	0.54	0.35	0.15	0.46
9	1	59.20	56.32	36.34	28.88	20.83	14.40	7.54	6.00	4.39	3.06	2.82	1.89	1.30	1.14	0.85	0.57	0.37	0.17	0.48
10	2	56.75	55.60	37.24	29.13	21.30	14.85	8.13	6.12	4.54	3.18	2.84	1.99	1.36	1.16	0.89	0.60	0.39	0.19	0.49
11	3	54.53	54.78	37.99	29.42	21.74	15.29	8.68	6.28	4.67	3.31	2.87	2.07	1.43	1.18	0.92	0.63	0.42	0.22	0.51
12	4	52.50	53.89	38.60	29.72	22.14	15.72	9.22	6.47	4.81	3.44	2.90	2.15	1.49	1.20	0.94	0.66	0.44	0.24	0.54
13	5	50.66	52.94	39.07	30.03	22.53	16.13	9.73	6.69	4.95	3.56	2.95	2.23	1.56	1.23	0.97	0.69	0.46	0.26	0.56
14	6	48.73	51.97	36.11	28.90	20.85	14.41	7.56	6.01	4.40	3.06	2.82	1.89	1.30	1.14	0.86	0.57	0.37	0.17	0.48
15	7	46.98	50.95	36.77	29.15	21.34	14.88	8.16	6.13	4.54	3.19	2.84	1.99	1.36	1.16	0.89	0.60	0.39	0.19	0.49
16	8	45.40	49.90	37.28	29.42	21.79	15.34	8.73	6.29	4.68	3.32	2.87	2.08	1.43	1.18	0.92	0.64	0.42	0.22	0.51
17	9	43.96	48.83	37.66	29.70	22.22	15.78	9.28	6.49	4.82	3.45	2.91	2.16	1.50	1.21	0.95	0.67	0.44	0.24	0.54
18	10	42.66	47.76	37.92	29.96	22.61	16.21	9.81	6.72	4.97	3.58	2.96	2.24	1.57	1.24	0.97	0.70	0.47	0.26	0.56
19	11	41.48	46.70	38.06	30.21	22.99	16.63	10.32	6.98	5.11	3.70	3.01	2.31	1.64	1.27	1.00	0.73	0.49	0.28	0.59
20	12	40.41	45.65	38.12	30.44	23.33	17.03	10.81	7.25	5.27	3.83	3.07	2.37	1.71	1.31	1.03	0.76	0.52	0.30	0.62
21	13	39.44	44.61	38.08	30.64	23.66	17.41	11.28	7.53	5.43	3.96	3.14	2.44	1.77	1.35	1.06	0.79	0.54	0.33	0.65
22	14	38.56	43.60	37.98	30.81	23.96	17.78	11.72	7.82	5.60	4.08	3.21	2.51	1.84	1.39	1.09	0.81	0.57	0.35	0.68
23	15	37.76	42.61	37.81	30.95	24.24	18.13	12.16	8.13	5.78	4.21	3.29	2.57	1.90	1.44	1.12	0.84	0.59	0.37	0.71
24	16	37.04	41.65	37.58	31.06	24.50	18.46	12.57	8.43	5.97	4.35	3.37	2.64	1.97	1.48	1.15	0.87	0.62	0.39	0.75
25	17	36.38	40.72	37.30	31.13	24.74	18.77	12.96	8.74	6.16	4.48	3.45	2.70	2.03	1.53	1.18	0.90	0.64	0.42	0.78
26	18	35.79	39.82	36.99	31.17	24.95	19.07	13.34	9.05	6.36	4.62	3.54	2.77	2.09	1.58	1.22	0.93	0.67	0.44	0.82
27	19	35.25	38.95	36.63	31.18	25.14	19.36	13.71	9.35	6.57	4.76	3.63	2.83	2.15	1.63	1.25	0.96	0.69	0.46	0.86
28	20	34.76	38.11	36.25	31.15	25.30	19.62	14.05	9.66	6.77	4.90	3.72	2.90	2.21	1.67	1.29	0.98	0.72	0.48	0.90
29	21	34.32	37.30	35.84	31.10	25.44	19.87	14.38	9.96	6.99	5.04	3.81	2.97	2.27	1.72	1.32	1.01	0.75	0.51	0.95
30	22	33.93	36.53	35.42	31.02	25.56	20.10	14.70	10.25	7.20	5.19	3.91	3.04	2.33	1.77	1.36	1.04	0.77	0.53	0.99
31	23	33.57	35.78	34.97	30.91	25.66	20.31	14.99	10.54	7.42	5.34	4.01	3.11	2.40	1.82	1.40	1.07	0.80	0.55	1.03
32	24	33.25	35.06	34.51	30.77	25.74	20.51	15.28	10.82	7.63	5.50	4.11	3.18	2.46	1.87	1.44	1.10	0.82	0.57	1.08
33	25	32.97	34.36	34.05	30.62	25.79	20.69	15.55	11.10	7.85	5.65	4.22	3.26	2.52	1.92	1.47	1.13	0.85	0.60	1.13
34	26	32.36	33.74	33.64	28.81	20.86	14.42	7.57	6.01	4.40	3.06	2.82	1.89	1.30	1.14	0.86	0.57	0.37	0.17	0.48
35	27	31.82	33.13	33.22	28.89	21.35	14.90	8.18	6.13	4.55	3.19	2.84	1.99	1.37	1.16	0.89	0.60	0.40	0.20	0.49

Stock-and-Cut | Stand Development | Production | Input Data | Sheet1 | Sheet2

Ready NUM

Figure 3—Part of the Stand Development worksheet showing the diameter distribution of softwoods over time (example 1).

If you scroll right, past the diameter distributions for both species groups, you will find the summary statistics, including the stand basal area, basal area by species groups, species group diversity and size class diversity for each year (fig. 4). The species group and size class diversity indices are based on basal area and measured by Shannon's Index (Pielou 1977, Shannon and Weaver 1963). Highest species group diversity occurs when there is the same basal area in each species group, and highest size diversity when there is the same basal area in each size class.

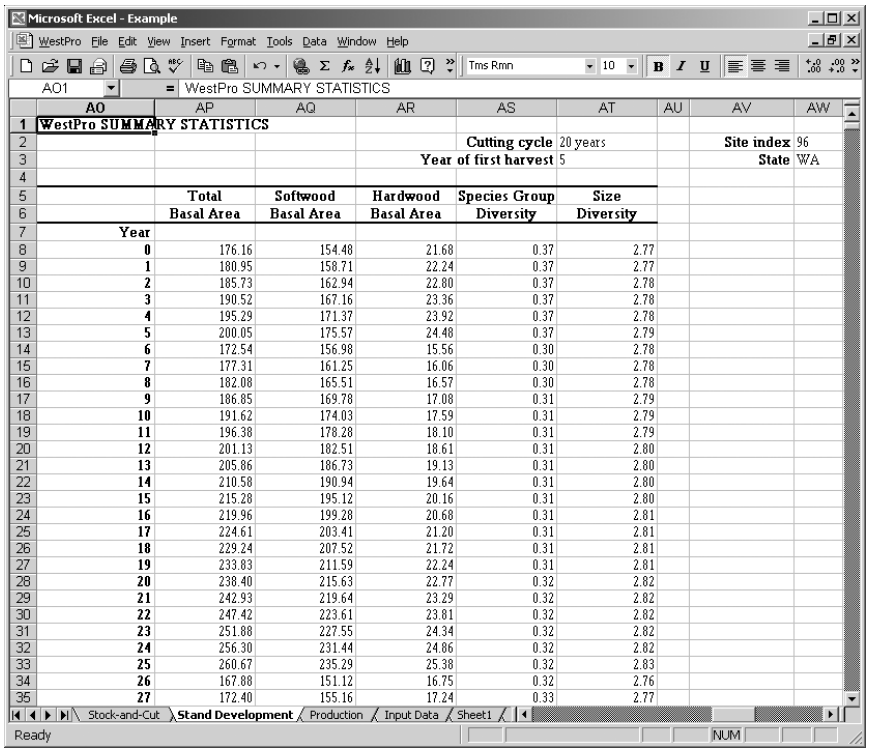
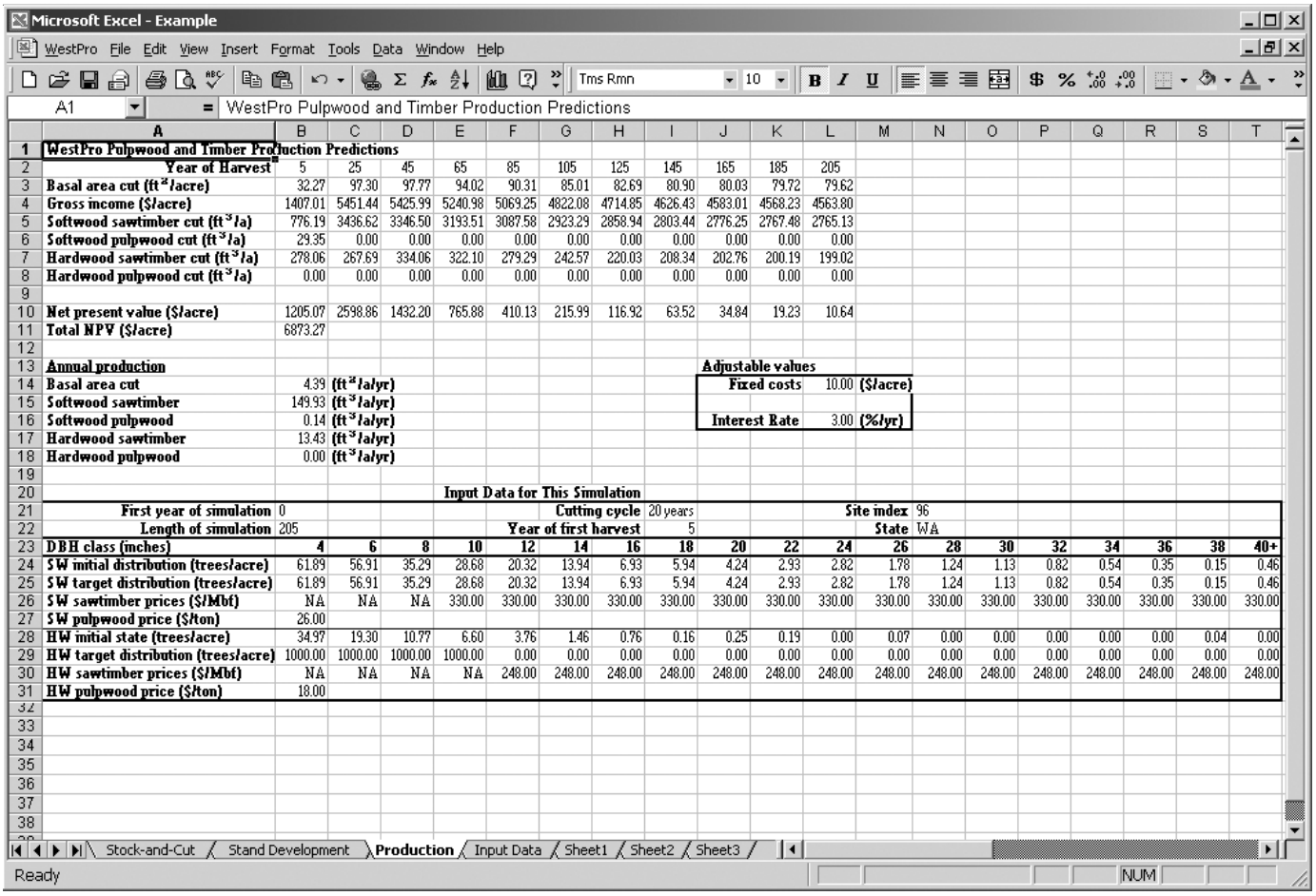


Figure 4—Part of the Stand Development worksheet showing the summary statistics (example 1).

The Production Worksheet

The Production worksheet (fig. 5) shows data for each harvest in terms of basal area cut, gross income, and the pulpwood and sawtimber volumes cut for each species group. The volumes are computed from equations linking tree volume to tree diameter and stand basal area (see app. B). The spreadsheet also shows the net present value of each harvest, the total net present value, and the annual production in basal area and volume cut.

The Adjustable values box allows you to see the effect of different interest rates or fixed costs, without having to rerun the simulation. The Production worksheet also shows the input data, as a reminder of the assumptions made in this simulation.



Microsoft Excel - Example

WestPro File Edit View Insert Format Tools Data Window Help

A1 = WestPro Pulpwood and Timber Production Predictions

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	WestPro Pulpwood and Timber Production Predictions																			
2	Year of Harvest	5	25	45	65	85	105	125	145	165	185	205								
3	Basal area cut (ft^2/acre)	32.27	97.30	97.77	94.02	90.31	85.01	82.69	80.90	80.03	79.72	79.62								
4	Gross income ($/acre)	1407.01	5451.44	5425.99	5240.98	5069.25	4822.08	4714.85	4626.43	4583.01	4568.23	4563.80								
5	Softwood sawtimber cut (ft^3/a)	776.19	3436.62	3346.50	3193.51	3087.58	2923.29	2858.94	2803.44	2776.25	2767.48	2765.13								
6	Softwood pulpwood cut (ft^3/a)	29.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00								
7	Hardwood sawtimber cut (ft^3/a)	278.06	267.69	334.06	322.10	279.29	242.57	220.03	208.34	202.76	200.19	199.02								
8	Hardwood pulpwood cut (ft^3/a)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00								
9																				
10	Net present value ($/acre)	1205.07	2598.86	1432.20	765.88	410.13	215.99	116.92	63.52	34.84	19.23	10.64								
11	Total NPV ($/acre)	6873.27																		
12																				
13	Annual production									Adjustable values										
14	Basal area cut	4.39	(ft^2/a/yr)							Fixed costs		10.00	($/acre)							
15	Softwood sawtimber	149.93	(ft^3/a/yr)																	
16	Softwood pulpwood	0.14	(ft^3/a/yr)							Interest Rate		3.00	(%/yr)							
17	Hardwood sawtimber	13.43	(ft^3/a/yr)																	
18	Hardwood pulpwood	0.00	(ft^3/a/yr)																	
19																				
20					Input Data for This Simulation															
21	First year of simulation	0					Cutting cycle	20 years				Site index	96							
22	Length of simulation	205					Year of first harvest	5				State	WA							
23	DBH class (inches)	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40+
24	SW initial distribution (trees/acre)	61.89	56.91	35.29	28.68	20.32	13.94	6.93	5.94	4.24	2.93	2.82	1.78	1.24	1.13	0.82	0.54	0.35	0.15	0.46
25	SW target distribution (trees/acre)	61.89	56.91	35.29	28.68	20.32	13.94	6.93	5.94	4.24	2.93	2.82	1.78	1.24	1.13	0.82	0.54	0.35	0.15	0.46
26	SW sawtimber prices ($/Mbf)	NA	NA	NA	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00
27	SW pulpwood price ($/ton)	26.00																		
28	HW initial state (trees/acre)	34.97	19.30	10.77	6.60	3.76	1.46	0.76	0.16	0.25	0.19	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.04	0.00
29	HW target distribution (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
30	HW sawtimber prices ($/Mbf)	NA	NA	NA	NA	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00
31	HW pulpwood price ($/ton)	18.00																		

Stock-and-Cut | Stand Development | Production | Input Data | Sheet1 | Sheet2 | Sheet3

Ready NUM

Figure 5—The Production worksheet for example 1.

4. Managing Data in WestPro

Storing Data in WestPro

The previous section discussed a basic WestPro simulation, which is sufficient if you only want to do one simulation. In that case, you can save the input data and results of a single simulation as an Excel file by choosing **File→Save As** and giving an appropriate name to the workbook. If, however, you would like to examine the effects of changing some of the simulation parameters and run several simulations, you may find it more efficient to manage data with the Setup Files feature of WestPro than to repeatedly set up and save individual simulations.

For that purpose, once you have entered data in the Input Data worksheet, you can store them for later use. When you store data, you are copying them from the Input Data worksheet to the Setup Files worksheet. The Setup Files worksheet acts as a holding area for all the data you have stored. It also contains data sets built into the program. The Setup Files worksheet is not visible, and you do not need to see it, but if you would like to view it, see the instructions in section 6.

Example 2: Adding Setup Files

Select **WestPro→Setup Files→Add**. WestPro will ask you if you would like a copy of the Setup Files worksheet inserted. Click **Yes**. The Add Setup Files window (fig. 6) should appear on your screen.

Check the **Add the Target Distribution** box, make sure that softwoods are selected, and name the softwood target distribution "Average WA SW."

Check the **Add the Management Schedule** box and name it "Start 0,Cut 5,Cycle 20,205 Yr."

Check the **Add the Fixed Costs** box and name it "10." Click **OK**.

As each file is copied, you may choose its position in the list of files. The names already shown in the lists are the setup files built into WestPro. Insert your setup files at the top of each list.

You need not copy the initial distribution, the hardwood target distribution, or the prices because they are built in as "Average WA plots," "11 inch max. diameter," and "Example Price 1," respectively.

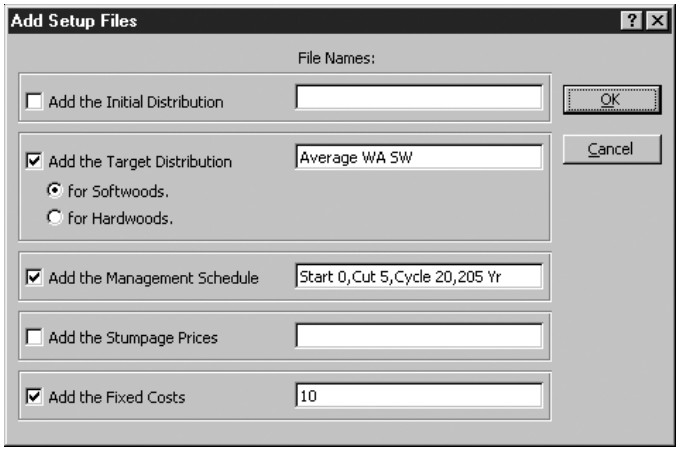


Figure 6—The Add Setup Files window (example 2).

Give detailed names to setup files. If you save many files, a detailed name will help you choose the correct file when you want to retrieve it.

Deleting Stored Data

To delete setup files, choose **WestPro→Setup Files→Delete**. Select the field that you want to delete a file from, and highlight that file in the list. After you hit **Delete**, only that file is removed from the Setup Files worksheet.

Retrieving Stored Data

Selecting **WestPro→Single Simulation→Setup** opens the Load Setup Files window (fig. 7). With this window, you can copy data from the Setup Files worksheet to the Input Data worksheet. If you have not added any data to the Setup Files worksheet, only the built-in data will be available.

To select the data to load into the Input Data worksheet, highlight the file name in the Initial Distribution list, the Softwoods Target list, and the other lists. To select the default interest rate, site index, or state, place a checkmark in the Insert box. You can change the default values by typing your choice in the respective text box. Click **OK** to copy the selected setup files to the Input Data worksheet.

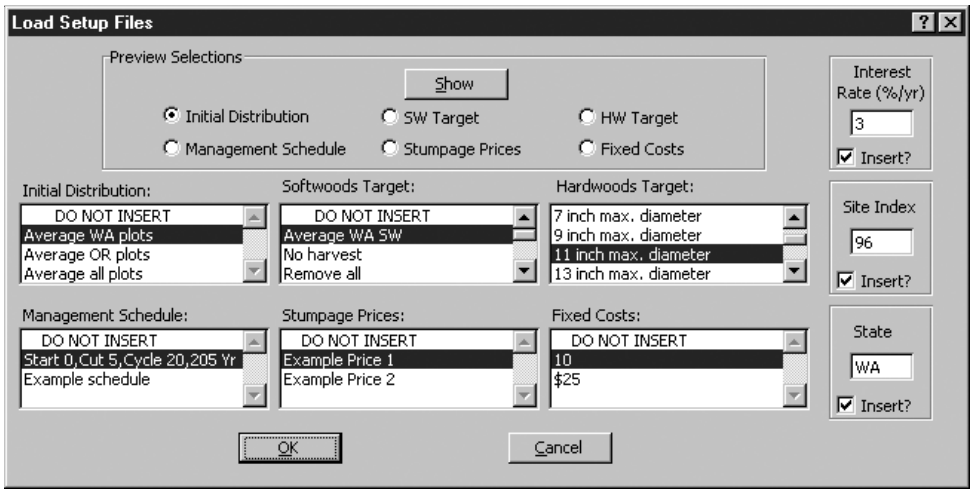


Figure 7—The Load Setup Files window.

To preview the data before loading them, click the appropriate button in the Preview selection box and click the **Show** button at the top of the window. For example, clicking Show in the window in figure 7 would show the initial distribution in the file named Average WA plots.

5. Advanced WestPro

The BDq Calculator

This calculator is meant to calculate the number of trees by size class in a stand with a specific BDq distribution (see "Glossary") (Smith 1997). The q-ratio is the ratio of the number of trees in successive size classes.

Going to **WestPro→ Setup Files→BDq Distributions** opens the BDq calculator (fig. 8). Use the arrow buttons to set the basal area (ft^2/acre), the maximum diameter (in), the q-ratio, and the minimum diameter (in) to the desired level, then click the **Calculate** button. Figure 8 shows the number of trees in each size class that would give a basal area of 125 ft^2/ac, with trees of diameters from 3 to 31 in, and a q-ratio of 1.4.

You can copy the calculated distribution to the Input Data worksheet as the initial distribution or as the target distribution for either softwoods or hardwoods by selecting the destination and clicking the **Copy** button. Clicking the **Cancel** button closes the calculator window.

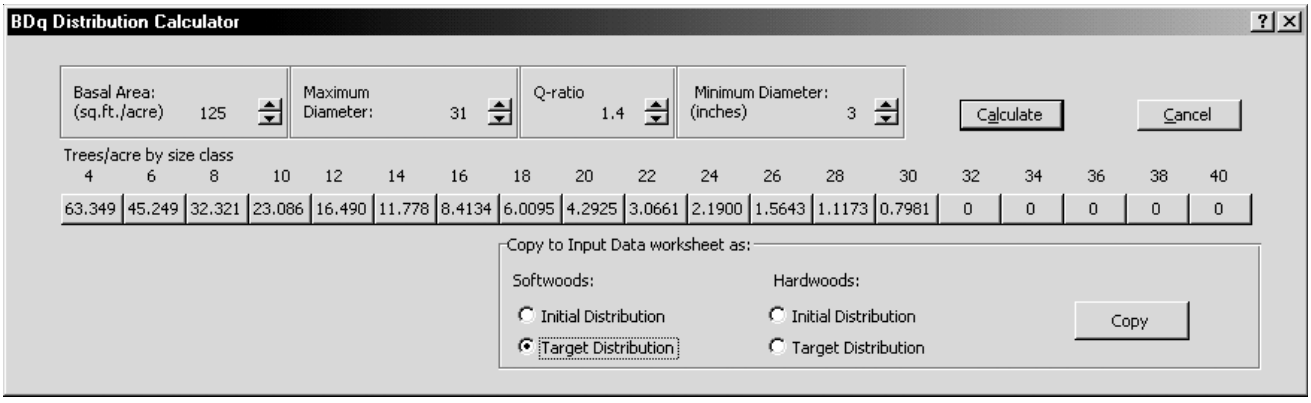


Figure 8—The BDq Distribution Calculator window.

Creating Charts

WestPro lets you create charts with data from the Stand Development worksheet and from the Production worksheet. Under the WestPro menu there are two headings, Stand Development Charts and Production Charts, each containing different chart types. To create one of the Stand Development charts, the Stand Development worksheet (figs. 3 and 4) must be visible; otherwise WestPro will prompt you to put this sheet in front. Similarly, to create a Production chart, the Production worksheet (fig. 5) must be visible.

There are four stand development charts:

- Size diversity (Shannon index)
- Species diversity (Shannon index)
- Size distribution (trees/acre)
- Stand basal area (ft^2/acre)

There are three production charts:

- Basal area cut (ft^2/acre)
- Gross income ($/acre)
- Volume cut (ft^3/acre)

The seven chart types are shown in figures 9 through 15. You can choose the year or range of years of the data. For the size distribution (fig. 11b) and stand basal area (fig. 12) charts, you also can select the species groups to plot, and for the volume cut chart, you can select the species and product (fig. 15a) to plot.

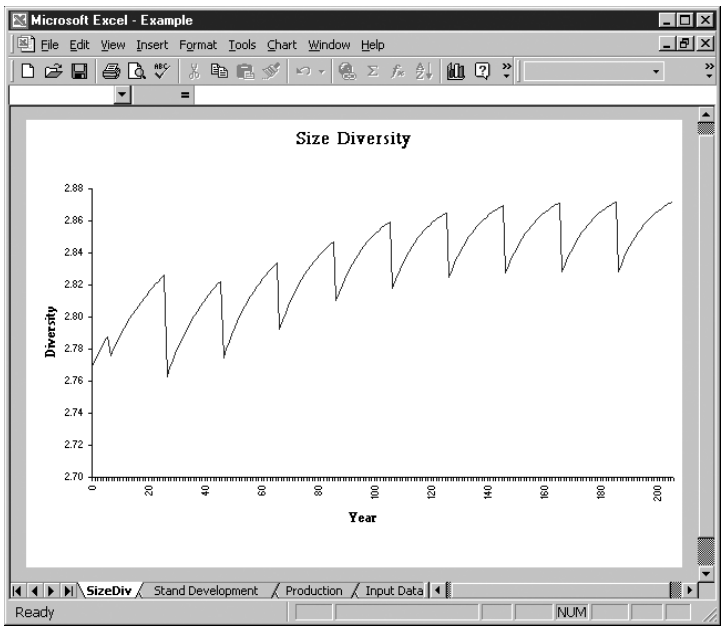


Figure 9—Chart of size diversity.

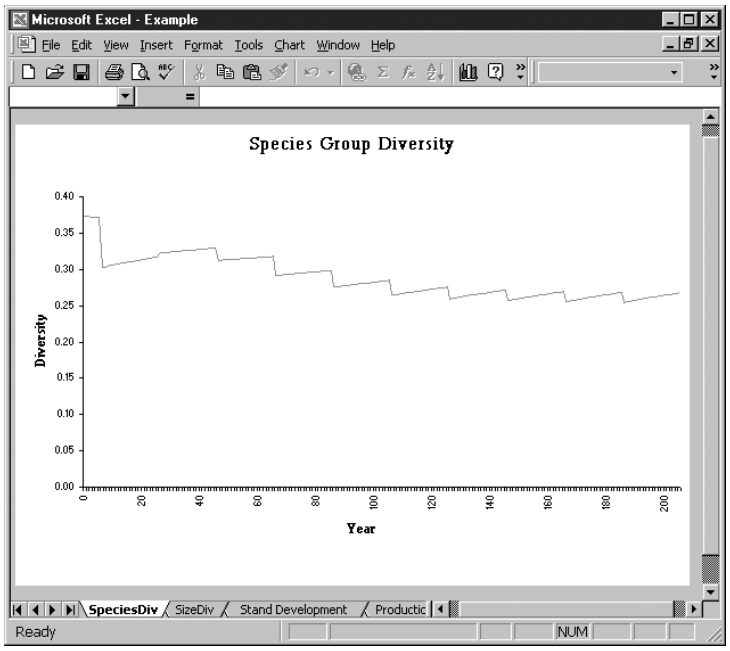


Figure 10—Chart of species group diversity.

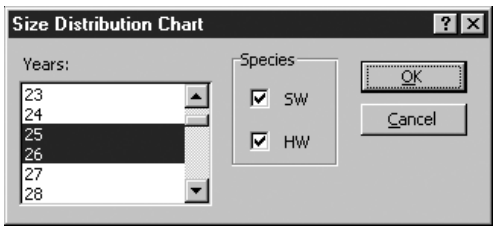


Figure 11a—Size Distribution Chart window (example 3).

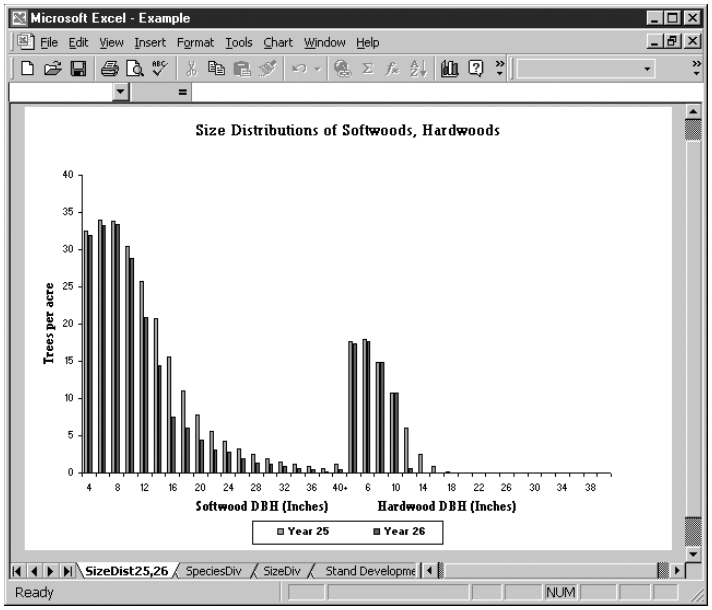


Figure 11b—Chart of size distributions (example 3).

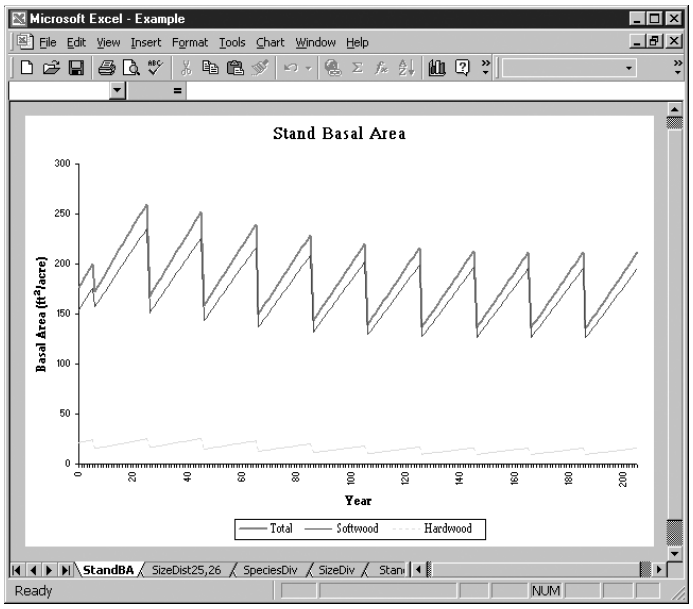


Figure 12—Chart of stand basal area.

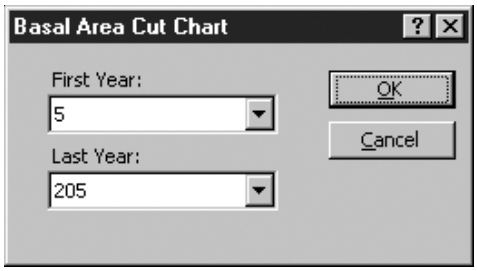


Figure 13a—Basal Area Cut Chart window (example 4).

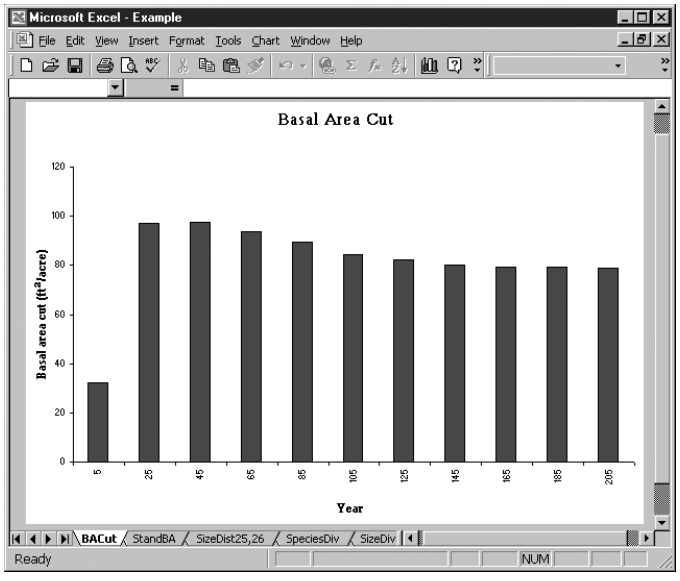


Figure 13b—Chart of basal area cut (example 4).

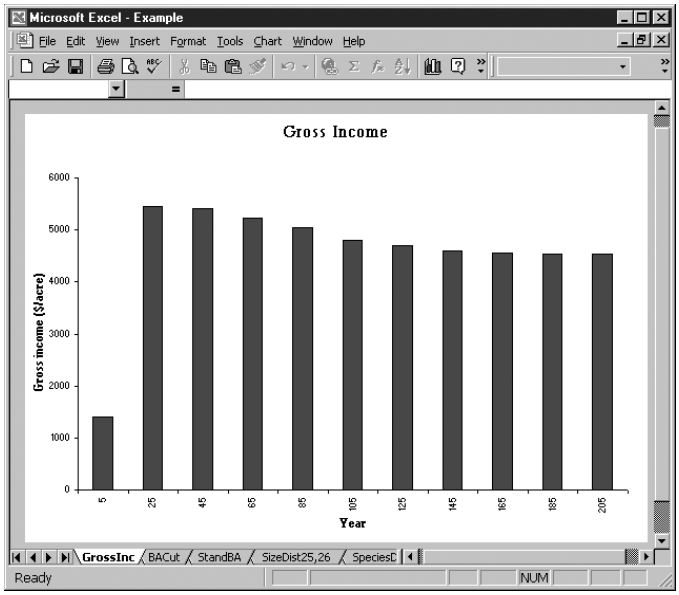


Figure 14—Chart of gross income.

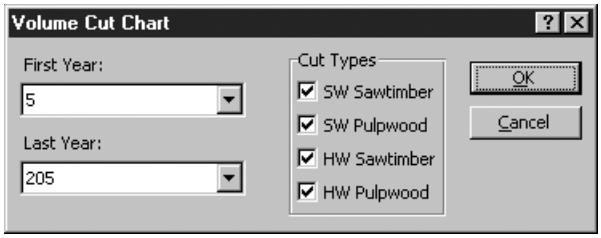


Figure 15a—Volume Cut Chart window.

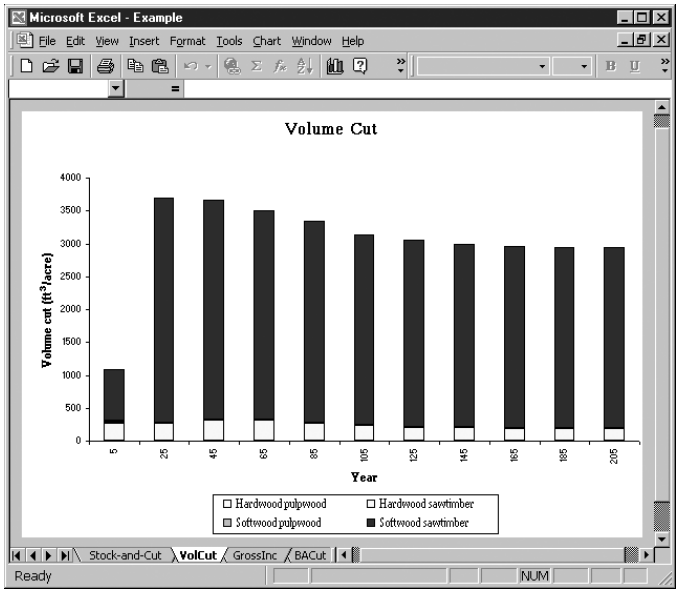


Figure 15b—Chart of volume cut.

Example 3: Charting Size Distribution

To chart size distribution for hardwoods and softwoods the year before and after the second harvest, do the following. With the Stand Development worksheet produced by example 1 in the foreground, go to **WestPro→Stand Development Charts→Size Distributions**. When the Size Distribution Chart window (fig. 11a) appears, highlight year "25," press the **Shift** key, then highlight year "26" also. Check both species groups. Click **OK**, and name the chart "SizeDist25,26" when prompted (fig. 11b).

Highlighting one year in the Size Distribution Chart window will plot the distribution for a single year. To plot sequential years, highlight the first year, press the Shift key, and then click the last year to plot all of the years between. To plot multiple, nonsequential years, click each year to plot while holding down the Ctrl key.

Example 4: Charting Basal Area Cut

To get a bar chart of the basal area cut at each harvest, do the following. With the Production worksheet produced by example 1 in the foreground, select **WestPro→Production Charts→Basal Area Cut**. When the Basal Area Cut Chart window appears (fig. 13a), leave the default selection (First Year: 5, Last Year: 205) as the years to plot. Click **OK** and name the chart "BACut" (fig. 13b).

The Stock-and-Cut Table

The Stock-and-Cut table gives information on the immediate effects of harvesting a particular initial stand to a target stand, and on how to do the harvest. The Stock-and-Cut table in figure 16 (on two pages) shows the initial stand and its annual growth (predicted by WestPro), the target stand and its annual growth, and the residual stand after harvest and its annual growth. The marking guide in the last column shows how the pole, small sawtimber, medium sawtimber, and large sawtimber trees should be selected for harvest.

Example 5: Generating a Stock-and-Cut Table

To get the Stock-and-Cut table in figure 16, with the year 25 stand obtained in example 1 as initial stand, and the target stand in example 1, do the following. With the Stand Development worksheet produced by example 1 in the foreground, select **WestPro→Stock-and-Cut Table**. In the Stock-and-Cut Table window (fig. 17a), click the **Stand Development** button to select that worksheet as the location of the initial and target stand distributions.

Next, in Stock-and-Cut Stand Development Selection window (fig. 17b), choose the Initial Distribution year of 25, and leave the selected Target Distribution as Target. Click **Table** to generate the Stock-and-Cut table in a new worksheet. Click **Cancel** to close the Stock-and-Cut Table window.

From the Stock-and-Cut Table window (fig. 17a), you also can choose data in the Setup Files or Input Data worksheets. Choosing the Input Data worksheet as the data source selects the preharvest and target distributions on that worksheet. Choosing the Setup Files worksheet as the data source opens a window that allows you to choose from the distributions in that worksheet (see section 4, "Storing Data in WestPro").

SOFTWOODS

DBH	Initial Stand						Target Stand					
	Trees	BA	Volume		Annual Growth		Trees	BA	Volume		Annual Growth	
(Inches)	(#/acre)	(ft^2/a)	(ft^3/a)	(Mbf/a)	(ft^3/a)	(Mbf/a)	(#/acre)	(ft^2/a)	(ft^3/a)	(Mbf/a)	(ft^3/a)	(Mbf/a)
4	32.97	2.88	NA	NA	NA	NA	61.89	5.40	NA	NA	NA	NA
6	34.36	6.75	232.64	NA	7.19	NA	56.91	11.17	0.00	NA	0.00	NA
8	34.05	11.88	429.52	NA	5.67	NA	35.29	12.32	190.74	NA	19.88	NA
10	30.62	16.70	619.46	1.81	6.97	0.05	28.68	15.64	373.45	0.45	13.89	0.07
12	25.79	20.26	763.97	2.64	9.99	0.06	20.32	15.96	455.35	1.19	19.77	0.08
14	20.69	22.11	843.54	3.23	13.87	0.07	13.94	14.90	467.93	1.57	21.29	0.09
16	15.55	21.71	834.90	3.43	19.08	0.09	6.93	9.68	322.22	1.23	31.82	0.13
18	11.10	19.61	759.27	3.29	22.22	0.10	5.94	10.50	363.51	1.50	6.37	0.03
20	7.85	17.13	666.32	3.00	21.20	0.10	4.24	9.25	329.31	1.44	13.84	0.06
22	5.65	14.92	582.77	2.71	18.21	0.09	2.93	7.73	281.02	1.28	13.52	0.06
24	4.22	13.25	519.43	2.47	14.71	0.07	2.82	8.86	326.90	1.53	1.49	0.01
26	3.26	12.00	471.72	2.29	12.03	0.06	1.78	6.56	245.12	1.18	16.10	0.08
28	2.52	10.76	423.77	2.10	11.07	0.06	1.24	5.30	199.96	0.98	9.99	0.05
30	1.92	9.44	372.70	1.87	10.43	0.05	1.13	5.55	210.84	1.05	2.56	0.01
32	1.47	8.24	325.75	1.66	9.16	0.05	0.82	4.58	175.22	0.89	7.80	0.04
34	1.13	7.13	282.61	1.45	8.01	0.04	0.54	3.40	130.98	0.67	7.96	0.04
36	0.85	5.98	237.40	1.23	7.45	0.04	0.35	2.47	95.62	0.49	6.06	0.03
38	0.60	4.69	186.27	0.98	7.20	0.04	0.15	1.18	45.84	0.24	6.91	0.04
40 +	1.13	9.85	391.63	2.07	17.33	0.09	0.46	4.01	156.30	0.82	5.59	0.03
Total	235.71	235.29	8943.66	36.23	221.78	1.06	246.36	154.48	4370.29	16.50	204.84	0.85

HARDWOODS

DBH	Initial Stand						Target Stand					
	Trees	BA	Volume		Annual Growth		Trees	BA	Volume		Annual Growth	
(Inches)	(#/acre)	(ft^2/a)	(ft^3/a)	(Mbf/a)	(ft^3/a)	(Mbf/a)	(#/acre)	(ft^2/a)	(ft^3/a)	(Mbf/a)	(ft^3/a)	(Mbf/a)
4	17.80	1.55	NA	NA	NA	NA	17.80	1.55	NA	NA	NA	NA
6	18.09	3.55	87.17	NA	-0.12	NA	18.09	3.55	64.82	NA	0.30	NA
8	15.09	5.27	135.43	NA	0.56	NA	15.09	5.27	116.79	NA	0.80	NA
10	10.82	5.90	160.78	NA	2.07	NA	10.82	5.90	147.41	NA	2.26	NA
12	6.06	4.76	136.19	0.63	4.70	0.02	0.00	0.00	0.00	0.00	13.64	0.07
14	2.55	2.73	81.28	0.28	5.64	0.02	0.00	0.00	0.00	0.00	0.00	0.00
16	0.82	1.15	35.21	0.11	4.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00
18	0.21	0.36	11.46	0.04	1.96	0.01	0.00	0.00	0.00	0.00	0.00	0.00
20	0.04	0.09	2.88	0.01	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.01	0.02	0.57	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.09	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40 +	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	71.48	25.38	651.07	1.08	19.76	0.06	61.79	16.27	329.03	0.00	17.00	0.07

STAND TOTALS

DBH	Initial Stand						Target Stand					
	Trees	BA	Volume		Annual Growth		Trees	BA	Volume		Annual Growth	
(Inches)	(#/acre)	(ft^2/a)	(ft^3/a)	(Mbf/a)	(ft^3/a)	(Mbf/a)	(#/acre)	(ft^2/a)	(ft^3/a)	(Mbf/a)	(ft^3/a)	(Mbf/a)
4	50.76	4.43	NA	NA	NA	NA	79.69	6.95	NA	NA	NA	NA
6	52.45	10.30	319.81	NA	7.07	NA	75.00	14.73	64.82	NA	0.30	NA
8	49.13	17.15	564.96	NA	6.23	NA	50.38	17.59	307.53	NA	20.68	NA
10	41.44	22.60	780.24	1.81	9.04	0.05	39.50	21.54	520.86	0.45	16.15	0.07
12	31.85	25.02	900.16	3.27	14.69	0.08	20.32	15.96	455.35	1.19	33.41	0.15
14	23.24	24.85	924.81	3.51	19.51	0.09	13.94	14.90	467.93	1.57	21.29	0.09
16	16.37	22.85	870.11	3.54	23.14	0.10	6.93	9.68	322.22	1.23	31.82	0.13
18	11.31	19.98	770.73	3.32	24.18	0.11	5.94	10.50	363.51	1.50	6.37	0.03
20	7.89	17.22	669.21	3.01	21.88	0.10	4.24	9.25	329.31	1.44	13.84	0.06
22	5.66	14.94	583.34	2.71	18.39	0.09	2.93	7.73	281.02	1.28	13.52	0.06
24	4.22	13.26	519.52	2.47	14.74	0.07	2.82	8.86	326.90	1.53	1.49	0.01
26	3.26	12.00	471.73	2.29	12.04	0.06	1.78	6.56	245.12	1.18	16.10	0.08
28	2.52	10.76	423.77	2.10	11.07	0.06	1.24	5.30	199.96	0.98	9.99	0.05
30	1.92	9.44	372.70	1.87	10.43	0.05	1.13	5.55	210.84	1.05	2.56	0.01
32	1.47	8.24	325.75	1.66	9.16	0.05	0.82	4.58	175.22	0.89	7.80	0.04
34	1.13	7.13	282.61	1.45	8.01	0.04	0.54	3.40	130.98	0.67	7.96	0.04
36	0.85	5.98	237.40	1.23	7.45	0.04	0.35	2.47	95.62	0.49	6.06	0.03
38	0.60	4.69	186.27	0.98	7.20	0.04	0.15	1.18	45.84	0.24	6.91	0.04
40 +	1.13	9.85	391.63	2.07	17.33	0.09	0.46	4.01	156.30	0.82	5.59	0.03
Total	307.19	260.67	9594.74	37.31	241.54	1.12	308.15	170.75	4699.32	16.50	221.84	0.92
	Sp. Div.	0.32					Sp. Div.	0.31				
	Size Div.	2.83					Size Div.	2.76				

Figure 16—Stock-and-Cut table (example 5).

SOFTWOODS

DBH (Inches)	Cut Trees (#/acre)	Cut BA (ft^2/a)	Cut Volume (ft^3/a)	Cut Volume (Mbf/a)	Residual Stand Trees (#/acre)	Residual Stand BA (ft^2/a)	Residual Stand Volume (ft^3/a)	Residual Stand Volume (Mbf/a)	Annual Growth (ft^3/a)	Annual Growth (Mbf/a)
4	0.00	0.00	NA	NA	32.97	2.88	NA	NA	NA	NA
6	0.00	0.00	0.0	NA	34.36	6.75	0.00	NA	0.00	NA
8	0.00	0.00	0.0	NA	34.05	11.88	163.86	NA	10.21	NA
10	1.94	1.06	13.8	0.00	28.68	15.64	356.47	0.34	12.02	0.06
12	5.47	4.30	90.4	0.13	20.32	15.96	443.31	1.12	19.38	0.08
14	6.75	7.21	186.7	0.52	13.94	14.90	459.67	1.52	21.13	0.08
16	8.62	12.03	349.8	1.22	6.93	9.68	318.12	1.20	31.95	0.13
18	5.16	9.12	285.3	1.12	5.94	10.50	359.99	1.48	6.32	0.03
20	3.61	7.88	259.1	1.09	4.24	9.25	326.80	1.42	13.92	0.06
22	2.72	7.18	245.0	1.09	2.93	7.73	279.28	1.27	13.63	0.06
24	1.40	4.39	153.9	0.71	2.82	8.86	325.23	1.52	1.46	0.01
26	1.48	5.44	194.4	0.92	1.78	6.56	244.06	1.17	16.29	0.08
28	1.28	5.45	198.2	0.96	1.24	5.30	199.23	0.98	10.11	0.05
30	0.79	3.89	143.3	0.71	1.13	5.55	210.17	1.05	2.57	0.01
32	0.65	3.66	136.0	0.68	0.82	4.58	174.73	0.88	7.90	0.04
34	0.59	3.73	140.0	0.71	0.54	3.40	130.66	0.67	8.06	0.04
36	0.50	3.51	132.8	0.68	0.35	2.47	95.41	0.49	6.15	0.03
38	0.45	3.51	133.5	0.70	0.15	1.18	45.75	0.24	7.02	0.04
40 +	0.67	5.84	223.3	1.17	0.46	4.01	156.03	0.82	5.67	0.03
Total	42.06	88.19	2885.6	12.42	193.65	147.10	4288.77	16.17	193.80	0.84

Marking Guide

Pulpwood/Poletimber
(3" to < 9")
Leave all trees

Sm. Sawtimber
(9" to < 15")
Cut 14 of 77 tr/a
or 1 tree in 5

Med. Sawtimber
(15" to < 21")
Cut 17 of 34 tr/a
or 1 tree in 2

Lg. Sawtimber
(21" and up)
Cut 11 of 23 tr/a
or 4 trees in 9

HARDWOODS

DBH (Inches)	Cut Trees (#/acre)	Cut BA (ft^2/a)	Cut Volume (ft^3/a)	Cut Volume (Mbf/a)	Residual Stand Trees (#/acre)	Residual Stand BA (ft^2/a)	Residual Stand Volume (ft^3/a)	Residual Stand Volume (Mbf/a)	Annual Growth (ft^3/a)	Annual Growth (Mbf/a)
4	0.00	0.00	NA	NA	17.80	1.55	NA	NA	NA	NA
6	0.00	0.00	0.0	NA	18.09	3.55	62.99	NA	0.25	NA
8	0.00	0.00	0.0	NA	15.09	5.27	115.26	NA	0.75	NA
10	0.00	0.00	0.0	NA	10.82	5.90	146.31	NA	2.23	NA
12	6.06	4.76	122.6	0.63	0.00	0.00	0.00	0.00	13.65	0.07
14	2.55	2.73	75.5	0.28	0.00	0.00	0.00	0.00	0.00	0.00
16	0.82	1.15	33.4	0.11	0.00	0.00	0.00	0.00	0.00	0.00
18	0.21	0.36	11.0	0.04	0.00	0.00	0.00	0.00	0.00	0.00
20	0.04	0.09	2.8	0.01	0.00	0.00	0.00	0.00	0.00	0.00
22	0.01	0.02	0.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40 +	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.69	9.11	245.9	1.08	61.79	16.27	324.56	0.00	16.88	0.07

Marking Guide

Pulpwood/Poletimber
(5" to < 11")
Leave all trees

Sm. Sawtimber
(11" to < 15")
Cut all trees

Med. Sawtimber
(15" to < 21")
Cut all trees

Lg. Sawtimber
(21" and up)
Cut all trees

STAND TOTALS

DBH (Inches)	Cut Trees (#/acre)	Cut BA (ft^2/a)	Cut Volume (ft^3/a)	Cut Volume (Mbf/a)	Residual Stand Trees (#/acre)	Residual Stand BA (ft^2/a)	Residual Stand Volume (ft^3/a)	Residual Stand Volume (Mbf/a)	Annual Growth (ft^3/a)	Annual Growth (Mbf/a)
4	0.00	0.00	NA	NA	50.76	4.43	NA	NA	NA	NA
6	0.00	0.00	0.0	NA	52.45	10.30	62.99	NA	0.25	NA
8	0.00	0.00	0.0	NA	49.13	17.15	279.12	NA	10.96	NA
10	1.94	1.06	13.8	0.00	39.50	21.54	502.78	0.34	14.25	0.06
12	11.53	9.06	213.0	0.76	20.32	15.96	443.31	1.12	33.04	0.14
14	9.30	9.94	262.3	0.80	13.94	14.90	459.67	1.52	21.13	0.08
16	9.44	13.18	383.2	1.33	6.93	9.68	318.12	1.20	31.95	0.13
18	5.37	9.48	296.3	1.15	5.94	10.50	359.99	1.48	6.32	0.03
20	3.65	7.97	261.9	1.10	4.24	9.25	326.80	1.42	13.92	0.06
22	2.73	7.20	245.5	1.09	2.93	7.73	279.28	1.27	13.63	0.06
24	1.40	4.40	154.0	0.71	2.82	8.86	325.23	1.52	1.46	0.01
26	1.48	5.44	194.5	0.92	1.78	6.56	244.06	1.17	16.29	0.08
28	1.28	5.45	198.2	0.96	1.24	5.30	199.23	0.98	10.11	0.05
30	0.79	3.89	143.3	0.71	1.13	5.55	210.17	1.05	2.57	0.01
32	0.65	3.66	136.0	0.68	0.82	4.58	174.73	0.88	7.90	0.04
34	0.59	3.73	140.0	0.71	0.54	3.40	130.66	0.67	8.06	0.04
36	0.50	3.51	132.8	0.68	0.35	2.47	95.41	0.49	6.15	0.03
38	0.45	3.51	133.5	0.70	0.15	1.18	45.75	0.24	7.02	0.04
40 +	0.67	5.84	223.3	1.17	0.46	4.01	156.03	0.82	5.67	0.03
Total	51.75	97.30	3131.5	13.50	255.44	163.37	4613.34	16.17	210.68	0.91

Sp. Div.	0.32
Size Div.	2.76

Figure 16—Stock-and-Cut table (example 5), continued.

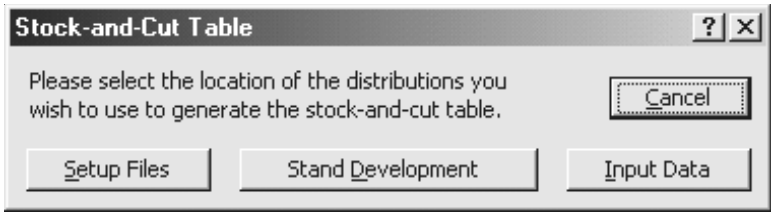


Figure 17a—Stock-and-Cut Table window.

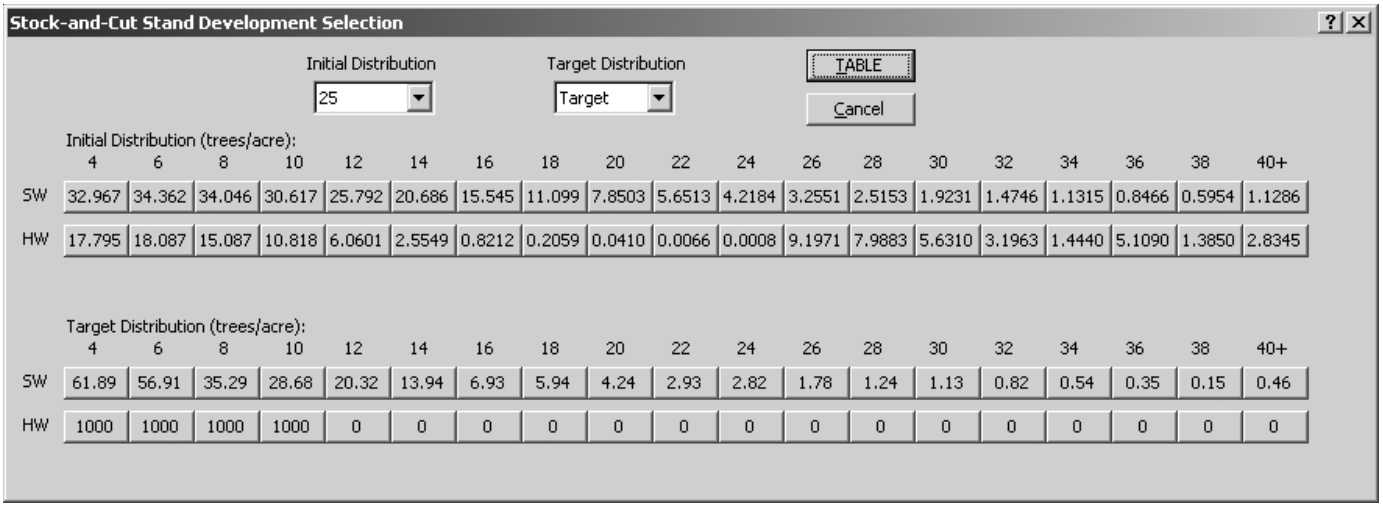


Figure 17b—Stock-and-Cut Stand Development Selection window (example 5).

Running Multiple Simulations

You can run many simulations sequentially. The results of each simulation are saved in a separate workbook containing only the Stand Development and Production worksheets.

Example 6: Running a Batch of Simulations

Note: The data used in this example will only be available if you have done the previous examples.

Choose **WestPro→Multiple Simulations→Setup**. Click **Yes** when asked if you would like the Batch File worksheet (fig. 18) inserted. The Update Batch File window (fig. 19) will appear on your screen. Highlight "Average WA plots" as the initial distribution, "Average WA SW" as the softwoods target, "11 inch max. diameter" as the hardwoods target, "Start 0,Cut 5,Cycle 20,205Yr" as the management schedule, "Example Price 1" as the stumpage prices, and "10" as the fixed costs. Leave the interest rate, site index, and state at the default settings of 3, 96, and WA, respectively. Click the **ADD** button. Change the interest rate to 5 (percent per year) and click **ADD**. Next, change the site index to 115 (feet) and click **ADD** again. Finally, change the Hardwoods Target to "7 inch max. diameter" and click **ADD**, then click **Close** to close the window.

Choose **WestPro→Multiple Simulations→Run**. Click **Yes** to confirm, then select a destination drive and save each simulation as the default name (in the last column of fig. 18) by clicking **Save**. Click **Yes** to run the batch of simulations. The final batch worksheet should look like figure 18, but the locations of your saved workbooks may be different.

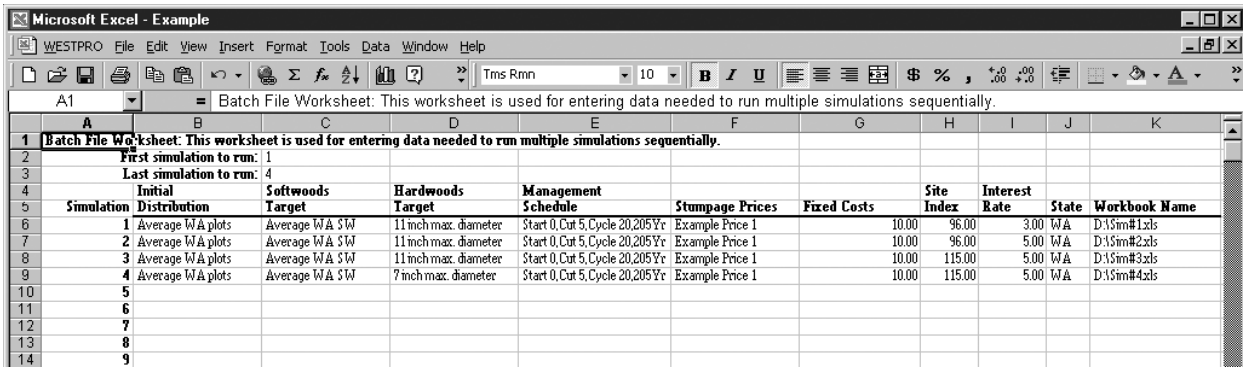


Figure 18—Batch File worksheet (example 6).

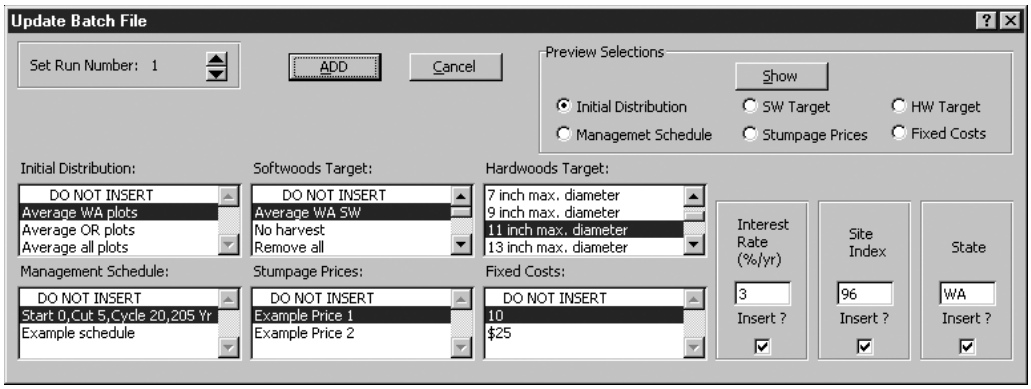


Figure 19—Update Batch File window (example 6).

In the upper left corner of the Update Batch File window (fig. 19) is a run number that corresponds to the simulation number in the Batch File worksheet (fig. 18). When first preparing a set of simulations to run, start with run number 1. After setting up a file and clicking **ADD**, the Update Batch File window remains open to setup run number 2, and this continues until you click **Cancel**. Notice the cells labeled “First simulation to run” and “Last simulation to run” at the top of the Batch File worksheet. These fields will automatically adjust to the number of batches you add. However, if you want to run only certain sequential simulations, you can manually enter the run numbers in those fields of the worksheet.

Interpreting the Examples

After working out the examples, you should have a better understanding of WestPro’s capabilities. You can look at the predictions on worksheets and charts to determine if the stand structure is sustainable over time. The examples presented in this paper exhibit an increase in size diversity (fig. 9) but a decrease in species group diversity (fig. 10) over time, while the stand basal area (ft^2/acre) decreases at first and then reaches a sustainable level (fig. 12). Also, the production predictions reveal that the total basal area cut (ft^2/acre), gross income (dollars/acre), and volume cut (ft^3/acre) reach steady levels over time (figs. 5, 13b through 15). The above examples represent only one possible management regime for an uneven-aged stand. You can use WestPro to investigate others.

6. Troubleshooting and Further Program Applications

Model Restrictions

The WestPro software is intended to serve as a guide for the management of uneven-aged Douglas-fir stands. Its equations represent the expected development of stands based on observations from 66 plots on wide-ranging sites in Washington and Oregon. Thus, like other models, WestPro predicts average expected values. Although it may not predict accurately the observed growth and yield on an individual stand, its predictions should be close to the average growth and yield over many stands (Ralston et al., in press).

Program Restriction

The WestPro program automatically corrects errors, or prompts users to correct errors in data entry. However, some errors may still go undetected. The following information will help you prevent or correct those errors.

Many of the worksheet cells in which you need not enter or change data are protected. This protection can be removed by going to the **Tools**→**Protection**→**Unprotect Sheet**. You will be prompted to enter a password, "Douglas-fir." If you remove the protection, you will be able to make changes in the sheet format. However, WestPro is designed to reference particular cells or ranges of cells. Any change to the format could produce an error or unintended results.

You can view the data in the Setup Files worksheet by going to **Format**→**Sheet**→ **Unhide**. When the Unhide window opens, choose Setup Files and that sheet will now be visible. If you change the format or enter data directly into the Setup Files worksheet, however, it will most likely result in an error.

Other errors can result when the management schedule does not make sense. WestPro is prepared for many errors of this kind and will instruct you on how to correct the problem. WestPro does have restrictions on the management schedule parameters. The maximum length of simulation is 2,000 years, no more than 254 harvests can be performed, and you must enter a cutting cycle greater than 1 year. Also, you cannot run more than 500 batch simulations at one time.

Further Applications of WestPro

This manual does not suggest a particular management regime for uneven-aged Douglas-fir stands, but using the WestPro software may help you choose a regime, based on the predicted economic and ecological consequences of different approaches. Although the example used in the paper has emphasized only a few methods of setting target distributions, target distributions of any shape could be investigated with WestPro. Coupled with the flexibility of setting cutting cycles, and targeting hardwoods as well as softwoods, WestPro is a tool with a wide range of applications for multipurpose forestry in the Pacific Northwest.

Acknowledgments

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	.304	Meters
Square feet (ft^2)	.0929	Square meters
Cubic feet (ft^3)	.0283	Cubic meters
Acres (ac)	.405	Hectares
Square feet per acre (ft^2/ac)	.2293	Square meters per hectare
Cubic feet per acre (ft^3/ac)	.06997	Cubic meters per hectare
Trees per acre	2.471	Trees per hectare

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Glossary

BDq distribution—A diameter distribution defined by stand basal area (ft^2/acre), maximum and minimum tree diameters (in), and a q-ratio, the ratio of trees per acre in a diameter class to the number of trees per acre in the next larger class.

Cutting cycle—The time interval between successive harvests in an uneven-aged stand.

DBH—The diameter of a tree recorded at breast height.

Fixed costs—The costs per acre not included in the stumpage price.

Initial distribution—The number of trees per acre in each diameter class, for both species groups, at year zero.

Management schedule—The time parameters of the stand simulation, including the first year of simulation, year of first harvest, the cutting cycle, and the length of the simulation.

Marking guide—The portion of the Stock-and-Cut Table that indicates the number of pulpwood and sawtimber trees that are cut from the initial distribution as dictated by the target distribution.

Net present value—The net revenue (gross income minus fixed costs), discounted to the present.

$$NPV = \frac{R - C}{(1 + r)^t} \quad ,$$

where R is the gross income (dollars/acre), C is the fixed cost (dollars/acre), r is the real interest rate (percent/year), and t is the number of years in the future. The total net present value is the sum of the net present value over all harvests.

Pulpwood—All softwood trees with a diameter smaller than 9 inches and all hardwood trees with diameters smaller than 11 inches.

Sawtimber—Trees large enough to produce sawlogs. All softwood trees with a diameter of 9 inches or larger and all hardwood trees with diameter of 11 inches or larger.

Site index—The average height of the five dominant Douglas-fir trees at 50 years of age. Original database measurements used King's selection method (King 1966).

State—The state where your stand is located, either Washington (WA) or Oregon (OR). The distinction is made because, all other things being equal, hardwoods in Washington grow faster than in Oregon, according to the data used to develop the growth equations.

Target distribution—The number of trees per acre, by diameter class and species group, desired after each harvest.

Appendix A—WestPro Data

This appendix summarizes the data used to develop the equations for the density-dependent matrix model used in the WestPro program. More detail on the data, equations, and model estimation and validation can be found in Ralston et al. (in press).

The data came from sample plots in Oregon and Washington measured by the Forest Inventory and Analysis Program (FIA) at the USDA Forest Service, Pacific Northwest (PNW) Research Station. All the plots had been measured at two successive inventories. The most recent inventory was conducted in 2000 in the state of Washington and between 1995 and 1997 in Oregon. The previous inventories occurred between 1988 and 1990 in Washington, and between 1984 and 1986 in Oregon.

The selected plots had the following characteristics: the primary forest type was Douglas-fir, the plot had been measured twice, and it was classified as timberland and uneven-aged. This gave 43 plots in Oregon and 23 in Washington.

Trees with a diameter at breast height of more than 3 inches were used to estimate model equations. The trees were grouped into softwoods or hardwoods. The primary softwood species were Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg), and the most common hardwoods included bigleaf maple (*Acer macrophyllum* Pursh), red alder (*Alnus rubra* Bong.), and Pacific madrone *(Arbutus menziesii* Pursh).

The matrix model in WestPro predicts growth, mortality, and ingrowth for softwoods and hardwoods as a function of basal area, site index, and individual tree size when those variables are statistically significant. The WestPro program also employs equations to predict volume from tree characteristics and stand basal area. Appendix B summarizes the equations and their parameters.

The dependent variables for the four equations were:

- The diameter growth rate of each tree, in inches per year, estimated from the difference in diameters at the time of the two inventories, divided by the number of years between inventories.
- The tree mortality between the two inventories, recorded as a binary variable: 1 if a tree had died, and 0 if it stayed alive.
- The ingrowth, or the number of trees per acre per year entering the smallest diameter class between the two inventories, measured on each plot.
- The tree volume, in cubic feet, recorded in the FIA database.

The explanatory variables were:

- The individual tree size, measured as diameter at breast height in inches, at the first inventory.
- The site index, measured by the height, in feet, of the dominant tree on the plot at age 50.
- The stand basal area, in square feet per acre, of all the trees of diameter larger than 3 inches on the plot in which a particular tree was growing.

The summary statistics for all the variables are in table 1. The data from Washington and Oregon have been combined because there was no statistical difference in the model parameters between the two states, except for the hardwood growth equation, which showed a slightly faster growth in Washington (see table 2 in app. B).

Table 1—Summary statistics for tree and plot data used in parameter estimation

	Diameter growth		Diameter			
	Softwoods	**Hardwoods**	**Softwoods**	**Hardwoods**	**Site index**	**Basal area**
	– – – – Inches per year – – – –		*– – – – – – Inches – – – – – –*		*Feet*	*Square feet per acre*
Mean	0.19	0.10	17.43	11.55	95.96	150.71
S.D.	.12	.09	10.14	6.54	23.41	66.47
Max	.69	.62	64.09	38.23	145.93	353.13
Min	.00	.00	3.03	3.03	47.21	52.95
	– Sample size –					
N	1,387	187	1,387	187	66	66

	Mortality rate (between inventories)		Ingrowth		Tree volume	
	Softwoods	**Hardwoods**	**Softwoods**	**Hardwoods**	**Softwoods**	**Hardwoods**
	– – – – – – – – – – – – Trees per acre per year – – – – – – – – – – – –				*– – – – Cubic feet – – – –*	
Mean	0.04	0.10	1.99	0.74	103.03	35.27
S.D.	.19	.30	4.81	2.31	123.13	46.17
Max	1.00	1.00	30.48	13.41	967.83	383.00
Min	.00	.00	.00	.00	.80	.50
	– Sample size –					
N	1,472	271	66	66	1,375	161

Appendix B—WestPro Model and Parameters

Growth Model Structure

The growth model uses a density-dependent matrix form, similar to that used by Lin et al. (1998) and Kolbe et al. (1999).

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

where $\mathbf{y}_t$ is a column vector representing the number of live trees per acre, $\mathbf{y}_t=[y_{ijt}]$, where i is the tree species, j is the diameter class, and t is the year. The column vector $\mathbf{h}_t=[h_{ijt}]$ represents the number of trees of species i and diameter class j harvested in year t. The growth matrix $\mathbf{G}_t$ is defined as:

$$\mathbf{G}_t = \begin{bmatrix} \mathbf{G}_{1t} & \\ & \mathbf{G}_{2t} \end{bmatrix}, \text{with:}$$

$$\mathbf{G}_{it} = \begin{bmatrix} a_{i1t} & & & & \\ b_{i1t} & a_{i2t} & & & \\ & \ddots & \ddots & & \\ & & b_{i,n-2,t} & a_{i,n-1,t} & \\ & & & 0 & a_{\text{int}} \end{bmatrix}, \tag{2}$$

where n is the number of diameter classes, b_{ijt} is the probability that a tree of species i and in diameter class j at t is alive and in diameter class j+1 at t+1, while a_{ijt} is the probability that the same tree is alive and still in diameter class j at t+1. The subscript t indicates that the probabilities a and b vary over time because they are functions of stand density.

If we let the m_{ijt} be the probability that a tree of species i and diameter class j dies between t and t+1, then a_{ijt} is given by:

$$a_{ijt} = 1 - b_{ijt} - m_{ijt}. \tag{3}$$

The ingrowth matrix, $\mathbf{I}_t$, is a column vector that contains the ingrowth for each species group at time t.

$$\mathbf{I}_t = \begin{bmatrix} \mathbf{I}_{1t} \\ \mathbf{I}_{2t} \end{bmatrix}, \tag{4}$$

where $\mathbf{I}_{it}$ is the ingrowth of species i, that is the number of trees that enters diameter class 1 between year t and year t+1. The subscript t indicates that the ingrowth varies over time because it, too, is a function of the stand density.

Growth Equation

The probability that a tree stays alive and moves from diameter class j to j+1 between years t and t+1 is:

$$b_{ijt} = \frac{g_{ijt}}{d}, \tag{5}$$

Table 2—Parameters of diameter growth equations

Species group	Constant	Explanatory variable				
		Diameter	Diameter squared	Site index	Basal area	State[a]
		Inches	*Square inches*	*Feet*	*Square feet per acre*	
Softwoods	0.035	0.0090	-0.00015	0.0016	-0.00055	
Hardwoods	.020	.0044	-.00011	.0008	-.00009	-.035

[a] 0 for Washington, 1 for Oregon.

where g_{ijt} is the yearly growth (in inches) of a tree of species *i* in diameter class *j*, and *d* is the width of a diameter class (2 inches). In turn, g_{ijt} is a function of tree diameter, diameter squared, site index, and stand basal area. The parameters of this function, estimated with the data described in appendix A are in table 2.

Mortality Equation

The probability, m_{ijt}, that a live tree of species *i* and diameter class *j* died between year *t* and *t*+1 was computed as:

$$m_{ijt} = \frac{m_{ijT}}{T}, \tag{6}$$

where m_{ijT} is the probability that a tree dies between year *t* and *t*+*T*, the interval between inventories, set at 10.6 years, the average interval between inventories across all plots. m_{ijT} was represented by the logit function:

$$m_{ijT} = \frac{e^{z_{ijT}}}{1+e^{z_{ijT}}}, \tag{7}$$

where z_{ijT} is a function of tree diameter, diameter squared, site index, and stand basal area. The parameters of this function are shown in table 3. For this and other equations, only variables that were statistically significant or conformed with a priori expectations were included. Where none of the explanatory variables was statistically significant or had the expected signs, the dependent variable was assumed to be constant, and set equal to the mean observed in the sample.

Ingrowth Equation

Although more complex ingrowth equations were tried during the empirical work, the final version of the model of ingrowth, in trees per acre per year, was a linear function of stand basal area only. The parameters of the ingrowth function are in table 4.

Tree Volume Equation

The equation used to predict tree volume expressed volume in cubic feet as a function of tree diameter, diameter squared, site index, and stand basal area. The parameters of the tree volume equations are in table 5 for trees of at least 5 inches in diameter. The volume of smaller trees was set equal to zero.

Table 3—Parameters of logit model for probability of tree mortality between two inventories

		Explanatory variable			
Species	**Constant**	**Diameter**	**Diameter squared**	**Site index**	**Basal area**
		Inches	*Square inches*	*Feet*	*Square feet per acre*
Softwoods	-2.42	-0.23	0.0034	0.0082	0.0029
Hardwoods	.0996				

Table 4—Parameters of ingrowth equation

Species	**Constant**	**Basal area**
		Square feet per acre
Softwoods	2.65	-0.0044
Hardwoods	.74	

Table 5—Parameters of tree volume equations

		Explanatory variable			
Species	**Constant**	**Diameter**	**Diameter squared**	**Site index**	**Basal area**
		Inches	*Square inches*	*Feet*	*Square feet per acre*
Softwoods	-64.8	-0.18	0.221	0.46	0.080
Hardwoods	-23.5	-.94	.22	.24	.01

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