Tree Volume Equations for Fifteen Urban Species in California

By

Norman H. Pillsbury

Jeffrey L. Reimer

Richard P. Thompson

Technical Report No. 7

Urban Forest Ecosystems Institute

California Polytechnic State University

San Luis Obispo

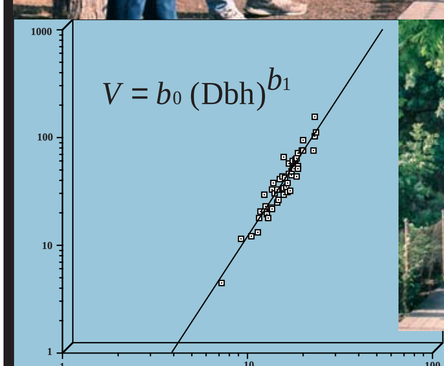
In Cooperation with the

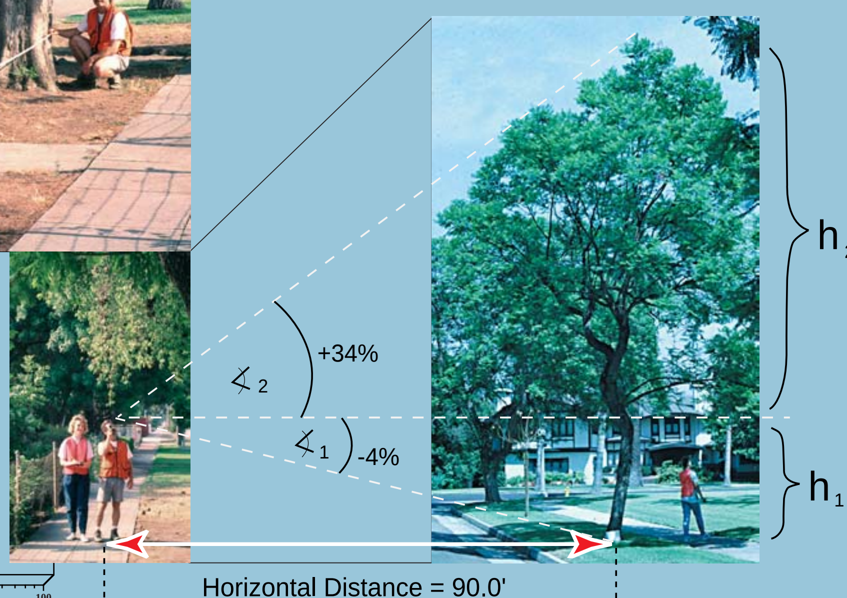
California Department of Forestry

and Fire Protection

Riverside, CA

June 1998





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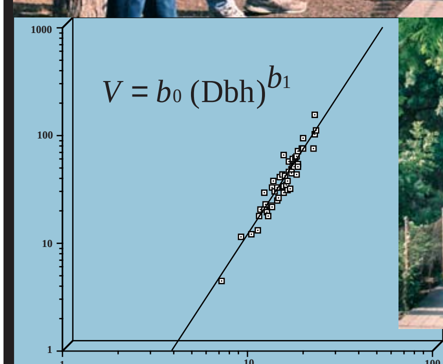

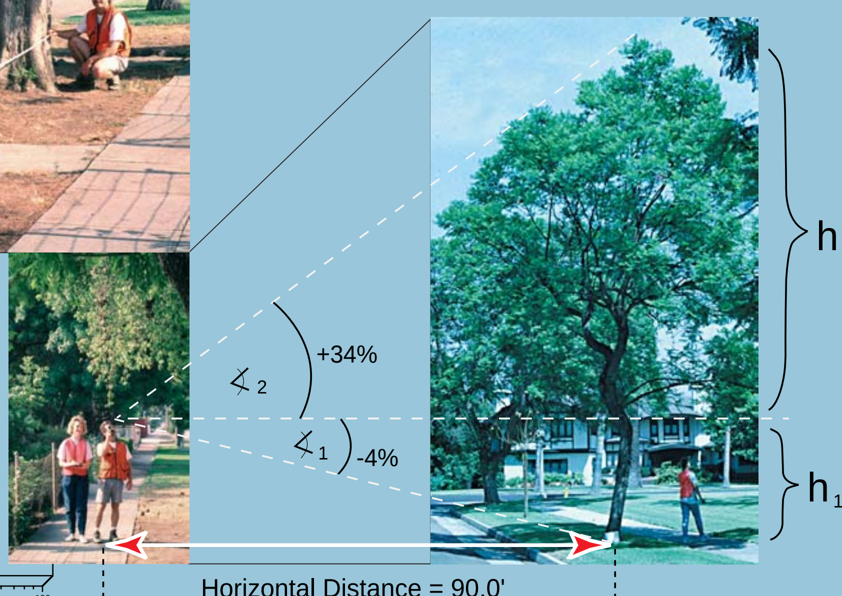

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Acknowledgements

The California Department of Forestry and Fire Protection and the Urban Forest Ecosystems Institute at Cal Poly State University, San Luis Obispo have developed a partnership to conduct an urban volume and biomass study for the communities of Anaheim, Pasadena, Glendale, San Luis Obispo, Oakland, Monterey Peninsula, Sacramento, Modesto and Visalia, California.

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Preface

The call for improved management and sustainability of California's urban forests has been heard.

This call has led to a number of projects that have been recently completed, while others are waiting to be implemented. Recently completed efforts include the "One California Forest" brochure that has been mailed to thousands of citizens, a public opinion survey documenting attitudes and preferences of Californian's toward urban forestry issues, two regional workshops leading to development of an urban forestry strategic planning document for participating communities, and a study identifying and evaluating the elements of sustainability in urban forestry.

This study describes three levels of forest inventory, and provides the basic volume prediction models and inventory techniques needed to take the next step toward sustainability of the urban forest resource.

Tree Volume Equations for Fifteen Urban Species in California

I. Introduction

Cities throughout California are facing tremendous challenges in funding and sustaining urban forestry programs. Some of the costliest operations are tree care and removal, and disposing of wood residues. Urban foresters can no longer afford to operate in a manner that treats urban forest wood residues as a costly disposal problem. Recycled uses for these wood residues could generate significant savings in handling and landfill costs, costs that are growing rapidly. Even more attractive is the prospect that these wood residues could actually generate net revenues if markets for energy and high quality woods could be identified and developed.

Perhaps the most current example showing use of green waste is discussed in a report titled: "Greenwaste Reduction Implementation Plan (GRIP), an Urban Forestry Biomass Utilization Project" prepared by Intregrated Urban Forestry, Inc. in conjunction with Cal Poly, San Luis Obispo (Larson and O'Keefe 1996).

To move urban forestry programs from the costly status quo to a more sustainable state, where wood residues are valued, a more comprehensive inventory of the urban forest is required. Many communities have developed a "street tree inventory" which typically describes the location and health condition of trees by species. Such an inventory is an important step in understanding the composition of the urban forest. However, much more information is needed to begin managing the urban forest in a sustainable fashion.

For an inventory to serve as a management tool, it should describe the structure, composition and "volumes" of the urban forest with reasonable accuracy. To achieve these results, data must be collected on tree size (i.e., diameter at breast height, and total height), and age (date planted) in addition to species, location, and health or damage rating. Data on maintenance activities, costs and timing would make the inventory even more useful. Because developing such comprehensive inventories requires a considerable investment in time and resources, standardized methods are needed to assist urban foresters in data collection, analysis and inventory assessment. The purpose of this report is to assist urban foresters in developing a comprehensive inventory.

A special section is presented on pages 2 and 3 for the reader to understand how this study fits into the multi-year Urban Forest Utilization project and its role in enhancing the sustainability of urban forests.

Modified versions of this report were presented as a video titled "Cal Poly Urban Forest Sustainability Project" (Pillsbury, Reimer and Thompson), and a paper titled "Tree volume equations for ten urban species in California" (Pillsbury and Reimer) at the Symposium on Oak Woodlands: Ecology, Management and Urban Interface Issues (March 21, 1996 Cal Poly, San Luis Obispo). It was also reported in the Symposium Proceedings (Technical editors: Pillsbury, N., J. Verner, and W. D. Tietje 1997).

Overview and Goals of the Urban Forest Utilization Project

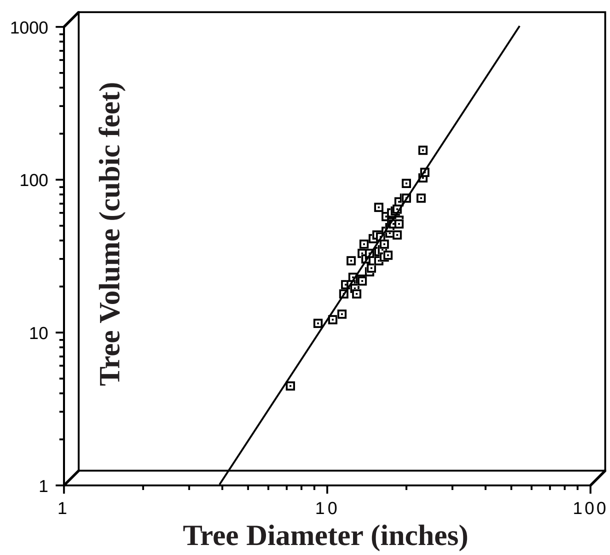
The goal of this project is to conduct a series of volume studies of the major urban forest species to further the development of management inventories in each California city for the purpose of promoting sustainable urban forests. To accomplish this goal, the project has been broken down into three phases:

Phase I - Development of Tree Volume Equations

The first phase involves biometric studies to enable the urban forester to predict the volume of various tree species for the future sustainable urban forests. Detailed measurements are made of sample trees in order to create a statistical model for each predetermined species. Volume prediction equations are developed.

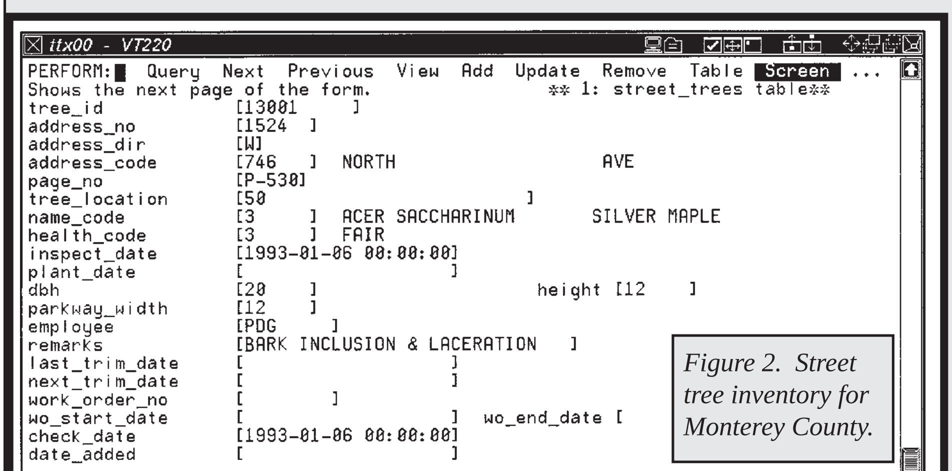
It is this phase that is presented in this report. Results of Phases II and III will be reported separately.

Figure 1. Tree prediction equation for Chinese Elm.



Phase II - Development of Community Forest Inventories

Using the prediction models from Phase I, cities can expand their current *street tree inventory* and begin to create a *management inventory*. Collecting data on tree diameter in addition to data on species, location, planting date, and tree condition is all that is necessary for estimating total inventory. Other data on maintenance activities, tree heights, useful life, growth rate, value and product utilization are needed to create a *comprehensive inventory*. A comprehensive inventory can be used to manage by rotation and develop product and sustainable budgets (see Phase III).



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Shows the next page of the form.                    ** 1: street_trees table**
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address_code       [746   ]  NORTH                  AVE
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health_code        [3     ]  FAIR
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date_added         [                   ]
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Figure 2. Street tree inventory for Monterey County.

Phase III - Information Management for Budgeting & Product Development

As urban forest management inventories are established, a whole range of management functions can be enhanced and new opportunities explored. Cities can use such inventories to design the urban forest to normalize its species composition and structure; better plan and organize planting, care, trimming and removal activities; and establish new uses and markets for the regularized wood residues flows. Combined with a GIS database, new ways of integrating the urban forest into the city infrastructure and interacting with the public can be developed.

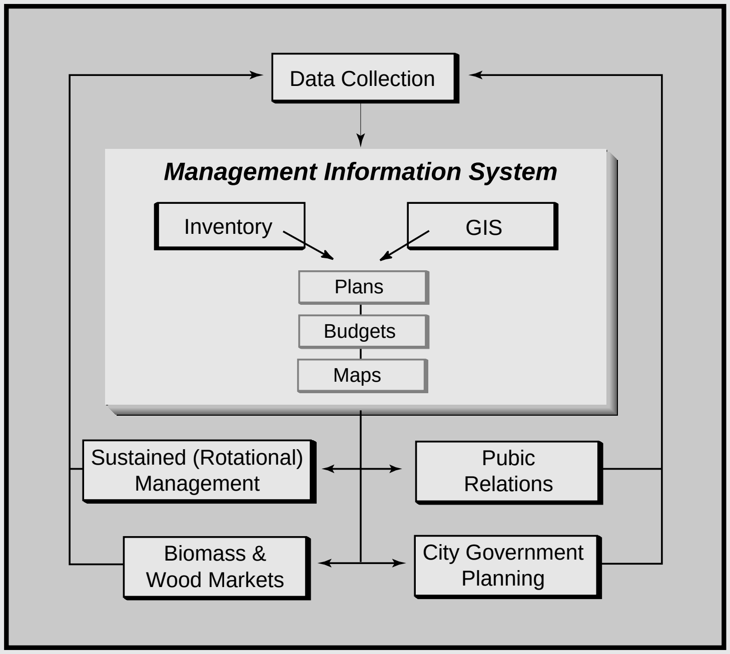


Figure 3. Multiple products of the urban forest are possible with a comprehensive inventory.

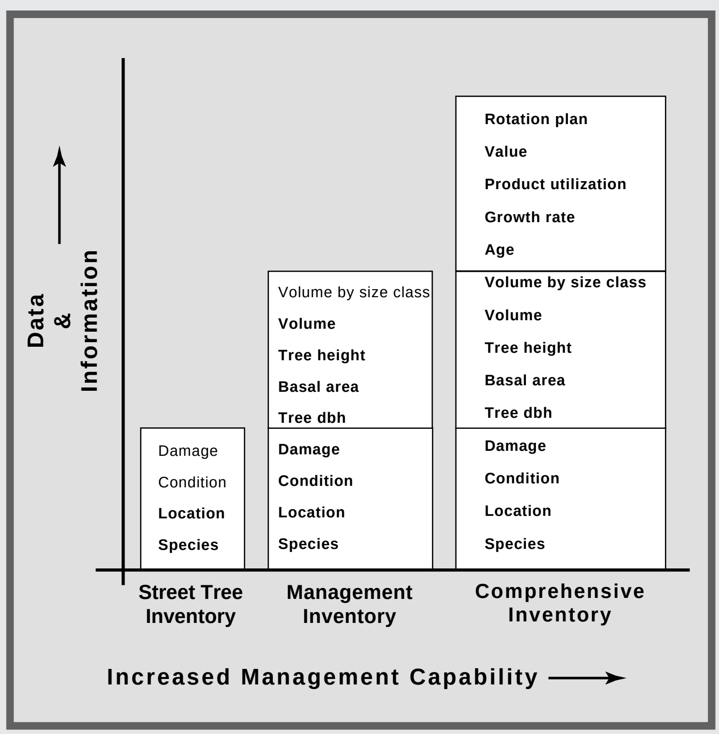


Figure 4. The potential to manage the urban forest in a sustainable manner substantially increases when specific tree data is collected and managed. ***Bold face*** *items are required, plain text is optional, to achieve each inventory level.*

III. Study Criteria and Design

As discussed earlier, the objective of this study is to develop equations that can be used to predict or estimate tree volume for urban forest species from various geographical regions and communities in California. The following sampling design was used to develop prediction equations for urban forest species in California.

Selecting Communities with Urban Forestry Programs

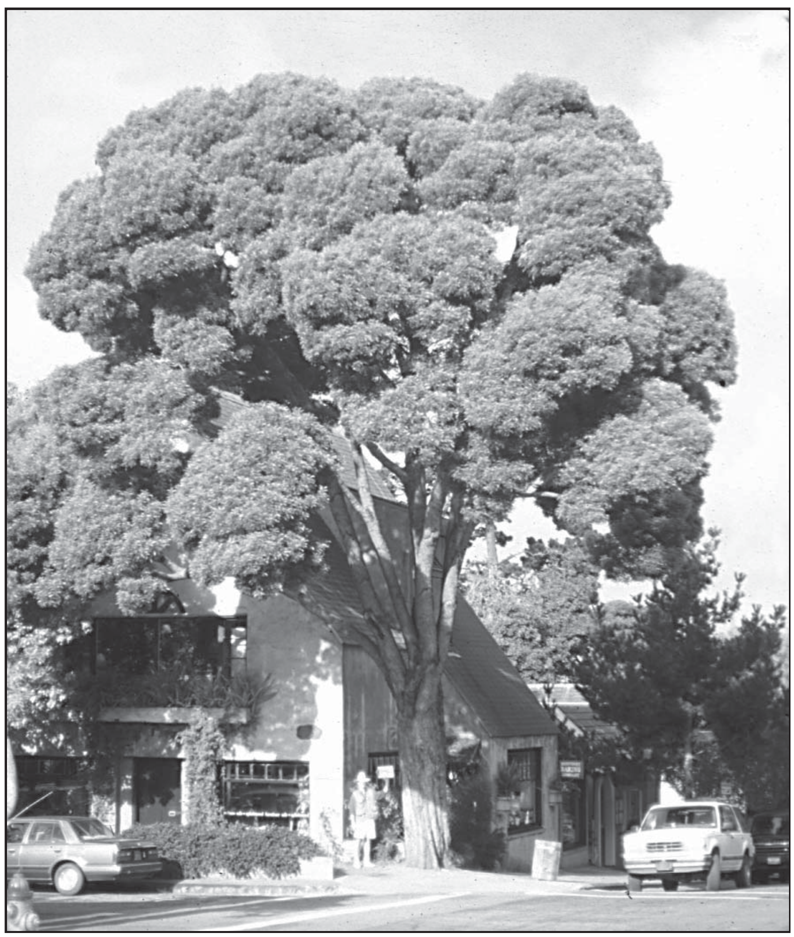
California was first divided into three broad geographic regions, Southland, Coastal and the Central Valley (see Figure 5). The rationale for this initial stratification is to ensure that species selected represent major climatic conditions found in the state.

Three communities in each geographic region were identified that could benefit from an evaluation of the volume potential of their urban forest. Communities were selected based on the criteria shown in Table 1 (Pillsbury and Thompson 1995).

Table 1. Criteria for selecting communities for urban forest sampling

1. The community must have an active urban forestry program. The program must be prominently visible in the city's organizational structure, and have an identified urban forester in charge.

2. The urban forestry program must be able to demonstrate a commitment to long-term urban forest development and be on the road to sustainability. The four core elements of sustainability are: species selection and diversity, inventory and landscape planning, tree care and wood utilization, and public relations and support. For more information on sustainability, see "The Elements of



A 53' tall Acacia, with a 29.9" dbh, was measured in the coastal town of Carmel.

Figure 5. Cities studied for volume table development of urban forests species.

Sustainability in Urban Forestry" by Thompson, Pillsbury and Hanna (1994).

3. The community must at least have the beginnings of a street tree inventory. The inventory must be computer-based and be accessible for future studies discussed in Phase II (on page 2), Development of Community Forest Inventories.

4. Within each geographic area of the state, urban foresters must agree on the species that will be sampled.

5. Communities having large, old trees that are facing removal in the next 5-10 years were favored because prediction equations would be more relevant in the near term.

Communities that were selected for study are shown in Table 2. Clearly many other communities could be included in the sample, and as the need and support arises, they can be added. The intent here is to provide specific information on selected communities from different parts of California rather than intensively sample in one or two cities. It is our hope that the value of these results will encourage equation development of additional species in the same or other communities. However, the information collected for the communities that were sampled will allow "preliminary" estimates of volume for other cities as well. See the discussion in section VII on equation use and limitations.

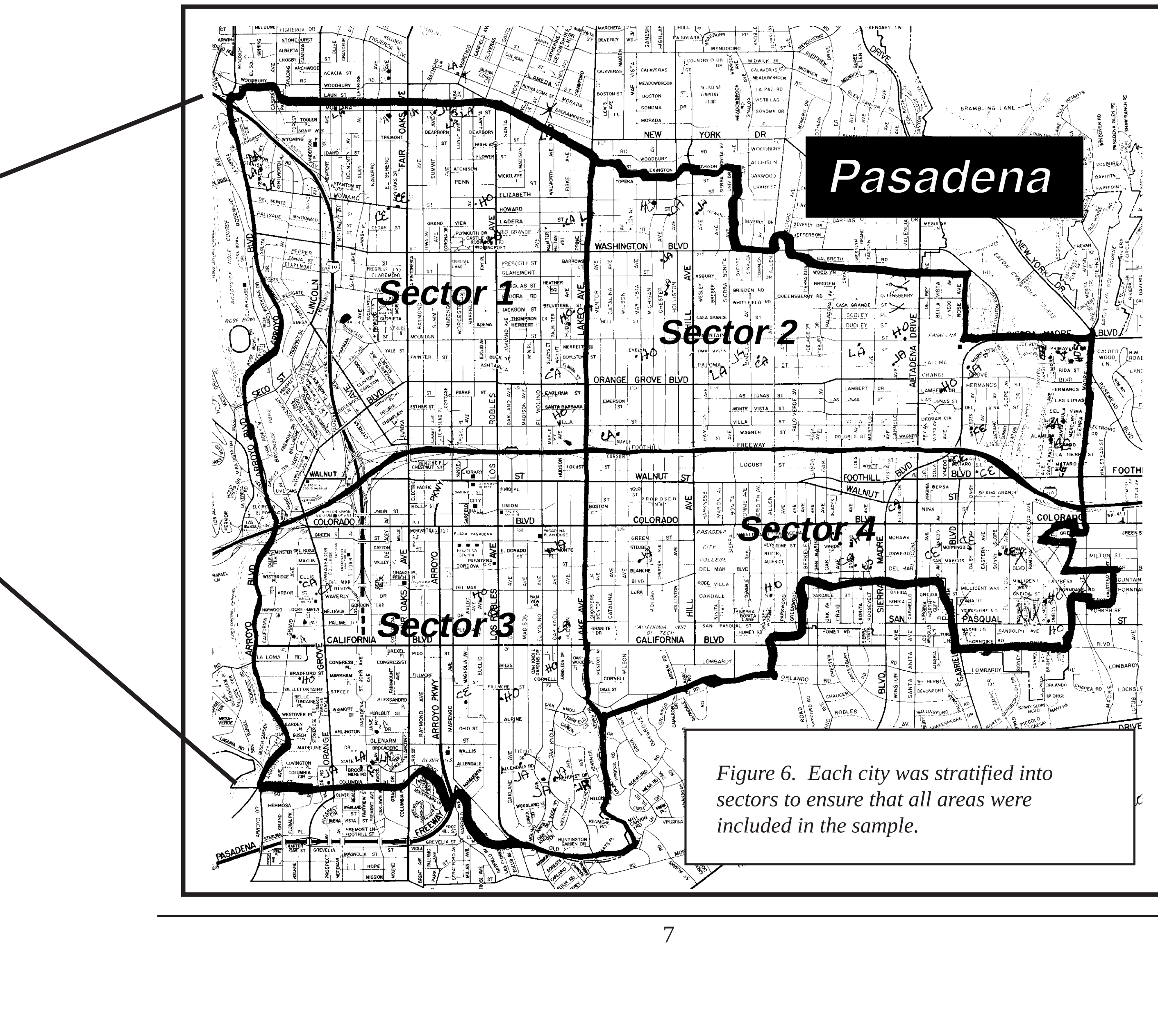


Figure 6. Each city was stratified into sectors to ensure that all areas were included in the sample.

Table 2. Communities selected for volume sampling.

Region	Community	Year of Sample
Southland	Anaheim	1994
	Glendale	1994
	Pasadena	1994
Coastal	San Luis Obispo	1995
	Monterey Peninsula	1995
	Oakland	1995
Central Valley	Visalia	1996
	Modesto	1996
	Sacramento	1996

Species Selection

Five species in each geographic region were selected for study. Species were selected based on the criteria presented in Table 3.

Table 3. Criteria for selecting tree species

1. Species had to be well represented in each community of the geographic region. This was evaluated by urban foresters and from street tree inventories.

2. Species with a high probability for removal in the next decade were given higher priority. We decided that the prediction equations developed in this study should represent species most likely to be harvested in the near future, rather than species recently planted that will not be removed soon.

3. Species that attain larger sizes were favored in the selection process, as they provide greater volumes for use and represent greater savings of disposal costs.

4. Species were favored for selection that were judged to be of higher wood quality, and value.

5. Five species were selected from each geographic region with the restriction that species not be duplicated among regions. Developing equations for the same species in different regions will be considered in the future; the focus of this study is to gather volume information on a greater number of species rather than on regional differences that might exist.

6. Species were ranked lower on the list if equations were available from other studies, even if the studies did not include trees from an urban environment. An example of this is coast live oak (*Quercus agrifolia*) which has been reported in several publications including Pillsbury and Kirkley (1984).

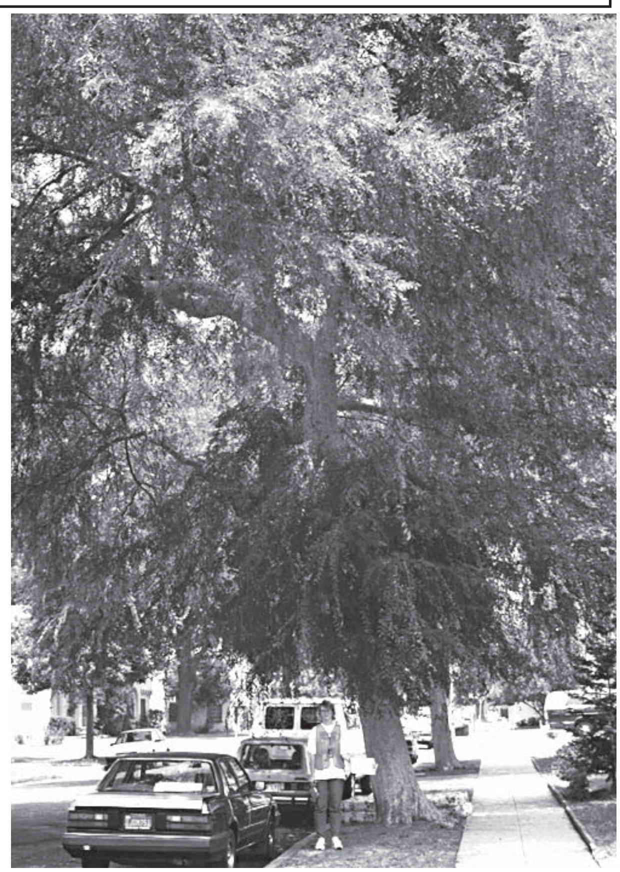
The selection process involved much discussion among the authors and urban foresters from these communities, and many additional species were considered. The species selected, by geographic region, are

Table 4. Species selected for volume estimation

Geographic Region		Species	Photos on page
Southland	Camphor Tree	*Cinnamomum camphora*	10
	Chinese Elm	*Ulmus parvifolia chinensis*	10
	Holly Oak	*Quercus ilex*	10
	Jacaranda	*Jacaranda mimosaifolia*	11
	American Sweet Gum	*Liquidambar styraciflua*	11
Coastal	Monterey Pine	*Pinus radiata*	11
	Blue Gum	*Eucalyptus globulus*	12
	Monterey Cypress	*Cupressus macrocarpa*	12
	Acacia	*Acacia longifolia*	12
	Carob	*Ceratonia siliqua*	13
Central Valley	Modesto Ash	*Fraxinus velutina 'Modesto'*	13
	Southern Magnolia	*Magnolia grandiflora*	13
	Sawleaf Zelkova	*Zelkova serrata*	14
	London Plane	*Platanus acerifolia*	14
	Chinese Pistache	*Pistacia chinensis*	14

presented in Table 4. Photographs of the trees are presented as a method of characterizing the range of tree size, shape, and branching habits that were included in the sample.

Each species is shown with representative pictures of small (left column), medium (center column), and large sized tree (right column).



This 21.6" Chinese Elm has 139 cubic feet of wood.

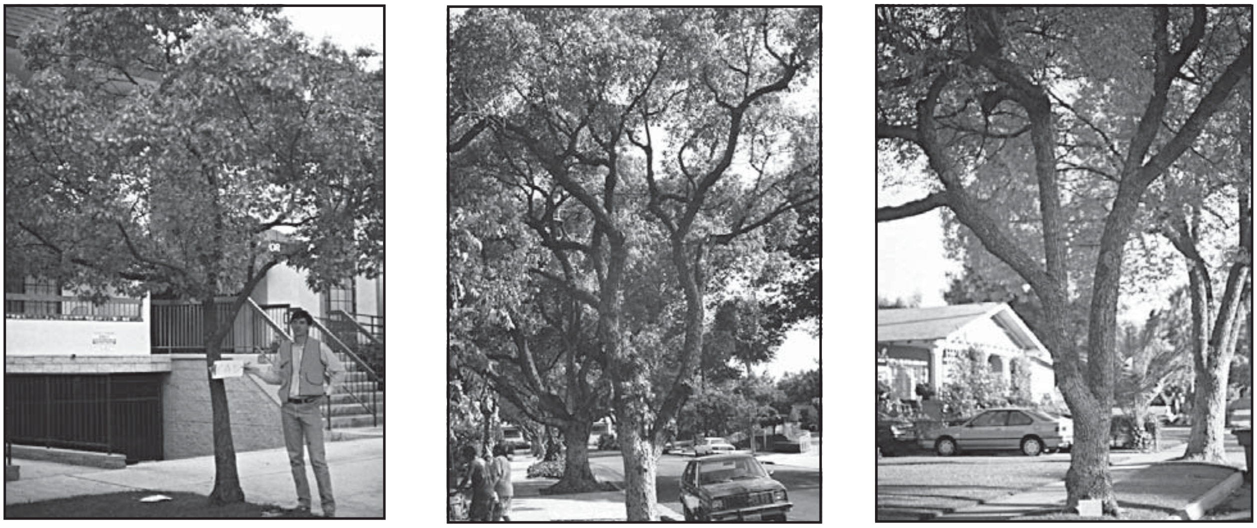


*Figure 7.1. Camphor Tree (*Cinnamomum camphora) *(l. to r., small, medium, large).*

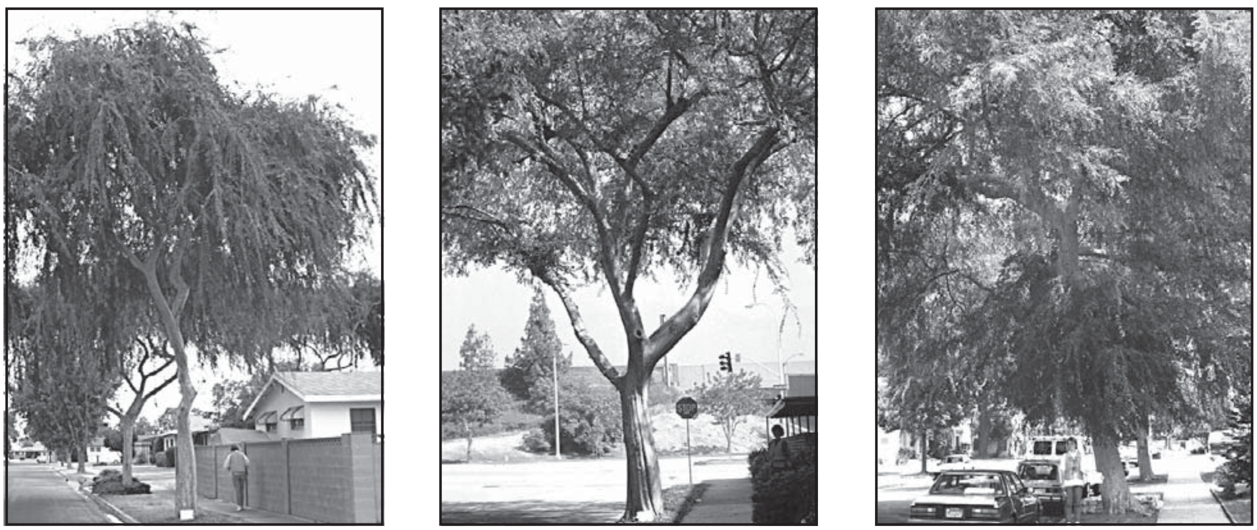


*Figure 7.2. Chinese Elm (*Ulmus parvifolia chinensis) *(l. to r., small, medium, large).*

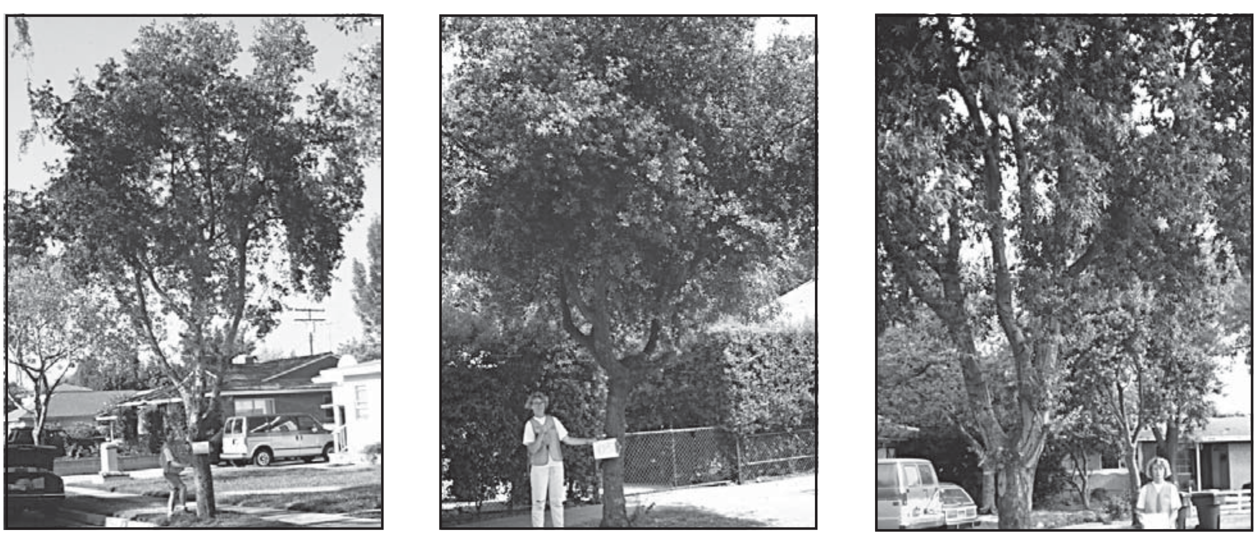


*Figure 7.3. Holly Oak (*Quercus ilex) *(l. to r., small, medium, large).*

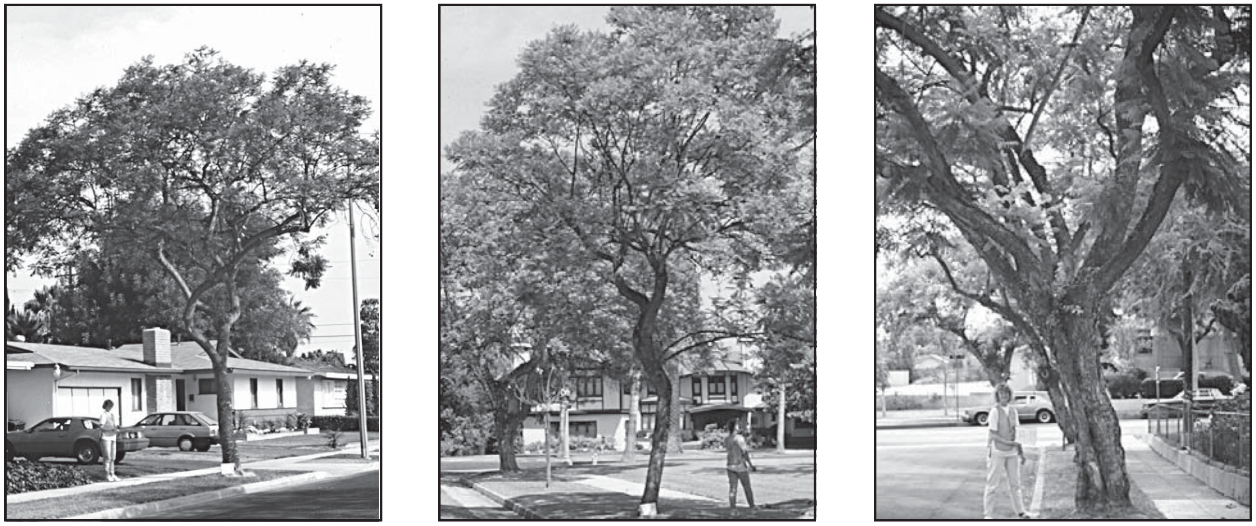


*Figure 7.4 Jacaranda (*Jacaranda mimosaifolia*) (l. to r., small, medium, large).*

*Figure 7.5 American Sweet Gum (*Liquidambar styraciflua*) (l. to r., small, medium, large).*

*Figure 7.6 Monterey Pine (*Pinus radiata*) (l. to r., small, medium, large).*

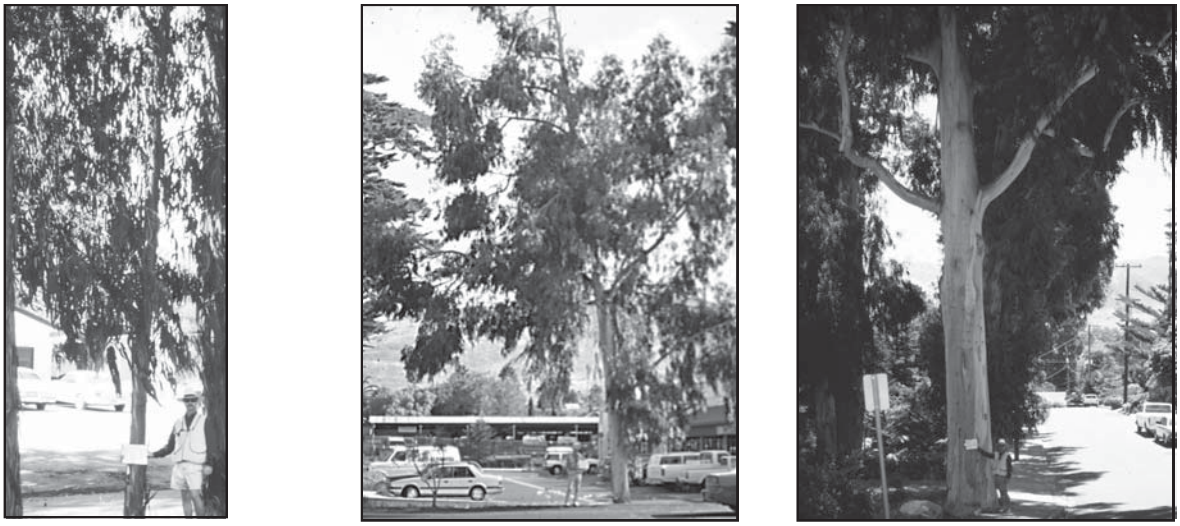


*Figure 7.7 Blue Gum (*Eucalyptus globulus) *(l. to r., small, medium, large).*

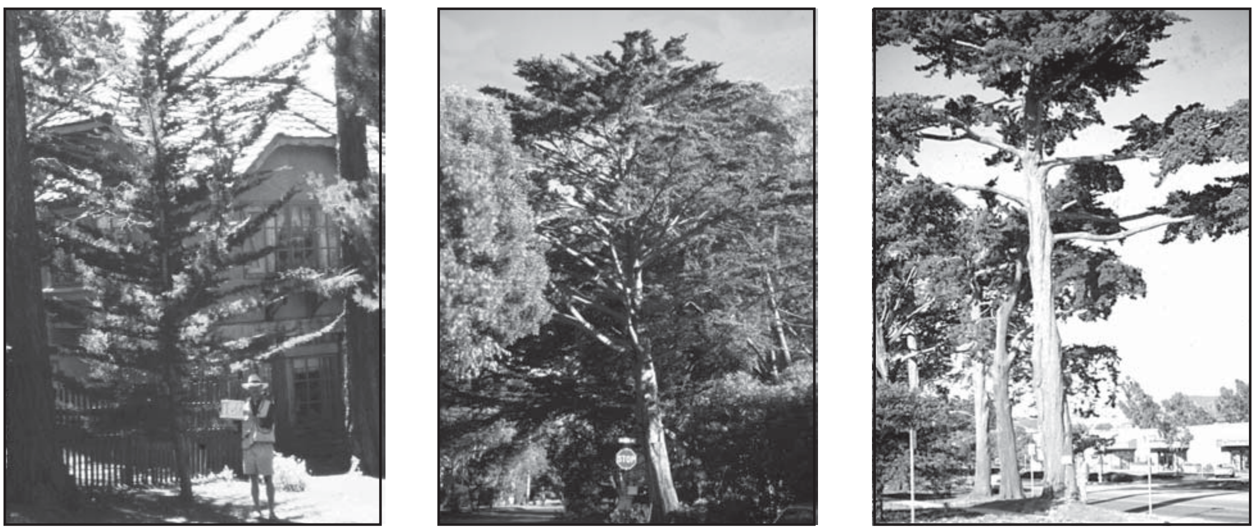


*Figure 7.8 Monterey Cypress (*Cupressus macrocarpa) *(l. to r., small, medium, large).*

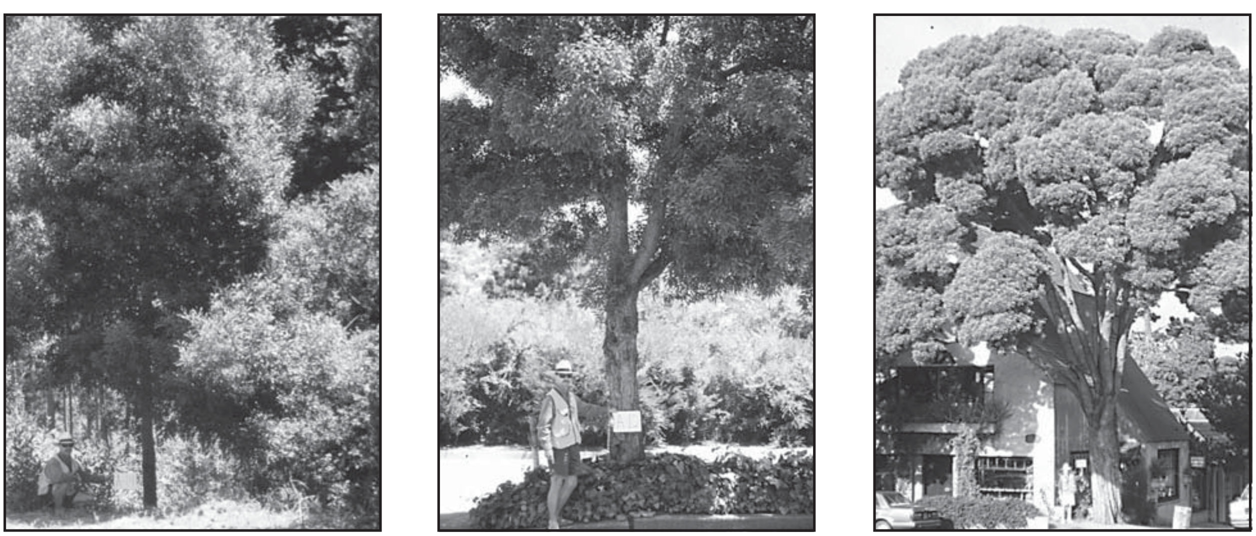


*Figure 7.9 Acacia (*Acacia longifolia*) (l. to r., small, medium, large).*

*Figure 7.10 Carob (*Ceratonia siliqua) *(l. to r., small, medium, large).*

Figure 7.11 Modesto Ash Fraxinus velutina 'Modesto' *(l. to r., small, medium, large).*

*Figure 7.12 Southern Magnolia (*Magnolia grandiflora) *(l. to r., small, medium, large).*

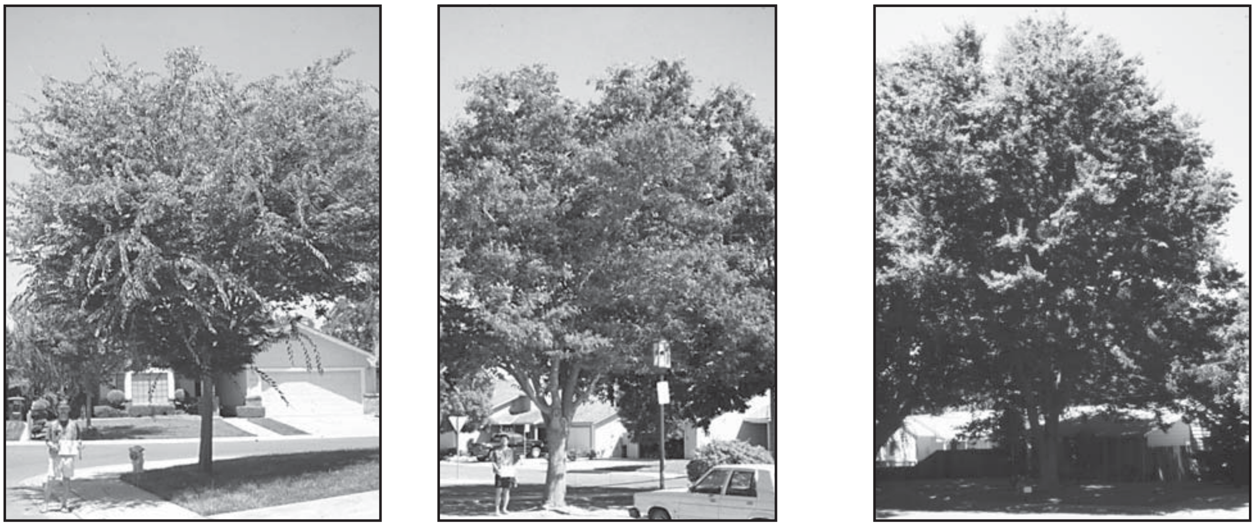


*Figure 7.13 Sawleaf Zelkova (*Zelkova serrata) *(l. to r., small, medium, large).*

*Figure 7.14 London Plane (*Platanus acerifolia) *(l. to r., small, medium, large).*

*Figure 7.15 Chinese Pistache (*Pistacia chinensis) *(l. to r., small, medium, large).*

IV. Procedures and Data Collection Methods

Sample Size

In similar volume studies[1] we found that a sample size of 50 to 60 trees is the minimum number necessary to develop a statistically reliable estimate of the equation parameters. Based on these studies, a sample size of 50 trees per species was adopted.

Geographic Stratification

Each geographic area is represented by 3 cities or communities, and the number of sample trees per species was equally proportioned among their urban forests. To further make certain that the sample design fully represents the geographic area, each community was stratified into 3 to 5 sectors of approximately equal area (in communities where species were widely spread), and an equal number of sample trees were selected among sectors. This design, illustrated in Figure 6 for the City of Pasadena, ensured that all sectors were sampled with similar intensity.

Diameter Distribution

In addition to sample size and geographic stratification concerns, the full range of tree sizes found in the population was included in the sample. Because volume is closely correlated to tree diameter, a graphical accounting of diameters was kept. As trees were measured, their diameters were recorded in order to be certain that the full range of tree sizes of each species was represented. In addition, we checked each sector carefully to be sure that representatives of the largest trees were included in the sample.

Tree Data Collected

The data collected for each sample tree is summarized in Table 5. The variables collected are listed and discussed below. A tree was defined as a evergreen or deciduous species 4.5' or more tall.

Species. The common name was recorded on the data form. Trees having major defects, unusually large damaged areas, or that were abnormally shaped or pruned were not included in the sample. A review of the photographs displayed earlier will provide a visual sense of the size, shape and condition of sample trees.

Diameter at breast height. Diameter at breast height outside bark (dbhob), was measured with a diameter tape at a point 4.5' above the ground on the uphill side. Diameters are used in volume equation development. If the tree was leaning, the 4.5' was measured along the central stem axis. For trees that forked at breast height or lower, the tree was considered to be two trees; however trees of this type were not included in the sample unless specifically noted. If forking occurred just above breast height, a single dbh measurement was made below joint swelling. This means that dbh measurements could vary

[1] Full references are provided in Section X; citations follow: Pillsbury, N. H. 1994; Pillsbury, N. H. and R. D. Pryor. 1994; Pillsbury, N. H. and D. R. Hermosilla. 1993; Pillsbury, N. H. and Pryor, R. D. 1992; De Lasaux, M. J. and Pillsbury, N. H. 1990; Pillsbury, N. H. and Pryor, R. D. 1989; Pillsbury, N. H., Standiford, R, Costello, L., Rhoades, T. and Regan (Banducci), P. 1989; and Pillsbury, N. H. and M. L. Kirkley. 1984.

anywhere from about 2’ to 4.5’ on the stem, or as high as 6’ if swelling biased dbh measurement at breast height. However these examples were few in number as almost all measurements were at 4.5’. It is important that use of the equations presented later in this report, follow these “rules” for greatest accuracy.

Dob at 1 foot. Diameter outside bark was also measured at 1 foot to compute the volume of the base segment. If butt swell was present, the measurement was taken where the tree taper was normal, usually no higher than 2 feet. A diameter tape was used.

Total Height. Total tree height was measured from the tree base on the uphill side to the tip or tallest live portion of the crown (see Figure 8). Heights of leaning trees were calculated using the vertical height to the tree tip and the angle of the bole. Heights are used in volume equation development.

Average Crown Diameter. Crown diameter was determined by averaging measurements of the long axis with a diameter taken at 90°. Readings were taken with a 100’ cloth tape. Data can be used to correlate with tree volume.

Number and Length of Terminal Branches. The last segment of a branch is referred to as a “terminal branch” or “terminal segment.” Terminal branches are defined as being 4” in diameter at the large end and zero inches at the tip or small end. Terminal branches or segments were included in the calculation of tree volume. For each sample tree, 5 or 6 terminal branches were measured for length. In all cases, lengths were consistent within 2-3’, and an average was obtained. The total number of terminal branches was counted for each sample tree.

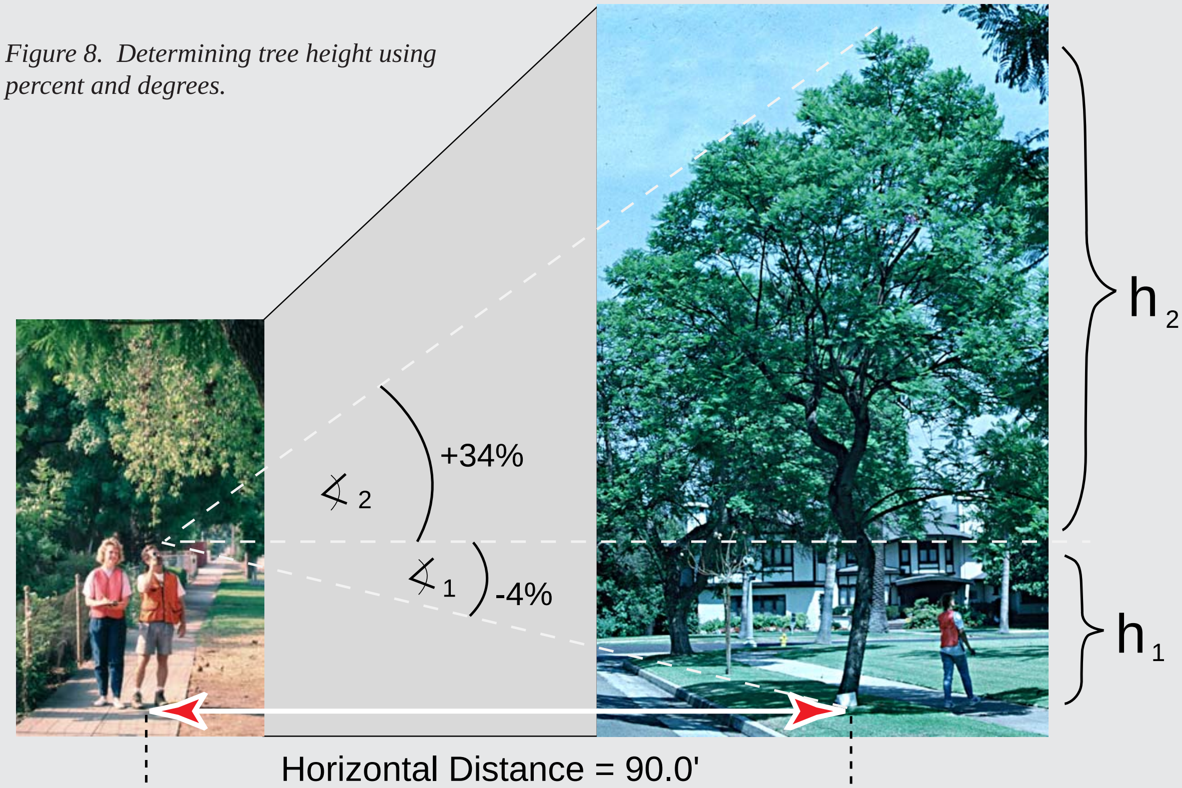
Tree Location and Number. Trees were located by house and street address. If more than one tree was growing at an address, the trees were numbered sequentially following the direction of house numbers.

Photo and Sketch. Each tree was photographed with a 35 mm camera using slide film. A placard was held to identify the tree. Also, as the segment data was collected, a sketch was drawn showing the relative location of each segment. This information was used for illustration and in a few cases when field notes were unclear.

Table 5. Data collected from urban tree species.

Characteristic	Units	Description	Used in development of equations by the authors	Data the Urban Forester will collect
A. Tree Information:				
Species	code	A = Acacia BG = Blue Gum C = Carob CA = Camphor CE = Chinese Elm CP = Chinese Pistache HO = Holly Oak JA = Jacaranda LA = Liquidambar LP = London Plane M = Southern Magnolia MA = Modesto Ash MC = Monterey Cypress MP = Monterey Pine Z = Sawleaf Zelkova	Yes	Yes
Dbh	inches	Diameter at breast height, to the nearest 0.1 inch.	Yes	Yes
Dob at 1’	inches	Diameter to the nearest 0.1 inch.	Yes	No
Total Height	feet	Estimated total height to top of terminal leader.	Yes	Yes
Average Crown Diameter	feet	Average of long and short axis, to the nearest foot.	Yes	No
Number and Average Length of Terminal Branches	#, feet	Count of the number of terminal branches; average length determined by measuring a sample for average of long and short axis.	Yes	No
B. Tree Identification Information:				
Date		Date of field measurement.	Yes	Yes
Photo Number		Roll number and photo number	Yes	No
Tree Location and Tree Number		Located by street address. If more than one tree at the same address, trees were numbered in the direction of increasing address numbers.	Yes	Yes

Figure 8. Determining tree height using percent and degrees.



Determining Tree Height. Total tree height (h_1 + h_2) is required to use the Standard volume equations and tables. A clinometer or abney level can be used to measure the vertical angle to the tree base and top in units of percent or degrees. The calculation procedure is different for the two types of units.

A. When using percent.

1. First measure the horizontal distance from the tree center to a point where you have a clear view of the tip. You may have to correct for slope on steep ground. Usually you will be between 60' and 120' from the tree.

2. With the clinometer measure the angle in percent to a) the tallest live point on the crown or tip ($\angle_2$), and, b) the tree base ($\angle_1$) uphill side.

3. Calculate the tree height as follows.

$$\text{Total tree height} = \frac{\text{Total angle x Horizontal Distance}}{100}$$

The total angle is between the tree tip and the tree base (uphill side), and is calculated by the top reading ($\angle_2$) minus the base reading ($\angle_1$), or ($\angle_2 - \angle_1$).

Assume that $\angle_2$ = +34%, and angle $\angle_1$ = -4% (see picture above).

Then:

$$\text{Total tree height} = \frac{[+34-(-4)] \times 90.0}{100} = 34.2'$$

B. When using degrees.

1. First measure the horizontal distance from the tree center to a point where you have a clear view of the tip. You may have to correct for slope on steep ground. Usually you will be between 60' and 120' from the tree.

2. With the clinometer measure the angle in degrees to a) the tallest live point on the crown or tip ($\angle_2$), and, b) the tree base ($\angle_1$) uphill side. Note that this forms two right triangles.

3. Calculate the tree height as follows.

$$\begin{aligned}\text{Total tree height} &= \text{Horizontal Distance x } (\tan \angle_1 + \tan \angle_2) \\ &= 90.0 \text{ x } (\tan 2° + \tan 19°) \\ &= 90.0 \text{ x } 0.379248 = 34.1'\end{aligned}$$

V. Tree Volume Calculation

Any level of use or management involving the cutting and removal of urban trees requires that accurate volume prediction equations be used. Volume equations can be used to determine tree removal volume, inventory, and for growth and yield studies. Reliable estimates of urban tree volume depend, in part, on the accuracy of the equations developed. Also, they are more reliable within the geographic area from which the field data were collected; the greater the distance from the collection area, the less reliable.

We have been unable to find volume equations developed from cities in California. Our search for equations included numerous urban foresters throughout the state, members of the California Urban Forests Advisory Council, the California Department of Forestry and Fire Protection, the Western Urban Forestry Research Center, Pacific Southwest Research Station, and faculty at Cal Poly, San Luis Obispo and the University of California, Berkeley.

Because equations for urban species do not exist, this study was initiated to develop equations in the three geographic regions of California discussed earlier.

For volume measurement, the branching pattern was defined on a segment basis. Segment length and the diameters at each end were measured using a Spiegel Relaskop (Pillsbury and Kirkley 1984, and others cited earlier). Segment length was determined from coordinates measured at both ends of each segment. Each tree was divided into segments based on four criteria:

1. Segments were defined as the distance from fork to fork in trees with very complex branching pattern, such as segment 11 in Figure 9.
2. If a branch had a sweep or crook, segments were measured to obtain a straight log length such as in segments 3 and 5.
3. Segments were defined if abrupt changes in taper were apparent such as in segments 16 and 17.
4. If a tree had an excurrent growth form, such as Liquidambar, the maximum segment length measured was approximately 10 feet.

If swelling was present on the stem, a common occurrence, relaskop diameter readings were taken slightly above or below the abnormality. A two-step process was used for branches not growing vertically. First the vertical distance between the ends was calculated based on relaskop coordinates. Secondly, an angle, to the nearest 1° from horizontal was measured with a clinometer, and segment length was computed. Segments growing less than 30° from horizontal were measured by projecting their length to the ground and measuring it with a cloth tape held parallel to the branch angle.

Cubic foot volume was calculated for each tree using three equations for determining the cubic volume of a solid. The stump (base segment) was treated as a cylinder (equation 1), the tip was treated as a cone (equation 2), and the remaining segments were treated as a paraboloid frustrum and Smalian's formula was used (equation 3).

$$V = A_u L \qquad [1]$$

$$V = \frac{L}{3}\left(A_b\right) \qquad [2]$$

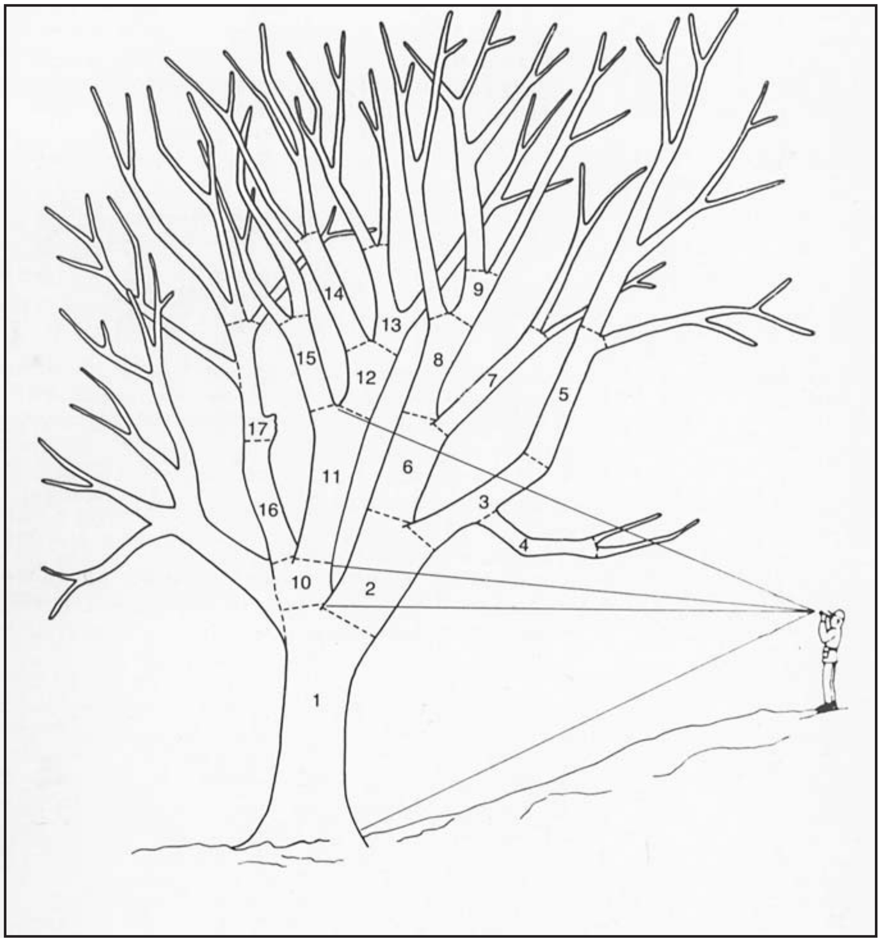


Figure 9. Sample trees were measured on a segment-by-segment basis to determine volume. Numbers on tree indicate tree segments.

$$V = L\frac{(A_u + A_b)}{2} \qquad [3]$$

where:

V = volume outside bark in cubic feet to 0-inch top,

A_b = cross sectional area outside bark at base in square feet,

A_u = cross sectional area outside bark at top in square feet, and,

L = length of segment in feet.

<u>Utilization Standards</u>. Total tree volume includes the volume of all stem segments from ground level including terminal branches and bark. It does not include the volume of roots and foliage. A spreadsheet formulated in Microsoft Excel® (Figure 10) was developed to calculate individual tree volumes using Equations 1-3. As there is no ready market for urban wood at this time, it is not known what branch or stem size will be needed by existing and developing wood manufacturing industries. For example, some companies might be equipped to handle large diameter, 8’ bolts, while others may operate in the small

Species: CE
Tree Number: 7

Location: 3190 Matero, Pasadena
tree #1

Page: 1 of 1

Dob @ 1': 23.6
Dbh: 22.0
Total Height: 56.5

Date: 6/27/94

Average length (ft): 21
Ave Crown Dia.: 55
Number of small branches: 20

Roll/Photo No.: 02--18

Setup	1	2	3	4
HD	33.0			

	Vol of Sm. Br.						Total Volume
Cu. Ft. =	12.22	12.57	23.86	27.18	5.69	18.25	99.77
% Vol =	*12.24*	*12.60*	*23.92*	*27.24*	*5.70*	*18.29*	*100.00*

Setup No.	Seg. No.	Lower Dob	Lower Coord.	Upper Dob	Upper Coord.	Angle (deg.)	H.D. Direct Length	0.005454 Ave. BA	Seg. Length	Volume 4.00 to 7.99 in.	Volume 8.00 to 11.99 in.	Volume 12.00 to 15.99 in.	Volume 16.00 to 19.99 in.	Volume 20.00> in.	Volume All Segments
1	1	23.6		23.6			1.0	3.04	1.00					3.04	3.04
1	2	23.6		22.0			3.5	2.84	3.50					9.94	9.94
1	3	22.0	-2.0	22.0	2.0			2.64	2.00					5.28	5.28
1	4	16.0	2.0	13.0	17.5	25.0		1.16	8.55			9.91			9.91
1	5	7.0	17.5	6.5	22.0	45.0		0.25	3.18	0.79					0.79
1	6	6.5		8.0			5.0	0.29	5.00	1.45					1.45
1	7	8.0	21.0	6.0	24.0			0.27	1.50	0.41					0.41
1	8	6.0		6.0			3.0	0.20	3.00	0.59					0.59
1	9	5.0	24.0	4.0	27.5			0.11	1.75	0.20					0.20
1	10	14.0	2.0	20.0	9.0			1.63	3.50				5.69		5.69
1	11	12.0	9.0	11.0	17.0			0.72	4.00		2.89				2.89
1	12	11.0	17.0	13.0	26.0	35.0		0.79	5.49			4.34			4.34
1	13	11.0	26.0	12.0	40.0	35.0		0.72	8.55		6.18				6.18
1	14	13.0	9.0	12.0	21.5	42.0		0.85	8.41			7.18			7.18
1	15	12.0	21.5	10.0	27.0	13.0		0.67	2.82		1.88				1.88
1	16	10.0	27.0	9.0	36.0	38.0		0.49	5.71		2.82				2.82
1	17	9.0		9.0			3.3	0.44	3.30		1.46				1.46
1	18	6.0		4.0			12.5	0.14	12.50	1.77					1.77
1	19	10.0		10.0			7.5	0.55	7.50		4.09				4.09
1	20	8.0		7.0			1.5	0.31	1.50	0.46					0.46
1	21	13.0	20.0	12.5	29.0	46.0		0.89	6.48			5.75			5.75
1	22	7.5	29.0	7.5	34.0			0.31	2.50	0.77					0.77
1	23	7.5		8.0			6.4	0.33	6.40	2.10					2.10
1	24	11.0		11.0			6.9	0.66	6.90		4.55				4.55
1	25	7.5		4.0			14.0	0.20	14.00	2.76					2.76
1	26	6.0		4.0			6.0	0.14	6.00	0.85					0.85
1	27	6.0	48.0	4.0	54.0			0.14	3.00	0.43					0.43

Figure 10. Spreadsheet showing cubic foot volume calculations.

mulching market. In order to provide estimates for a variety of uses, the spreadsheet was created to calculate wood volume in the following diameter size classes: less than 4", 4-8", 8-12", 12-16", 16-20", greater than 20" as well as total volume. The average diameter of each segment was used to determine its diameter class. Further, these size classes were set as variables, and can be changed to obtain volume proportions based on different diameter groupings. For instance, if one were interested in firewood potential, the volumes of all segments in the 4-8" and 8-12" diameter classes would be combined.

Based on field measurements, the average percent volume for the segment diameter classes discussed above are shown in Figure 11.

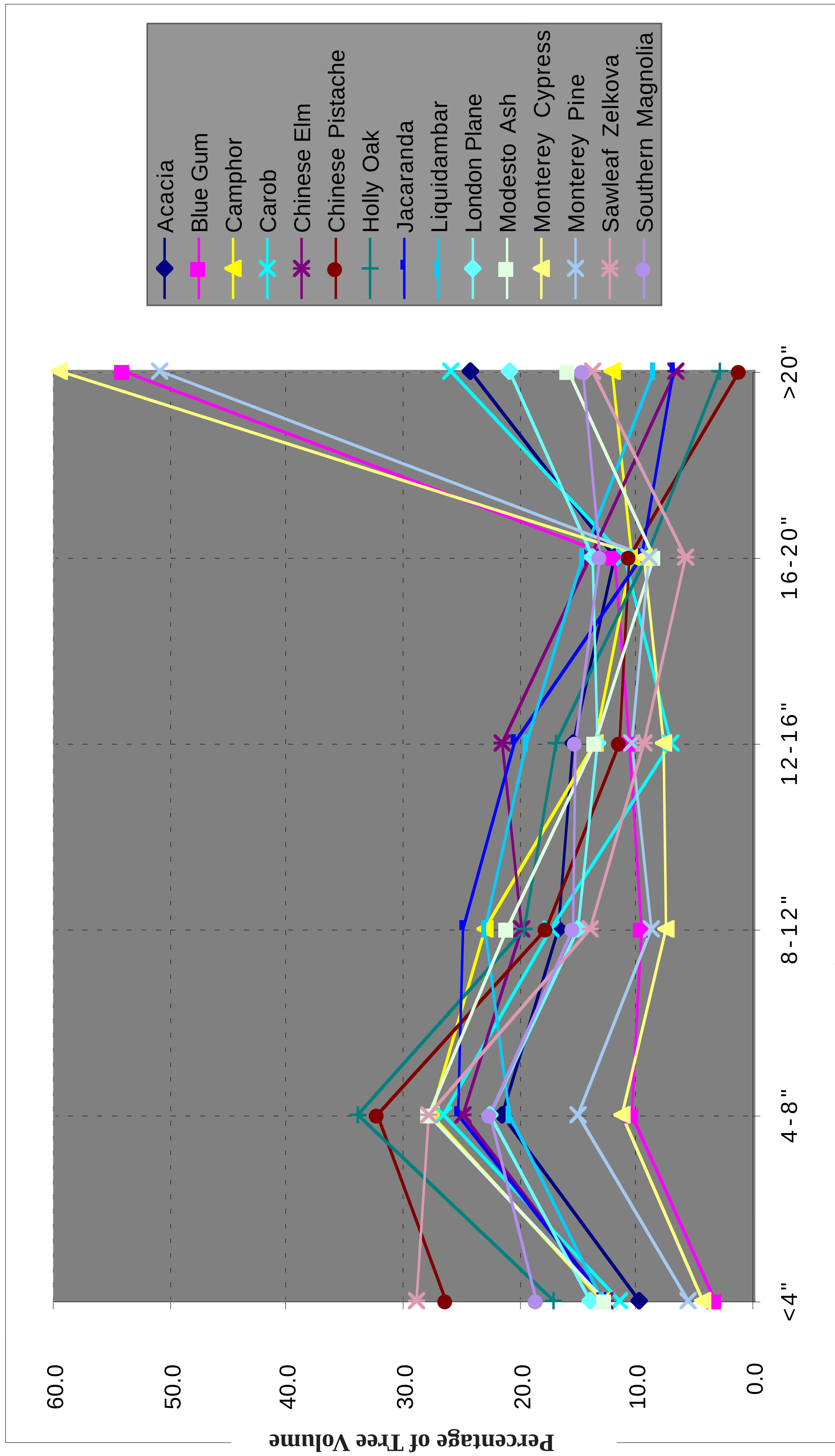


Figure 11. Percentage of tree volume by diameter class for selected urban forest species.

VI. Volume Equations

Two types of equations are commonly used to predict tree volume, local and standard volume equations. Local volume equations use one variable, diameter at breast height (dbh) to estimate tree volume, while a standard volume equation uses both dbh and height. Including height in the equation generally provides a better estimate as it helps account for soil, climate and some cultural variations. Because not all street tree inventories include height, both types of equations are presented here to provide flexibility for the user.

The relationship between volume and dbh and height is a power function that can be linearized as described by equations 4 and 5.

$$V = b_0\,(\text{Dbh})^{b_1} \qquad [4]$$

$$V = b_0\,(\text{Dbh})^{b_1}\,(\text{Ht.})^{b_2} \qquad [5]$$

where:

V = volume outside bark in cubic ft,

Dbh = diameter outside bark at breast-height in inches,

Ht. = total tree height in feet, and,

b_i = regression coefficients.

Simple and multiple regression analysis (equations 4 and 5, respectively) was used to develop the volume prediction equations (Tables 6 and 7). A logarithmic transformation of volume, dbh, and height was used to equalize the variation about the regression line, and linearize a non-linear function so that ordinary least squares regression can be preformed. The data were converted to the logarithmic form to compute the regression coefficients b_0, b_1, and b_2. This is the normal procedure when fitting nonlinear tree volume equations because the logarithmic forms tends to reduce variance in homogeneous samples (Husch *et al.* 1982).

From these equations, local and standard volume tables were developed and are presented in the Appendix.

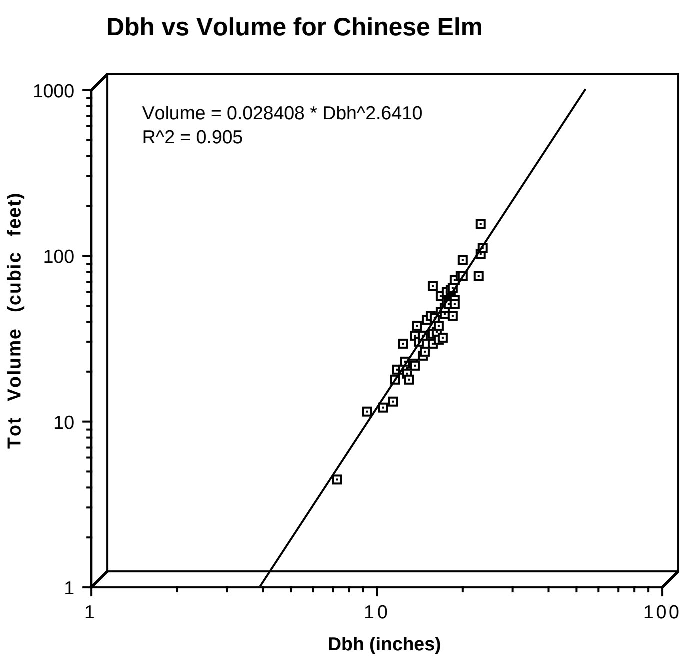


Figure 12. Example of dbh vs. volume graph for Chinese Elm using equation 4.

Table 6--Local volume equations for selected urban forest species

Species	Equation	Adj. R^2	N	SE	Average Percent Deviation	Percent Aggregate Difference	Eqn. No.
Blue Gum	Vol (cf) = 0.055113 ($dbh^{2.436970}$)	0.968	50	1.27	18.6	0.6	6
Acacia	Vol (cf) = 0.048490 ($dbh^{2.347250}$)	0.938	50	1.24	15.8	-3.0	7
Monterey Pine	Vol (cf) = 0.019874 ($dbh^{2.666079}$)	0.969	50	1.27	18.9	-1.7	8
Monterey Cypress	Vol (cf) = 0.035598 ($dbh^{2.495263}$)	0.980	50	1.23	15.7	1.9	9
Carob	Vol (cf) = 0.066256 ($dbh^{2.128861}$)	0.910	50	1.29	18.9	-2.3	10
Camphor	Vol (cf) = 0.031449 ($dbh^{2.534660}$)	0.970	50	1.17	12.5	-1.2	11
Chinese Elm	Vol (cf) = 0.028530 ($dbh^{2.639347}$)	0.903	50	1.22	16.6	-2.3	12
Holly Oak	Vol (cf) = 0.025169 ($dbh^{2.607285}$)	0.938	50	1.24	17.0	-1.3	13
Jacaranda	Vol (cf) = 0.036147 ($dbh^{2.486248}$)	0.949	49	1.19	13.9	0.0	14
Liquidambar	Vol (cf) = 0.030684 ($dbh^{2.560469}$)	0.979	50	1.15	10.5	-0.5	15
Modesto Ash	Vol (cf) = 0.022227 ($dbh^{2.633462}$)	0.940	50	1.29	20.4	-4.5	16
Sawleaf Zelkova	Vol (cf) = 0.021472 ($dbh^{2.674757}$)	0.969	50	1.21	15.7	-0.7	17
Chinese Pistache	Vol (cf) = 0.019003 ($dbh^{2.808625}$)	0.958	49	1.24	17.3	-0.3	18
Southern Magnolia	Vol (cf) = 0.022744 ($dbh^{2.622015}$)	0.958	50	1.24	15.6	0.8	19
London Plane	Vol (cf) = 0.025170 ($dbh^{2.673578}$)	0.965	50	1.22	16.2	-3.3	20

Note: For an explanation of terms used here, see the discussion in the text.

Table 7--Standard volume equations for selected urban forest species

Species	Equation	Adj. R^2	N	SE	Average Percent Deviation	Percent Aggregate Difference	Eqn. No.
Blue Gum	Vol (cf) =0.003089 ($dbh^{2.151822}$)($ht^{0.835731}$)	0.983	50	1.19	10.9	-1.0	21
Acacia	Vol (cf) = 0.014058 ($dbh^{2.186485}$)($ht^{0.467357}$)	0.976	50	1.14	14.5	-2.7	22
Monterey Pine	Vol (cf) = 0.005325 ($dbh^{2.226808}$)($ht^{0.668993}$)	0.979	50	1.22	16.0	-1.1	23
Monterey Cypress	Vol (cf) = 0.005764 ($dbh^{2.260353}$)($ht^{0.630129}$)	0.989	50	1.16	11.9	2.2	24
Carob	Vol (cf) = 0.008573 ($dbh^{1.795854}$)($ht^{0.926668}$)	0.933	50	1.24	17.8	-1.4	25
Camphor	Vol (cf) = 0.009817 ($dbh^{2.134803}$)($ht^{0.634042}$)	0.976	50	1.15	10.9	-1.3	26
Chinese Elm	Vol (cf) = 0.010456 ($dbh^{2.324812}$)($ht^{0.493171}$)	0.915	50	1.21	14.8	-1.9	27
Holly Oak	Vol (cf) = 0.004307 ($dbh^{1.821580}$)($ht^{1.062691}$)	0.976	50	1.15	10.4	0.3	28
Jacaranda	Vol (cf) = 0.011312 ($dbh^{2.185780}$)($ht^{0.548045}$)	0.956	49	1.17	12.7	0.1	29
Liquidambar	Vol (cf) = 0.011773 ($dbh^{2.315815}$)($ht^{0.415711}$)	0.982	50	1.13	9.2	-0.6	30
Modesto Ash	Vol (cf) = 0.001287 ($dbh^{1.762964}$)($ht^{1.427822}$)	0.978	50	1.17	12.6	-1.3	31
Sawleaf Zelkova	Vol (cf) = 0.006664 ($dbh^{2.363178}$)($ht^{0.551904}$)	0.975	50	1.18	14.2	0.5	32
Chinese Pistache	Vol (cf) = 0.002921 ($dbh^{2.191572}$)($ht^{0.943669}$)	0.969	49	1.20	15.2	0.4	33
Southern Magnolia	Vol (cf) = 0.004486 ($dbh^{2.070408}$)($ht^{0.845627}$)	0.973	50	1.19	13.2	0.5	34
London Plane	Vol (cf) = 0.010425 ($dbh^{2.436420}$)($ht^{0.391682}$)	0.966	50	1.21	16.0	-2.6	35

Note: For an explanation of terms used here, see the discussion in the text.

VII. Tests of Equation Fit, Reliability and Measures of Accuracy

There is no one measure of the adequacy of volume equations. We examined several of the more common tests to determine the overall fit and reliability of the equations. In Tables 6 and 7, several statistics are provided that helps the reader understand the relative precision of the relationships that have been developed. The statistical terms used in this section are further discussed in basic statistical texts such as Draper, N. R. and H. Smith (1981) and Snedecor, George W. and William G. Cochran (1967).

Error and Outlier Analysis. Concurrent with the development of the prediction equations, the data were carefully checked to determine if measurement or recording errors were present. We developed computer programs to "look" for possible errors in diameter, height, and tree segment data. Tree volumes were checked by examining the standardized residual calculated for each tree. Even if a tree showed an unusual relationship between the dbh and height values and volume, the tree was checked against the sketch and photograph for legitimacy. After all checks were performed, only one tree was removed from the data set based on these tests.

Measures of reliability and accuracy are discussed in detail in the sidebar.

Other Measures. In addition to the reliability tests previously discussed in the sidebar, several other tests were conducted. These included analysis of the F-value, the root mean squared error (another measure of the residual variation), and plots of residuals to check for nonlinearity, and nonconstant error variance. In no case did we find reason to believe a problem in the database existed.

Measures of reliability and accuracy

Coefficient of Determination. The term R^2, or the Coefficient of Determination, is provided in Tables 6 and 7 to show the proportion or percentage of the variation about the average sample volume that is explained by the regression. In previous work we have found that equations with R^2 values of .90 (90%) or higher are considered very good and make good predictors. All equations developed for this study had R-squares between 0.90 and 0.98.

Standard Error of the Estimate. SE is the abbreviation used in these tables for this measure of reliability. The standard error of the estimate indicates, in volume units, the error associated with the mean volume of each species. For example, the standard error for the Camphor standard volume equation (Table 7) is 1.15, or 1.15 cubic feet. In studies cited earlier, the standard error varied between 1.00 - 1.40, indicating that these tree volume equations have the high level of precision desired.

Average Percentage Deviation. The average percentage deviation measures the extent to which the individual observations of sample tree volume deviate from the regression surface. This percentage gives an idea of the amount by which any single calculated value (or value read from a volume table) will vary from the actual value. It is calculated by:

Average percentage deviation =

$$\sum\left[\left(\frac{|Va - Ve| \times 100}{Ve}\right)\right] \div N \qquad [36]$$

where Va is the actual volume, Ve is the equation or table volume, and N is the number of sample trees. These values, shown in Table 8, range from about 9% to 19%. For example, using the local volume equation (LVE) for Camphor, the volume of an individual tree is expected to deviate from the actual volume by 12.5%. In practice these percent differences can be higher as equations are applied to new individuals; in extreme cases as high as 30-40%. For this reason, volume prediction equations are usually not meant to be used on a tree by tree basis except where only a rough estimate is needed.

continued

Limitations of Equations

It must be emphasized, that the measures of reliability and accuracy presented above only pertain to the accuracy of the equations in the context of the data used in their construction. Despite the efforts of the authors to develop and implement a sound sampling design, and to carefully evaluate the results, there is still no guarantee that these equations and tables will always apply equally well to an independent sample. However, past experience has shown that equations developed by these rigorous measures will perform well, usually within 10-12%, if field procedures follow the methods outlined in this report. When a more accurate estimate is required, say in the case of a sale or purchase of standing trees, the equations (or tables) should be checked against the measured volumes of a representative sample of trees obtained from the area of interest.

Volume equations will best represent the communities where the data was originally collected. To apply the equations in a different portion of the state runs the risk of unacceptable errors (Pillsbury, McDonald, Simon 1995). The question of “how well will they do” in a new environment cannot be answered without additional study. Often equations are used out of their geographic area simply because they are the “best” equations available. Clearly the user takes the responsibility for the results.

There are two ways that people use equations in different areas. First, they are often used “as is,” however, the user should always indicate that the equations were not developed in that area, that the results are “preliminary” or “ball park”, and that the degree of error is unknown. A more desirable approach is first, to select 15 or 20 trees per species that span the range of diameters, secondly, to carefully measure them by the approach discussed here, or if cut, use equations 1,2 and 3 to estimate their volume, and last, to develop a ratio of the total volume from the new sample to the total volume produced by the equations (or tables). The ratio is used to adjust volumes calculated using the equations in the new area.

Significant errors can also result if the prediction equations are used to estimate volume of trees whose dbh and height values are outside the sample range. For best results, tree sizes should fit into the range of data collected and extrapolation avoided. Table 8 shows the range of diameters and tree heights measured for each species. Errors may also occur if the tree shape or form deviates significantly from the portraits shown in

***Measures of reliability and accuracy* -- continued**

Percent Aggregate Difference. The aggregate difference approach is considered to be a better indicator of reliability because most users are interested in the accuracy of the volume of a large number of trees rather than individual tree volumes. Aggregate difference is the difference between the sum of the predicted and the sum of the actual volumes for a given sample. When applied to the sample trees in this study, the percents ranged from 0.0% to 3.0% (plus or minus), Table 8. These values compare favorably with previous studies, including, a range of 0.3% - 2.7% for redwood (Pillsbury and De Lasaux 1990), and 2.1% - 5.8% for 13 California hardwoods (Pillsbury and Kirkley 1984).

Table 8. Range of values for diameter and height of measured trees.

Species	Diameter range (in)	Height range (ft)
Acacia	5.9 - 22.5	30.6 - 53.5
Blue Gum	6.1 - 51.2	46.3 - 144.0
Camphor	5.2 - 27.1	17.0 - 56.0
Carob	6.1 - 28.1	15.3 - 35.5
Chinese Elm	6.8 - 22.0	25.0 - 62.0
Chinese Pistache	5.0 - 20.2	22.0 - 52.0
Holly Oak	5.0 - 20.5	17.0 - 56.0
Jacaranda	6.8 - 23.5	22.5 - 57.5
Liquidambar	5.5 - 21.4	24.0 - 65.5
London Plane	6.1 - 29.1	26.0 - 91.5
Modesto Ash	5.7 - 33.4	18.5 - 74.0
Monterey Cypress	6.2 - 57.7	26.5 - 101.0
Monterey Pine	6.6 - 41.5	18.0 - 105.8
Sawleaf Zelkova	5.7 - 34.0	20.0 - 69.0
Southern Magnolia	5.7 - 29.2	19.0 - 62.0

section III. The same species may have considerably different growth characteristics and thus size-to-volume relationships in different regions.

Of the two types of equations presented, generally the standard volume equations (using both dbh and height) are considered more accurate, as the height variable adds more precision to the estimate. However, in the case of trees that have been recently topped, the correlation of dbh and height to volume will have been significantly altered. In this situation, the local volume equation (use of dbh only) may provide a better volume estimate.

Lastly, trees were not included in the sample when through extensive trimming the crown was virtually deciminated. Two options are possible for measuring trees cultured this way. First, the equations can be used, although error is introduced. Fortunately trees of this condition are infrequent, and if small, will represent little volume having little effect on the overall estimate. Secondly, the main segment volumes can be obtained by measuring their average diameter. The segment height (or length) can be measured or approximated. To estimate its volume, use equation [37] below for a cylinder for the main segments.

$$Volume = 0.005454 D^2 H$$

where D is the average segment diameter in inches, and H is the segment height (or length) in feet, and volume is in cubic feet. The tree shown in Figure 13 would be a candidate for this procedure.

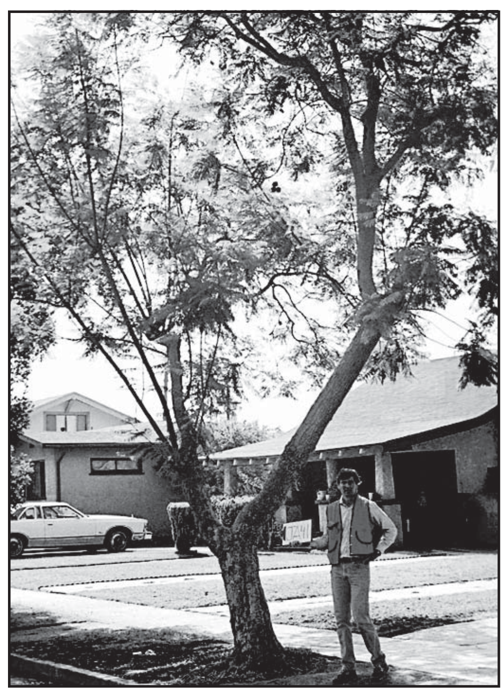


Figure 13. This tree would be a candidate tree for direct measurement using equation [37], rather than using the volume equations or tables.

VIII. Application of Equations to an Independent Inventory

The following discussion outlines the steps necessary to conduct a field inventory for volume and an office estimate for trees scheduled for removal from your urban forest.

Your field crews have input street tree inventory data that shows 200 trees are scheduled for removal in the northeast part of your community during the next three years. The species involved are those for which equations have been developed. (If equations were not available for some species, what would you do? See discussion on page 27, column 2).

Rather than cut and haul the wood to the landfill over a three year period, you decide to contact two area-wide hardwood manufacturers, and obtain bids on the wood. This strategy, in addition to providing revenue for your urban forestry program, will also reduce the time frame to one summer, and relieve the extra burden from your fully committed crews. The purchasers and you agree to sell the wood based on a measure of the cut trees, however, to provide a reasonable estimate of cubic foot quantity available for the bid, you perform the following analysis. (If the conditions of sale were based on the volume estimate of the standing trees, what important step would come first? See the "Limitation of Equations" discussion on page 26).

Field verification: A quick verification of the information in your street tree inventory is needed. A crew is dispatched to check and update the database for location, species, and diameter, and if time is available, for total tree height. Field equipment needed, is a diameter tape, clinometer, and a 100' tape. A written notice is left on the nearest premise advising residents of the project.

Diameter and height measurements should follow the methods discussed in section IV. Total tree height is calculated as shown in Figure 8.

Office calculations: An example of how to obtain tree volume estimates for the equations and tables is presented here. The data should be kept separate by species.

Use of Volume Equations. A Chinese Elm was measured and found to have a 16.8" dbh and a total height of 54.2'. Substitute your data into equation [22] a standard volume equation from Table 7, as follows:

1. $\text{Vol (cf)} = 0.010456450\ (\text{dbh}^{\,2.324812059})\ (\text{ht}^{\,0.493171357})$
2. $\text{Vol (cf)} = 0.010456450\ (16.8^{\,2.324812059})\ (54.2^{\,0.493171357})$
3. $\text{Vol (cf)} = 0.010456450 \times 705.690 \times 7.164 = 52.9$ cubic feet

If height data was not collected, be sure to use the local volume equation (number [7] from Table 6), as follows:

1. $\text{Vol (cf)} = 0.028530182\ (\text{dbh}^{\,2.639347250})$
2. $\text{Vol (cf)} = 0.028530182\ (16.8^{\,2.639347250})$
3. $\text{Vol (cf)} = 0.028530182 \times 1714.023 = 48.9$ cubic feet.

This approach is greatly simplified by setting up a spreadsheet with the regression coefficients referenced as absolute, and the tree data referenced as relative. See Figure 14 for an example using Microsoft Excel®.

Figure 14. Example spreadsheet for calculating tree volumes for street tree inventories.

Coefficient Lookup Table

Row	Species	Species Code	Local Volume Coefficients Intercept	Local Volume Coefficients Dbh Coeff	Standard Volume Coefficients Intercept	Standard Volume Coefficients Dbh Coeff	Standard Volume Coefficients Ht Coeff
5	Camphor	CA	0.000318170	2.530500000	0.009947648	2.132169200	0.632508800
6	Chinese Elm	CE	0.028530182	2.639347250	0.010456450	2.324812059	0.493171357
7	Holly Oak	HO	0.025170973	2.606800000	0.004310976	1.821386700	1.062632400
8	Jacaranda	JA	0.032967000	2.520400000	0.009377898	2.129332900	0.640042400
9	Liquidambar	LA	0.030647000	2.561200000	0.011827891	2.320029300	0.411514100
10	Species 6	S6	0.030647000	2.561200000	0.011827891	2.320029300	0.411514100
11	Species 7	S7	0.030647000	2.561200000	0.011827891	2.320029300	0.411514100

Row	Tree No.	Species Code	Dbh (in)	Tree Height: Base Angle (%)	Tip Angle (%)	Hor. Dist. (ft)	Total Ht (ft)	Total Volume (cf)	Volume by Species, cubic feet: CA	CE	HO	JA	LA	S6	S7
16	1	JA	6.9	-3	22	100.0	25.0	4.5				4.5			
17	2	JA	16.0	3	36	84.6	27.9	28.9				28.9			
18	3	CA	8.5	2	19	60.0	11.2	4.4	4.4						
19	4	JA	12.1				0.0	17.7				17.7			
20	5	LA	19.3	-3	33	92.5	33.3	48.1					48.1		
21	6	CE	18.4	-4	29	112.0	37.0	54.1		54.1					
22	7	CE	16.8	-2	43	75.0	33.8	41.9		41.9					
23	8	CE	20.7	0	35	100.0	35.0	69.2		69.2					
24	9	HO	8.6				0.0	6.9			4.5				
25	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
26	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
27	199	S6	9.0	-50	-3	99.2	46.6	11.7						11.7	
28	200	S7	12.0	0	1	65.0	0.7	3.2							3.2
29							Sum =	290.5	4.4	165.2	4.5	51.1	48.1	11.7	3.2

Height calculation formula:

=IF(D15>E15,"Error!",IF(AND(D15<0,E15>0),(ABS(D15)+E15)*F15/100,IF(AND(D15>=0,E15>=0),(E15-D15)*F15/100,IF(AND(D15<0,E15<0),(ABS(D15)-ABS(E15))*F15/100,"Error"))))

- This checks to see if tree top is taller than tree base.
- This checks for Case A (see sketch).
- This checks for Case B (see sketch).
- This checks for Case C (see sketch).

Volume calculation formula:

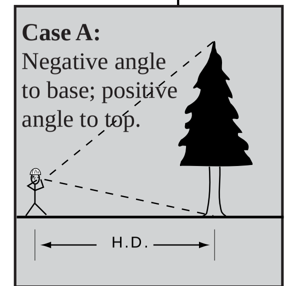
=IF(OR(G15=0,G15=""),LOOKUP(B15,$C$4:$D$10)*C15^LOOKUP(B15,$C$4:$E$10),LOOKUP(B15,$C$4:$F$10)*C15^LOOKUP(B15,$C$4:$G$10)*G15^LOOKUP(B15,$C$4:$H$10))

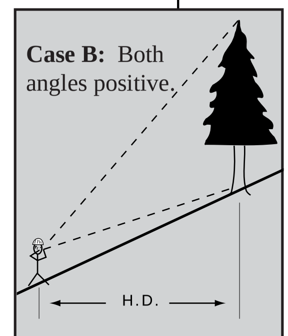
- This checks to see if a tree ht was measured. If not, it uses the local volume equation.
- This selects the local volume equation coefficients for each species, and calculates tree volume.
- This selects the standard volume equations coefficients for each species, and calculates tree volume.

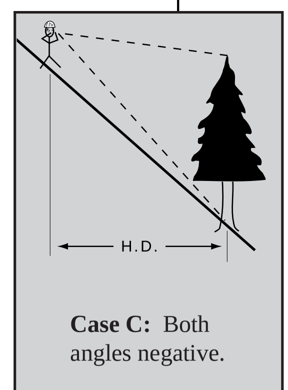
Distribution of volume:

=IF(B15=$L$14,H15,"")

- This sorts the volume into separate species.







Use of Volume Tables. Volume tables are best used when the volume of only a few trees is needed. The volume tables in the Appendix are arranged in diameter classes of 1” and height classes of 5’. Two options are possible, depending on your need. Diameter and height data can either be rounded to the nearest inch, and nearest 5’ respectively to obtain a rough volume estimate, or, you will need to double interpolate the table to eliminate rounding error (see “Calculating tree volume from a volume table by the rounding, and the double interpolation method” in the Appendix.).

Regardless of the method used, the process is repeated for each tree until finished. Next volume estimates are summed by species, and again for all species. The proportion of volume by segment diameter can be estimated from Figure 11.

IX. Summary and Conclusions

As communities strive for sustainability of their urban forestry programs, increased attention must be paid to the wood resource of the urban forest. To manage for these values, comprehensive inventories and databases are needed. A new level of sophistication and commitment is necessary to build these inventories and to make use of them to further the program's goals.

The urban forester must be capable of properly measuring specific characteristics of a tree such as diameter, height and age in order to use them in calculating the typical managerial measures (e.g., basal area, volume and growth rates). These measures can then be combined with other quantitative and qualitative measures such as species, location, health and vigor rating, expected life and past treatments to establish a database which will form the foundation for wood marketing, policymaking and public relations activities.

Practicing urban foresters may have already had education and training in forest inventory as part of their bachelor's degree. However, the nuances of measuring native and exotic species in open-grown settings influenced by urbanization requires special knowledge and training that is not typical of most forest measurement and inventory coursework . To acquire the field and analytical skills needed for this work the urban forester may need to continue their education through shortcourses, workshops, field demonstrations and educational videos similar to the one presented at the Symposium on Oak Woodlands: Ecology, Management and Urban Interface Issues (Pillsbury and Reimer 1996). These continuing education experiences will also facilitate better networking between practicing urban foresters on a broad range of issues, concerns and potential solutions.

Although considerable resources must be committed to designing and maintaining these comprehensive urban forest inventories, long-term benefits including a healthy urban forest that is both biologically and economically sound, will more than justify the expense through improved forest management, regularized maintenance, and new funding sources. It is these types of outcomes that the urban forester can point to as evidence of sustainable management.

X. Literature Cited

De Lasaux, M. J. and N. H. Pillsbury. 1990. Young-Growth Sierra Redwood Volume Equations for Mountain Home Demonstration State Forest, California Department of Forestry and Fire Protection, Sacramento, CA. Natural Resources Management Department, Cal Poly State University, San Luis Obispo, CA. 12 p.

Draper, N. R. and H. Smith. 1981. Applied Regression Analysis. Second edition. John Wiley and Sons. New York. 709 p.

Husch, B., C. Miller and T. Beers. 1982. Forest Mensuration. Third Edition. John Wiley and Sons, New York. 402 p.

Larson, T. and T. O'Keefe. 1996. Greenwaste Reduction Implementation Plan (GRIP), an Urban Forestry Biomass Utilization Project. Intregrated Urban Forestry, Inc., Laguna Hills, and Cal Poly, San Luis Obispo. 5 p.

Pillsbury, N. H. 1994. Aspen Inventory, Assessment, and Management on the Kern Plateau, Sequoia National Forest. (USDA-Forest Service, Porterville, CA.) Natural Resources Management Dept., Cal Poly State Univ., San Luis Obispo, California. 551 p.

Pillsbury, N. H. and D. R. Hermosilla. 1993. Biomass Farm Demonstration Project; 1992 Measurements. California Department of Forestry and Fire Protection, Sacramento, CA. Natural Resources Management Dept., Cal Poly State Univ., San Luis Obispo, California. 230 p.

Pillsbury, N. H. and M. L. Kirkley. 1984. Equations for Total, Wood, and Saw-Log Volume for Thirteen California Hardwoods. Research Note PNW-414. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 52 p.

Pillsbury, N., P. McDonald and V. Simon. 1995. Reliability of Tanoak Volume Equations When Applied To Different Areas. Western Journal of Applied Forestry 10(2). pp. 1-7.

Pillsbury, N. H. and R. D. Pryor. 1989. Volume Equations for Young Growth Softwood and Hardwood Species at Boggs Mountain Demonstration State Forest, California Department of Forestry and Fire Protection, Sacramento, CA. Natural Resources Management Dept., Cal Poly State Univ., San Luis Obispo, California. 100 p.

Pillsbury, N. H. and R. D. Pryor. 1992. Volume Equations for Young Growth Softwood and Hardwood Species at Boggs Mountain Demonstration State Forest. California State Forest Note. California Department of Forestry and Fire Protection, Sacramento, CA. 8 p.

Pillsbury, N. H. and R. D. Pryor. 1994. Volume Equations for Canyon Live Oak in the San Bernardino Mountains of Southern California. West. J. Appl. Forestry 9 (2): 46-51.

Pillsbury, N. H., J. L. Reimer and R. Thompson. 1996. Cal Poly Urban Forest Sustainability Project. A 22 minute digital video presented at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, Cal Poly, San Luis Obispo, CA.

Pillsbury, N. H. and J. L. Reimer. 1997. Tree Volume Equations for 10 Urban Species in California in Proceedings of a Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues (Technical Coordinators: Pillsbury, N. H., J. Verner and W. D. Tietje); 19-22 March 1996; San Luis Obispo, CA. Gen. Tech. Rep. PSW-GTR-160. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 738 p.

Pillsbury, N. H. and R. Thompson. 1995. Tree Volume Equations for Fifteen Urban Species in California. Interim Report. Urban Forest Ecosystems Institute, Cal Poly, San Luis Obispo, and California Department of Forestry and Fire Protection, Riverside. 45 p.

Pillsbury, N. H., R. Standiford, L. Costello, T. Rhoades, and P. Regan (Banducci). 1989. Wood Volume Equations for Central Coast Blue Gum (*Eucalyptus globulus*). Published in California Agriculture, Volume 43, Number 6. University of California.

Snedecor, George W. and William G. Cochran. 1967. Statistical Methods. Sixth edition. The Iowa State University Press. Ames. 593 p.

Thompson, R., N. Pillsbury and J. Hanna. 1994. The Elements of Sustainability in Urban Forestry. Tech. Rept. No. 1. Urban Forest Ecosystems Institute, Cal Poly State University, San Luis Obispo. 56 p.

X. Appendix

Calculating tree volume from a volume table by the rounding, and the double interpolation method.

Example is for a Chinese elm 16.8” in dbh, and 54.2’ in ht.

Table 10. Standard volume table for Chinese Elm, in cubic feet.

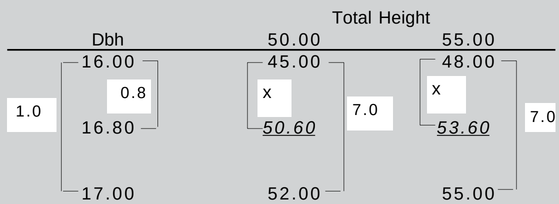
Diameter breast-height outside bark (inches)	Total height (feet)									
	15	20	25	30	35	40	45	50	55	60
5	2	2	2	2	3	3				
6	3	3	3	4	4	4				
7	4	4	5	5	6	6				
8	5	6	6	7	8	8				
9	7	8	8	9	10	11				
10	8	10	11	12	13	14	14	15		
11	10	12	13	15	16	17	18	19		
12	13	15	17	18	19	21	22	23		
13	15	18	20	22	23	25	27	28	29	31
14	18	21	24	26	28	30	32	33	35	36
15	22	25	28	30	33	35	37	39	41	43
16	25	29	32	35	38	41	43	45	48	50
17	29	33	37	41	44	47	50	52	55	57
18	33	38	42	46	50	53	57	60	63	65

1. Rounding diameter and height to the nearest class

Using rounded values gives a diameter of 17” and a height of 55’. Intersecting the volume table gives a cubic foot value of 55.

2. Double interpolating to obtain volume

a) The first step is to interpolate the volume of a 16.8” diameter tree for heights of 50’ and 55’. The ratio for each is shown below.

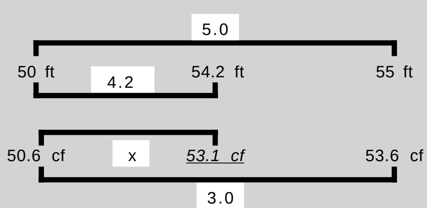


Note: For simplicity, values in the volume table shown above are rounded to the nearest integer.

For 50', 16.8" tree: $\frac{0.8}{1.0} = \frac{x}{7}$ $x = 5.6,$ $45.0 + 5.6 = 50.6$ cf

For 55', 16.8" tree: $\frac{0.8}{1.0} = \frac{x}{7}$ $x = 5.6,$ $48.0 + 5.6 = 53.6$ cf

b) The last step is to interpolate the volume for a 54.2’ tree, by the following ratio. Note the answer is close to the equation result, but a lot more work.



$\frac{x}{3.0} = \frac{4.2}{5.0}$ $x = 2.52.$ $50.6 + 2.52 = 53.1\ cf$

Table 9. Local volume tables for selected urban forest species, in cubic feet (outside bark).

DBH outside bark (inches)	Southland Species					Coastal Species					Central Valley Species					DBH outside bark (inches)
	Camphor	Chinese Elm	Holly Oak	Jacaranda	Liquidambar	Blue Gum	Monterey Pine	Monterey Cypress	Acacia	Carob	Chinese Pistache	London Plane	Modesto Ash	Sawleaf Zelkova	Southern Magnolia	
5	1.9	2.0	1.7	2.0	1.9	2.8	1.5	2.0	2.1	2.0	1.7	1.9	1.5	1.6	1.5	5
6	3.0	3.2	2.7	3.1	3.0	4.3	2.4	3.1	3.3	3.0	2.9	3.0	2.5	2.6	2.5	6
7	4.4	4.9	4.0	4.6	4.5	6.3	3.6	4.6	4.7	4.2	4.5	4.6	3.7	3.9	3.7	7
8	6.1	6.9	5.7	6.4	6.3	8.8	5.1	6.4	6.4	5.5	6.5	6.5	5.3	5.6	5.3	8
9	8.2	9.4	7.7	8.5	8.5	11.7	7.0	8.6	8.4	7.1	9.1	9.0	7.2	7.7	7.2	9
10	10.8	12.4	10.2	11.1	11.2	15.1	9.2	11.1	10.8	8.9	12.2	11.9	9.6	10.2	9.5	10
11	13.7	16.0	13.1	14.0	14.2	19.0	11.9	14.1	13.5	10.9	16.0	15.3	12.3	13.1	12.2	11
12	17.1	20.1	16.4	17.4	17.8	23.5	15.0	17.5	16.5	13.1	20.4	19.3	15.4	16.5	15.4	12
13	20.9	24.9	20.2	21.3	21.8	28.6	18.5	21.4	20.0	15.6	25.6	23.9	19.1	20.5	19.0	13
14	25.3	30.2	24.5	25.6	26.4	34.2	22.6	25.8	23.8	18.2	31.5	29.2	23.2	25.0	23.0	14
15	30.1	36.3	29.3	30.3	31.5	40.5	27.2	30.6	27.9	21.1	38.2	35.1	27.8	30.0	27.6	15
16	35.5	43.0	34.7	35.6	37.2	47.4	32.3	36.0	32.5	24.2	45.8	41.7	33.0	35.7	32.7	16
17	41.3	50.5	40.6	41.4	43.4	54.9	37.9	41.9	37.5	27.6	54.3	49.0	38.7	42.0	38.3	17
18	47.8	58.7	47.2	47.8	50.2	63.1	44.2	48.3	42.9	31.2	63.7	57.1	44.9	48.9	44.5	18
19	54.8	67.7	54.3	54.6	57.7	72.0	51.0	55.2	48.7	35.0	74.2	66.0	51.8	56.5	51.3	19
20	62.4	77.5	62.1	62.1	65.8	81.6	58.5	62.8	54.9	39.0	85.7	75.7	59.3	64.8	58.6	20
21	70.6	88.1	70.5	70.1	74.5	91.9	66.6	70.9	61.6	43.3	98.3	86.3	67.4	73.9	66.6	21
22	79.5	99.6	79.6	78.6	84.0	103.0	75.4	79.6	68.7	47.8	112.0	97.7	76.2	83.7	75.3	22
23	88.9	112.0	89.4	87.8	94.1	114.7	84.9	89.0	76.2	52.5	126.9	110.0	85.7	94.2	84.6	23
24	99.1	125.4	99.9	97.6	104.9	127.3	95.1	98.9	84.2	57.5	143.0	123.3	95.9	105.6	94.6	24
25	109.9	139.6		108.1	116.5	140.6	106.0	109.6	92.7	62.7	160.4	137.5	106.7	117.8	105.3	25
26	121.4	154.8		119.1		154.7	117.7	120.8	101.6	68.2	179.0	152.7	118.3	130.8	116.7	26
27	133.5	171.1				169.6	130.1	132.8		73.9	199.1	168.9	130.7	144.7	128.8	27
28	146.4					185.3	143.4	145.4		79.8	220.5	186.2	143.9	159.5	141.7	28
29	160.1					201.9	157.5	158.7		86.0	243.3	204.5	157.8	175.2	155.3	29
30	174.4					219.3	172.3	172.7		92.4	267.6	223.9	172.5	191.8	169.8	30
31						237.5	188.1	187.4					188.1	209.4	185.0	31
32						256.6	204.7	202.8					204.5	227.9	201.1	32
33						276.6	222.2	219.0					221.7	247.5	218.0	33
34						297.5	240.6	236.0					239.9	268.0	235.7	34
35						319.2	260.0	253.7					258.9	289.7	254.4	35
36						341.9	280.2	272.2					278.8	312.3	273.9	36
37						365.5	301.5	291.4					299.7	336.1	294.3	37
38						390.1	323.7	311.5					321.5	360.9	315.6	38
39						415.6	346.9	332.3					344.3	386.9	337.8	39
40						442.0	371.1	354.0					368.0	414.0	361.0	40
41						469.4	396.4	376.5								41
42						497.8	422.7	399.8								42
43						527.2	450.0	424.0								43
44						557.6	478.5	449.0								44
45						589.0	508.0	474.9								45
46						621.4		501.7								46
47						654.8		529.4								47
48						689.3		557.9								48
49						724.8		587.4								49
50						761.4		617.7								50
51						799.0		649.0								51
52						837.7		681.2								52
53						877.5		714.4								53
54						918.4		748.5								54
55						960.4		783.6								55
56								819.6								56
57								856.6								57
58								894.6								58
59								933.6								59
60								973.6								60

Table 10. Standard volume table for Chinese Elm, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
5	1.7	1.9	2.2	2.4	2.5	2.7								
6	2.6	3.0	3.3	3.6	3.9	4.2								
7	3.7	4.2	4.7	5.2	5.6	5.9								
8	5.0	5.8	6.4	7.0	7.6	8.1								
9	6.6	7.6	8.5	9.3	10.0	10.7								
10	8.4	9.7	10.8	11.8	12.8	13.6	14.4	15.2						
11	10.5	12.1	13.5	14.8	15.9	17.0	18.0	19.0						
12	12.8	14.8	16.5	18.1	19.5	20.8	22.1	23.2						
13	15.5	17.8	19.9	21.8	23.5	25.1	26.6	28.0	29.3	30.6				
14	18.4	21.2	23.6	25.8	27.9	29.8	31.6	33.3	34.9	36.4				
15	21.6	24.8	27.7	30.3	32.7	35.0	37.1	39.0	40.9	42.7	44.4			
16	25.0	28.9	32.2	35.3	38.0	40.6	43.1	45.4	47.5	49.6	51.6			
17	28.8	33.2	37.1	40.6	43.8	46.8	49.6	52.2	54.7	57.1	59.4			
18	32.9	38.0	42.4	46.4	50.0	53.4	56.6	59.6	62.5	65.3	67.9			
19		43.0	48.0	52.6	56.7	60.6	64.2	67.6	70.9	74.0	77.0	79.8	82.6	
20		48.5	54.1	59.2	63.9	68.3	72.3	76.2	79.9	83.4	86.7	89.9	93.1	
21			60.6	66.3	71.6	76.5	81.0	85.3	89.5	93.4	97.1	100.8	104.2	
22				73.9	79.8	85.2	90.3	95.1	99.7	104.0	108.2	112.3	116.1	119.9
23				82.0	88.4	94.5	100.1	105.4	110.5	115.4	120.0	124.5	128.8	133.0
24					97.6	104.3	110.5	116.4	122.0	127.4	132.5	137.4	142.2	146.8
25					107.4	114.7	121.5	128.0	134.2	140.0	145.7	151.1	156.3	161.4
26					117.6	125.6	133.1	140.2	147.0	153.4	159.6	165.5	171.3	176.8
27					128.4	137.1	145.3	153.1	160.4	167.5	174.2	180.7	187.0	193.0
28							158.2	166.6	174.6	182.3	189.6	196.7	203.5	210.0
29							171.6	180.7	189.4	197.8	205.7	213.4	220.8	227.9
30							185.7	195.6	205.0	214.0	222.6	230.9	238.9	246.6

Table 11. Standard volume table for Camphor, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
5	1.7	2.0	2.3	2.6	2.9	3.2								
6	2.5	3.0	3.5	3.9	4.3	4.7								
7	3.5	4.2	4.8	5.4	6.0	6.5								
8	4.6	5.6	6.4	7.2	7.9	8.6								
9	6.0	7.1	8.2	9.2	10.2	11.1								
10	7.5	8.9	10.3	11.6	12.8	13.9	15.0	16.0						
11	9.1	11.0	12.6	14.2	15.6	17.0	18.3	19.6						
12	11.0	13.2	15.2	17.1	18.8	20.5	22.1	23.6						
13	13.1	15.7	18.0	20.3	22.3	24.3	26.2	28.0	29.8	31.4				
14	15.3	18.4	21.1	23.7	26.2	28.5	30.7	32.8	34.9	36.8				
15	17.7	21.3	24.5	27.5	30.3	33.0	35.6	38.0	40.4	42.7	44.9			
16	20.3	24.4	28.1	31.6	34.8	37.9	40.8	43.6	46.3	49.0	51.5			
17	23.1	27.8	32.0	35.9	39.6	43.1	46.4	49.7	52.7	55.7	58.6			
18	26.1	31.4	36.1	40.6	44.7	48.7	52.5	56.1	59.6	63.0	66.3			
19		35.2	40.6	45.5	50.2	54.7	58.9	63.0	66.9	70.7	74.4	77.9	81.4	
20		39.3	45.3	50.8	56.0	61.0	65.7	70.2	74.6	78.9	83.0	87.0	90.8	
21			50.2	56.4	62.2	67.7	72.9	78.0	82.8	87.5	92.1	96.5	100.8	
22				62.3	68.7	74.7	80.5	86.1	91.5	96.7	101.7	106.6	111.3	116.0
23				68.5	75.5	82.2	88.6	94.7	100.6	106.3	111.8	117.2	122.4	127.5
24					82.7	90.0	97.0	103.7	110.1	116.4	122.4	128.3	134.1	139.7
25					90.2	98.2	105.8	113.1	120.2	127.0	133.6	140.0	146.3	152.4
26					98.1	106.8	115.0	123.0	130.7	138.1	145.3	152.2	159.1	165.7
27					106.3	115.7	124.7	133.3	141.6	149.7	157.4	165.0	172.4	179.6
28							134.8	144.1	153.1	161.7	170.2	178.3	186.3	194.1
29							145.3	155.3	165.0	174.3	183.4	192.2	200.8	209.2
30							156.2	166.9	177.3	187.4	197.2	206.6	215.9	224.9

Table 12. Standard volume table for Holly Oak, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
5	1.4	1.9	2.5	3.0	3.5	4.1								
6	2.0	2.7	3.4	4.2	4.9	5.7								
7	2.7	3.6	4.6	5.5	6.5	7.5								
8	3.4	4.6	5.8	7.1	8.3	9.6								
9	4.2	5.7	7.2	8.8	10.3	11.9								
10	5.1	6.9	8.7	10.6	12.5	14.4	16.3	18.2						
11	6.0	8.2	10.4	12.6	14.9	17.1	19.4	21.7						
12	7.1	9.6	12.2	14.8	17.4	20.1	22.7	25.4						
13	8.2	11.1	14.1	17.1	20.1	23.2	26.3	29.4	32.6	35.7				
14	9.4	12.7	16.1	19.6	23.1	26.6	30.1	33.7	37.3	40.9				
15	10.6	14.4	18.3	22.2	26.1	30.1	34.1	38.2	42.3	46.4	50.5			
16	12.0	16.2	20.6	25.0	29.4	33.9	38.4	43.0	47.5	52.1	56.8			
17	13.3	18.1	23.0	27.9	32.8	37.8	42.9	48.0	53.1	58.2	63.4			
18	14.8	20.1	25.5	30.9	36.4	42.0	47.6	53.2	58.9	64.6	70.4			
19		22.2	28.1	34.1	40.2	46.3	52.5	58.8	65.0	71.3	77.6	84.0	90.4	
20		24.4	30.9	37.5	44.2	50.9	57.7	64.5	71.4	78.3	85.2	92.2	99.2	
21			33.8	41.0	48.3	55.6	63.0	70.5	78.0	85.6	93.2	100.8	108.5	
22				44.6	52.5	60.5	68.6	76.7	84.9	93.1	101.4	109.7	118.1	126.4
23				48.4	57.0	65.6	74.4	83.2	92.1	101.0	110.0	119.0	128.0	137.1
24					61.5	70.9	80.4	89.9	99.5	109.1	118.8	128.6	138.3	148.2
25					66.3	76.4	86.6	96.9	107.2	117.6	128.0	138.5	149.0	159.6
26					71.2	82.1	93.0	104.0	115.1	126.3	137.5	148.7	160.1	171.4
27					76.3	87.9	99.6	111.4	123.3	135.3	147.3	159.3	171.4	183.6
28							106.5	119.1	131.8	144.5	157.3	170.2	183.2	196.2
29							113.5	126.9	140.4	154.1	167.7	181.5	195.3	209.1
30							120.7	135.0	149.4	163.9	178.4	193.0	207.7	222.5

Table 13. Standard volume table for Jacaranda, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
5	1.7	2.0	2.2	2.5	2.7	2.9								
6	2.5	2.9	3.3	3.7	4.0	4.3								
7	3.5	4.1	4.6	5.1	5.6	6.0								
8	4.7	5.5	6.2	6.9	7.5	8.0								
9	6.1	7.1	8.0	8.9	9.7	10.4								
10	7.7	9.0	10.1	11.2	12.2	13.1	14.0	14.8						
11	9.4	11.0	12.5	13.8	15.0	16.1	17.2	18.2						
12	11.4	13.3	15.1	16.7	18.1	19.5	20.8	22.1						
13	13.6	15.9	18.0	19.9	21.6	23.2	24.8	26.3	27.7	29.0				
14	16.0	18.7	21.1	23.3	25.4	27.3	29.2	30.9	32.5	34.1				
15	18.6	21.7	24.6	27.1	29.5	31.8	33.9	35.9	37.8	39.7	41.5			
16	21.4	25.0	28.3	31.3	34.0	36.6	39.0	41.4	43.6	45.7	47.8			
17	24.4	28.6	32.3	35.7	38.8	41.8	44.6	47.2	49.8	52.2	54.5			
18	27.7	32.4	36.6	40.4	44.0	47.3	50.5	53.5	56.4	59.1	61.8			
19		36.4	41.2	45.5	49.5	53.3	56.8	60.2	63.4	66.5	69.5	72.4	75.2	
20		40.8	46.1	50.9	55.4	59.6	63.6	67.4	71.0	74.4	77.8	81.0	84.1	
21			51.3	56.6	61.6	66.3	70.7	74.9	79.0	82.8	86.5	90.1	93.6	
22				62.7	68.2	73.4	78.3	83.0	87.4	91.7	95.8	99.8	103.6	107.3
23				69.1	75.2	80.9	86.3	91.4	96.3	101.0	105.6	109.9	114.2	118.3
24					82.5	88.8	94.7	100.3	105.7	110.9	115.9	120.7	125.3	129.8
25					90.2	97.1	103.6	109.7	115.6	121.2	126.7	131.9	137.0	141.9
26					98.3	105.8	112.8	119.5	125.9	132.1	138.0	143.7	149.3	154.7
27					106.8	114.9	122.5	129.8	136.8	143.5	149.9	156.1	162.1	167.9
28							132.7	140.6	148.1	155.3	162.3	169.0	175.5	181.8
29							143.2	151.8	159.9	167.7	175.2	182.5	189.5	196.3
30							154.3	163.4	172.2	180.6	188.7	196.5	204.1	211.4

Table 14. Standard volume table for Liquidambar, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
5	1.5	1.7	1.9	2.0	2.1	2.3								
6	2.3	2.6	2.8	3.1	3.3	3.5								
7	3.3	3.7	4.1	4.4	4.7	4.9								
8	4.5	5.0	5.5	6.0	6.4	6.7								
9	5.9	6.6	7.3	7.8	8.4	8.8								
10	7.5	8.5	9.3	10.0	10.7	11.3	11.9	12.4						
11	9.4	10.6	11.6	12.5	13.3	14.1	14.8	15.4						
12	11.5	12.9	14.2	15.3	16.3	17.2	18.1	18.9						
13	13.8	15.5	17.0	18.4	19.6	20.7	21.8	22.7	23.7	24.5				
14	16.4	18.4	20.2	21.8	23.3	24.6	25.8	27.0	28.1	29.1				
15	19.2	21.6	23.7	25.6	27.3	28.9	30.3	31.7	33.0	34.2	35.3			
16	22.3	25.1	27.6	29.7	31.7	33.5	35.2	36.8	38.3	39.7	41.0			
17	25.7	28.9	31.7	34.2	36.5	38.6	40.5	42.3	44.0	45.7	47.2			
18	29.3	33.0	36.2	39.1	41.7	44.0	46.3	48.3	50.3	52.1	53.9			
19		37.4	41.1	44.3	47.2	49.9	52.4	54.8	57.0	59.1	61.1	63.0	64.8	
20		42.1	46.2	49.9	53.2	56.2	59.0	61.7	64.2	66.5	68.8	70.9	73.0	
21			51.8	55.8	59.5	62.9	66.1	69.1	71.8	74.5	77.0	79.4	81.7	
22				62.2	66.3	70.1	73.6	76.9	80.0	83.0	85.8	88.5	91.0	93.5
23				68.9	73.5	77.7	81.6	85.2	88.7	92.0	95.1	98.0	100.9	103.6
24					81.1	85.7	90.0	94.1	97.9	101.5	104.9	108.2	111.3	114.4
25					89.2	94.2	99.0	103.4	107.6	111.5	115.3	118.9	122.4	125.7
26					97.6	103.2	108.4	113.2	117.8	122.2	126.3	130.2	134.0	137.7
27					106.5	112.6	118.3	123.6	128.6	133.3	137.8	142.1	146.3	150.2
28							128.7	134.4	139.9	145.0	149.9	154.6	159.1	163.4
29							139.6	145.8	151.7	157.3	162.6	167.7	172.6	177.3
30							151.0	157.7	164.1	170.1	175.9	181.4	186.7	191.8

Table 15. Standard volume table for Blue Gum, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)													
	30	40	50	60	70	80	90	100	110	120	130	140	150	160
6	2.5	3.2	3.8	4.5	5.1	5.7								
8	4.7	5.9	7.1	8.3	9.4	10.6								
10	7.5	9.6	11.5	13.4	15.3	17.1								
12	11.1	14.2	17.1	19.9	22.6	25.3								
14	15.5	19.7	23.8	27.7	31.5	35.2								
16	20.7	26.3	31.7	36.9	42.0	46.9	51.8	56.5						
18	26.6	33.9	40.8	47.5	54.1	60.5	66.7	72.9						
20	33.4	42.5	51.2	59.6	67.8	75.8	83.7	91.4						
22	41.0	52.2	62.9	73.2	83.3	93.1	102.7	112.2	121.5	130.7				
24	49.5	62.9	75.8	88.3	100.4	112.3	123.9	135.3	146.5	157.6				
26	58.8	74.7	90.1	104.9	119.3	133.4	147.2	160.7	174.1	187.2	200.1			
28	68.9	87.7	105.6	123.0	139.9	156.5	172.6	188.5	204.2	219.6	234.7			
30	80.0	101.7	122.5	142.7	162.3	181.5	200.3	218.7	236.8	254.7	272.3			
32	91.9	116.8	140.8	164.0	186.5	208.5	230.1	251.3	272.1	292.6	312.9			
34		133.1	160.4	186.8	212.5	237.6	262.2	286.3	310.0	333.4	356.5	379.3	401.8	
36		150.5	181.4	211.3	240.3	268.7	296.5	323.8	350.6	377.1	403.1	428.9	454.4	
38			203.8	237.3	270.0	301.8	333.1	363.7	393.9	423.6	452.9	481.8	510.4	
40				265.0	301.5	337.1	371.9	406.2	439.8	473.0	505.7	538.0	570.0	601.6
42				294.4	334.8	374.4	413.1	451.1	488.5	525.4	561.7	597.6	633.1	668.2
44					370.1	413.8	456.6	498.6	540.0	580.7	620.9	660.5	699.7	738.5
46					407.2	455.3	502.4	548.7	594.2	639.0	683.2	726.8	770.0	812.6
48					446.3	499.0	550.6	601.3	651.1	700.3	748.7	796.5	843.8	890.6
50					487.3	544.8	601.2	656.5	710.9	764.5	817.4	869.7	921.3	972.3
52							654.1	714.3	773.5	831.9	889.4	946.3	1002.4	1058.0
54							709.4	774.7	839.0	902.2	964.7	1026.3	1087.2	1147.5
56							767.2	837.8	907.3	975.7	1043.2	1109.8	1175.7	1240.9

Table 16. Standard volume table for Monterey Pine, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)											
	10	20	30	40	50	60	70	80	90	100	110	120
6	1.3	2.1	2.8	3.4	3.9	4.5						
8	2.5	4.1	5.3	6.4	7.5	8.5						
10	4.2	6.7	8.7	10.6	12.3	13.9						
12	6.3	10.0	13.1	15.9	18.5	20.8						
14	8.9	14.1	18.5	22.4	26.0	29.4						
16	11.9	19.0	24.9	30.2	35.0	39.6	43.9	48.0				
18	15.5	24.7	32.3	39.2	45.5	51.4	57.0	62.3				
20	19.6	31.2	40.9	49.6	57.6	65.0	72.1	78.8				
22	24.2	38.5	50.6	61.3	71.2	80.4	89.1	97.5	105.4	113.1		
24	29.4	46.8	61.4	74.4	86.4	97.6	108.2	118.3	128.0	137.3		
26	35.2	55.9	73.3	88.9	103.2	116.6	129.3	141.4	153.0	164.1	174.9	
28	41.5	66.0	86.5	104.9	121.7	137.5	152.5	166.7	180.4	193.6	206.3	
30	48.4	76.9	100.9	122.3	142.0	160.4	177.8	194.4	210.4	225.7	240.6	
32	55.8	88.8	116.5	141.2	163.9	185.2	205.3	224.5	242.9	260.6	277.8	
34		101.6	133.3	161.6	187.6	211.9	235.0	256.9	278.0	298.3	317.9	337.0
36		115.4	151.4	183.5	213.1	240.7	266.8	291.8	315.7	338.8	361.1	382.7
38			170.8	207.0	240.3	271.5	301.0	329.1	356.1	382.1	407.3	431.7
40				232.0	269.4	304.3	337.4	368.9	399.2	428.3	456.5	483.9
42				258.7	300.3	339.3	376.1	411.3	445.0	477.5	508.9	539.4
44					333.1	376.3	417.2	456.2	493.6	529.6	564.5	598.3
46					367.8	415.5	460.6	503.6	544.9	584.7	623.2	660.6
48					404.3	456.8	506.4	553.7	599.1	642.8	685.2	726.2

Table 17. Standard volume table for Monterey Cypress, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)											
	20	30	40	50	60	70	80	90	100	110	120	130
6	2.2	2.8	3.4	3.9	4.4	4.8						
8	4.2	5.4	6.5	7.5	8.4	9.2						
10	6.9	9.0	10.7	12.3	13.9	15.3						
12	10.5	13.5	16.2	18.6	20.9	23.1						
14	14.8	19.1	23.0	26.4	29.6	32.7						
16	20.1	25.9	31.0	35.7	40.1	44.2	48.0	51.7				
18	26.2	33.8	40.5	46.6	52.3	57.6	62.7	67.5				
20	33.2	42.9	51.4	59.2	66.4	73.1	79.6	85.7				
22	41.2	53.2	63.8	73.4	82.3	90.7	98.7	106.3	113.6	120.6		
24	50.2	64.8	77.6	89.3	100.2	110.4	120.1	129.4	138.3	146.8		
26	60.1	77.6	93.0	107.1	120.1	132.3	144.0	155.1	165.7	176.0	185.9	
28	71.1	91.7	110.0	126.6	142.0	156.5	170.2	183.3	195.9	208.0	219.8	
30	83.1	107.2	128.5	147.9	166.0	182.9	198.9	214.3	229.0	243.2	256.9	
32	96.1	124.1	148.7	171.2	192.0	211.6	230.2	247.9	264.9	281.3	297.2	
34		142.3	170.6	196.3	220.2	242.7	264.0	284.3	303.9	322.7	340.8	358.5
36		161.9	194.1	223.4	250.6	276.2	300.4	323.6	345.8	367.2	387.9	407.9
38			219.3	252.4	283.2	312.1	339.5	365.6	390.7	414.9	438.3	460.9
40				283.5	318.0	350.4	381.2	410.6	438.7	465.9	492.1	517.6
42				316.5	355.1	391.3	425.6	458.4	489.9	520.2	549.5	578.0
44					394.4	434.7	472.8	509.3	544.2	577.9	610.5	642.0
46					436.1	480.6	522.8	563.1	601.7	639.0	675.0	709.9
48					480.2	529.1	575.6	619.9	662.5	703.5	743.1	781.6
50					526.6	580.3	631.2	679.9	726.5	771.5	815.0	857.1
52							689.7	742.9	793.9	843.0	890.5	936.6
54							751.2	809.0	864.6	918.1	969.8	1020.0
56							815.5	878.4	938.7	996.8	1052.9	1107.4
58								950.9	1016.1	1079.0	1139.8	1198.8
60								1026.6	1097.1	1165.0	1230.6	1294.3

Table 18. Standard volume table for Acacia, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)											
	20	25	30	35	40	45	50	55	60	65	70	75
5	1.9	2.1	2.3	2.5	2.7	2.8						
6	2.9	3.2	3.5	3.7	4.0	4.2						
7	4.0	4.5	4.9	5.2	5.6	5.9						
8	5.4	6.0	6.5	7.0	7.4	7.9						
9	7.0	7.7	8.4	9.0	9.6	10.2						
10	8.8	9.7	10.6	11.4	12.1	12.8	13.4					
11	10.8	12.0	13.0	14.0	14.9	15.8	16.6					
12	13.0	14.5	15.8	16.9	18.0	19.1	20.0	20.9				
13	15.5	17.3	18.8	20.2	21.5	22.7	23.9	24.9				
14	18.3	20.3	22.1	23.7	25.3	26.7	28.1	29.3				
15	21.3	23.6	25.7	27.6	29.4	31.1	32.6	34.1	35.5			
16	24.5	27.2	29.6	31.8	33.8	35.8	37.6	39.3	40.9			
17	27.9	31.0	33.8	36.3	38.6	40.8	42.9	44.8	46.7			
18	31.7	35.1	38.3	41.1	43.8	46.3	48.6	50.8	52.9			
19		39.6	43.1	46.3	49.3	52.1	54.7	57.2	59.6			
20		44.3	48.2	51.8	55.1	58.2	61.2	64.0	66.6	69.2		
21			53.6	57.6	61.3	64.8	68.1	71.2	74.1	77.0		
22				63.8	67.9	71.7	75.4	78.8	82.1	85.2	88.2	
23				70.3	74.8	79.1	83.1	86.8	90.4	93.9	97.2	
24					82.1	86.8	91.2	95.3	99.3	103.0	106.7	
25					89.8	94.9	99.7	104.2	108.5	112.7	116.6	120.5
26					97.8	103.4	108.6	113.5	118.2	122.7	127.1	131.2

Table 19. Standard volume table for Carob, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)													
	12	14	16	18	20	22	24	26	28	30	32	34	36	38
5	1.5	1.8	2.0	2.2	2.5	2.7								
6	2.1	2.5	2.8	3.1	3.4	3.8								
7	2.8	3.3	3.7	4.1	4.5	5.0								
8	3.6	4.1	4.7	5.2	5.8	6.3								
9	4.4	5.1	5.8	6.5	7.1	7.8								
10	5.4	6.2	7.0	7.8	8.6	9.4	10.2	11.0						
11	6.4	7.3	8.3	9.3	10.2	11.2	12.1	13.0						
12	7.4	8.6	9.7	10.8	11.9	13.0	14.1	15.2						
13	8.6	9.9	11.2	12.5	13.8	15.1	16.3	17.6	18.8	20.1				
14	9.8	11.3	12.8	14.3	15.7	17.2	18.6	20.1	21.5	22.9				
15	11.1	12.8	14.5	16.2	17.8	19.5	21.1	22.7	24.3	25.9	27.5			
16	12.5	14.4	16.3	18.1	20.0	21.9	23.7	25.5	27.3	29.1	30.9			
17	13.9	16.0	18.1	20.2	22.3	24.4	26.4	28.4	30.5	32.5	34.5			
18	15.4	17.8	20.1	22.4	24.7	27.0	29.3	31.5	33.8	36.0	38.2			
19		19.6	22.2	24.7	27.2	29.8	32.3	34.7	37.2	39.7	42.1	44.5	47.0	
20		21.5	24.3	27.1	29.9	32.6	35.4	38.1	40.8	43.5	46.2	48.8	51.5	
21			26.5	29.6	32.6	35.6	38.6	41.6	44.5	47.5	50.4	53.3	56.2	
22				32.1	35.4	38.7	42.0	45.2	48.4	51.6	54.8	58.0	61.1	64.2
23				34.8	38.4	41.9	45.5	49.0	52.4	55.9	59.3	62.8	66.2	69.6
24					41.4	45.3	49.1	52.8	56.6	60.3	64.1	67.8	71.4	75.1
25					44.6	48.7	52.8	56.9	60.9	64.9	68.9	72.9	76.9	80.8
26					47.8	52.3	56.7	61.0	65.4	69.7	74.0	78.2	82.5	86.7
27					51.2	55.9	60.6	65.3	69.9	74.6	79.1	83.7	88.3	92.8
28							64.7	69.7	74.7	79.6	84.5	89.4	94.2	99.1
29							68.9	74.2	79.5	84.8	90.0	95.2	100.4	105.5
30							73.3	78.9	84.5	90.1	95.6	101.2	106.7	112.1

Table 20. Standard volume table for Chinese Pistache in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)											
	10	15	20	25	30	35	40	45	50	55	60	65
5	0.9	1.3	1.7	2.1	2.5	2.8						
6	1.3	1.9	2.5	3.1	3.7	4.2						
7	1.8	2.7	3.5	4.3	5.1	6.0						
8	2.4	3.6	4.7	5.8	6.9	8.0						
9	3.2	4.6	6.1	7.5	8.9	10.3						
10	4.0	5.8	7.7	9.5	11.2	13.0	14.8	16.5				
11	4.9	7.2	9.5	11.7	13.9	16.0	18.2	20.3				
12	5.9	8.7	11.4	14.1	16.8	19.4	22.0	24.6				
13	7.1	10.4	13.6	16.8	20.0	23.1	26.2	29.3	32.4	35.4		
14	8.3	12.2	16.0	19.8	23.5	27.2	30.8	34.5	38.1	41.7		
15	9.7	14.2	18.7	23.0	27.4	31.6	35.9	40.1	44.3	48.5	52.6	
16	11.2	16.4	21.5	26.5	31.5	36.4	41.3	46.2	51.0	55.8	60.6	
17	12.8	18.7	24.5	30.3	36.0	41.6	47.2	52.8	58.3	63.8	69.2	
18	14.5	21.2	27.8	34.3	40.8	47.2	53.5	59.8	66.0	72.3	78.4	
19		23.9	31.3	38.7	45.9	53.1	60.2	67.3	74.4	81.4	88.3	95.2
20		26.7	35.0	43.3	51.4	59.4	67.4	75.3	83.2	91.0	98.8	106.6
21			39.0	48.1	57.2	66.1	75.0	83.8	92.6	101.3	110.0	118.6
22				53.3	63.3	73.2	83.1	92.8	102.5	112.2	121.8	131.3
23				58.8	69.8	80.7	91.6	102.3	113.0	123.7	134.2	144.8
24					76.6	88.6	100.5	112.3	124.1	135.7	147.4	158.9
25					83.8	96.9	109.9	122.8	135.7	148.5	161.2	173.8
26					91.3	105.6	119.8	133.9	147.9	161.8	175.6	189.4
27					99.2	114.7	130.1	145.4	160.6	175.7	190.8	205.7
28							140.9	157.5	173.9	190.3	206.6	222.8
29							152.2	170.1	187.8	205.5	223.1	240.6
30							163.9	183.2	202.3	221.4	240.3	259.2

Table 21. Standard volume table for London Plane, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)											
	10	20	30	40	50	60	70	80	90	100	110	120
6	2.0	2.7	3.1	3.5	3.8	4.1						
8	4.1	5.3	6.3	7.0	7.7	8.2						
10	7.0	9.2	10.8	12.1	13.2	14.2						
12	10.9	14.4	16.8	18.8	20.6	22.1						
14	15.9	20.9	24.5	27.4	29.9	32.1						
16	22.1	28.9	33.9	38.0	41.4	44.5	47.3	49.8				
18	29.4	38.6	45.2	50.6	55.2	59.3	63.0	66.4				
20	38.0	49.8	58.4	65.4	71.3	76.6	81.4	85.8				
22	47.9	62.9	73.7	82.5	90.0	96.7	102.7	108.2	113.3	118.1		
24	59.2	77.7	91.1	101.9	111.2	119.5	126.9	133.7	140.0	145.9		
26	72.0	94.4	110.7	123.9	135.2	145.2	154.3	162.5	170.2	177.4	184.1	
28	86.2	113.1	132.6	148.4	162.0	173.9	184.8	194.7	203.9	212.5	220.6	
30	102.0	133.8	156.9	175.6	191.6	205.8	218.6	230.3	241.2	251.4	260.9	
32	119.4	156.6	183.6	205.5	224.2	240.8	255.8	269.6	282.3	294.2	305.4	
34		181.5	212.8	238.2	259.9	279.2	296.5	312.5	327.2	341.0	354.0	366.2
36		208.7	244.6	273.8	298.8	320.9	340.9	359.2	376.1	392.0	406.9	421.0
38			279.0	312.3	340.8	366.1	388.8	409.7	429.1	447.1	464.1	480.2
40				353.9	386.2	414.8	440.6	464.3	486.2	506.7	525.9	544.2

Table 22. Standard volume table for Modesto Ash, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)									
	10	20	30	40	50	60	70	80	90	100
6	0.8	2.2	3.9	5.9	8.1	10.5				
8	1.3	3.6	6.5	9.7	13.4	17.4				
10	2.0	5.4	9.6	14.4	19.9	25.8				
12	2.8	7.4	13.2	19.9	27.4	35.6				
14	3.6	9.7	17.3	26.1	36.0	46.7				
16	4.6	12.3	21.9	33.1	45.5	59.0	73.6	89.0		
18	5.6	15.1	27.0	40.7	56.0	72.7	90.5	109.6		
20	6.8	18.2	32.5	49.0	67.4	87.5	109.0	131.9		
22	8.0	21.6	38.5	58.0	79.8	103.5	129.0	156.1	184.7	214.6
24	9.3	25.1	44.8	67.6	93.0	120.7	150.4	181.9	215.3	250.2
26	10.8	28.9	51.6	77.9	107.1	138.9	173.2	209.5	247.9	288.1
28	12.3	33.0	58.9	88.7	122.0	158.3	197.3	238.8	282.5	328.4
30	13.8	37.3	66.5	100.2	137.8	178.8	222.8	269.6	319.0	370.8
32	15.5	41.7	74.5	112.3	154.4	200.4	249.7	302.1	357.5	415.5
34		46.5	82.9	125.0	171.9	223.0	277.9	336.2	397.8	462.4
36		51.4	91.7	138.2	190.1	246.6	307.3	371.9	440.0	511.4
38			100.8	152.0	209.1	271.3	338.1	409.1	484.0	562.5
40				166.4	228.9	296.9	370.0	447.8	529.8	615.8

Table 23. Standard volume table for Sawleaf Zelkova, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)									
	10	20	30	40	50	60	70	80	90	100
6	1.6	2.4	3.0	3.5	4.0	4.4				
8	3.2	4.7	5.9	7.0	7.9	8.7				
10	5.5	8.0	10.0	11.8	13.3	14.7				
12	8.4	12.4	15.5	18.1	20.5	22.7				
14	12.1	17.8	22.3	26.1	29.5	32.6				
16	16.6	24.4	30.5	35.8	40.5	44.7	48.7	52.4		
18	22.0	32.2	40.3	47.2	53.4	59.1	64.3	69.3		
20	28.2	41.3	51.7	60.6	68.5	75.8	82.5	88.8		
22	35.3	51.8	64.8	75.9	85.9	94.9	103.4	111.3	118.8	125.9
24	43.4	63.6	79.5	93.2	105.5	116.6	127.0	136.7	145.9	154.6
26	52.4	76.8	96.1	112.6	127.4	140.9	153.4	165.1	176.2	186.8
28	62.4	91.5	114.5	134.2	151.8	167.9	182.8	196.8	210.0	222.5
30	73.5	107.8	134.8	158.0	178.7	197.6	215.1	231.6	247.2	261.9
32	85.6	125.5	157.0	184.0	208.1	230.2	250.6	269.8	287.9	305.1
34		144.8	181.2	212.3	240.2	265.6	289.2	311.3	332.2	352.1
36		165.8	207.4	243.1	274.9	304.0	331.0	356.3	380.3	403.0
38			235.6	276.2	312.4	345.5	376.1	404.9	432.1	458.0
40				311.8	352.6	390.0	424.6	457.1	487.8	517.0

Table 24. Standard volume table for Southern Magnolia, in cubic feet (outside bark).

Diameter breast-height outside bark (inches)	Total height (feet)									
	10	20	30	40	50	60	70	80	90	100
6	1.3	2.3	3.3	4.1	5.0	5.8				
8	2.3	4.2	5.9	7.5	9.1	10.6				
10	3.7	6.6	9.4	11.9	14.4	16.8				
12	5.4	9.7	13.7	17.4	21.0	24.5				
14	7.4	13.3	18.8	24.0	28.9	33.8				
16	9.8	17.6	24.8	31.6	38.2	44.5	50.7	56.8		
18	12.5	22.4	31.6	40.3	48.7	56.8	64.7	72.5		
20	15.5	27.9	39.3	50.2	60.6	70.7	80.5	90.1		
22	18.9	34.0	47.9	61.1	73.8	86.1	98.1	109.8	121.3	132.6
24	22.7	40.7	57.4	73.2	88.3	103.1	117.4	131.5	145.2	158.8
26	26.7	48.0	67.7	86.3	104.3	121.6	138.6	155.2	171.4	187.4
28	31.2	56.0	78.9	100.7	121.6	141.8	161.6	180.9	199.8	218.4
30	36.0	64.6	91.0	116.1	140.2	163.6	186.4	208.7	230.5	252.0
32	41.1	73.8	104.1	132.7	160.3	187.0	213.0	238.5	263.5	288.0
34		83.7	118.0	150.5	181.7	212.0	241.5	270.4	298.7	326.5
36		94.2	132.8	169.4	204.5	238.6	271.8	304.3	336.2	367.5
38			148.5	189.4	228.8	266.9	304.0	340.4	376.0	411.1
40				210.6	254.4	296.8	338.1	378.5	418.2	457.1

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