CUFR-3

City of San Francisco, California Street Tree Resource Analysis

BY

Scott E. Maco
E. Gregory McPherson
James R. Simpson
Paula J. Peper
Qingfu Xiao

Center for Urban Forest Research
Pacific Southwest Research Station, USDA Forest Service

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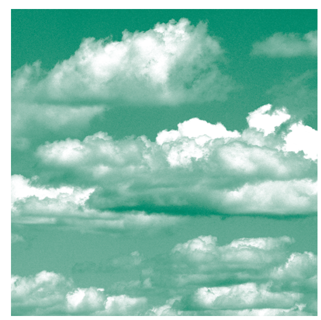

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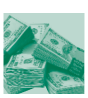
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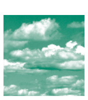
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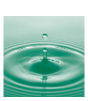
Water Quality


Firewise Landscapes

Mission Statement

We conduct **research** that demonstrates new ways in which **trees add value** to your community, converting results into **financial** terms to assist you in stimulating more **investment in trees.**

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Acknowledgments

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Executive Summary

City of San Francisco, California
Street Tree Resource Analysis

Scott E. Maco[1], E. Gregory McPherson[1], James R. Simpson[1], Paula J. Peper[1], Qingfu Xiao[2]

Street trees in San Francisco are comprised of two distinct populations, those managed by the city's Department of Public Works (DPW) and those managed by private property owners with or without the help of San Francisco's urban forestry nonprofit, Friends of the Urban Forest (FUF). These two entities believe that the public's investment in stewardship of San Francisco's urban forest produces benefits that outweigh the costs to the community. Hence, the primary question that this study asks is *whether the accrued benefits from San Francisco's street trees justify the annual expenditures?*

This analysis combines results of a citywide sample inventory with benefit-cost modeling data to produce four types of information (Maco 2003):

1. Resource structure (species composition, diversity, age distribution, condition, etc.)
2. Resource function (magnitude of environmental and aesthetic benefits)
3. Resource value (dollar value of benefits realized)
4. Resource management needs (sustainability, pruning, planting, and conflict mitigation)

Resource Structure

- Based on the FUF inventoried sample of 2,625 trees, there were an estimated 98,534 (±9,677) street trees in San Francisco. Publicly managed trees accounted for 18.5% (18,234 ±2,779) of the total, while privately cared for trees comprised the remaining 81.5% (80,301 ±9,634).
- While San Francisco is on par with the statewide average of 104 trees per street mile, there are many opportunities to increase the resource extent. Approximately 127,500 sites—56% of all street tree-planting sites—were unplanted, ranging from 28% to 74% among districts.
- Citywide, the resource represented 115 different tree species and diversity was high. However, several districts were dominated by few species and lack of diversity should be of concern to managers.
- Having the most numbers, leaf area, and canopy cover, Victorian box and London plane were found to be the two most important street trees in San Francisco.
- Age distribution varied by district, but citywide the street tree population was immature, lacking adequate numbers of functionally mature trees.

Resource Function and Value

- Because of San Francisco's moderate summer weather, potential energy savings from trees are lower than those that would be found in warmer inland locations. Electricity and natural gas saved annually from both shading and climate effects totaled 651 MWh and 1,646 Mbtu, respectively, for a total retail savings of $85,742 ($0.87/tree).
- Citywide, public trees sequestered 611 tons of the greenhouse gas carbon dioxide. The same trees offset an additional 71 tons through reductions in energy plant emissions. Private trees had an annual net

[1]Center for Urban Forest Research
USDA Forest Service, Pacific Southwest Research Station
c/o Dept. of Environmental Horticulture
University of California
Davis, CA 95616-8587

[2]Department of Land, Air, and Water Resources
University of California, Davis, CA

sequestration rate of approximately 1,660 tons and reduced emissions by another 186 tons. The combination of these savings was valued at $37,907 ($0.38/tree) annually.

- Annual air pollutant uptake by tree foliage (pollutant deposition and particulate interception) was 12.5 tons combined. The total value of this benefit for all street trees was $189,375, or about $1.92/tree.

- Because of the relatively small avoided hydrocarbon emissions benefit at power plants due to energy savings, and the fact that many species have high biogenic volatile organic compound (BVOC) emission rates, trees had a negative net impact on avoided pollutant emissions—causing more harm than good. The net *cost* of avoided and BVOC emissions was valued at approximately $135,000, or $1.37/tree.

- The ability of San Francisco's street trees to intercept rain—thereby avoiding stormwater runoff—was substantial, estimated at 13,270,050 ft^3 annually. The total value of this benefit to the city was $467,000. These values ranged by district and population subset. Citywide, the average street tree intercepted 1006 gallons, valued at $4.73, annually. Thus, street trees were found to provide a particularly important function in maintaining environmental quality of San Francisco's important water resources.

- The estimated total annual benefit associated with property value increases and other less tangible benefits was approximately $6.9 million, or $70/tree on average. London plane ($146/tree), blackwood acacia ($110/tree), and Chinese elm ($361/tree) were on the high end, while New Zealand Christmas tree ($40/tree), evergreen pear ($23/tree), and maidenhair tree ($23/tree) averaged the least benefits.

- Overall, annual benefits were determined largely by tree size, where large-stature trees typically produce greater benefits. For example, average small (lemon bottlebrush), medium (New Zealand Christmas tree), and large (blackwood acacia) broadleaf evergreen trees produced annual benefits totaling $16, $44, and $125 per tree, respectively.

- The street tree resource of San Francisco is a valuable asset, providing approximately $7.5 million ($77/tree) in total annual benefits to the community. However, approximately the same amount is spent on their care. With a Benefit-Cost Ratio (BCR) of 1.01, managers are faced with a fragile resource that requires strategic care to increase the BCR as the resource matures.

Resource Management Needs

- Achieving resource sustainability requires focusing new plantings with proven, long-lived species that maximize available growth space to provide the largest amount of leaf area and canopy coverage as the trees mature.

- Focusing planting efforts in districts where stocking levels are lowest will improve the distribution of benefits provided to all neighborhoods.

- Tree health, pruning, and conflict management needs were substantial. Controlling costs while improving tree functionality and longevity can be bolstered through more frequent pruning schedules and efficient use of available resources.

San Francisco's street trees are a fantastically dynamic resource. Managers of this resource and the community alike can delight in knowing that street trees do improve the quality of life in San Francisco, but they are also faced with a fragile resource that needs constant care to maximize and sustain these benefits through the foreseeable future. In a city where costs are high, this is no easy task. The challenge will be to maximize net benefits from available growth space over the long-term, providing a resource that is both functional and sustainable.

Chapter One—Introduction

City of San Francisco, California
Street Tree Resource Analysis

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Street trees in San Francisco are comprised of two distinct populations, those managed by the city's Department of Public Works (DPW) and those managed by private property owners with or without the help of San Francisco's urban forestry nonprofit, Friends of the Urban Forest (FUF). With a total street tree population of nearly 100,000, these two entities believe that the public's investment in stewardship of San Francisco's urban forest produces benefits that outweigh the costs to the community. As a world-class city, renown for its quality of life, San Franciscans maintain street trees as an integral component to the city infrastructure. Research indicates that healthy city trees can mitigate impacts associated with urban environs: polluted stormwater runoff, poor air quality, energy consumption for heating and cooling buildings, and heat islands. Additionally, street trees increase real estate values, provide neighborhoods with a sense of place, and foster psychological well-being. Trees are associated with other intangibles, too, such as increased community attractiveness to tourism and business and providing wildlife habitat and corridors. Simply, street trees make San Francisco a more enjoyable place to live, work and recreate, while mitigating the city's environmental impact.

In an era of dwindling public funds and rising costs, however, there is need to scrutinize public—as well as private—expenditures that are deemed "non-essential" such as planting and maintaining street trees. Previous work—*The Trees of San Francisco: A Plan for the Management of the City's Urban Forest* (City and County of San Francisco 1991) have addressed policy in regard to city street trees, but questions remain regarding the need for the level of service presently provided by the city, FUF, and private property owners. Hence, the primary question that this study asks is *whether the accrued benefits from San Francisco's street trees justify the annual expenditures?*

In answering this question, information is provided to:

1. Assist decision-makers assess and justify the degree of funding and type of management program appropriate for this city's urban forest.
2. Provide critical baseline information for the evaluation of program cost-efficiency and alternative management structures.
3. Highlight the relevance and relationship of San Francisco's street tree resource to local quality of life issues such as environmental health, economic development, and psychological well-being.
4. Provide quantifiable data to assist in developing alternative funding sources through utility purveyors, air quality districts, federal or state agencies, legislative initiatives, or local assessment fees.

This report consists of seven chapters and four appendices:

Chapter One—Describes the purpose of this study.

Chapter Two—Describes benefits, procedures and methodology in calculating structure, function, and value of the street tree resource.

Chapter Three—Describes the current structure of the street tree resource.

Chapter Four—Costs of Managing San Francisco's Street Trees: Details management expenditures for publicly and privately managed trees. Quantifies estimated value of tangible benefits and calculates net benefits and a benefit-cost ratio for each population segment.

Chapter Five—Benefits of San Francisco Street Trees: Quantifies estimate value of tangible benefits and calculates net benefits and a benefit-cost ratio for each population segment.

Chapter Six—Management Implications: Evaluates relevancy of this analysis to current programs and posits management challenges with goals of street tree management.

Chapter Seven—Final word on the use of this analysis.

Chapter Eight—Lists publications cited in the study and the contributions made by various participants not cited as authors.

Appendix A: Rapid Sample Field Inventory Data Collection Protocols

Appendix B: Resident/Owner Street Tree Care Survey

Appendix C: Species Code Reference List

Appendix D: Total Citywide and District Street Tree Numbers

Chapter Two—Methodology and Procedures

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This analysis combines results of a citywide sample inventory (Jaenson et al. 1992) with benefit-cost modeling data to produce four types of information (Maco 2003):

1. Resource structure (species composition, diversity, age distribution, condition, etc.)
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This section describes the inputs and calculations used to derive the afore mentioned outputs: growth modeling, identifying and calculating benefits, estimating magnitude of benefits provided, assessing resource unit values, calculating net benefits and benefit-cost ratio, and assessing structure.

Growth Modeling

Drawn from San Francisco's DPW street tree database, a stratified random sample of trees was inventoried to establish relations between tree age, size, leaf area and biomass; in turn, estimates for determining the magnitude of annual benefits and costs were derived. Estimated to account for 75% of the total municipal street tree population, the sample was composed of the 22 most abundant species, and was used to infer growth of all trees, public and private.

To obtain information spanning the life cycle of each species the sample was stratified into 10 diameter at breast height (DBH) classes: 0-3 in, 3-6 in, 6-12 in, 12-18 in, 18-24 in, 24-30 in, 30-36 in, 36-42 in, 42-48 in, and >48 in. Thirty-five to 70 randomly selected trees of each species were selected to survey, along with an equal number of alternative trees. Tree metrics sampled included DBH (to nearest 0.1 cm by tape), tree crown and bole height (to nearest 0.5m by altimeter), crown diameter in two directions (maximum and minimum axis, to nearest 0.5m by tape), tree condition and location, and crown pruning level (percentage of crown removed by pruning). Replacement trees were sampled when trees from the original sample population could not be located. Carrie Durkee (City of San Francisco, DPW) determined tree age based on historical planting records. Field work was conducted August through September, 2002.

Crown volume and leaf area were estimated from computer processing of tree crown images obtained using a digital camera. The method has shown greater accuracy than other techniques (±10 percent of actual leaf area) in estimating crown volume and leaf area of open-grown trees (Peper and McPherson 1998).

Linear and nonlinear regression was used to fit predictive models—DBH as a function of age—for each of the 22 sampled species. Predictions of leaf surface area (LSA), crown diameter, and height metrics were modeled as a function of DBH using best-fit models (Peper et al. 2001).

Identifying & Calculating Benefits

Annual benefits for San Francisco's street trees were estimated for the year 2002. Growth rate modeling information was used to perform computer-simulated growth of the existing tree population for one year and account for the associated annual benefits. This "snapshot" analysis assumed that no trees were added to, or removed from, the existing population during the year. The approach directly connects benefits with tree size variables such DBH and LSA. Many functional benefits of trees are related to leaf-atmosphere processes (e.g., interception, transpiration, photosynthesis), and, therefore, benefits increase as tree canopy cover and leaf surface area increase.

Prices were assigned to each benefit (e.g., heating/cooling energy savings, air pollution absorption, stormwater runoff reduction) and cost (e.g., planting, pruning, removal, irrigation, infrastructure repair, liability) through direct estimation and implied valuation as environmental externalities. Implied valuation is used to price society's willingness to pay for the air quality and stormwater runoff benefits trees produce. For example, air quality benefits are estimated using transaction costs, which reflect the typical market value of pollutant emission credits for the Bay Area Air Quality Management District. If a corporation is willing to pay $1 per pound for a credit that will allow it to increase future emissions, then the air pollution mitigation value of a tree that absorbs or intercepts 1 lb of air pollution should be $1.

Energy Savings

Buildings and paving, along with low canopy and soil cover, increase the ambient temperatures within a city. Research shows that even in moderated climates—such as San Francisco—temperatures in urban centers are steadily increasing by approximately 0.5°F per decade. Winter benefits of this warming do not compensate for the detrimental effects of magnifying summertime temperatures. Because electric demand of cities increases about 1-2% per 1°F increase in temperature, approximately 3-8% of current electric demand for cooling is used to compensate for this urban heat island effect of the last four decades (Akbari et al. 1992).

Warmer temperatures in cities, compared to surrounding rural areas, have other implications. Increases in CO_2 emissions from fossil fuel power plants, municipal water demand, unhealthy ozone levels, and human discomfort and disease are all symptoms associated with urban heat islands. In San Francisco, there are many opportunities to ameliorate the problems associated with hardscape through strategic tree planting and stewardship of existing trees allowing for streetscapes that reduce stormwater runoff, conserve energy and water, sequester CO_2, attract wildlife, and provide other aesthetic, social, and economic benefits through urban renewal developments.

Street trees modify climate and conserve building-energy use in three principal ways:

1. Shading—reduces the amount of radiant energy absorbed and stored by built surfaces.

2. Transpiration—converts moisture to water vapor and thus cools by using solar energy that would otherwise result in heating of the air.

3. Wind speed reduction—reduces the infiltration of outside air into interior spaces and conductive heat loss where thermal conductivity is relatively high (e.g., glass windows) (Simpson 1998).

Trees and other greenspace within individual building sites may lower air temperatures 5°F compared to outside the greenspace. At the larger scale of urban climate (6 miles), temperature differences of more than 9°F have been observed between city centers and more vegetated suburban areas (Akbari et al. 1992). The relative importance of these effects depends on the size and configuration of trees and other landscape elements (McPherson 1993). Tree spacing, crown spread, and vertical distribution of leaf area influence the transport of cool air and pollutants along streets and out of urban canyons.

For individual buildings, street trees can increase energy efficiency in the summer and winter, depending on placement. Solar angles are important when the summer sun is low in the east and west for several hours each day. Tree shade to protect east—and especially west—walls help keep buildings cool. In the winter, solar access on the southern side of buildings can warm interior spaces.

Rates at which outside air infiltrates into a building can increase substantially with wind speed. In cold, windy weather, the entire volume of air in a poorly sealed home may change two to three times per hour. Even in newer or tightly sealed homes, the entire volume of air may change every two to three hours. Trees can reduce wind speed and resulting air infiltration by up to 50%, translating into potential annual heating savings of 25% (Heisler 1986). Reductions in wind speed reduce heat transfer through conductive materials as well. Cool winter winds, blowing against single-pane windows, can contribute significantly to the heating load of homes and buildings by increasing the temperature gradient between inside and outside temperatures. Trees reduce air infiltration and conductive heat loss from buildings.

Electricity and Natural Gas Methodology

Calculating annual building energy use per residential unit (Unit Energy Consumption [UEC]) is based on computer simulations that incorporate building, climate and shading effects, following methods outlined by McPherson and Simpson (1999). Changes in UECs from trees (ΔUECs) were calculated on a per tree basis by comparing results before and after adding trees. Building characteristics (e.g., cooling and heating equipment saturations, floor area, number of stories, insulation, window area, etc.) are differentiated by a building's vintage, or age of construction: pre-1950, 1950-1980 and post-1980. Typical meteorological year (TMY) weather data for San Francisco International Airport were used. Shading effects for each tree species measured were simulated at 3 tree-building distances, 8 orientations and 9 tree sizes.

Shading coefficients for tree crowns in leaf were based on a photographic method for measured species, which estimates visual density. These techniques have been shown to give good estimates of light attenuation for trees in leaf (Wilkinson 1991). Visual density was calculated as the ratio of crown area computed with and without included gaps. Crown areas were obtained from digital images isolated from background features using the method of Peper and McPherson (2003). Values for trees not measured, and for all trees not in leaf, were based on published values where available (McPherson 1984, Hammond et al. 1980). Values for remaining species were assigned based on taxonomic considerations (trees of the same genus assigned the same value) or observed similarity in the field to known species. Foliation periods for deciduous trees were obtained from the literature (McPherson 1984, Hammond et al. 1980) or based on consultation with local arborists and city tree managers.

Tree distribution by location (e.g. frequency of occurrence at each location) specific to San Francisco was determined to calculate average energy savings per tree as a function of distance and direction. Distance between trees and buildings (setbacks), and tree orientation with respect to buildings, were based on the field measurements of DPW street trees. Setbacks were assigned to four distance classes: 0-20 ft, 20-40 ft, 40-60 ft and >60 ft. It was assumed that street trees within 60 ft of buildings provided direct shade on walls and windows. Savings per tree at each location were multiplied by tree distribution to determine location-weighted savings per tree for each species and DBH class that was independent of location. Location-weighted savings per tree were multiplied by number of trees in each species/DBH class and then summed to find total savings for the city. Land use (single family residential, multifamily residential, commercial/industrial, other) was based on field measurements. The same tree distribution was used for all land uses.

Three prototype buildings were used in the simulations to represent pre-1950, 1950 and post-1980 construction practices for San Francisco (Ritschard et al. 1992). Building footprints were square, which was found to be reflective of average impacts for large building populations (Simpson 2002). Buildings were simulated with 1.5-ft overhangs. Blinds had a visual density of 37%, and were assumed closed when the air conditioner is operating. Summer and winter thermostat settings were 78° F and 68° F during the day, respectively, and 60° F at night. Unit energy consumptions were adjusted to account for saturation of central air conditioners, room air conditioners, and evaporative coolers (Table 1).

Single-Family Residential Adjustments

Unit energy consumptions for simulated single-family residential buildings were adjusted for type and saturation of heating and cooling equipment, and for various factors that modified the effects of shade and climate modifications on heating and cooling loads, using the expression,

$$\Delta UEC_x = \Delta UEC^{sh}_{SFD} \times F_{sh} + \Delta UEC^{cl}_{SFD} \times F_{cl} \qquad \text{Equation 1}$$

where $F_{sh} = F_{equipment} \times APSF \times F_{adjacent\ shade} \times F_{multiple\ tree}$

$F_{cl} = F_{equipment} \times PCF$

and $F_{equipment} = Sat_{CAC} + Sat_{window} \times 0.25 + Sat_{evap} \times (0.33$ for cooling and 1.0 for heating).

Total change in energy use for a particular district and land use was found by multiplying change in UEC per tree by the number of trees (N):

$$\text{Total change} = N \times \Delta UEC_x. \qquad \text{Equation 2}$$

Subscript *x* refers to residential structures with 1, 2-4 or 5 or more units, SFD to single family detached structures which were simulated, and *sh* to shade and

Table 1. Saturation adjustments for cooling.

	Equipment factors	Equipment Adjusted Saturations		
		pre-1950	1950-1980	post-1980
Central air/heat pump	100%	5%	5%	5%
Evaporative cooler	33%	0%	0%	0%
Wall/window unit	25%	8%	8%	8%
None	0%	87%	87%	87%
		7%	7%	7%

Saturations based on American Housing Survey for the San Francisco Metropolitan Area (1998), adjustments on Sarkovich 1996.

cl to climate effects. Unit energy density (UED)—sometimes referred to as unit energy use intensity—is defined as UEC/CFA. Unit energy density and CFA (conditioned floor area) data were taken from DOE/EIA (1993) for climate zone 4. Similar adjustments were used to account for UEC and CFA differences between single-family detached residences for which simulations were done, and attached residences and mobile homes. Average potential shade factors (APSF) and potential climate factors (PCF) were 1.0 for single-family residential buildings.

Estimated shade savings for all residential structures were adjusted by factors that accounted for shading of neighboring buildings, and reductions in shading from overlapping trees. Homes adjacent to those with shade trees may benefit from their shade. For example, 23% of the trees planted for the Sacramento Shade program shaded neighboring homes, resulting in an estimated energy savings equal to 15% of that found for program participants. This value is used here ($F_{adjacent\ shade}$ = 1.15). In addition, shade from multiple trees may overlap, resulting in less building shade from an added tree than would result if there were no existing trees. Simpson (2002) estimated that the fractional reduction in average cooling and heating energy use per tree were approximately 6% and 5% percent per tree, respectively, for each tree added after the first. Simpson (1998) also found an average of 2.5 to 3.4 existing trees per residence in Sacramento. A multiple tree reduction factor of 85% was used here, equivalent to approximately 3 existing trees per residence.

In addition to localized shade effects, which were assumed to accrue only to street trees within 18-60 ft of buildings, lowered air temperatures and wind speeds from neighborhood tree cover (referred to as climate effects) produce a net decrease in demand for summer cooling (reduced wind speeds by themselves may increase or decrease cooling demand, depending on the circumstances) and winter heating. To estimate climate effects on energy use, air temperature and wind speed reductions as a function of neighborhood canopy cover were estimated from published values following McPherson and Simpson (1999), then used as input for building energy use simulations described earlier. Peak summer air temperatures were assumed to be reduced by 0.4 °F for each percentage increase in canopy cover. Wind speed reductions were based on the canopy cover resulting from the addition of the particular tree being simulated to that of the building plus other trees. Median lot size was 7,000 ft^2 (U. S. Census Bureau 1998).

Dollar value of electrical energy savings (Pacific Gas & Electric 2003a) and natural gas savings (Pacific Gas & Electric 2003b) were based on electricity and natural gas prices of \$0.116 per kWh and \$0.626 per therm, respectively. Cooling and heating effects were reduced based on the type and saturation of air conditioning (Table 1) or heating (Table 2) equipment by vintage. Equipment factors of 33% and 25% were assigned to homes with evaporative coolers and room air conditioners, respectively. These factors were combined with equipment saturations to account for reduced energy use and

Table 2. Saturation adjustments for heating.

a. Electric heating:		Equipment efficiencies		
		pre-1950	1950-1980	post-1980
Natural gas	AFUE[a]	0.75	0.78	0.78
Heat pump	HSPF[b]	6.8	6.8	8
Electric resistance	HSPF	3.412	3.412	3.412
	Equipment factors	Saturation factors		
Electric resistance	100%	13%	13%	13%
Heat pump	100%	22%	22%	22%
Adj. elec. heat saturations		4.9%	5.1%	5.1%

[a]Annual Fuel Utilization Efficiency, a measure of space heating equipment efficiency defined as the fraction of energy output/energy input
[b]Heating Seasonal Performance Factor, the ratio of heating output to power consumption.
Electric heat saturations are adjusted to convert natural gas results that were simulated to kWh

b. NG and other heating[c]:				
Natural gas	100%	74%	74%	74%
Oil	100%	1%	1%	1%
Other	100%	2%	2%	2%
NG Heat saturations:		77%	77%	77%

[c.] Oil and "Other" heating categories treated as natural gas; all residences assumed to be heated savings compared to those simulated for homes with central air conditioning ($F_{equipment}$). Building vintage distribution was combined with adjusted saturations to compute combined vintage/saturation factors for air conditioning (Table 3). Heating loads were converted to fuel use based on efficiencies in Table 3. The "other" and "fuel oil" heating equipment types were assumed to be natural gas for the purpose of this analysis. Building vintage distributions were combined with adjusted saturations to compute combined vintage/saturation factors for natural gas and electric heating

Multi-Family Residential Analysis

Unit energy consumptions from shade for multi-family residences (MFRs) were calculated from single-family residential UECs adjusted by APSFs to account for reduced shade resulting from common walls and multi-story construction. Average potential shade factors were estimated from potential shade factors (PSFs), defined as ratios of exposed wall or roof (ceiling) surface area to total surface area, where total surface area includes common walls and ceilings between attached units in addition to exposed surfaces (Simpson 1998). Potential shade factor=1 indicates that all exterior walls and roof are exposed and could be shaded by a tree, while PSF=0 indicates that no shading is possible (i.e., the common wall between duplex units). Potential shade factors were estimated separately for walls and roofs for both single and multi-story structures. Average potential shade factors were 0.74 for land use MFR 2-4 units and 0.41 for MFR 5+ units.

Unit energy consumptions were also adjusted for climate effects to account for the reduced sensitivity of multi-family buildings with common walls to outdoor temperature changes with respect to single family detached residences. Since estimates for these PCFs were unavailable for multi-family structures, a multi-family PCF value of 0.80 was selected (less than single family detached PCF of 1.0 and greater than small commercial PCF of 0.40; see next section).

Commercial and Other Buildings

Unit energy consumptions for C/I and I/T land uses due to presence of trees were determined in a manner similar to that used for multi-family land uses. Potential shade factors of 0.40 were assumed for small C/I, and 0.0 for large C/I. No energy impacts were ascribed to large C/I structures since they are expected to have surface to volume ratios an order of magnitude larger than smaller buildings and less extensive glazed area. Average potential shade factors for I/T structures were estimated to lie between these extremes; a value of 0.15 was used here. A multiple tree reduction factor of 0.85 was used and no benefit was assigned for shading of buildings on adjacent lots.

Potential climate factors of 0.40, 0.25 and 0.20 were used for small C/I, large C/I and I/T, respectively. These values are based on estimates by Akbari and others (1990), who observed that commercial buildings are less sensitive to outdoor temperatures than houses.

Change in UECs due to shade tend to increase with CFA for typical residential structures. As building surface area increases so does the area shaded. This occurs up to a certain point because the projected

Table 3. Residential building vintage distribution and combined vintage/saturation factors for heating and air conditioning.

Distributions of vintage or building type and trees	Single family residential			Multi-family residential			Commercial/ Industrial		Institutional/ Transportation
	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	Small	Large	
Vintage distribution[a]	44	46	10	44	46	10	100%	100%	100%
Tree distribution	14.2%	14.8%	3.3%	15.7%	16.4%	3.6%	12.6%	12.1%	7.2%
Combined vintage, equipment saturation factors for cooling									
Cooling factor: shade	1.0%	1.0%	0.2%	0.5%	0.6%	0.1%	2.9%	1.4%	0.8%
Cooling factor: climate	1.0%	1.0%	0.2%	0.8%	0.9%	0.2%	3.4%	2.4%	1.0%
Combined vintage, equipment saturation factors for heating									
Heating factor: nat. gas	10%	11%	2%	6%	7%	1%	3%	2%	1%
Heating factor: electric	0.7%	0.7%	0.2%	0.4%	0.4%	0.1%	0.2%	0.1%	0.1%

[a] U.S. Census Bureau, American Housing Survey for the San Francisco Metropolitan Area (1998) converts kBtu natural gas heat to kWh electricity used for heat based on heat pump and electric resistance saturation values, and AFUE and SEER by vintage.

crown area of a mature tree (approximately 700 to 3,500 ft^2) is often larger than the building surface areas being shaded. Consequently, more area is shaded with increased surface area. However, for larger buildings, a point is reached at which no additional area is shaded as surface area increases. Therefore, ΔUECs will approach a constant value as CFA increases. Since information on the precise relationships between change in UEC, CFA, and tree size are not known, it was conservatively assumed that ΔUECs don't change in Equation 1 for C/I and I/T land uses.

Atmospheric Carbon Dioxide Reduction

Urban forests can reduce atmospheric CO_2 in two ways:

1. Trees directly sequester CO_2 as woody and foliar biomass while trees grow.

2. Trees near buildings can reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production.

On the other hand, vehicles, chain saws, chippers, and other equipment release CO_2 during the process of planting and maintaining trees. And eventually, all trees die and most of the CO_2 that has accumulated in their woody biomass is released into the atmosphere through decomposition. The combustion of gasoline and diesel fuels by vehicle fleets, and equipment such as chainsaws, chippers, stump removers, and leaf blowers is a relatively minor source of CO_2. Typically, CO_2 released due to tree planting, maintenance, and other program-related activities is about 2-8% of annual CO_2 reductions obtained through sequestration and avoided power plant emissions (McPherson and Simpson 1999).

Sequestered and Released CO_2 Methodology

Sequestration, the net rate of CO_2 storage in above- and below-ground biomass over the course of one growing season, is calculated by species using tree growth equations for DBH and height described above to calculate tree volume with equations from Pillsbury et. al (1998) and Frangi and Lugo (1985) for palms (see McPherson and Simpson [1999] for additional information). Fresh weight (kg/m^3) and specific gravity ratios from Alden (1995) were applied to convert volume to biomass.

Carbon dioxide released through decomposition of dead woody biomass varies with characteristics of the wood itself, fate of the wood (e.g., left standing, chipped, burned), and local soil and climatic conditions. Recycling of urban waste is now prevalent, and we assume here that most material is chipped and applied as landscape mulch. Calculations were conservative because they assume that dead trees are removed and mulched in the year that death occurs, and that 80% of their stored carbon is released to the atmosphere as CO_2 in the same year. Total annual decomposition is based on the number of trees in each species and age class that die in a given year and their biomass. Tree survival rate is the principal factor influencing decomposition. Tree mortality was based on weighted average annual mortality rates for public and private trees for the city of San Francisco (Table 4). Finally, CO_2 released from tree maintenance was estimated to be 0.76 lb CO_2/in DBH based on national average figures (McPherson and Simpson 1999).

Avoided CO_2 Emissions Methodology

Reductions in building energy use result in reduced emissions of CO_2. Emissions were calculated as the product of energy use and CO_2 emission factors for electricity and heating. Heating fuel is largely natural gas and electricity in San Francisco (Table 2). San Francisco imported about 70% of its electrical power from PG&E and the statewide grid in 2001; 22% was generated at Hunter's Point and 8% at Portrero facilities (San Francisco Public Utilities Commission 2002). The overall fuel mix for this power was approximately 55% natural gas, 18% hydroelectric, 13% nuclear, 4% coal, 4% geothermal, and 6% alternative (U.S. EPA 2001). Emissions factors for electricity (lb/MWh) and natural gas (lb/MBtu) weighted by the appropriate fuel mixes are given in Table 5. Implied value of avoided CO_2 was \$0.008/lb based on average high and low estimates for emerging carbon trading markets in the U.S. (CO2e.com 2002) (Table 5). Values for criteria air

Table 4. Population-weighted annual tree mortality

	Year								
	5	10	20	30	40	50	60	70	80
All tree (weighted average)	3.53%	1.16%	1.16%	1.16%	1.16%	1.16%	1.16%	1.16%	1.16%
Public trees[1]	5.00%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
Private trees[2]	3.20%	1.08%	1.08%	1.08%	1.08%	1.08%	1.08%	1.08%	1.08%

[1]Paul Sacamano, DPW, personal communication, 5/1/03

[2]Doug Wildman, FUF, Personal communication, 6/26/03

pollutants were based on a 3-year weighted average of transaction costs for California emission reduction credits in the Bay Area Air Quality District (Table 5).

Improving Air Quality

Urban trees provide air quality benefits in five main ways:

1. Absorbing gaseous pollutants (e.g., ozone, nitrogen oxides, and sulfur dioxide) through leaf surfaces.
2. Intercepting particulate matter (e.g., dust, ash, pollen, and smoke).
3. Reducing emissions from power generation by limiting building energy consumption.
4. Releasing oxygen through photosynthesis.
5. Transpiring water and shading surfaces, which lowers local air temperatures, thereby reducing ozone levels.

In the absence of the cooling effects of trees, higher air temperatures contribute to ozone formation. Most trees emit various biogenic volatile organic compounds (BVOCs) such as isoprenes and monoterpenes that can contribute to ozone formation. The ozone-forming potential of different tree species varies considerably. A computer simulation study for the Los Angeles basin found that increased tree planting of low BVOC emitting tree species would reduce ozone concentrations and exposure to ozone, while planting of medium- and high-emitters would increase overall ozone concentrations (Taha 1996).

Another possible cost of street trees includes their allergenic potential. Plant-related allergies stem from inhalant pollen allergy, odor allergy, and reactions from contact with leaves, stems, and sap (Ogren 2000). One scale—Ogren Plant-Allergy Scale (OPALS™)—rates trees based on their potential to cause allergic reaction and is weighted to rate trees that provoke asthma the highest (worst rating) (Ogren 2000). Using this classification (scale of 1-10), San Francisco street trees—as a population—appear to rate in the middle, capable of causing itch and rash, but not so high as to induce asthma or hay fever (Table 6). It is important to remember, however, that allergy response is determined by many factors: type of contact, proximity to tree, wind direction, precipitation patterns, etc. This area of research is only now emerging and is neither well documented nor understood.

Differing from much of the Bay Area, San Francisco's peninsula location affords the city with low atmospheric pollution potential even though pollutant emission densities are high due to high population density, heavy vehicle use, and industrialization (BAAQMD 2003). Because of tighter controls and winds that are generally frequent and fast enough to carry pollutants away before they accumulate, the city has rarely exceeded U.S. Environmental Protection Agency (EPA) or stricter standards of California State in recent years. However, atmospheric pollutants are transported into the Central Valley where they adversely affect human health. Continued progress is needed to meet and sustain mandated air quality standards.

Table 5. Emissions factors and implied values for CO_2 and criteria air pollutants.

	Emission Factor		Implied
	Electricity[a]	Natural gas[b]	value
	(lb/MWh)	(lb/MBtu)	($/lb)
CO_2	788	117.5	0.008[c]
NO_2	0.886	0.1016	7.36[d]
PM_{10}	0.110	0.0075	7.86[d]
VOCs	0.064	0.0053	7.84[d]

[a]EPA 2001, San Francisco Public Utilities Commission 2002
[b]U. S. Environmental Protection Agency 1998
[c]$15/ton for CO2 from CO2e.com 2002
[d]California Air Resources Board 2001; 2002; 2003

Table 6. Prominent street trees of San Francisco and their plant-allergy rating (1 is best, 10 is worst).

Species	% of total	OPALS™ rating
Victorian box	8.6	5
London plane	6.6	9
Indian laurel	6.1	2
New Zealand Christmas tree	4.9	6
cherry plum	4.6	3
red-flowering gum	3.6	5
blackwood acacia	3.5	10
Japanese flowering cherry	3.5	7
Brisbane box	3.4	5
mayten tree	2.9	7
small-leaf tristania	2.9	5
Arbutus 'Marina'	2.8	3
lemon bottlebrush	2.2	9
evergreen pear	2.2	4
maidenhair tree	2.2	7
Average (weighted)		5.7

Avoided Emissions Methodology

Reductions in building energy use also result in reduced emissions of criteria air pollutants from power plants and space heating equipment. This analysis considered volatile organic hydrocarbons (VOCs) and nitrogen dioxide (NO_2), both precursors of ozone (O_3) formation, as well as particulate matter of <10 micron diameter (PM_{10}). Changes in average annual emissions and their offset values were calculated in the same way as for CO_2, again using utility-specific emission factors for electricity and heating fuels (Table 5).

Deposition and Interception Methodology

Trees also remove pollutants from the atmosphere. The hourly pollutant dry deposition per tree is expressed as the product of a deposition velocity $V_d = 1/(R_a+R_b+R_c)$, a pollutant concentration C, a canopy projection area CP, and a time step. Hourly deposition velocities for each pollutant were calculated using estimates for the resistances R_a, R_b, and R_c estimated for each hour for a year using formulations described by Scott et al. (1998). Exceedances of state or national air quality standards in San Francisco have occurred only for PM_{10}, and only for the more stringent state standards. Data from 1999 was selected as representative for modeling deposition based on ozone and PM_{10} concentrations, limiting the period for consideration to the last 10 years of available data (1992-2001) due to the decline noted in overall concentrations over the past 20 years. The year 1999 with ozone and PM_{10} somewhat above average was selected for analysis.

Deposition was determined for deciduous species only when trees were in-leaf. Hourly concentrations for NO_2 , O_3, and PM_{10} were obtained from the Bay Area Air Quality Management District's San Francisco air monitoring station located bayside at 10 Arkansas St. in the Potrero district. This station monitors air pollutant concentrations representative of areas of high population density, at spatial scales of up to 3 miles. A 50% re-suspension rate was applied to PM_{10} deposition. Transaction costs from *Table 5* were used to value emissions reductions; NO_2 prices were used for ozone since ozone control measures are primarily aimed at NO_x reduction in California. Hourly meteorological data for wind speed and precipitation came from the Weather Service Office located at San Francisco International Airport. Closest available solar radiation data was for California Department of Water Resources monitoring sites for San Jose and Oakland, except for a unique set of data collected from November 2001 until October 2002 for San Francisco itself (San Francisco Solar Monitoring Network 2003). Comparison of monthly totals for this period with that of San Jose and Oakland showed best agreement with San Jose from January to April and September to December, better agreement with Oakland for May to August. Agreement was 5% or better for 8 of 12 months, and 10% or better for 11 of 12 months. Consequently, data from these locations and periods were combined to construct solar radiation estimates for 1999 in San Francisco.

BVOC Emissions Methodology

Emission of biogenic volatile organic carbon (sometimes called biogenic hydrocarbons) associated with increased ozone formation were estimated for the tree canopy using methods described by McPherson et al. (1998). In this approach, the hourly emissions of carbon as isoprene and monoterpene are expressed as products of base emission factors and leaf biomass factors adjusted for sunlight and temperature (isoprene) or temperature (monoterpene). Hourly emissions were summed to get annual totals. This is a conservative approach, since we do not account for the benefit associated with lowered summertime air temperatures and the resulting reduced hydrocarbon emissions from biogenic as well as anthropogenic sources. The cost of these emissions is priced at \$7.84/lb (Table 5).

Reducing Stormwater Runoff and Hydrology

Urban stormwater runoff is an increasing concern as a significant pathway for contaminants entering San Francisco Bay and surrounding Pacific coastal waters. These waters are vital components of the local economy. Fishing, surfing, and sailing are important defining characteristics of the city's recreational preferences. As with many coastal estuary systems, improving water quality in the Bay, and keeping shorelines clean will require increasingly broad, stringent, and costly stormwater management requirements; cost-effective means of mitigation are needed. Healthy urban trees can reduce the amount of runoff and pollutant loading in receiving waters in three primary ways:

1. Leaves and branch surfaces intercept and store rainfall, thereby reducing runoff volumes and delaying the onset of peak flows.
2. Root growth and decomposition increase the capacity and rate of soil infiltration by rainfall and reduce overland flow.
3. Tree canopies reduce soil erosion and surface transport by diminishing the impact of raindrops on barren surfaces.

Studies that have simulated urban forest effects on stormwater report annual runoff reductions of 2-7%. Annual interception of rainfall by Sacramento's urban forest for the urbanized area was only about 2% due to the winter rainfall pattern and predominance of non-evergreen species (Xiao et al. 1998). However, average interception on land with tree canopy cover ranged from 6-13% (150 gal per tree on average), close to values reported for rural forests. In Modesto, CA, each street and park tree was estimated to reduce stormwater runoff by 845 gal annually, with a benefit valued at $7 per tree (McPherson et al. 1999b). A typical medium-sized tree in coastal southern California was estimated to intercept 2,380 gal ($5) annually (McPherson et al. 2000). These studies showed that broadleaf evergreens and conifers intercept more rainfall than deciduous species where winter rainfall patterns prevail.

Stormwater Methodology

A numerical simulation model was used to estimate annual rainfall interception (Xiao et al. 1998). The interception model accounts for water intercepted by the tree, as well as throughfall and stem flow. Intercepted water is stored temporarily on canopy leaf and bark surfaces. Once the leaf is saturated it drips from the leaf surface and flows down the stem surface to the ground, or evaporates. Tree canopy parameters include species, leaf surface area, shade coefficient, (visual density of the crown), foliation period, and tree dimensions (i.e., height, crown height, crown diameter, LSA, and DBH). Tree height data are used to estimate wind speed at different heights above the ground and resulting rates of evaporation. The volume of water stored in the tree crown is calculated from crown projection area (area under tree dripline), leaf area indexes (LAI, the ratio of leaf surface area to crown projection area), and water depth on the canopy surface. Species-specific shade coefficients influence the amount of projected throughfall.

Based on available data sources, hourly meteorological and rainfall data for 1999 from the California Irrigation Management Information System (CIMIS, Station ID: 149 in Oakland) are used for this simulation. Annual precipitation during 1999 was 28.2 inches, somewhat greater than the recent ten-year mean annual precipitation amount of 25 inches for the region (U.S. NOAA). A more complete description of the interception model can be found in Xiao et al. (1998).

Atypical of most California cities, San Francisco has a combined sewer system where dry-weather flows (sewage) and wet-weather flows (stormwater runoff) are collected in a single system. Prior to the early eighties, nearly every rain event caused sewers to overflow at the shoreline, contaminating beaches that required recreational closures (SFPUC 2003). However, in 1997 the city completed its waste water facility improvement plan—a project that cost more than $1.4 billion dollars. Now, over 900 miles of sewer pipe convey nearly all stormwater runoff to the city perimeter where it is stored and treated, along with sewage, in large underground box-like structures before entering the Bay or ocean. Because the combined system treats rainwater like sewage, it has associated costs for treating and storing large volumes of water.

In FY2001-2, the costs for operations and management—including capital write-off and replacement—for the water pollution control system was $155 million. During the "average" year, the combined system treats approximately 33 billion gallons of sewage and stormwater for a cost of $4.70 per 1,000 gallons controlled and treated (Kenck 2003). This estimate was used as the implied value of rainfall intercepted by street trees in San Francisco. The treatment cost is multiplied by gallons of rainfall intercepted each year to calculate water quality benefit.

Aesthetics & Other Benefits

Trees provide a host of aesthetic, social, economic, and health benefits that should be included in any benefit-cost analysis. One of the most frequently cited reasons that people plant trees is for beautification. Trees add color, texture, line, and form to the landscape. In this way, trees soften the hard geometry that dominates built environments. Research on the aesthetic quality of residential streets has shown that street trees are the single strongest positive influence on scenic quality (Schroeder and Cannon 1983). Consumer surveys have found that preference ratings increase with the presence of trees in the commercial streetscape. In contrast to areas without trees, shoppers indicated that they shop more often and longer in well-landscaped business districts, and were willing to pay more for goods and services (Wolf 1999).

Research in public housing complexes found that outdoor spaces with trees were used significantly more often than spaces without trees. By facilitating interactions among residents, trees can contribute to reduced levels of domestic violence, as well as foster safer and more sociable neighborhood environments (Sullivan and Kuo 1996).

Well-maintained trees increase the "curb appeal" of properties. Research comparing sales prices of residential properties with different tree resources suggests that people are willing to pay 3-7% more for properties with ample tree resources versus few or no trees. One of the most comprehensive studies of the influence of trees on residential property values was based on actual sales prices and found that each large front-yard tree was associated with about a 1% increase in sales price (Anderson and Cordell 1988). A much greater value of 9% ($15,000) was determined in a U.S. Tax Court case for the loss of a large black oak on a property valued at $164,500 (Neely 1988). Depending on average home sales prices, the value of this benefit can contribute significantly to cities' property tax revenues.

Scientific studies confirm our intuition that trees in cities provide social and psychological benefits. Humans derive substantial pleasure from trees, whether it is inspiration from their beauty, a spiritual connection, or a sense of meaning (Dwyer et al. 1992; Lewis 1996). Following natural disasters, people often report a sense of loss if the urban forest in their community has been damaged (Hull 1992). Views of trees and nature from homes and offices provide restorative experiences that ease mental fatigue and help people to concentrate (Kaplan & Kaplan 1989). Desk-workers with a view of nature report lower rates of sickness and greater satisfaction with their jobs compared to those having no visual connection to nature (Kaplan 1992). Trees provide important settings for recreation and relaxation in and near cities. The act of planting trees can have social value, for community bonds between people and local groups often result.

The presence of trees in cities provides public health benefits and improves the well-being of those who live, work and recreate in cities. Physical and emotional stress has both short term and long-term effects. Prolonged stress can compromise the human immune system. A series of studies on human stress caused by general urban conditions and city driving show that views of nature reduce stress response of both body and mind (Parsons et al. 1998). City nature also appears to have an "immunization effect," in that people show less stress response if they've had a recent view of trees and vegetation. Hospitalized patients with views of nature and time spent outdoors need less medication, sleep better, and have a better outlook than patients without connections to nature (Ulrich 1985). Trees reduce exposure to ultraviolet light, thereby lowering the risk of harmful effects from skin cancer and cataracts (Tretheway and Manthe 1999).

Certain environmental benefits from trees are more difficult to quantify than those previously described, but can be just as important. Noise can reach unhealthy levels in cities. Trucks, trains, and planes can produce noise that exceeds 100 decibels, twice the level at which noise becomes a health risk. Thick strips of vegetation in conjunction with landforms or solid barriers can reduce highway noise by 6-15 decibels. Plants absorb more high frequency noise than low frequency, which is advantageous to humans since higher frequencies are most distressing to people (Miller 1997).

Although urban forests contain less biological diversity than rural woodlands, numerous types of wildlife inhabit cities and are generally highly valued by residents. For example, older parks, cemeteries, and botanical gardens often contain a rich assemblage of wildlife. Street tree corridors can connect a city to surrounding wetlands, parks, and other greenspace resources that provide habitats that conserve biodiversity (Platt et al. 1994).

Urban forestry can provide jobs for both skilled and unskilled labor. Public service programs and grassroots-led urban and community forestry programs provide horticultural training to volunteers across the U.S. Also, urban and community forestry provides educational opportunities for residents who want to learn about nature through first-hand experience (McPherson and Mathis 1999). Local nonprofit tree groups, along with municipal volunteer programs, often provide educational materials, work with area schools, and hands-on training in the care of trees.

Property Value and Other Benefits Methodology

Many benefits attributed to urban trees are difficult to translate into economic terms. Beautification, privacy, shade that increases human comfort, wildlife habitat, sense of place and well-being are products that are difficult to price. However, the value of some of these benefits may be captured in the property values for the land on which trees stand. To estimate the value of these "other" benefits, results of research that compares differences in sales prices of houses are used to statistically quantify the difference associated with trees. The amount of difference in sales price reflects the willingness of buyers to pay for the benefits and costs associated with the trees. This approach has the virtue of capturing what buyers perceive to be as both the benefits and costs of trees in the sales price. Some limitations to using this approach in San Francisco include the difficulty associated with 1) determining the value of individual street trees adjacent to private properties, 2) the need to extrapolate results from studies done years ago in the east and south to California, and 3) the need to extrapolate results from front yard trees on residential properties to street trees in various locations (e.g., commercial vs. residential).

In an Athens, GA study (Anderson and Cordell 1988), a large front yard tree was found to be associated with a 0.88% increase in average home resale values. Along with identifying the LSA of a typical mature large tree (40-year old plane tree) in San Francisco (2,943 ft^2) and using the average annual change in LSA (ft^2) for trees within each DBH class as a resource unit, this increase was the basis for valuing trees' capacity to increase property value.

Assuming the 0.88% increase in property value held true for San Francisco, each large tree would be worth $4,805 based on the average [2002] single-family home resale prices in San Francisco ($546,000) (DataQuick 2002). However, not all trees are as effective as front yard residential trees in increasing property values. For example, trees adjacent to multifamily housing units will not increase the property value at the same rate as trees in front of a single-family home. Therefore, a citywide reduction factor (0.76) was applied to prorate trees' value based on the assumption that trees adjacent to differing land-use—single home residential, multi-home residential, commercial/industrial, vacant, park and institutional—were valued at 100%, 75%, 50%, 25%, 50%, and 50%, repectively, of the full $4,805 (McPherson et al. 2001).

Given these assumptions, a typical large tree was estimated to increase property values by $1.24/$ft^2$ of LSA. For example, it was estimated that a single Victorian box adds about 20.95 ft^2 of LSA per year when growing in the DBH range of 12-18 in. During this period of growth, therefore, Victorian box trees effectively added $25.98, annually, to the value of an adjacent home, condominium, or business property (20.95ft^2 x $1.63/$ft^2$ x 76% = $25.98).

Estimating Magnitude of Benefits

Defined as *resource units*, the absolute value of the benefits of San Francisco's street trees—electricity (kWh/tree) and natural gas savings (kBtu/tree), atmospheric CO_2 reductions (lbs/tree), air quality improvement (NO_2, PM_{10} and VOCs [lbs/tree]), stormwater runoff reductions (precipitation interception [ft^3/tree]) and property value increases (Δ LSA [ft^2/tree])—were assigned prices through methods described above for model trees.

Estimating the magnitude of benefits (resource units) produced by all street trees in San Francisco required four procedures: 1) categorizing street trees by species and DBH based on results of the sample inventory, 2) matching significant species with those from the 22 modeled species 3) grouping remaining "other" trees by type, and 4) applying resource units to each tree in each district.

Categorizing Trees by DBH Class

The first step in accomplishing this task involved categorizing the estimated total number of public and private street trees by relative age (DBH class). Results of the sample inventory were used to group trees—both citywide and by districts—using the following classes:

1. 0-3 in
2. 3-6 in
3. 6-12 in
4. 12-18 in
5. 18-24 in
6. 24-30 in
7. >30 in

Because DBH classes represented a range, the median value for each DBH class was determined and subsequently utilized as a single value representing all trees encompassed in each class. Linear interpolation was used to estimate resource unit values (Y-value) for each of the 22 modeled species for the 7 midpoints (X-value) corresponding to each of the DBH classes assigned to the city's street trees.

Applying Benefit Resource Units to Each Tree

Once categorized, the interpolated resource unit values were matched on a one-for-one basis. For example, the sample inventory results suggested that out of an estimated 4,873 New Zealand Christmas trees citywide, 2,730 were within the 6-12 in DBH class size. The interpolated electricity and natural gas resource unit values for the class size midpoint (9 in) were 5.1 kWh/tree and 4.4 kBtu/tree, respectively. Therefore, multiplying the size class resource units by 2,730 equals the magnitude of annual heating and cooling benefits produced by this segment of the population: 1.4 MWh in electricity saved and 1.2 MBtu natural gas saved.

Matching Significant Species with Modeled Species

To infer from the 22 municipal species modeled for growth to the entire public and private street tree population, each species representing over one percent of the population citywide, and by district, were matched directly with corresponding model species or, where there was no corresponding tree, the best match was determined by identifying which of the 22 species was most similar in leaf shape/type and habit; size was not necessarily determinant. For example, the citywide structural analysis estimated a total private street tree population comprised of 115 species, of which only 26 represented 1% or more of the population. Of these 26 species, 21 corresponded directly with the public tree model taxa sampled. The five remaining species were matched with the next closest species: the private Arbutus 'Marina' (*Arbutus* 'Marina') with the modeled small-leaf tristania (*Tristania laurina*); the private Australian peppermint willow (*Agonis flexuosa*) with the modeled mayten tree (*Maytenus boaria*); the private myoporum (*Myoporum laetum*) with the modeled privet (Ligustrum lucidum); the private Indian hawthorn (*Raphiolepsis* 'Majestic Beauty') with the modeled small-leaf tristania; the private karo (*Pittosporum crassifolium*) with the modeled Victorian box (*Pittosporum undulatum*).

Grouping Remaining "Other" Trees by Type

The species that were less than 1% of the population were labeled "other" and were categorized according to tree type classes based on tree type (one of four life forms and three mature sizes):

- Broadleaf deciduous - large (BDL), medium (BDM), and small (BDS).
- Broadleaf evergreen - large (BEL), medium (BEM), and small (BES).
- Conifer - large (CL), medium (CM), and small (CS).
- Palm – large (PL), medium (PM), small (PS)

Large, medium, and small trees measured >35 ft, 20-35 ft, and <20 ft in mature height, respectively; palms were categorized by crown width. A typical tree was chosen for each of the above 12 categories to obtain growth curves for "other" trees falling into each of the categories:

BDL Other = London plane (*Platanus acerifolia*)

BDM Other = Chinese elm (*Ulmus parvifolia*)

BDS Other = Scaled @ 2/3 Chinese elm

BEL Other = Brisbane box (*Tristania conferta*)

BEM Other = Victorian box (*Pittoporum undulatum*)

BES Other = small-leaf tristania (*Tristania laurina*)

CL Other = Monterey pine (*Pinus radiata*)

CM Other = Scaled @ 2/3 Monterey pine

CS Other = Scaled @ 1/3 Monterey pine

PL Other = Canary Island date palm (*Phoenix Canariensis*)

PM Other = Mexican fan palm (Washingtonia robusta)

PS Other = Scaled @ ½ Mexican fan palm

Because palms were not sampled in San Francisco, growth data from Claremont, CA were utilized. Where modeled species did not exist for specific categories—BDS Other, CM Other, CS Other, and PS Other—larger-stature species were scaled-down in size metrics to be used as surrogates for Other trees falling into these categories.

Calculating Costs

Errors of estimates presented with these results include only measurement errors based on the population sampling procedure. The effects of modeling are also important to consider, and, therefore, error may be underestimated.

Public Street Trees

Expenditures associated with public trees were evaluated based on data provided by Paul Sacamano (City of San Francisco, DPW) for Fiscal Year 2001-2002. While cost data were specific to public street trees, some emergency services provided for non-DPW managed trees were inseparable based on available data and, thus, may inaccurately portray actual costs as slightly elevated.

Private Street Trees

To understand frequency by which maintenance activities occur—including infrastructure repair caused by root-hardscape conflicts—a mail-back questionnaire was randomly administered to approximately 600 residents by FUF volunteers during the rapid sample inventory (Appendix B). There were 105 respondents, for a response rate of approximately 15%. Trees were stratified into four height class categories: <10 ft, 10-20 ft, 20-40 ft, and 40-60 ft. Costs for infrastructure repairs (sidewalk and sewerline replacement) were derived from respondents and calculated as weighted averages. Contracted arboriculture-related services (planting, pruning, pest management, etc.) were founded on a survey of San Francisco-based commercial arborists, and calculated as an average of prices charged. Removal and disposal contract frequencies were derived from a survey of residents in Sacramento, CA (Summit and McPherson 1998). Other costs, such as watering, were based on FUF recommended regimes to assess total gallons delivered on an annual basis. Annual costs were summed for each tree based on DBH and height classes of typical small (evergreen pear), medium (Victorian box), and large trees (London plane) (Table 7).

The average caretaker of a single private street tree spent 11.5 hours, annually, on maintenance activities. In this analysis, "volunteer" hours are not included as a "cost" of planting and maintaining private street trees. For example, the average newly outplanted medium-stature tree less than <10 ft in height was watered 47 times throughout the year at a rate of 15 gallons per watering. However, based on the survey, only 68% of the trees in this height class received water, and residential water rates were priced at ~$0.002 per gallon. Therefore, total cost to water the "typical" tree in this size class was calculated as $0.96 per year (47 waterings X 15 gals X 68% X $0.002 = $0.96). Not included was the 15 minutes it may have taken for the adjacent resident to set out and retrieve the hose for each watering. In this respect, it is difficult to make direct comparisons of costs between private and publicly managed trees, where paid staff conduct all aspects of maintenance.

Calculating Net Benefits and Benefit-Cost Ratio

It is impossible to quantify all the benefits and costs that trees produce. For example, property owners with large street trees can receive benefits from increased property values, but they may also benefit directly from improved human health (e.g., reduced exposure to cancer-causing UV radiation) and greater psychological well-being through visual and direct contact with trees. On the cost side, increased health care costs may be incurred because of nearby trees, as with allergies and respiratory ailments related to pollen. The value of many of these benefits and costs are difficult to determine. We assume that some of these intangible benefits and costs are reflected in what we term "property value and other benefits." Other types of benefits we can only describe, such as the social, educational, and employment/training benefits associated with the city's street tree resource. To some extent connecting people with their city trees reduces costs for health care, welfare, crime prevention, and other social service programs.

San Francisco residents can obtain additional economic benefits from street trees depending on tree location and condition. For example, street trees can provide air conditioning savings by shading buildings and pavement. This benefit can extend to the neighborhood, as the aggregate effect of many street trees is to reduce air temperatures and lower cooling costs. Neighborhood property values can be influenced by the extent of tree canopy cover on streets. The community benefits from cleaner air and water. Reductions in atmospheric CO_2 concentrations due to trees can have global benefits.

Net Benefits and Costs Methodology

To assess the total value of annual benefits (*B*) for each street tree (*i*) in each district (*j*) benefits were summed (see Equation 3, next page):

Table 7. Annual costs associated with private trees categorized by stature and DBH class.

	DBH Class (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Avg.
Planting										
All	$6.03	$6.03	$6.03	$6.03	$6.03	$6.03	$6.03	$6.03	$6.03	$6.03
Trimming & disposal										
Small	$10.44	$10.44	$31.48	$31.48	$31.48	$31.48	$31.48	$31.48	$31.48	$26.80
Medium	$3.65	$10.44	$31.48	$31.48	$31.48	$31.48	$31.48	$31.48	$31.48	$26.05
Large	$10.44	$31.48	$31.48	$53.33	$53.33	$53.33	$53.33	$53.33	$53.33	$43.71
Removal & disposal										
All	$0.28	$1.37	$2.74	$4.57	$6.40	$8.23	$10.06	$11.88	$12.80	$6.48
Watering										
Small	$0.60	$0.60	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.24
Medium	$0.96	$0.60	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.28
Large	$0.60	$0.13	$0.13	$0.46	$0.46	$0.46	$0.46	$0.46	$0.46	$0.40
Pest & disease control										
Small	$0.03	$0.09	$0.48	$0.79	$1.11	$1.43	$1.74	$2.06	$2.22	$1.11
Medium	$0.00	$0.09	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.01
Large	$0.03	$0.24	$0.48	$0.02	$0.03	$0.04	$0.05	$0.06	$0.06	$0.11
Infrastructure repair										
Small	$0.22	$0.65	$1.03	$1.71	$2.39	$3.08	$3.76	$4.45	$4.79	$2.45
Medium	$0.05	$0.65	$1.03	$1.71	$2.39	$3.08	$3.76	$4.45	$4.79	$2.43
Large	$0.22	$0.51	$1.03	$0.12	$0.17	$0.22	$0.27	$0.32	$0.35	$0.36

$$B = \sum_{1}^{n} j \left(\sum_{1}^{n} i \left(e_{ij} + a_{ij} + c_{ij} + h_{ij} + p_{ij} \right) \right)$$

where

e = price of net annual energy savings = annual natural gas savings + annual electricity savings

a = price of annual net air quality improvement = PM_{10} interception + NO_2 and O_3 absorption + avoided power plant emissions - BVOC emissions

c = price of annual carbon dioxide reductions = CO_2 sequestered less releases + CO_2 avoided from reduced energy use

h = price of annual stormwater runoff reductions = effective rainfall interception

p = price of aesthetics = annual increase in property value

(Equation 3)

Total net expenditures were calculated based on all identifiable internal and external costs associated with the annual management of public and private street trees citywide. Annual costs for public street trees (*C*) were summed:

$$C = p + t + r + d + e + s + c + l + a + q$$

where,

p = annual planting expenditure

t = annual pruning expenditure

r = annual tree and stump removal and disposal expenditure

d = annual pest and disease control expenditures

e = annual establishment / irrigation expenditure

s = annual price of repair / mitigation of infrastructure damage

c = annual price of litter / storm clean - up

l = average annual litigation and settlements expenditures due to tree - related claims

a = annual expenditure for program administration

q = annual expenditures for inspection / answer service requests

(Equation 4)

Total citywide annual net benefits as well as the benefit–cost ratio (BCR) were calculated using the sums of benefits and costs:

$$\text{Citywide Net Benefits} = B\text{-}C \quad \text{(Equation 5)}$$

$$\text{BCR} = B/C \quad \text{(Equation 6)}$$

Assessing Structure

No preexisting database was available to assess structure of the street tree population in San Francisco. While DPW maintained an inventory of municipal trees—and FUF, of recent FUF-planted private trees—no single comprehensive collection of *all* street trees and their attributes existed. A rapid sampling inventory method, requiring no level of preexisting information, such as knowing the total number of existing street trees in the city, was used to provide the comprehensive data needed (Jaenson et al. 1992). With this method, street tree information, including species composition, DBH, health, total number of trees, and vacant planting spaces were collected and analyzed for a targeted 2,300 trees, providing a database that yielded accurate baseline information pertaining to the function and structure of the vegetation resource on both a citywide and district (neighborhood) level (Figure 1). This sampling technique has been described elsewhere, however a brief summary of the authors' steps and its application in San Francisco is warranted here.

As a first step, DPW staff stratified the city's area into homogenous *districts* based on existing political boundaries and street layout, for a total of 11 districts, with district 10 further subdivided into 'a' and 'b' areas (Figure 1). Each district was then divided into *sampling units*—uniform blocks, or equivalent street segments, that were randomly sampled throughout the city. In order to determine the distribution of the targeted 2,300 trees to be sampled amongst districts, a *pre-sample* was conducted to estimate district street tree density, or average number of trees per sampling unit in each of the districts. Based on the results of this "windshield" survey, the desired number of sampling units to be inventoried per district was calculated and 133 were drawn randomly.

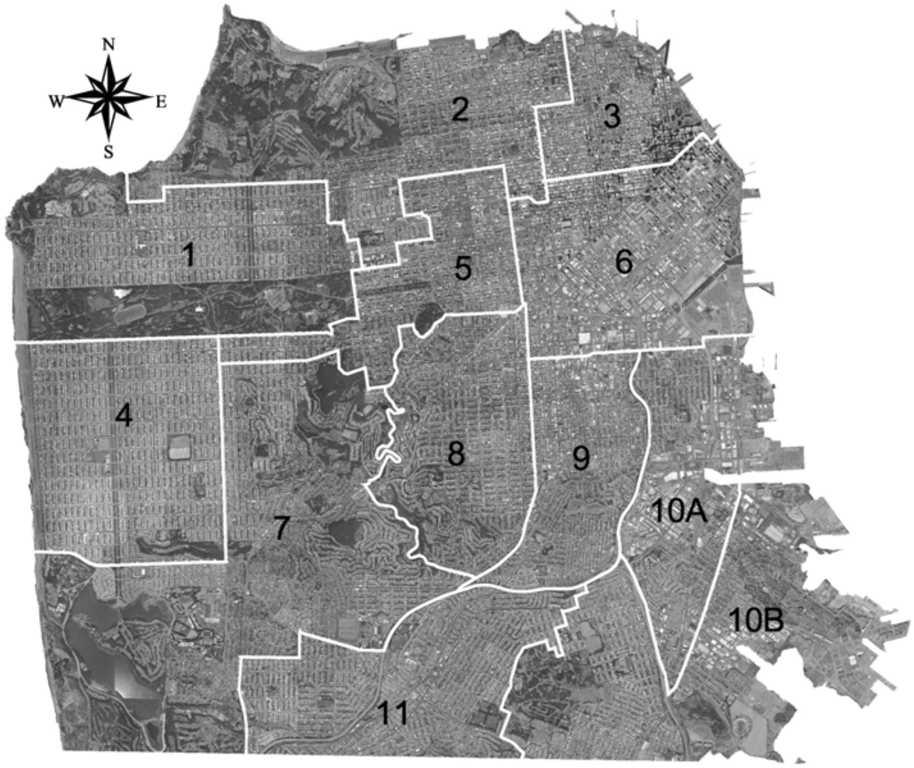


Figure 1. San Francisco district map.

Inventory Protocols

All trees in the city right of way (ROW) within each unit were surveyed, using trained FUF volunteers. Two-person teams (a measurer and a recorder) were used to record data using the field inventory data collection protocols (Appendix A), later entered into an electronic spreadsheet for data analysis.

Calculating Structural Attributes

As Jaenson et al. (1992) described, the pre-sampling procedure was used to initially determine the proportion of individual trees in each district, and subsequently the sampling intensity targeted for each district. Citywide total numbers of individual tree species (X) and their attributes were estimated based on the proportions of trees counted in the actual sample inventory. The model for stratified random sampling with proportional allocation (Cochran 1977) was used to make the calculation:

$$\bar{y} = \frac{\sum_{h=1}^{L} n_h \bar{y}_h}{n} \quad \text{where,}$$

$$y_h = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h} \qquad \text{(Equation 7)}$$

$L =$ number of strata

$n_h =$ number of units in sample

$y_{hi} =$ value obtained for the ith unit

Following Eq. (1), district (Eq. [2]) and citywide (Eq. [3]) totals for each inventoried species were calculated:

$$\text{Estd. \# of species } X \text{ per zone segment} = \left(\begin{array}{c}\text{Actual \# of sampling}\\ \text{units per zone segment}\end{array}\right) * \left(\frac{\text{Total \# of species } X \text{ counted in zone segment}}{\text{\# of sampling units sampled in zone segment}}\right) \qquad \text{(Equation 8)}$$

$$\text{Estd. \# of each species } X \text{ citywide} = \sum \text{Estd. \# of species } X \text{ per zone segment} \qquad \text{(Equation 9)}$$

Estimating the percentage of the citywide population represented by species *X* was calculated with Eq. (4):

$$\text{Species } X \text{ as percentage of population} = \left(\frac{\text{Estd. number of species } X}{\sum \text{Estd. number of all city trees}}\right) \qquad \text{(Equation 10)}$$

These calculations were repeated for inventoried attributes of both public and private trees.

City of San Francisco, California
Street Tree Resource Analysis

Scott E. Maco, E. Gregory McPherson, James R. Simpson, Paula J. Peper, Qingfu Xiao

Tree Numbers

Based on the FUF inventoried sample of 2,625 trees, there were an estimated 98,534 (±9,677) street trees in San Francisco (Table 8). Publicly managed trees accounted for 18.5% (18,234 ±2,779) of the total, while privately cared for trees comprised the remaining 81.5% (80,301 ±9,634). While the geographic distribution of population totals by district are important to understanding how resources should be allocated by district, it is important to understand that the land area of management districts were not equal size. Direct comparisons between districts, therefore, can only be made when relating the population proportions to district size.

Medium-sized broadleaf evergreen trees were the most prevalent tree type (Table 9). Public trees consisted of a much larger proportion of large-stature trees (42%) compared with private trees (24%). Ranging from 1-4% by population, coniferous and palm species were the least abundant when compared with broadleaved species.

Species Richness

A total of 115 different street tree species and cultivars were found throughout the city. Considered alone, city-managed trees were represented by 45 different taxa—close to the mean of 53 species

Table 8. Public and private street tree numbers with standard error (se) by district.

District	Public	*se*	Private	*se*	All	*se*	% of total population
1	3,384	±1,385	3,604	±1,741	6,988	±1,817	7.1
2	3,463	± 996	7,160	±1,690	10,624	±1,770	10.8
3	899	±475	2,724	±4,630	3,623	±1,380	3.7
4	-	-	7,115	±2,596	7,115	±2,770	7.2
5	2,094	±993	6,747	±1,071	8,841	±1,618	9.0
6	75	±306	9,421	±3,424	9,496	±3,382	9.6
7	2,780	±1,021	8,677	±3,619	11,457	±3,685	11.6
8	504	±294	12,636	±1,497	13,140	±1,494	13.3
9	1,482	±686	9,063	±1,403	10,546	±1,592	10.7
10a	774	±472	3,053	±2,582	3,827	±2,678	3.9
10b	279	±424	5,385	±2,456	5,664	±2,438	5.7
11	2,500	±848	4,714	±1,473	7,214	±1,624	7.3
Citywide Total	18,234	±2,779	80,301	±9,634	98,534	±9,677	100.0

Table 9. Citywide street tree numbers by mature size class and tree type.

Tree type	Public trees				Private trees				All trees			
	Small	Medium	Large	% of total	Small	Medium	Large	% of total	Small	Medium	Large	% of total
Broadleaf evergreen	1,570	6,880	2,823	62	15,750	31,590	9,572	71	17,320	38,470	12,394	69
Broadleaf deciduous	387	1,126	4,351	32	9,296	3,565	5,986	23	9,682	4,691	10,337	25
Coniferous	-	-	490	3	-	-	3,421	4	-	-	3,911	4
Palm	607	-	-	3	472	543	107	1	1,079	543	107	2
% of total	14	44	42	100	32	44	24	100	28	44	27	100

Table10. Top five species in each of the three street tree populations listed in order by percent (in parentheses) of total district tree numbers (see Appendix D).

	District	1st	2nd	3rd	4th	5th
Public Trees	1	Siberian elm (21.7)	London plane tree (14.1)	blue gum (13.0)	blackwood acacia (7.6)	myoporum (5.4)
	2	London plane tree (32.4)	Victorian box (17.6)	Indian laurel, ficus (9.5)	blackwood acacia (8.1)	olive (8.1)
	3	London plane tree (56.3)	Indian laurel, ficus (15.6)	blackwood acacia (12.5)	red-flowering gum (6.3)	Lombardy poplar (6.3)
	4	NA	NA	NA	NA	NA
	5	Victorian box (44.4)	New Zealand Christmas tree (11.1)	Indian laurel, ficus (11.1)	maiden hair tree (9.3)	blackwood acacia (5.6)
	6	silver dollar gum (50.0)	Indian laurel, ficus (50.0)	NA	NA	NA
	7	New Zealand Christmas tree (29.7)	red-flowering gum (24.3)	London plane tree (17.6)	glossy privet (8.1)	lemon bottlebrush (5.4)
	8	mayten tree (42.9)	Indian laurel, ficus (21.4)	cherry plum (21.4)	Brazilian pepper (14.3)	NA
	9	Chinese elm (59.1)	English hawthorn (9.1)	Brisbane box (6.8)	maiden hair tree (4.5)	small-leaf tristania (4.5)
	10a	London plane tree (55.6)	red-flowering gum (16.7)	Monterey pine (11.1)	Lombardy poplar (11.1)	New Zealand Christmas tree (5.6)
	10b	Chinese photinia (100)	NA	NA	NA	NA
	11	windmill palm (17.1)	small-leaf tristania (14.3)	New Zealand Christmas tree (11.4)	Chinese elm (10.0)	New Zealand tea tree (8.6)
	Citywide	London plane tree (16.6)	Victorian box (9.8)	New Zealand Christmas tree (8.4)	red-flowering gum (6.2)	Chinese elm (6.2)
Private Trees	1	Victorian box (19.4)	New Zealand Christmas tree (9.2)	cherry plum (7.1)	weeping bottlebrush (7.1)	myoporum (7.1)
	2	Indian laurel, ficus (17.6)	Victorian box (12.4)	southern magnolia (6.5)	blackwood acacia (5.9)	myoporum (4.6)
	3	Indian laurel, ficus (27.8)	New Zealand Christmas tree (15.5)	Victorian box (9.3)	London plane tree (8.2)	blackwood acacia (6.2)
	4	Monterey pine (11.2)	Japanese flowering cherry (10.1)	karo (9.5)	Autralian tea tree (8.9)	myoporum (8.9)
	5	mayten tree (14.9)	Indian laurel, ficus (12.6)	London plane tree (10.3)	Victorian box (9.8)	Japanese flowering cherry (8.6)
	6	Brisbane box (21.0)	Victorian box (11.1)	Indian laurel, ficus (9.9)	London plane tree (7.9)	evergreen pear (5.6)
	7	red-flowering gum (10.0)	Victorian box (10.0)	Japanese flowering cherry (9.5)	cherry plum (9.1)	lemon bottlebrush (6.1)
	8	blackwood acacia (9.7)	Victorian box (9.7)	cherry plum (6.8)	New Zealand Christmas tree (5.1)	red-flowering gum (4.6)
	9	cherry plum (12.3)	Australian peppermint willow (10.8)	Victorian box (5.9)	mayten tree (5.2)	Brisbane box (4.8)
	10a	London plane tree (38)	New Zealand Christmas tree (8.5)	lemon bottlebrush (7.0)	Bailey's acacia (5.6)	tulip tree (5.6)
	10b	Arbutus 'Marina' (36.3)	small-leaf tristania (16.3)	Indian hawthorn (11.9)	evergreen pear (5.2)	blackwood acacia (4.4)
	11	cajeput tree (15.2)	Japanese flowering cherry (12.1)	New Zealand tea tree (8.3)	Victorian box (6.1)	Australian peppermint willow (5.3)
	Citywide	Victorian box (8.3)	Indian laurel, ficus (6.4)	cherry plum (5.4)	London plane tree (4.3)	Japanese flowering cherry (4.3)
All Trees	1	Victorian box (11.6)	Siberian elm (10.5)	London plane tree (8.9)	New Zealand Christmas tree (6.8)	blue gum (6.3)
	2	Indian laurel, ficus (15)	Victorian box (14.1)	London plane tree (11.9)	blackwood acacia (6.6)	southern magnolia (5.7)
	3	Indian laurel, ficus (24.8)	London plane tree (20.2)	New Zealand Christmas tree(11.6)	blackwood acacia (7.8)	Victorian box (7.0)
	4	Monterey pine (11.2)	Japanese flowering cherry (10.1)	karo (9.5)	Autralian tea tree (8.9)	myoporum (8.9)
	5	Victorian box (18.0)	Indian laurel, ficus (12.3)	mayten tree (11.8)	London plane tree (7.9)	New Zealand Christmas tree (7.0)
	6	Brisbane box (20.9)	Victorian box (11.0)	Indian laurel, ficus (10.2)	London plane tree (7.9)	evergreen pear (5.5)
	7	red-flowering gum (13.4)	Victorian box (8.2)	New Zealand Christmas tree (7.5)	Japanese flowering cherry (7.2)	cherry plum (6.9)
	8	blackwood acacia (9.3)	Victorian box (9.3)	cherry plum (7.4)	New Zealand Christmas tree (4.9)	Indian laurel, ficus (4.7)
	9	cherry plum (10.5)	Australian peppermint willow (9.3)	Chinese elm (8.3)	Victorian box (5.1)	Brisbane box (5.1)
	10a	London plane tree (41.6)	New Zealand Christmas tree (7.9)	lemon bottlebrush (5.6)	Bailey's acacia (4.5)	tulip tree (4.5)
	10b	Arbutus 'Marina' (34.5)	small-leaf tristania (15.5)	Indian hawthorn (11.3)	Chinese photinia (4.9)	evergreen pear (4.9)
	11	cajeput tree (9.9)	New Zealand tea tree (8.4)	Japanese flowering cherry (7.9)	New Zealand Christmas tree (6.9)	windmill palm (5.9)
	Citywide	Victorian box (8.6)	London plane tree (6.6)	Indian laurel, ficus (6.1)	New Zealand Christmas tree (4.9)	cherry plum (4.6)

McPherson and Rowntree (1989) reported in their nationwide survey of 22 US cities. Private plantings alone consisted of 112 different taxa, a rich assemblage. This richness could be accounted for by the relatively mild climate, homeowner preference, and/or planning forethought.

Species Composition

Considered alone, the public tree population had only one tree, citywide, that exceeded the commonly held standard that no single species should exceed 10% of the population (Clark et al. 1997): London plane (16.6%) (Table 10). However, considering private and public trees together, no single species represented more than 10% of the citywide population, with, Victorian box (*Pittosporum undulatum*) being the most common street tree species, numbering 8,500 and accounting for 8.6% of the population. Examinations of management districts, however, belie this interpretation.

In nine of the 12 districts, one or more species represents 10% or more of the total street tree population, and four of these have species representing over 20%. In contrast, the public street tree population, has one or more trees representing over 15% in every district. Ten of these districts have a single species compromising 20% or more of the population, and 5 districts where a single species accounts for more than 50% of the trees. Considering private trees only, all but one district has at least one species accounting for more than 10% of the population and 4 districts where one species accounts for more than 20%. To this end, it is clear that both populations work dynamically to improve the compositional variety on a citywide basis.

Diversity

Using Simpson's diversity index number (C) denotes the probability that two trees, chosen at random, will be of the same species; the lower the number, the more diverse the population (Simpson 1949). For example, C=0.10 can be interpreted as having the equivalent of 10 species evenly distributed. Twenty species evenly distributed would have an index value of 0.05, equivalent to each species representing about 5% of the population.

Table 11 shows that citywide the three street tree populations were diverse. However, a complete understanding of street tree diversity must reflect concern for local vulnerability of districts (Sanders 1981). Considering only public trees, all districts had indices 0.10 or over and are potential subjects of concern. Catastrophic street tree loss in any one district, however, would be a function of both public and private populations, where only three districts had relatively low diversity and are a concern: 3 (China Town and North Beach), 10a and 10b (Potrero Hill, south to Bay View and Hunters Point). The predominant species in these districts were London plane in districts 3 and 10a and Arbutus 'Marina' in district 10b.

Table 11. Simpson's diversity index by district (C)

District	Public	Private	All
1	0.13	0.07	0.06
2	0.17	0.07	0.08
3	0.37	0.13	0.13
4	0.00	0.06	0.06
5	0.24	0.08	0.08
6	0.50	0.09	0.09
7	0.18	0.05	0.05
8	0.30	0.04	0.04
9	0.37	0.05	0.04
10a	0.36	0.17	0.20
10b	1.00	0.18	0.17
11	0.10	0.06	0.05
Citywide	0.06	0.03	0.03

Species Importance

Importance values are particularly meaningful to managers because they suggest a community's reliance on the functional capacity of particular species. In other words, importance value (IV) provides meaningful interpretation with respect to the degree a city might depend on particular urban trees insofar as their environmental benefits are concerned. This evaluation takes into account not only total numbers, but their canopy cover, leaf area and spatial distribution (frequency), providing a useful comparison to the total population distribution.

As a mean of four relative values, importance values (IVs), in theory, can range between 0 and 100; where an IV of 100 suggests total reliance on one species and an IV of 0 suggests no reliance. For the most abundant 1% of all street trees, IVs in San Francisco ranged between 14 (i.e., London plane [*Platanus* x *acerifolia*]) and one (e.g., maiden hair [*Ginko biloba*]) (Table 12).

Table 12. Importance Values (IV) calculated as the mean of tree numbers, leaf area, and canopy cover for the most abundant 1% of all street trees.

Species	# of trees	% of Tot.	Leaf area (m2)	% of Tot.	Canopy cover (m2)	% of Tot.	IV
Victorian box	8,500	11	692,346	10	204,856	10	10
London plane tree	6,514	8	880,537	13	441,686	21	14
Indian laurel, ficus	6,042	8	409,118	6	151,812	7	7
New Zealand Christmas tree	4,873	6	347,836	5	100,885	5	5
cherry plum	4,537	6	158,821	2	35,315	2	3
red-flowering gum	3,508	5	493,348	7	146,895	7	6
blackwood acacia	3,429	4	683,484	10	166,490	8	7
Japanese flowering cherry	3,413	4	166,627	2	34,243	2	3
Brisbane box	3,366	4	283,545	4	70,272	3	4
mayten tree	2,890	4	147,173	2	41,783	2	3
small-leaf tristania	2,852	4	70,630	1	24,013	1	2
Arbutus 'Marina'	2,731	4	21,789	0	8,875	0	1
lemon bottlebrush	2,157	3	81,273	1	26,907	1	2
evergreen pear	2,151	3	82,553	1	38,707	2	2
maiden hair tree	2,140	3	25,066	0	7,222	0	1
Chinese elm	2,040	3	661,778	10	135,051	6	6
Monterey pine	2,035	3	570,766	8	172,794	8	6
myoporum	1,992	3	194,189	3	61,569	3	3
southern magnolia	1,914	2	61,908	1	24,367	1	2
Australian peppermint willow	1,645	2	95,798	1	27,751	1	2
cajeput tree	1,549	2	33,582	0	7,742	0	1
olive	1,423	2	89,557	1	24,138	1	1
Indian hawthorn	1,415	2	4,986	0	2,552	0	1
Monterey cypress	1,292	2	317,522	5	117,388	6	4
glossy privet	1,258	2	57,764	1	21,793	1	1
karo	1,206	2	121,241	2	37,825	2	2
Total	76,872	100	6,753,236	100	2,132,934	100	100

Although Victorian box trees account for 11% of all trees, they account for only 10% of total leaf area and canopy cover. In contrast, London plane accounts for 8% of the population, but 13% and 21% of LA and CC, respectively, explaining its rank as the most important street tree in San Francisco. Indian laurel (*Ficus nitida*), blackwood acacia (*Acacia melanoxylon*), Chinese elm (*Ulmus parviflora*) and Monterey pine (*Pinus radiata*) all rank high in importance. Many of the benefits associated with San Francisco's street trees are associated with these species. Some species are very abundant but relatively unimportant. For example, cherry plum's (*Prunus cerasifera*) and lemon bottlebrush's *(Callistemon citrinus*) small mature size explain why these species account for relatively small percentages of total leaf area and canopy cover, despite being among the most abundant trees.

Street Trees Per Capita

Calculations of street trees per capita are important in determining how well forested a city is. The more residents and dense housing cities posses, the more need for trees to provide benefits. Citywide, San Francisco averaged 0.13 street trees per capita, or approximately one street tree for every eight residents, assuming a human population of 764,049 (U.S. Census Bureau 2003). Compared with 22 other cities across the U.S.—with a mean of slightly more than one tree per three resident (0.37)—San Francisco rates on the low end of the spectrum (McPherson and Rowntree 1989). However, at 104.2, San Francisco's ratio of street trees per street mile is on par with the California statewide average of 103.5 (Bernhardt and Swiecki 1993).

Stocking Level

The adequacy of street tree density must include all streetside tree plantings—both private and public (Richards 1992). Therefore, calculations of stocking level included all public and private street trees and vacant planting sites (Table 13) (Wray and Prestemon 1983; McPherson and Rowntree 1989).

Approximately 127,500 sites—56% of all street tree-planting sites—were unplanted, ranging from 28% to 74% among districts. Of these, 97.6% were void space requiring cutting out concrete and 2.4% (~5,000) were empty basin planting sites, where sidewalk cutouts exist but trees no longer exist. Sites available for medium trees (20-35 ft tall) predominated, but only 16% could accommodate large trees (> 35 ft tall).

Age Structure

The distribution of ages within a tree population influences present and future costs as well as the flow of benefits. An uneven-aged population allows managers to allocate annual maintenance costs uniformly over many years and assure continuity in overall tree canopy cover. An ideal distribution has a high proportion of new transplants to offset establishment-related mortality, while the percentage of older trees declines with age (Richards 1982/83).

The age structure for all public trees in San Francisco differed from the ideal only in having slightly fewer numbers of newly outplanted trees, where as the private tree population had many newly outplanted trees, but fewer trees classified as mature or old (Figure 2); the pattern for all trees reflected the dominating numbers of the private population.

Table 13. Available planting spaces based on observed void space and empty basins.

District	# of "void" spaces		# of "empty basins"		# of plantable spaces	% of zone unplanted	% available as tree size		
	Public	Private	Public	Private			Small	Medium	Large
1	1,214	6,105	37	331	7,687	52	45	53	2
2	983	4,165	94	47	5,288	33	37	45	17
3	618	4,830	0	112	5,560	61	12	41	47
4	0	19,199	0	835	20,034	74	40	57	4
5	0	3,257	39	155	3,451	28	20	75	5
6	299	12,300	37	411	13,047	58	2	41	57
7	338	23,477	38	225	24,078	68	10	79	12
8	144	4,752	72	468	5,436	29	26	59	15
9	539	5,357	67	606	6,570	38	26	53	21
10a	86	7,052	43	172	7,353	66	40	43	17
10b	319	10,531	0	239	11,089	66	33	61	6
11	786	15,929	214	1,071	18,000	71	28	67	5
Citywide Total	5,325	116,954	641	4,674	127,594	56	25	59	16

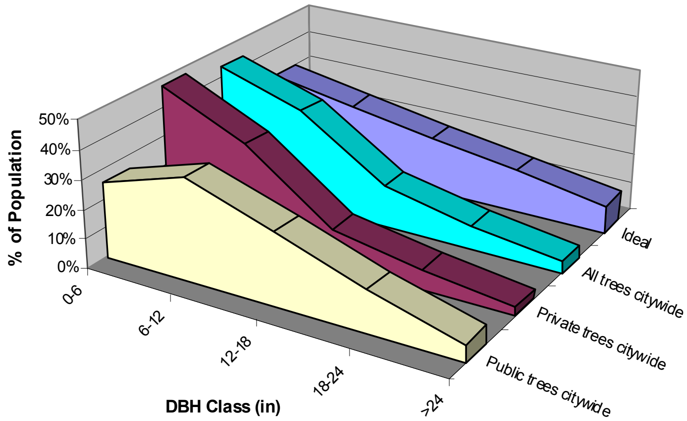


Figure 2. Ideal relative age distribution shown with San Francisco's different street tree populations.

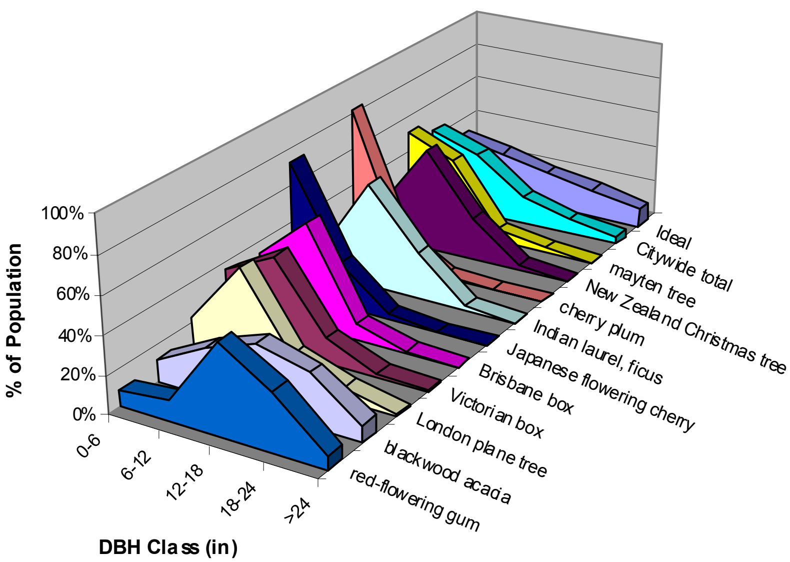


Figure 3. Relative age distribution for San Francisco's 10 most abundant street trees.

Age curves for different tree species help explain their relative importance and suggest how tree management needs may change as these species grow older. Figure 3 shows the importance of understanding relative age at different scales. Red-flowering gum (*Eucalyptus ficifolia*) and blackwood acacia (*Acacia melanoxylon*) exhibit largely mature populations. These trees have provided benefits over a long period of time, and because of their size associated with leaf area, are particularily important. Species that showed the most intense new planting numbers—cherry plum (*Prunus cerasifera*) and Japanese flowering cherry (*P. serrulata*)—are small-stature trees that likely will not provide the level of benefits larger species afford. Compounding the problem is that these species appear to be unproven in San Francisco with respect to longevity, where future benefits will be closely linked to the long-term health of these trees.

By management district, street trees appeared to lack large, mature trees when compared to the ideal (Figure 4). Varying by district, one interpretation is that tree functionality will increase as these populations mature; another is that the composition of species is such that mature large-stature trees will never be a component of the population given historical planting selections.

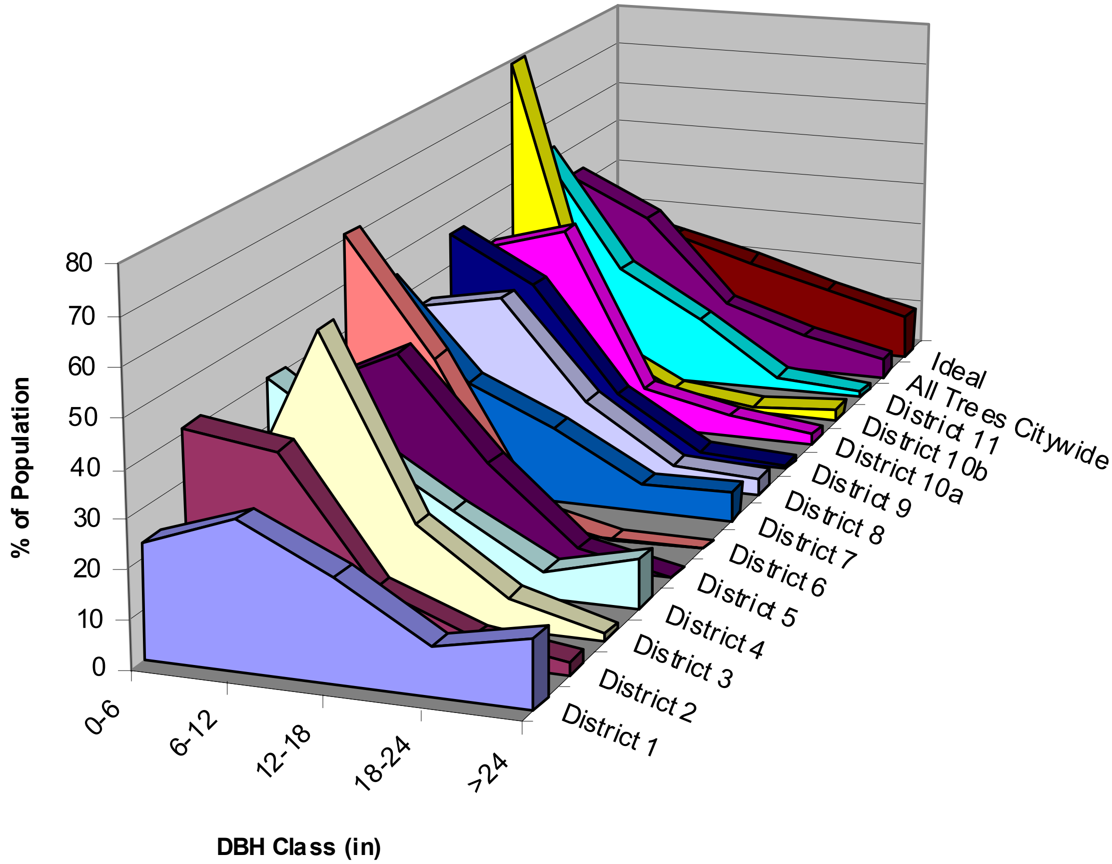


Figure 2. Relative age distribution of all street trees by management district.

Tree Condition

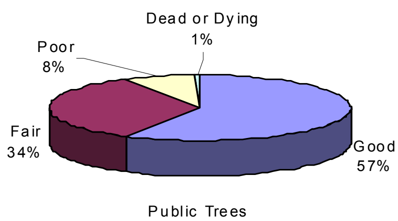
Tree condition indicates both how well trees are managed and their relative performance given site-specific conditions. Because of neglect and inconsistent management, street trees privately cared for are typically in poorer condition relative to those publicly managed (Bernstein 1981). In San Francisco, however, there was little difference between the citywide condition of public and private trees (Figure 5). Trees in "good" condition accounted for nearly 60% of the population, 30% were "fair", and 10% "poor or dead".

While, overall, street trees appeared healthy, examination of condition by district highlights some areas of localized concern (Table 14). For example, populations needing attention include private street trees in districts three, eight, nine, and eleven, while significant populations of poorly rated public trees can be found in districts nine, ten, and eleven.

The relative condition of tree species provides an indication of their suitability to local growing conditions, as well as their performance. Species with larger percentages of trees in good condition are likely to provide greater benefits at less cost than species with more trees in fair and poor condition. Abundant species rated as having the best condition, overall, are maiden hair, Brisbane box (*Tristania conferta*), southern magnolia (*Magnolia grandiflora*), Japanese flowering cherry (*Prunus serrulata*), London plane and cajeput (*Melaleuca quinquenervia*). These species are widely adapted to growing conditions throughout the city, whether publicly or privately cared for. Amongst abundant species having had the lowest condition ratings were Arbutus 'Marina', glossy privet (*Ligustrum lucidum*), myoporum (*Myoporum laetum*), and blackwood acacia (*Acacia melanoxylon*); all still planted today with some (e.g., Arbutus 'Marina) in large numbers as private trees.

Table 14. Condition of public and private street tree population by district (%).

	Public Trees				Private Trees			
Zone	Good	Fair	Poor	Dead or Dying	Good	Fair	Poor	Dead or Dying
1	47	45	9	0	42	50	6	2
2	69	24	7	0	76	16	7	1
3	59	31	6	3	27	42	31	0
4	-	-	-	-	54	39	4	3
5	54	35	9	2	61	31	6	1
6	50	50	0	0	85	12	3	0
7	64	32	4	0	67	25	4	3
8	36	57	7	0	50	38	10	1
9	61	25	14	0	50	28	19	3
10a	22	61	17	0	61	30	7	3
10b	0	43	57	0	25	44	24	7
11	76	23	0	1	72	22	5	1



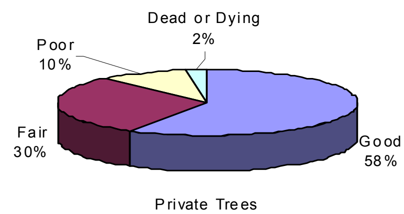


Figure 5. Citywide distribution of public and private street trees by condition class.

Location & Land-use

The majority of street trees in San Francisco were located in cutout spaces (~76%), an estimated 75,369 trees, citywide. Other locations included planting strips (11%), median trees (5%), and "other" (7%), with tree numbers estimated at 11,282, 5,281, and 6,602, respectively. As expected, the majority of median trees were publicly managed and the majority of "other" location (e.g., front yards) were privately managed.

Distribution of street trees by land-use followed the basic composition of the city, with the majority of trees split between single-family (36%) and multiple-family (31%) residential neighborhoods (Table 15). Private trees accounted for 90% of the estimated 35,707 trees adjacent to single-family housing, and 82% of trees where multi-family housing predominates. Public trees were proportionately more abundant in commercial/industrial, vacant, park-like, and institutional land uses.

Street Tree Conflicts

Assessing condition is one method of evaluating tree suitability. Another method includes assessing problems associated with street trees that lead to increased liability and infrastructure expenditures. By assessing the problems associated with street tree conflicts, managers will be better prepared to decrease the instances of future conflicts in new plantings, while targeting specific areas and species to abate current problems.

Amongst the two populations, public trees were associated with a higher percentage of conflicts relative to their numbers. The distribution of these conflicts can be seen in Figure 6.

Sidewalk Heave

Root-infrastructure conflicts are of particular concern to street tree managers due to the large costs associated with repairs. Sidewalk heave provides the additional burden associated with potential legal costs from trip and fall incidents. In San Francisco, where over 75% of all street trees are planted in sidewalk cutouts, the potential for these conflicts is tremendous. Fortunately, only 15% (14,764 trees) of all street trees were associated with heave greater than ½ inch (Figure 7).

Citywide, within the publicly managed population, there were an estimated 2,906 trees heaving sidewalk

Table 15. Distribution of all street trees by land-use.

District	Single-family residential (%)	Multi-family residential (%)	Commercial/ industrial (%)	Vacant (%)	Park (%)	Institutional (%)
1	24	31	1	0	34	10
2	9	70	6	0	0	14
3	2	39	59	0	0	0
4	37	3	6	0	55	0
5	13	68	6	0	1	12
6	0	57	40	3	0	1
7	71	14	14	0	0	0
8	55	27	0	0	10	8
9	54	24	7	0	0	15
10a	33	6	47	10	4	0
10b	25	1	15	0	0	58
11	75	3	0	0	8	13
Citywide total	36	31	13	1	9	10
# of trees citywide	35,707	30,878	12,569	732	8,396	10,252
% public trees citywide	10	18	34	36	37	13
% private trees citywide	90	82	66	64	63	87

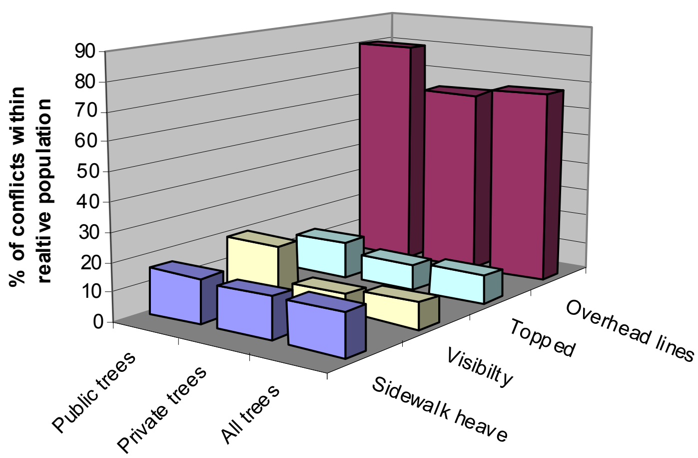


Figure 6. Distribution of conflict type by population.

beyond 0.5 inches: 2,059 (0.5-2 in), 692 (2-4 in), and 156 (>4 in). Heave for the private population was estimated at 11,858 trees: 7,618 (0.5-2 in), 3,560 (2-4 in), and 680 (>4 in). Considering the average tree-related sidewalk repair in California costs $480 per incident, public trees represented a potential $1,395,000 abatement cost, while costs for private trees could amount to $5,692,000 (McPherson 2000).

Five species accounted for 58% of the sidewalk heave problems associated with public street trees and 44% of private trees (Figure 8). This is significant because the level of heave was proportionately higher for most of these species compared with their numbers. For example, red-flowering gum (*Eucalyptus ficifolia*) and blacwood acacia (*Acacia melanoxylon*) accounted for only 6% and 4% of the public street tree population, respectively, while they represented two to three times this level in sidewalk damage. Private trees followed a similar pattern, where all species listed in Figure 7 had sidewalk conflicts at approximately twice the level of their numbers.

Overhead Utility Lines & Topping

Utility lines are a great source of conflict for tree managers. San Francisco is not afforded the benefits of underground utilities as newer cities are. As a result, approximately 80% of all public and 65% of

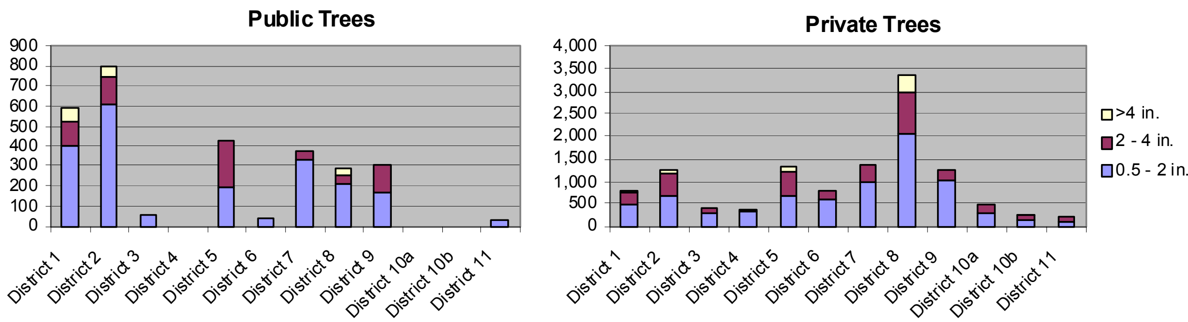


Figure 7. Number of trees associated with sidewalk heave (heave classes: 0.5-2 in, 2-4 in, > 4 in.).

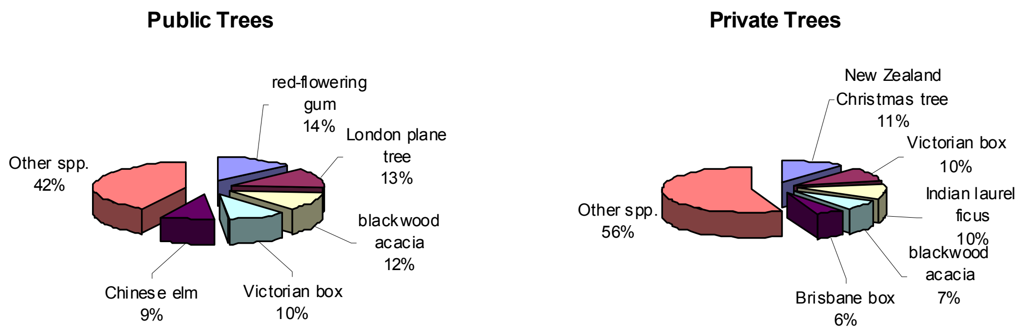


Figure 8. Percentage of sidewalk heave caused by top five offending species.

private street trees were planted under overhead utility lines. Forethought can limit these potential conflicts by planting small-stature trees, though the drawback is that smaller stature trees are limited not only in size attained, but in the amount of benefits they can provide as well. A combination of choosing the right tree and pruning existing large trees has limited these conflicts in San Francisco to an estimated 12% of the public tree population and 9% of the private trees, as inferred from the number of trees under powerlines that had crowns previously topped.

Visibility

Other conflicts associated with public safety are those that obstruct visibility to streetside signage or traffic at intersections. An estimated 9% of all street trees (8,905) were found to have visibility conflicts. At 18% (3,434), public trees were more than twice as likely to be associated with these conflicts than privately managed trees. Districts 1 and 7 accounted for disproportionately more visibility conflicts—21% (736) and 53% (1,465), respectively—amongst public tree populations.

The private tree population had an estimated 5,471 visibility conflicts, accounting for approximately 7% of the trees. Considering only these trees, districts 1, 3, and 6 had comparatively more conflicts—24% (882), 18% (505), and 17% (1,465)—within their respective populations.

Maintenance Needs

General

Understanding species distribution, age structure, and tree condition may aid in determining proper pruning cycle length, but it is important to understand the actual pruning and maintenance needs of the city trees. Not only will this provide clues to whether or not the pruning is adequate, but what level of risk and liability is associated with the city's street tree population.

Figure 9 displays the significant level of pruning needed by San Francisco's street trees. Overall, 19% of the trees needed pruning or removal. The private population, alone, had 20% of its trees requiring maintenance, 12.7% in the form of general pruning, 3.8% needing safety pruning, and 3.6% calling for removal. Within the publicly managed population,

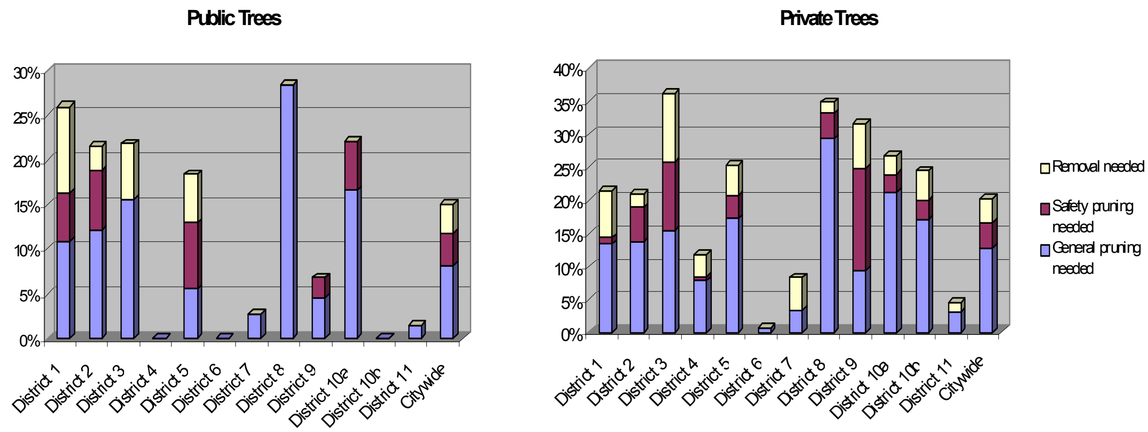


Figure 9. Percent of street tree population with maintenance needs.

trees were in slightly better shape overall, with 15% of the citywide population needing one of the three maintenance procedures: general pruning (8.1%), safety pruning (3.5%), and removal (3.2%). By district, however, these percentages were sometimes much higher. In five districts, public trees exceeded 20% of the population in need of pruning or removal; eight districts had private trees exceeding the same threshold. Numbers of all trees that needed general pruning are shown by district in Table 16.

Safety

A safety prune implies remedy for hazardous tree conditions. Since three-quarters of street trees are located in sidewalk cutouts, trees that were categorized with this maintenance need could be public safety liabilities. There were an estimated 650 public trees falling into this category and were primarily found in districts one, two, and five. Five species accounted for approximately 72% of these trees: Victorian box (25%), Indian laurel (14%), London plane (14%), blue gum (*Eucalyptus globulus*) (11%), and blackwood acacia (7%). Stands of blue gum in district one, Indian laurel in district 2, and Victorian box in district 5 accounted for the most numbers.

Private trees determined to need safety pruning (3,093) were broader in distribution, with the top five species accounting for 42% of all trees in this category: Indian laurel (12%), Australian peppermint willow (*Agonis flexuosa*) (10%), red-flowering gum (7%), evergreen pear (*Pyrus kawakamii*) (7%), and southern magnolia (*Magnolia grandiflora*) (7%). District 9 accounted for half the total, with an estimated 1,415 trees. Stands of particular concern are Indian laurel in district 3, red-flowering gum in district 8, and Australian peppermint willow, southern magnolia, jacaranda (*Jacaranda mimosifolia*), Brisbane box, and small-leaf tristania trees in district 9. Total numbers of trees that needed safety pruning for both populations are summed in Table 17.

Removals

Trees requiring removal indicate severe problems, although these are not necessary related to safety hazards. Numbers may simply reflect dead or dying new outplants, or they may reflect unmanageable tree defects and hazards. Regardless, trees classified as needing removal and replacement detract from aesthetic appearance at best, and represent substantial costs or public safety hazards at worst. Over 3% (~600 trees) of the public street tree population, and almost 4% (~2,900) of private trees, fell into this category.

Considering public trees only, myoporum (19%), blackwood acacia (17%), blue gum (12%), Indian laurel (11%), and maiden hair (8%) accounted for 67% of the total. Myoporum in district 1 and maidenhair trees in district 2 stood out as species with relatively high numbers. Private trees, again, followed a pattern of broader distribution, with the five most prevalent species accounting for 39% of trees requiring removal: Victorian box (12%), red-flowering gum (8%), blackwood acacia (8%), Indian laurel (6%), and olive (5%). Private tree stands of concern were Victorian box in district 3, Monterey pine in district 4, blackwood acacia in district 7, and evergreen pear in district 9. Total numbers of trees that required removal for both populations are summed in Table 18.

Table 16. *Total number of street trees in San Francisco needing general pruning by DBH class.*

District	DBH Class (in.)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
1	37	74	294	221	37	74	110	846
2	94	94	842	187	187	0	0	1,404
3	0	84	309	140	28	0	0	562
4	80	159	80	159	0	0	80	557
5	39	271	620	194	155	0	0	1,280
6	0	75	0	0	0	0	0	75
7	188	75	38	38	38	0	0	376
8	72	324	1,980	936	324	180	36	3,852
9	34	270	438	168	0	0	0	910
10a	43	258	344	43	86	0	0	774
10b	359	80	239	160	40	0	40	917
11	0	36	107	36	0	0	0	179
Citywide	944	1,799	5,292	2,281	895	254	266	11,730

Table 17. *Total number of street trees in San Francisco needing safety pruning by DBH class.*

District	DBH Class (in.)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
1	0	0	74	0	37	0	110	221
2	0	47	140	421	0	0	0	608
3	0	0	169	112	0	0	0	281
4	0	0	0	0	0	0	40	40
5	0	0	271	78	39	0	0	388
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	252	180	0	0	36	468
9	67	640	741	0	0	0	0	1,449
10a	43	43	43	0	0	0	0	129
10b	0	0	120	0	0	0	40	160
11	0	0	0	0	0	0	0	0
Citywide	110	730	1,810	791	76	0	226	3,743

Table 18. *Total number of street trees in San Francisco requiring removal by DBH class.*

District	DBH Class (in.)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
1	110	74	147	37	110	37	74	588
2	47	94	47	47	0	0	0	234
3	28	0	225	84	0	0	0	337
4	40	80	80	0	40	0	0	239
5	116	194	116	0	0	0	0	427
6	0	0	0	0	0	0	0	0
7	0	0	113	150	113	38	0	413
8	0	108	108	0	0	0	0	216
9	67	202	303	34	0	0	0	606
10a	0	0	86	0	0	0	0	86
10b	80	40	80	0	0	0	40	239
11	0	36	0	36	0	0	0	71
Citywide	488	826	1,304	387	263	74	113	3,457

City of San Francisco, California
Street Tree Resource Analysis

Scott E. Maco, E. Gregory McPherson, James R. Simpson, Paula J. Peper, Qingfu Xiao

Fiscal Year 2001-2002 Program Expenditures

Costs of Managing Public Trees

The Fiscal Year 2001-02 operating budget for the DPW Street Tree Program was approximately $3.432 million, with no abnormal expenditures recorded during the year (Sacamano 2003b). This amount represents 0.007% of the City's total operating budget ($4.773 billion) and $4.49 per person (764,049 pop.) (Table 19). Assuming the estimated public street tree population stands at 18,234, DPW spent $188 per tree on average during the fiscal year. The per tree expenditure is considerably greater than the 1997 mean value of $19 per tree reported for 256 California cities (Thompson and Ahern 2000). However, the per capita cost of $4.49 spent by DPW is considerably less than the statewide average of $5.35. An additional $1.345 million was spent on street tree-related matters by other city departments. These external expenditures involve hardscape repair and legal issues. Overall, about $4.777 million was spent on management of San Francisco's municipal street trees.

Costs of Managing Private Trees

Costs associated with private street tree management are not centralized in San Francisco and were more difficult to assess. Friends of the Urban Forest spends money to plant and maintain approximately half of the young private tree population, while developers, resident landowners, and tenants pay to plant and maintain the remaining trees. With many entities playing a role, these trees are often not treated equally. On one end of the spectrum there are owners who religiously contract services of commercial arborists on an annual basis whether the tree is in need of maintenance or not. Others neglect their trees to the point of not even meeting basic watering requirements. The majority of private trees fall somewhere in the middle: routine maintenance (watering, minor pruning, etc.) is carried out by adjacent residents through the trees' juvenile years and slows as the tree matures, leaving less frequent, but major activities (limbing, thinning, hazard abatement, etc.) to contracted services.

Table 19. San Francisco Fiscal Year 2001-02 expenditures on municipal trees.

Program expenditures	Total	$/tree	$/capita
Tree purchasing & planting	$ 28,798.80	$ 1.58	$ 0.04
Pruning	$ 2,261,497.02	$ 124.03	$ 2.96
Tree removals	$ 140,030.40	$ 7.68	$ 0.18
Stump removals	$ 35,798.40	$ 1.96	$ 0.05
Establishment/irrigation	$ 213,315.00	$ 11.70	$ 0.28
Pest and disease management	$ -	$ -	$ -
Inspection/permits	$ 434,551.57	$ 23.83	$ 0.57
Administration	$ 318,200.75	$ 17.45	$ 0.42
Program subtotal	$ 3,432,191.94	$ 188.23	$ 4.49
External expenditures			
Infrastructure repair	$ 264,201.60	$ 14.49	$ 0.35
Litigation/settlments	$ 1,080,796.00	$ 59.27	$ 1.41
External subtotal	$ 1,344,997.60	$ 73.76	$ 1.76
Grand total	$ 4,777,189.54	$ 261.99	$ 6.25

Table 20 displays the estimated expenditures by private parties to maintain street trees in each district. Citywide, this amounted to $2.7 million and ranged from $25 to $41 per tree among districts. The difference in these averages accounted for tree stature and age amongst districts, but survey data were not detailed enough to distinguish between other district factors such as tree care and species composition.

While the average cost of maintaining private trees, citywide, was $34, newly outplanted trees of less than three inches cost approximately $16 to maintain, whereas the largest trees cost nearly $68 (Figure 10). In general, costs increase as a function of increasing DBH. However, watering costs decreased with size and planting costs remained static at $6. The largest costs were associated with trimming followed by removal costs and infrastructure repair, respectively.

Table 20. Total costs of maintaining private trees categorized by DBH and district.

District	DBH (in)							Total	Avg./tree
	0-3	3-6	6-12	12-18	18-24	24-30	>30		
1	$11,891	$13,459	$45,860	$42,554	$9,325	$0	$2,597	$125,688	$35
2	$26,339	$39,070	$107,017	$33,787	$12,746	$3,211	$9,018	$231,189	$32
3	$1,600	$8,690	$64,143	$22,609	$10,601	$1,913	$1,966	$111,525	$41
4	$33,912	$15,323	$81,013	$55,888	$22,593	$7,840	$39,871	$256,444	$36
5	$8,714	$36,189	$120,830	$66,926	$18,274	$1,909	-	$252,847	$37
6	$33,431	$93,583	$140,191	$15,350	-	-	-	$282,560	$30
7	$46,423	$36,020	$68,777	$63,438	$25,936	$18,429	$31,015	$290,046	$33
8	$35,217	$48,200	$211,308	$118,814	$33,033	$18,978	$14,489	$480,048	$38
9	$22,646	$65,703	$151,445	$36,688	$10,786	$4,577	-	$291,855	$32
10a	$5,954	$21,806	$59,174	$16,652	$8,570	-	-	$112,157	$37
10b	$68,495	$7,017	$31,600	$12,084	$4,515	-	$11,232	$134,943	$25
11	$21,592	$30,352	$50,479	$21,845	$4,717	$6,035	-	$135,031	$29
Citywide	$316,213	$415,411	$1,131,839	$506,635	$161,096	$62,892	$110,189	$2,704,276	$34

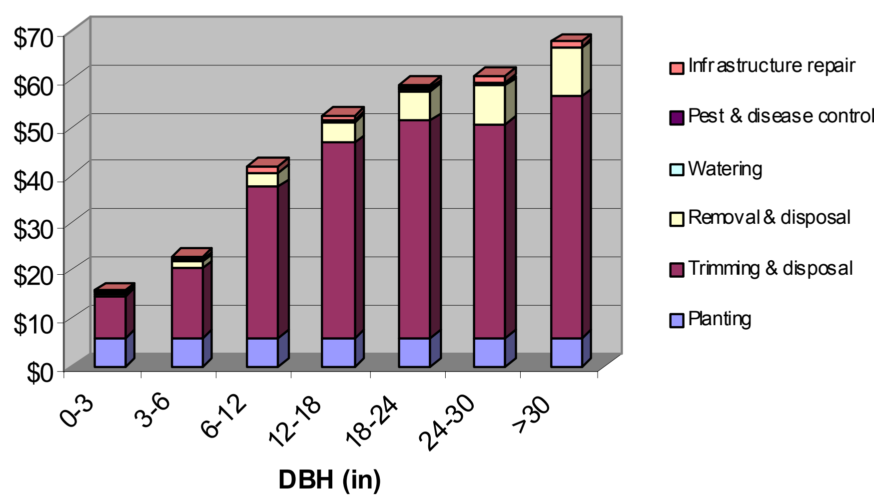


Figure 10. Average cost of maintaining private trees as a function of diameter class.

City of San Francisco, California
Street Tree Resource Analysis

Scott E. Maco, E. Gregory McPherson, James R. Simpson, Paula J. Peper, Qingfu Xiao

Introduction

Estimates of benefits and costs are initial approximations—as some benefits and costs are intangible or difficult to quantify (e.g., impacts on psychological health, crime, and violence). Also, limited knowledge about the physical processes at work and their interactions make estimates imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Tree growth and mortality rates are highly variable and benefits and costs depend on the specific conditions at the site (e.g., tree species, growing conditions, maintenance practices). Therefore, this method of quantification was not intended to account for every penny. Rather, this approach was meant to be a general accounting of the benefits produced by street trees in San Francisco; an accounting with an accepted degree of uncertainty that can nonetheless, provide a platform on which decisions can be made (Maco 2003).

Electricity and Natural Gas Results

Because of San Francisco's moderate summer weather, potential energy savings from trees are lower than those that would be found in warmer inland locations. Electricity and natural gas saved annually from both shading and climate effects totaled 651 MWh and 1,646 Mbtu, respectively, for a total retail savings of $85,742 (Table 21). Savings per tree for private trees were smaller than for public trees, averaging $0.77/tree compared to $1.30/tree for public trees, reflecting the fact that private trees were typically smaller in stature. Although public trees represented only 18.5% of total street tree numbers, they produced nearly 28% of the total energy benefit.

In general, larger trees produced larger benefits. Interestingly, differences in benefits between life forms (evergreen, deciduous, conifer, palm) were not dramatic (Table 22). The benefit of wind speed reduction (a climate effect) by non-deciduous species compensated for the detrimental effect of their winter shade.

Atmospheric Carbon Dioxide Reductions

Carbon dioxide reductions by trees are dependent on individual sequestration rates, emission offsets from energy saving, mortality, and the amount of maintenance the trees are provided. As Table 23

Table 21. Net annual energy savings produced by San Francisco street trees.

District	Public				Private				All		
	Electricity (MWh)	Natural Gas (Mbtu)	Total $	Avg. $/tree	Electricity (MWh)	Natural Gas (Mbtu)	Total $	Avg. $/tree	Total $	Avg. $/tree	% of Total
1	51.3	107.3	6,616	1.96	24.8	66.0	3,290	0.91	9,907	1.42	11.6
2	35.5	106.4	4,777	1.38	38.0	81.1	4,914	0.69	9,691	0.91	11.3
3	11.3	25.1	1,466	1.63	21.5	56.3	2,849	1.05	4,315	1.19	5.0
4	-	-	-	-	46.9	74.5	5,901	0.83	5,901	0.83	6.9
5	12.9	37.6	1,726	0.82	49.4	121.0	6,480	0.96	8,206	0.93	9.6
6	1.1	4.1	149	1.99	35.2	96.1	4,679	0.50	4,828	0.51	5.6
7	24.1	74.2	3,260	1.17	53.8	148.6	7,169	0.83	10,429	0.91	12.2
8	2.6	8.2	353	0.70	90.4	227.1	11,896	0.94	12,249	0.93	14.3
9	18.7	68.7	2,596	1.75	49.8	151.1	6,722	0.74	9,318	0.88	10.9
10a	7.2	0.9	842	1.09	24.8	47.4	3,171	1.04	4,013	1.05	4.7
10b	0.4	1.1	54	0.19	15.0	32.7	1,948	0.36	2,002	0.35	2.3
11	14.1	44.9	1,910	0.76	22.1	65.4	2,973	0.63	4,882	0.68	5.7
Citywide	179.1	478.3	23,749	1.30	471.9	1,167.5	61,993	0.77	85,742	0.87	100

Table 22. Average per tree energy benefit ($) by tree type.

Tree Type	Public	Private	All
Lg. Broadleaf Evergreen	1.79	1.26	1.38
Med. Broadleaf Evergreen	0.87	0.73	0.76
Sm. Broadleaf Evergreen	0.40	0.33	0.33
Lg. Conifer	2.11	1.51	1.59
Med. Conifer	-	-	-
Sm. Conifer	-	-	-
Lg. Deciduous	1.78	1.02	1.34
Med. Deciduous	2.61	1.28	1.60
Sm. Deciduous	0.52	0.51	0.51
Lg. Palm	-	2.04	2.04
Med. Palm	-	1.09	1.09
Sm. Palm	0.24	0.24	0.24
Citywide total	1.30	0.77	0.87

shows, the amount of CO_2 benefits produced was dependent on species present and their age. Citywide, public trees reduced energy plant CO_2 emissions by approximately 71 tons. And through net sequestration, the same trees produced savings of an additional 611 tons. Private trees had an annual net sequestration rate of approximately 1,660 tons and reduced emissions by another 186 tons. The combination of these savings was valued at $37,907 annually. On average, CO_2 benefits for publicly managed trees were 65% higher than private trees on a per tree basis.

Total sequestered CO_2 was nearly nine times greater than reduced CO_2 emission. This can be explained by the fact that San Francisco has a relatively clean mix of fuels that produce energy to heat and cool buildings, influencing potential CO_2 emission reductions. Further, San Francisco's climate is moderated by the Pacific Ocean, resulting in relatively small cooling and heating loads compared to inland California locations.

Air Quality Improvement

Net Avoided Emissions Result

Energy savings resulted in avoided air pollutant emissions of nitrogen dioxide (NO_2), small particulate matter (PM_{10}), and volatile organic compounds (VOCs) (Table 24). More significant were biogenic volatile organic compound (BVOC) emissions. The net cost of avoided and BVOC emissions was valued at approximately $135,000 (Table 24). This result is due to the relatively small effect trees have on energy use in San Francisco, where the climate is mild year-round. Many species have high BVOC emission rates, and these emissions are substantially greater than avoided emissions. Hence, the average cost per tree is $1.37.

On an annual basis, public trees emitted BVOC at a slightly higher rate than private trees, averaging 0.27 lbs/tree ($2.14) and 0.15 lbs/tree ($1.22), respectively (Table 25). This difference can be attributed to the larger size of high emitters in the public population—greater leaf mass for these trees results in higher emission rates. Species—those representing 1% or more of the population—that were primarily responsible for these BVOC emission rates were red flowering gum, New Zealand Christmas tree, blackwood acacia, Brisbane box, Monterey cypress, blue gum, and Indian laurel. Their emission rates were 3 to 18 times greater than values for "other" trees. The total cost of emissions was valued at $39,177 for public trees and $96,601 for private trees.

Deposition and Interception Result

Annual pollutant uptake by tree foliage (pollutant deposition and particulate interception) was 12.5 tons

Table 23. Net CO_2 reductions of San Francisco street trees by district.

District	Public				Private				All		
	Total CO_2 sequestered less releases (lbs)	Total CO_2 emissions avoided (lbs)	Total $	Avg. $/tree	Total CO_2 sequestered less releases (lbs)	Total CO_2 emissions avoided (lbs)	Total $	Avg. $/tree	Total $	Avg. $/tree	% of Total
1	274,115	40,439	2,359	0.70	137,413	19,573	1,177	0.33	3,537	0.51	9%
2	230,662	27,965	1,940	0.56	275,768	29,971	2,293	0.32	4,233	0.40	11%
3	75,005	8,906	629	0.70	162,786	16,980	1,348	0.49	1,978	0.55	5%
4	-	-	-	-	450,298	36,966	3,654	0.51	3,654	0.51	10%
5	86,085	10,140	722	0.34	272,218	38,930	2,334	0.35	3,055	0.35	8%
6	5,806	836	50	0.67	283,871	27,732	2,337	0.25	2,387	0.25	6%
7	204,148	19,016	1,674	0.60	454,622	42,442	3,728	0.43	5,402	0.47	14%
8	12,072	2,054	106	0.21	613,546	71,250	5,136	0.41	5,242	0.40	14%
9	140,192	14,736	1,162	0.78	281,838	39,287	2,408	0.27	3,570	0.34	9%
10a	72,870	5,690	589	0.76	150,475	19,554	1,275	0.42	1,864	0.49	5%
10b	2,303	321	20	0.07	106,970	11,858	891	0.17	911	0.16	2%
11	117,950	11,080	968	0.39	130,081	17,436	1,106	0.23	2,074	0.29	5%
Citywide	1,221,207	141,183	10,218	0.56	3,319,886	371,982	27,689	0.34	37,907	0.38	100%

Table 24. Annual avoided pollutant emissions of San Francisco street trees by district.

District	Public					Private					All		
	NO_2 (lbs)	PM_{10} (lbs)	VOCs (lbs)	Total ($)	Avg. $/tree	NO_2 (lbs)	PM_{10} (lbs)	VOCs (lbs)	Total ($)	Avg. $/tree	Total $	Avg. $/tree	% of Total
1	21.7	2.4	-1,445	-11,150	-3.29	11.8	1.3	-435	-3,316	-0.92	-14,466	-2.07	11%
2	17.6	1.9	-627	-4,769	-1.38	16.7	1.8	-943	-7,252	-1.01	-12,022	-1.13	9%
3	4.9	0.5	-244	-1,871	-2.08	10.2	1.1	-548	-4,210	-1.55	-6,081	-1.68	4%
4	-	-	0	-	-	18.5	2.1	-1,455	-11,254	-1.58	-11,254	-1.58	8%
5	6.4	0.7	-387	-2,985	-1.43	22.7	2.5	-1,132	-8,686	-1.29	-11,671	-1.32	9%
6	0.6	0.1	-56	-436	-5.81	17.2	1.8	-1,149	-8,869	-0.94	-9,305	-0.98	7%
7	12.3	1.3	-1,438	-11,175	-4.02	26.0	2.8	-2,018	-15,608	-1.80	-26,783	-2.34	20%
8	1.3	0.1	-62	-478	-0.95	42.0	4.5	-2,578	-19,866	-1.57	-20,344	-1.55	15%
9	10.1	1.1	-41	-240	-0.16	25.4	2.7	-1,032	-7,883	-0.87	-8,123	-0.77	6%
10a	2.0	0.3	-269	-2,090	-2.70	10.3	1.1	-364	-2,767	-0.91	-4,857	-1.27	4%
10b	0.2	0.0	-17	-133	-0.48	6.7	0.7	-423	-3,260	-0.61	-3,393	-0.60	3%
11	7.3	0.8	-405	-3,113	-1.25	11.1	1.2	-491	-3,760	-0.80	-6,873	-0.95	5%
Citywide	84.5	9.1	-4,991	-38,440	-2.11	218.8	23.6	-12,567	-96,731	-1.20	-135,170	-1.37	100%

Table 25. Highest BVOC emitters in San Francisco.

Public			Private			All		
Species	Avg./tree ($)	Total cost ($)	Species	Avg./tree ($)	Total cost ($)	Species	Avg./tree ($)	Total cost ($)
blue gum	-15.58	-6,871	red-flowering gum	-8.36	-19,801	red-flowering gum	-8.39	-29,424
red-flowering gum	-8.45	-9,622	blackwood acacia	-3.01	-8,060	New Zealand Christmas tree	-3.33	-16,162
New Zealand Christmas tree	-4.12	-6,337	New Zealand Christmas tree	-2.94	-9,825	blackwood acacia	-3.13	-10,708
Brisbane box	-3.74	-1,639	Brisbane box	-2.69	-7,881	Brisbane box	-2.83	-9,520
blackwood acacia	-3.45	-2,647	Indian laurel	-1.77	-9,097	Indian laurel, ficus	-1.89	-11,374
All other trees	-0.86	-12,060	All other trees	-0.67	-41,937	All other trees	-0.75	-58,591
Citywide	-2.14	-39,177	Citywide	-1.22	-96,601	Citywide	-1.37	-135,778

Table 26. Annual pollutant uptake of San Francisco street trees by district.

District	Public					Private					All		
	O_3 (lbs)	NO_2 (lbs)	PM_{10} (lbs)	Total ($)	Avg. $/tree	O_3 (lbs)	NO_2 (lbs)	PM_{10} (lbs)	Total ($)	Avg. $/tree	Total $	Avg. $/tree	% of Total
1	1,209.1	552.8	980.7	20,676	6.11	363.8	169.3	325.2	6,480	1.80	27,156	3.89	14%
2	446.7	199.9	396.7	7,877	2.27	592.3	269.1	525.1	10,467	1.46	18,344	1.73	10%
3	110.0	47.6	103.4	1,973	2.19	219.3	102.7	222.2	4,117	1.51	6,090	1.68	3%
4	-	-	-	-	-	1,144.8	538.0	981.7	20,101	2.83	20,101	2.83	11%
5	146.1	68.6	142.4	2,699	1.29	735.8	333.2	631.3	12,830	1.90	15,530	1.76	8%
6	13.3	6.2	12.4	241	3.21	265.4	124.1	293.8	5,176	0.55	5,416	0.57	3%
7	331.6	154.7	293.9	5,889	2.12	1,102.0	515.3	938.4	19,279	2.22	25,168	2.20	13%
8	35.4	16.6	32.7	639	1.27	1,454.0	672.6	1,274.3	25,668	2.03	26,307	2.00	14%
9	478.7	211.9	346.5	7,805	5.27	667.8	306.4	593.5	11,835	1.31	19,641	1.86	10%
10a	245.8	105.0	181.3	4,007	5.18	277.8	120.5	248.4	4,883	1.60	8,890	2.32	5%
10b	1.4	0.7	2.5	35	0.12	251.0	117.4	226.4	4,491	0.83	4,526	0.80	2%
11	337.4	155.5	270.6	5,755	2.30	371.1	170.7	313.6	6,453	1.37	12,207	1.69	6%
Citywide	3,355.4	1,519.5	2,762.9	57,596	3.16	7,445.0	3,439.3	6,573.9	131,779	1.64	189,375	1.92	100%

of combined uptake. The total value of this benefit for all street trees was $189,375, or about $1.92 per tree (Table 26). Again, because of larger total leaf area per tree, public trees produced an uptake benefit that was nearly double the per tree average of private trees—$3.16 vs. $1.64, respectively. In both populations, ozone uptake accounted for approximately 43% of the total benefit, while PM_{10} (37%) and NO_2 (20%) accounted for the remainder.

Net air quality savings (Table 27) were due to pollutant uptake, since the amount of avoided pollutants were insignificant and BVOC emissions were negative. As a result, net savings of all pollutants taken together, for both populations, were valued at $42,719. Savings per tree averaged $0.97/public tree and $0.31/private tree on an annual basis.

Stormwater Runoff Reductions

The ability of San Francisco's street trees to intercept rain was substantial, estimated at 13,270,050 ft^3 annually (Table 28). The total value of this benefit to the city was $467,000 when all street trees were considered. These values ranged by district and population subset. Average per tree values for public trees ranged between less than a dollar to over $9, averaging $6.44, based on 1,370 gals per tree intercepted. The low value was limited to district 10b, where the only public trees present were an estimated 270 small Chinese photinia (*Photinia fraseri*). Private trees followed the general trend of providing a slightly reduced benefit due to their smaller stature, varying between $2 and $7 dollars and averaging $4.35 citywide based on an average interception of 925 gals.

When averaged throughout the entire street tree population, certain species were much better at reducing stormwater runoff than others (Table 29). Leaf type and area, branching pattern and bark, as well as tree size and shape all affected the amount of precipitation trees can intercept and hold to avoid direct runoff. Trees such as blackwood acacia and Monterey pine performed this function very well, while cherry plum and arbutus were among the worst performers.

Property Values and Other Benefits

The estimated total annual benefit associated with property value increase and other less tangible benefits was approximately $6.9 million, or $70/tree on average (Table 30). This value appeared on par with other California communities where median home values were high. For example, street trees in Santa Monica averaged $65/tree in annual property value increases (McPherson and Simpson 2002). In San Francisco, public street trees were responsible for 26% of this benefit, having had per tree averages between $21 and $276; private trees averaged $64, but ranged by district between $30 and $99.

Tree species adding the largest amount of leaf area over the course of a year tend to produce the highest average annual benefit. London plane ($146/tree), blackwood acacia ($110/tree), and Chinese elm

Table 27. Net annual air pollutant benefit of San Francisco street trees by district.

District	Public		Private		All	
	Total ($)	Avg. $/tree	Total ($)	Avg. $/tree	Total ($)	Avg. $/tree
1	8,380.51	2.48	2,560.57	0.71	10,941.07	1.57
2	3,350.73	0.97	2,930.59	0.41	6,281.32	0.59
3	359.58	0.40	-535.15	-0.20	-175.57	-0.05
4	-	-	6,460.45	0.91	6,460.45	0.91
5	-611.49	-0.29	3,828.84	0.57	3,217.35	0.36
6	-224.31	-2.99	-4,244.26	-0.45	-4,468.57	-0.47
7	-5,823.96	-2.09	1,591.55	0.18	-4,232.41	-0.37
8	85.48	0.17	3,684.40	0.29	3,769.88	0.29
9	7,548.86	5.09	3,076.62	0.34	10,625.49	1.01
10a	2,608.09	3.37	2,683.89	0.88	5,291.98	1.38
10b	-102.63	-0.37	755.30	0.14	652.67	0.12
11	2,169.26	0.87	2,185.77	0.46	4,355.03	0.60
Citywide	17,740.12	0.97	24,978.56	0.31	42,718.67	0.43

Table 28. Annual stormwater reduction benefits of San Francisco street trees by district.

District	Public			Private			All			
	Rainfall interception (ft^3)	Total $	Avg. $/tree	Rainfall interception (ft^3)	Total $	Avg. $/tree	Rainfall interception (ft^3)	Total $	Avg. $/tree	% of Total
1	871,944	30,656	9.06	559,527	19,672	5.46	1,431,471	50,328	7.20	11%
2	583,283	20,507	5.92	861,983	30,306	4.23	1,445,266	50,813	4.78	11%
3	151,921	5,341	5.94	471,358	16,572	6.08	623,280	21,914	6.05	5%
4	-	-	-	1,396,260	49,090	6.90	1,396,260	49,090	6.90	11%
5	318,074	11,183	5.34	867,764	30,509	4.52	1,185,838	41,692	4.72	9%
6	16,194	569	7.59	679,159	23,878	2.53	695,353	24,448	2.57	5%
7	476,811	16,764	6.03	1,200,108	42,194	4.86	1,676,919	58,958	5.15	13%
8	59,816	2,103	4.17	1,904,855	66,972	5.30	1,964,671	69,075	5.26	15%
9	343,536	12,078	8.15	821,294	28,875	3.19	1,164,829	40,954	3.88	9%
10a	147,393	5,182	6.70	309,594	10,885	3.57	456,987	16,067	4.20	3%
10b	3,581	126	0.45	389,107	13,680	2.54	392,688	13,806	2.44	3%
11	367,054	12,905	5.16	469,433	16,505	3.50	836,487	29,410	4.08	6%
Citywide	3,339,606	117,415	6.44	9,930,442	349,139	4.35	13,270,050	466,554	4.73	100%

($361/tree) were on the high end, while New Zealand Christmas tree ($40/tree), evergreen pear ($23/tree), and maidenhair tree ($23/tree) averaged the least benefits (Table 31). Consequently, districts dominated by stands of fast growing trees had property values increasing upwards of $100/tree, while those with slower growing trees produced benefits in the $60-$70/tree range.

Total Annual Net Benefits and Benefit-Cost Ratio (BCR)

During the 2001-2002 fiscal year, publicly maintained street trees were estimated to produce benefits that ranged from $1.67 to $2.27 million (Table 32). During the same time, expenditures were estimated to range from $4.05 to $5.51 million. Net annual benefits for the public street trees were

Table 29. Annual stormwater benefit of significant San Francisco street trees.

Species	Total ($)	% of citywide of population	% of total ($)	Avg. $/tree
Victorian box	49,056	8.6	10.5	5.77
London plane tree	26,688	6.6	5.7	4.10
Indian laurel, ficus	27,426	6.1	5.9	4.54
New Zealand Christmas tree	24,147	4.9	5.2	4.96
cherry plum	1,270	4.6	0.3	0.28
red-flowering gum	35,028	3.6	7.5	9.98
blackwood acacia	46,900	3.5	10.1	13.68
Japanese flowering cherry	1,376	3.5	0.3	0.40
Brisbane box	18,721	3.4	4.0	5.56
mayten tree	10,249	2.9	2.2	3.55
small-leaf tristania	4,704	2.9	1.0	1.65
Arbutus 'Marina'	1,385	2.8	0.3	0.51
lemon bottlebrush	5,592	2.2	1.2	2.59
evergreen pear	5,041	2.2	1.1	2.34
maiden hair tree	708	2.2	0.2	0.33
Chinese elm	21,628	2.1	4.6	10.60
Monterey pine	40,171	2.1	8.6	19.74
myoporum	13,467	2.0	2.9	6.76
southern magnolia	4,012	1.9	0.9	2.10
Australian peppermint willow	6,754	1.7	1.5	4.11
cajeput tree	2,267	1.6	0.5	1.46
olive	6,211	1.4	1.3	4.36
Indian hawthorn	289	1.4	0.1	0.20
Monterey cypress	20,544	1.3	4.4	15.91
glossy privet	3,853	1.3	0.8	3.06
karo	8,515	1.2	1.8	7.06
Other street trees	80,554	22.0	17.3	3.72
Citywide total	466,554	100	100	4.73

Table 30. Total annual increases in property value from San Francisco street trees by district.

District	Public				Private				All			
	Total $	% of citywide tree population	% of total ($)	Avg. $/tree	Total $	% of citywide tree population	% of total ($)	Avg. $/tree	Total $	% of citywide tree population	% of total ($)	Avg. $/tree
1	343,665	18.6	19.1	102	219,866	4.5	4.3	61	563,530	7.1	8.2	81
2	319,909	19.0	17.8	92	439,333	8.9	8.6	61	759,242	10.8	11.0	71
3	119,221	4.9	6.6	133	191,557	3.4	3.8	70	310,779	3.7	4.5	86
4	-	-	-	-	438,481	8.9	8.6	62	438,481	7.2	6.3	62
5	125,953	11.5	7.0	60	553,861	8.4	10.8	82	679,814	9.0	9.8	77
6	6,334	0.4	0.4	85	494,070	11.7	9.7	52	500,405	9.6	7.2	53
7	175,498	15.2	9.7	63	459,793	10.8	9.0	53	635,291	11.6	9.2	55
8	22,936	2.8	1.3	46	897,748	15.7	17.6	71	920,685	13.3	13.3	70
9	409,573	8.1	22.7	276	648,775	11.3	12.7	72	1,058,348	10.7	15.3	100
10a	98,440	4.2	5.5	127	301,536	3.8	5.9	99	399,976	3.9	5.8	105
10b	5,891	1.5	0.3	21	162,876	6.7	3.2	30	168,766	5.7	2.4	30
11	174,819	13.7	9.7	70	298,998	5.9	5.9	63	473,817	7.3	6.9	66
Citywide	1,802,240	100	100	99	5,106,896	100	100	64	6,909,136	100	100	70

estimated to range from -$2.38 to -$3.23 million, with the average being -$2.81 million. The net benefit per tree was -$153.87 and the BCR was 0.41. The net benefit per capita ranged from $-3.11 to $-4.23.Privately managed trees were estimated to yield $4.90 to $6.24 million in benefits annually, while management costs ranged between $2.38 and $3.03 million. Net annual benefits for privately managed street trees were estimated to fall between $2.52 and $3.21 million, with a mean of $2.85 million. This amounted to an average net benefit of $35.69 per privately maintained tree and the BCR was 2.06. The net benefit per capita ranged from $3.30 to $4.20. The private trees returned $2.06 to the community for every $1 spent on their management, whereas public trees returned $0.41 for every dollar spent.

In its entirety the street tree population was estimated to produce annual benefits ranging from $6.80 to $8.28 million at costs estimated to range between $6.75 and $8.22 million, annually. Net benefits were small, estimated to range between $54,000 and $66,000 Hence, the BCR was 1.01 and the net annual benefit per tree was estimated to be $0.61. The net benefit per capita ranged from $0.07 to $0.9. Essentially, costs equaled quantifiable benefits.

San Francisco street trees have beneficial effects on the environment (Table 33). Approximately 8% of the annual benefits were attributed to environmental values. Of this, stormwater interception—a benefit that is locally realized—was 75% of this value, a substantial sum of about $5 per tree. Net air quality

Table 31. Annual property value benefit produced by significant San Francisco street trees.

Species	Total ($)	% of Citywide of Population	% of Total ($)	Avg. $/tree
Victorian box	471,705	8.6	6.8	55.49
London plane tree	948,027	6.6	13.7	145.53
Indian laurel, ficus	354,580	6.1	5.1	58.68
New Zealand Christmas tree	193,887	4.9	2.8	39.79
cherry plum	256,841	4.6	3.7	56.61
red-flowering gum	236,633	3.6	3.4	67.45
blackwood acacia	377,147	3.5	5.5	109.99
Japanese flowering cherry	248,469	3.5	3.6	72.80
Brisbane box	276,377	3.4	4.0	82.11
mayten tree	109,109	2.9	1.6	37.76
small-leaf tristania	59,242	2.9	0.9	20.77
Arbutus 'Marina'	42,190	2.8	0.6	15.45
lemon bottlebrush	26,960	2.2	0.4	12.50
evergreen pear	49,606	2.2	0.7	23.06
maiden hair tree	45,296	2.2	0.7	21.16
Chinese elm	735,874	2.1	10.6	360.69
Monterey pine	347,070	2.1	5.0	170.59
myoporum	131,786	2.0	1.9	66.16
southern magnolia	80,972	1.9	1.2	42.31
Australian peppermint willow	62,430	1.7	0.9	37.95
cajeput tree	102,314	1.6	1.5	66.05
olive	65,588	1.4	0.9	46.08
Indian hawthorn	17,743	1.4	0.3	12.54
Monterey cypress	187,392	1.3	2.7	145.09
glossy privet	59,749	1.3	0.9	47.49
karo	59,970	1.2	0.9	49.72
Other Street Trees	1,362,177	22	19.7	62.89
Citywide total	6,909,137	100	100	70.12

Table 32. Benefit-Cost summary with high and low estimates based on population standard error.

	Public			Private			All		
	low	mean	hi	low	mean	hi	low	mean	hi
Trees	15,455	18,234	21,013	70,667	80,301	89,935	88,857	98,534	108,21
Benefit/tree	$ 108	$ 108	$ 108	$ 69	$ 69	$ 69	$ 77	$ 77	$ 7
Total Benefit	$ 1,670,995	$ 1,971,460	$ 2,271,926	$ 4,902,170	$ 5,570,480	$ 6,238,791	$ 6,801,115	$ 7,541,792	$ 8,282,47
Cost/tree	$ 262	$ 262	$ 262	$ 34	$ 34	$ 34	$ 76	$ 76	$ 7
Total Cost	$ 4,049,055	$ 4,777,126	$ 5,505,196	$ 2,380,065	$ 2,704,538	$ 3,029,011	$ 6,746,912	$ 7,481,687	$ 8,216,46
Net Benefit	$ (2,378,061)	$ (2,805,666)	$ (3,233,270)	$ 2,522,105	$ 2,865,943	$ 3,209,780	$ 54,203	$ 60,106	$ 66,00
BCR	0.41	0.41	0.41	2.06	2.06	2.06	1.01	1.01	1.
Net/tree	$ (153.87)	$ (153.87)	$ (153.87)	$ 35.69	$ 35.69	$ 35.69	$ 0.61	$ 0.61	$ 0.6
Net/capita	$ (3.11)	$ (3.67)	$ (4.23)	$ 3.30	$ 3.75	$ 4.20	$ 0.07	$ 0.08	$ 0.0

improvements and CO_2 benefits accounted for approximately 0.05% each, while energy benefits were 1% of the total. As in most cities, annual increases in property value were the largest benefits produced by street trees in San Francisco, accounting for an annual value of $6.9 million.

On average, privately maintained trees along the streets of San Francisco did not perform as well as publicly cared for trees, providing about 64% of the net benefits on a per tree basis. The proportionately larger trees in the public tree population, along with intensive care and management, accounted for the increased level of benefits. However, with only the private trees affecting a positive BCR, this segment appears to be a valuable investment for the community.

While species varied in their ability to produce benefits, common characteristics of trees within tree type classes aid in identifying the most beneficial street trees in San Francisco (Figure 11). Within tree types, larger trees generally produced the most benefits; the anomaly in San Francisco was medium-stature deciduous trees. Where total benefits are a concern, these trees provide the highest average return for the investment dollar, primarily due to increased property value benefits. Conversely, where environmental benefits are the primary concern, large conifers provide the highest level of average benefits. Conifers provide substantial stormwater interception and higher than average atmospheric CO_2 reduction.

The values represented in Figure 12 reflect the presence of specific tree types and population age.

Table 33. Benefits and costs summary of San Francisco street tree populations.

Benefit	Public			Private			All		
	Total ($)	$/capita	$/tree	Total ($)	$/capita	$/tree	Total ($)	$/capita	$/tree
Energy	23,749	0.03	1.30	61,993	0.08	0.77	85,742	0.11	0.87
CO_2	10,218	0.01	0.56	27,689	0.04	0.34	37,907	0.05	0.38
Air Quality	17,740	0.02	0.97	24,978	0.03	0.31	42,718	0.05	0.43
Stormwater	117,415	0.15	6.44	349,139	0.45	4.35	466,554	0.60	4.73
Property Increase	1,802,240	2.32	98.84	5,106,898	6.57	63.60	6,909,138	8.90	70.12
Total benefits	1,971,362	2.58	107.62	5,570,697	7.29	69.11	7,542,059	9.87	76.54
Total costs	4,777,190	6.25	261.99	2,704,276	3.54	33.68	7,481,466	9.79	75.93
Net benefits	- 2,805,828	- 3.67	- 154.38	2,866,421	3.75	35.43	60,593	0.08	0.61
Benefit-cost ratio	0.41	0.41	0.41	2.06	2.06	2.05	1.01	1.01	1.01

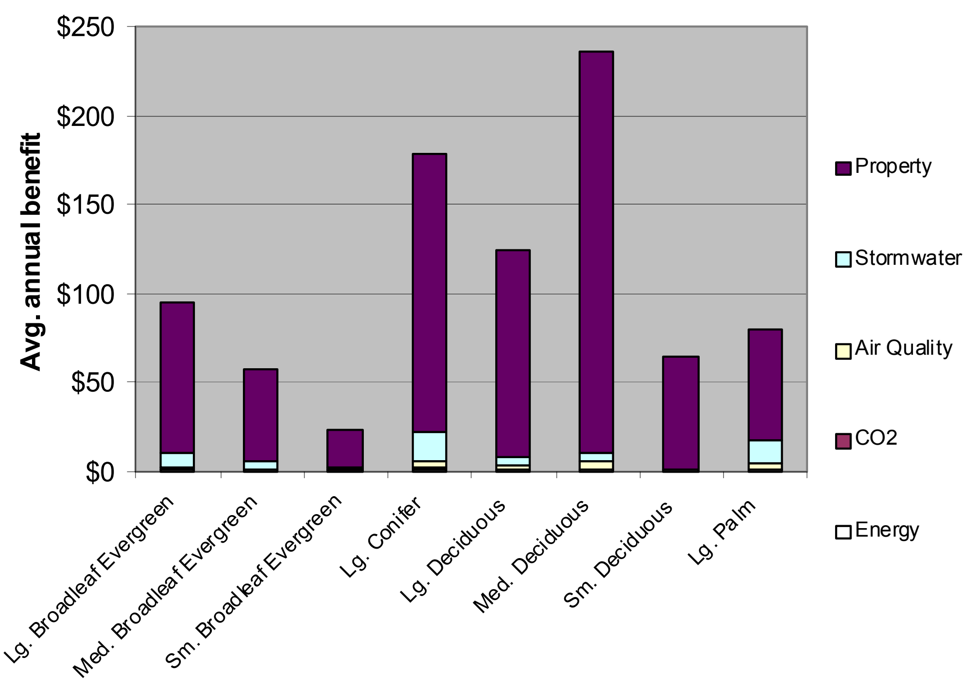


Figure 11. Average annual benefits per tree by tree types.

For example, district 10b—comprising Bayview, Hunters Point, and Visitacion Valley—produced the lowest average annual benefits of any district, approximately $33/tree. Its neighbor to the north, district 10a—Potrero Hill and Silver Terrace—possessed trees producing the highest average annual benefits per tree ($111). While both districts have a broad range of tree types present, the disparity can be explained by prevailing tree age class size: 71% of trees in district 10b were less than 3 inches in DBH, whereas 61% of trees in district 10a were in DBH classes greater than 6 in.

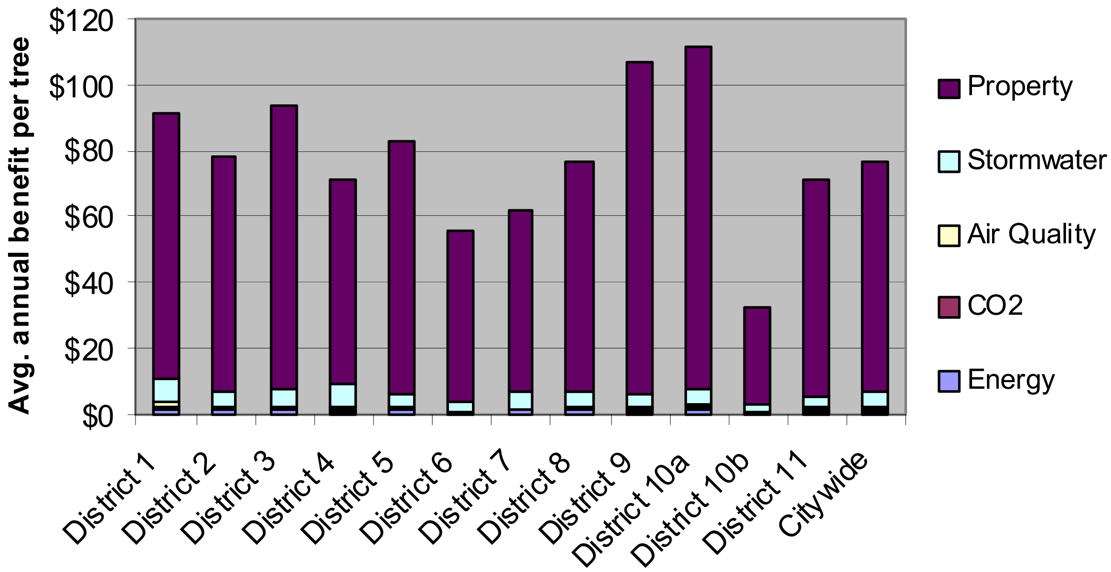


Figure 12. Average annual benefits per tree by district.

Chapter Six—Management Implications

City of San Francisco, California Street Tree Resource Analysis

Scott E. Maco, E. Gregory McPherson, James R. Simpson, Paula J. Peper, Qingfu Xiao

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Street trees are only one component of a functional urban forest. In some cities, they are the most important component, defining the values of the community, thereby providing a portal to different neighborhoods and shopping districts. In other cities, street trees are treated with less concern than are parks, greenbelts, and private plantings. In any case, cities must seek to maintain a functional municipal forest that is both healthy and safe. In San Francisco, with a street tree population approaching 100,000, there is no doubt that street trees are valued as an integral component of the urban forest. Moreover, judging by the costs allocated to planting and maintenance, management of this resource is not deemed trivial.

San Francisco's street trees reflect the values, lifestyles, preferences, and aspirations of current and past residents. It is a dynamic legacy, on one hand dominated by trees planted over 40 years ago and at the same time constantly changing as new trees are planted and others mature. Although this study provides a "snapshot" in time of the resource, it also serves as an opportunity to speculate about the future. Given the status of San Francisco's street tree population, what future trends are likely, what management challenges will need to be met, and how can net benefits be increased and sustained?

Achieving resource sustainability will produce long-term net benefits to the community while reducing the associated costs incurred with managing the resource. Structural features of a sustainable urban street tree population include adequate complexity (species and age diversity), well-adapted healthy trees, appropriate tree numbers, and cost-efficient management. To this end, focusing on these components refines the broader street tree management goals and are discussed below.

Resource Complexity

Species diversity was adequate when viewed on a citywide scale, but planting for population stability requires more than simply planting "other trees" when a single species is planted beyond a set threshold (e.g., 10% of total population). Figure 13 displays new and replacement planting trends. A

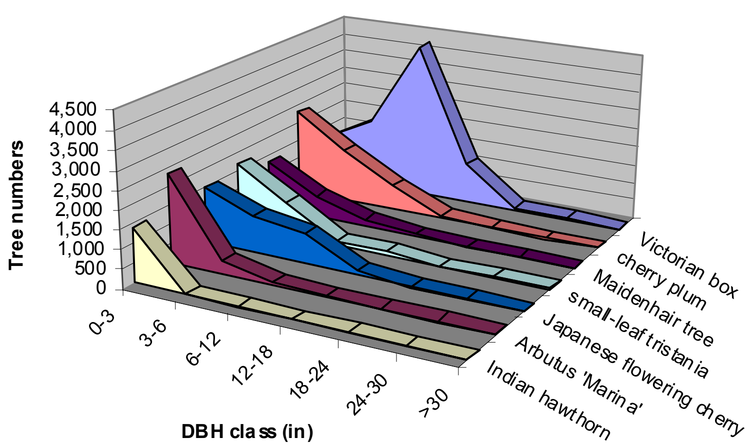

Figure 13. Top trees currently planted by numbers and DBH.

preponderance of trees were in the smallest size classes. Some of these species have not proven to be well adapted or have the longevity to produce benefits the community depends on. Victorian box was the only species with individuals present in functionally large DBH classes. All other species were either untested or lack mature stature to attain functional size.

As evident in Figure 14, large, long-lived deciduous trees were those that reach functional age. Substantial tree numbers in large DBH classes indicate proven adaptability amongst these trees. Some of these species are no longer planted in large numbers. For example, blackwood acacia Monterey pine, and Siberian elm. The shift towards planting small-statured species or trees that have not proven to be long-lived has the potential to reduce the future level of benefits afforded the community. Further evaluation of species performance over the long-term is recommended.

Recent pruning and stand age may be factors, but condition class is likely to be an overriding indicator of selecting well-adapted and appropriate trees. Table 34 displays relative performance index (RPI) values based on the proportion of each public tree classified as “good” divided by the proportion of the total population that that tree represented. An RPI value of ‘1’ indicates those trees that typified the citywide example of having approximately 60% of its constituents in “good” condition. Any value higher than ‘1’ indicated species that had proportionately more individuals classified as ‘good’. Likewise, index values below ‘1’ were species with below average ‘good’ condition ratings when compared with other San Francisco street trees.

While RPI values can be used to indicate trees well suited to San Francisco conditions, it is important to remember that some species with low values may have represented species populations with an even age distribution that were senescing as a population. An example would be blackwood acacia or Monterey pine. Though most of these trees’ functional lives were past, they had served the city well throughout their long lives and to not replant these species based on current condition of these senescing individuals would be shortsighted.

On the other hand, with an index value of 0.7, the fact that Arbutus ‘Marina’ are currently being heavily planted, suggested that managers were putting faith in some species unlikely to provide stability or cost effective functionality. Other species, such as glossy privet, myoporum, and lemon bottle brush, were exhibiting relatively poor condition at young ages, suggesting that these were not trees that will age gracefully. In addition to returning reliance back to the trees presently providing high levels of benefits, evaluation of condition values and relative age suggests that several species appeared to be well-adapted, long-lived, and have the potential to provide reasonable levels of benefits, deserving further consideration for increasing numbers: Chinese elm, carob, southern magnolia, Victorian box, and New Zealand Christmas tree.

The citywide age distribution of all trees was inline with the “ideal” distribution as described above, though the numbers of young trees were elevated and the number of functional trees were slightly less than ideal (Figure 2). This distribution suggests that a strong young tree care program is needed as well as targeted maintenance for functionally mature trees.

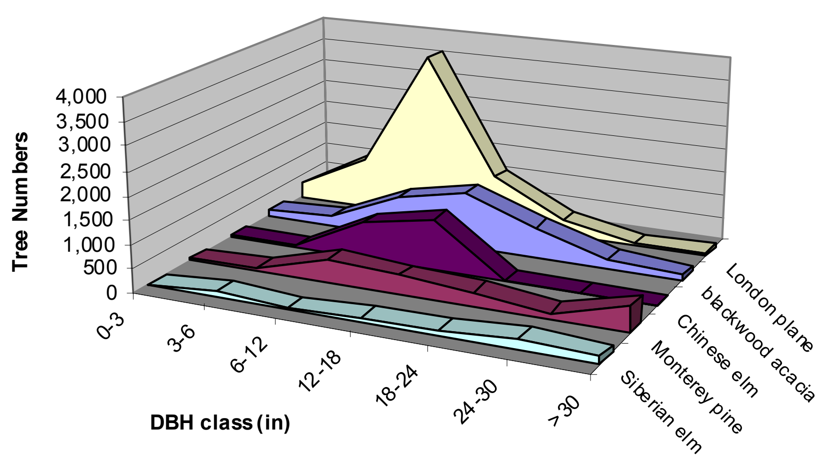

Figure 14. Age distribution of trees in San Francisco that are currently producing the largest average annual benefits on a per tree basis.

These priorities will insure that young trees will transition through their lifecycle in good health, minimizing the resources needed to maintain them, while functionally mature trees will perform at their peak to compensate for their lack in number.

Resource Extent

Canopy cover, or more precisely the amount and distribution of leaf surface area, is the driving force behind the urban forest's ability to produce benefits for the community. As canopy cover increases, so too do the benefits afforded by leaf area. It is important to remember that street trees throughout the US—and those of San Francisco—likely represent less than 10% of the entire urban forest (Moll and Kollin 1993). In other words, the benefits San Francisco residents realize from all urban vegetation is far greater than the values found through this analysis. But due to their location and conflicts, street trees are typically the most expensive component to manage. Maximizing the return on this investment is contingent upon maximizing and maintaining the canopy cover of these trees.

Increasing the street tree canopy cover requires a multifaceted approach in San Francisco. Plantable spaces must be filled and use of large stature trees must be encouraged wherever feasible. There are nearly 128,000 available street tree-planting spaces in the city, current canopy cover and associated benefits could be more than doubled if all these sites were filled. Short-term priority plantings should focus on the estimated 5,000 empty planting basins as the most cost-effective measure to planting more trees. Long-term, planting efforts should be focused on large sites first, followed by those allowing medium and small trees. Approximately 75% of all available planting sites can accept medium and large tree, as these will provide the highest level of future benefits for the same per tree cost of planting. Districts 3, 4, 7, 10a, 10b, and 11 have the lowest stocking levels and should take precedence.

Pruning & Maintenance

Unfortunately, budget constraints of municipal tree programs often dictate the length of pruning cycles and maintenance regimes rather than the needs of the urban forest and its constituent components. In fact, in San Francisco, there is no programmed pruning plan, rather the city's DPW maintains trees under "request" and "crisis" mode, finding themselves with a backlog of pruning every year. Programmed pruning, under a reasonable timeline, can improve public safety by eliminating conflicts, reduce costs by improving program efficiency, and increase benefits by improving tree health and condition. Any short-

Table 34. Relative performance index for public and private trees species representing over 1% of the respective population.

Public		Private	
Species	Value	Species	Value
London plane tree	1.3	Victorian box	1.0
Victorian box	1.0	Indian laurel, ficus	1.1
New Zealand Christmas tree	1.2	cherry plum	1.0
red-flowering gum	0.8	London plane tree	1.2
Chinese elm	1.2	Japanese flowering cherry	1.3
Indian laurel, ficus	1.0	New Zealand Christmas tree	1.1
blackwood acacia	0.3	Brisbane box	1.5
Siberian elm	0.6	Arbutus 'Marina'	0.7
small-leaf tristania	1.5	blackwood acacia	0.5
maiden hair tree	1.0	mayten tree	0.8
blue gum	0.9	red-flowering gum	0.9
Brisbane box	1.5	small-leaf tristania	1.0
windmill palm	1.7	evergreen pear	1.2
myoporum	0.4	lemon bottlebrush	0.8
glossy privet	0.8	Monterey pine	0.8
olive	1.0	southern magnolia	1.3
mayten tree	0.2	maiden hair tree	1.5
Chinese photinia	0.0	Australian peppermint willow	0.8
New Zealand tea tree	1.2	myoporum	0.5
carob tree	1.4	cajeput tree	1.2
southern magnolia	1.0	Indian hawthorn	1.0
Monterey pine	0.3	Monterey cypress	1.0
lemon bottlebrush	0.4	olive	1.0
All public trees	1	karo	0.9
		glossy privet	0.5
		Chinese elm	1.2
		All private trees	1

term dollar savings realized by cities deferring pruning only do so at a loss in tree value (Miller and Sylvester 1981).

Managed programmed pruning by district is recommended on a 3-6 yr cycle in residential areas; annual maintenance is suggested for commercial districts segments (Miller 1997). In their study of Milwaukee, Miller and Sylvester's (1981) found that extending pruning cycles beyond 4 or 5 years resulted in a loss of tree value that exceeded any savings accrued by deferring maintenance. In order to maintain consistency and maximize urban forest benefits while reducing city liabilities and public safety conflicts, the city of Modesto, CA had also found 4 years to be the ideal pruning cycle for their municipal forest (Gilstrap 1983). Furthermore, Anderson and Eaton (1986) suggested that an adequate and systematic pruning and inspection program was the first step to avoiding liability stemming from trees. In five districts, public trees were in high need of pruning (>20% of trees), while the same need was present in eight districts when examining only the private tree population; here, intensive education on appropriate pruning frequencies could improve functionality and longevity of private trees.

Results of the sample inventory also suggested that certain tree species may contribute a disproportionately large percentage of trees that require pruning. While not ideal, utilizing—or "recommending" in the case of private tree care—"species pruning" to target specific tree species could potentially reduce the total number of trees needing pruning over the short-term. For example, in district 5, the pruning of mayten trees, London plane, and New Zealand Christmas trees would rectify 50% of the trees categorized as in need of general pruning.

Controlling Costs

With the average street tree in San Francisco providing over $76 in annual benefits, the lack of a sizeable positive BCR is surprising. While San Franciscans are no strangers to high prices, controlling costs is the simplest and fastest approach to realizing positive net benefits. The first step in controlling costs is determining program efficacy. In San Francisco, where many entities play a role in street tree management, this is no simple task.

Private citizens with the help of FUF and commercial arborists, appear to be doing a good job of maintaining trees. Average trees in this segment of the population produce $69 in annual benefits while costing only $34 to maintain. On the other hand, the city's DPW—along with other departments—are spending $262 per tree annually while benefits are estimated to average only $108. Furthermore, public trees and their associated benefits are not equitably distributed over all city districts, as are costs. For example, district 5 residents—those located in the Haight or Jordan and Laurel Heights—benefit from approximately 2,100 public trees that provide $139,000 in annual benefits. In district 8— the Castro, Noe Valley, and Diamond Heights—only 500 public trees are present, providing about $25,000 in benefits that are locally realized. Privately managed trees differ insofar as their costs are typically paid by the benefactor.

San Francisco could benefit from a cooperative approach to management, whereby each managing entity focuses on what it does best, and more importantly, what it can do cost-effectively, leaving other entities to fill the management void. For example, FUF, utilizing volunteers, can plant and maintain young trees at a significantly lower cost than DPW. Moneys spent by DPW for this activity might be better utilized by contracting with FUF to perform these tasks on all public trees. Similarly, some private tree managers appeared to be providing cost-effective care to their street trees by contracting professional arborist services without compromising overall health of the trees—overall condition was similar between both populations. However, some private trees received minimal care.

Chapter Seven—Conclusion

City of San Francisco, California Street Tree Resource Analysis

Scott E. Maco, E. Gregory McPherson, James R. Simpson, Paula J. Peper, Qingfu Xiao

The approach used in this analysis not only provided sufficient data to describe structural characteristics of the street tree population, but, by using tree growth data modeled for the city, assessed the environmental benefits trees afford the city and its residents. In addition, the BCR was calculated and management needs were identified. This approach was based on established statistical methods and was intended to provide a general accounting of the benefits produced by street trees in San Francisco that can be utilized to make informed management and planning decisions.

Street trees in San Francisco are a valuable asset, providing approximately $7.5 million in annual benefits. Trees' benefits to the community were most pronounced in their contribution to local property values, but environmental benefits were also significant; stormwater control benefits were notably high. Thus, street trees were found to provide a particularly important function in maintaining environmental quality of San Francisco's important water resources.

San Francisco's street trees are a fantastically dynamic resource. Managers of this resource and the community alike can delight in knowing that street trees do improve the quality of life in San Francisco, but they are also faced with a fragile resource that needs constant care to maximize and sustain these benefits through the foreseeable future. In a city where costs are high, this is no easy task. The challenge will be to maximize net benefits from available growth space over the long-term, providing a resource that is both functional and sustainable.

This analysis has provided the information necessary for resource managers to weigh the citywide needs with the more specific needs of districts. Utilizing the structural indices outlined above—diversity index, importance values, condition values, and age distribution tables, conflicts, etc.—along with benefit data, provide the requisite understanding for short- and long-term resource management.

Management concerns addressed in this analysis are fourfold: 1) focus new plantings with proven, long-lived species that maximize available growth space; 2) plant in districts where stocking levels are lowest to provide more equitable distribution of benefits provided; 3) improve pruning frequency to promote tree functionality and longevity; and 4) control costs through cost-sharing and use of most efficient organization.

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Appendix A:

Rapid Sample Field Inventory Data Collection Protocols

Appendix A: Rapid Sample Field Inventory Data Collection Protocols[1]

Utilizing the rapid sampling technique proposed by Jaenson et al. (1992)[2] approximately 2,300 street trees will be inventoried in San Francisco's urban forest. All data collected will be recorded using the attached field inventory sheet and entered weekly into an Excel spreadsheet format.

The following will be recorded for each inventoried block or segment:

1. Beginning address

2. Ending address

3. Zone number (typically relates to supervisor districts, except for District 10 where its size was too large and split into 'A' and 'B').

4. Block or segment # (Note that some blocks will be only 3-sided with the fourth side backing up to, say, the Presidio where no data can be collected. Look for additional information when you have a curved street segment. The start and end locations usually begin with an intersection. And remember that both sides of the street will be surveyed on these curving street segments).

5. Date (date surveyed).

6. Names of person(s) who conducted the survey.

The following will be recorded for each tree (note: the number reflects the data field or column number):

1. **Tree #** – typically the survey team will begin at a corner building or lot and proceed in a clockwise direction around the block until they return and 'close' the block. Remember that the tree you start with may be on a street other than the beginning address.

2. **Species Code** – the first two letters of the tree's genus are followed by the first two letters of the species. For example, a Chinese Hackberry (*Celtis sinensis*) would be coded as "CESI". See the Tree Species Code List included in your 'Zone Survey Bag'. For a vacant planting area (an existing open basin or planting strip) within the right-of-way enter "EMBA" for empty basin. If there is a shrub in an existing basin, write in "EMBA". If there is space for a new basin to be cut where a tree could be located, enter "VOID". The spatial needs to be able to plant a tree must consider the visible utilities and the City guidelines in locating new trees, as well as the existing precedent on that side of the block. If you are surveying a block in Bernal Heights where the sidewalks are too narrow (less than 6' not including the curb) and there are currently no trees, it is highly likely that there is no location for a tree. You therefore would not enter "VOID" but continue to the next tree or potential tree site. You need only enter information in columns 3, 4, 5 and 14 when you enter either "EMBA" or "VOID".

3. **City Tree** – trees are considered a City owned tree, when they are on a Department of Public Works planted and maintained street. If the tree is a City owned tree then, (1=Yes). All other trees are considered private (0=No). Determination of City owned trees will be noted on your street map within your 'Zone Survey Bag'. Note that median trees are typically City owned (DPW trees).

4. **Land-use** – a number (1-6) is entered to correspond with the type of neighborhood or environment adjacent to the inventoried tree:

   1 = Single home residential
   2 = Multi-home residential (look for two or more doors/addresses)

[1] Author: Doug Wildman, Friends of the Urban Forest.
[2] Jaenson, R., N. Bassuk, S. Schwager, and D. Headley. 1992. A statistical method for the accurate and rapid sampling of urban street tree populations. J. Arboric. 18(4):171-183.

3 = Commercial/ industrial (warehouse, stores, businesses, etc.)
4 = Vacant (empty undeveloped lot)
5 = Park (typically SF Rec. & Park, yet could be a privately owned park)
6 = Institutional (churches, schools and school bldgs., City/Fed. Bldgs.)

5. **Tree Location** – a number (1-4) is entered that corresponds to the description of the inventoried trees planting location:

   1 = Planting strip (length greater than 4' along the curb side)
   2 = Cutout (typical 2'x 3', 3'x 3', or 4'x 4' basin)
   3 = Median (a 'planting island' in the middle of the street)
   4 = Other (where there is no curb and/or sidewalk)

6. **Diameter at Breast Height (DBH)** – a DBH measuring tape will be used to measure bole (trunk) diameter at a 4.5 ft height from ground level. MAKE SURE TO USE THE SIDE OF THE MEASURING TAPE THAT HAS THE UNITS OF MEASUREMENT THAT SAYS, " Diameter equivalents of circumference in terms of inches and tenths of inches". Diameter measurement (inches) will be rounded to the nearest 1 inch. Enter the appropriate class (1-7). For additional information, if you are interested, come into the FUF office to reference the ISA publication, *Guide for Plant Appraisal, 8th Ed.*, for correct measurement procedure. IF the tree possesses large bulges and/or irregularities at the 4.5' height, locate the measuring tape either just below or just above to get a measurement that best represents the trunk diameter of this tree. When the tree is a multi-trunk tree with more than one trunk at 4.5', measure all 'contributing' trunks at 4.5' above the ground and add them together for a single total diameter entry. When the tree is leaning, measure along the axis of the tree (parallel to the tree trunk).

7. **Crown Diameter** – using a measuring tape (on the inches side, not trunk diameter side), the crown diameter will be measured by averaging two measurements. First, measure the crown diameter running parallel to the curb. Second, measure the diameter perpendicular to the curb. Be careful of traffic. If you do not feel safe taking this measurement, don't take it! Make your best guess based on your first measurement. Remember to look for the branch that is farthest out and begin your measurement from there going to the branch furthest on the other side of the canopy. Record the measurements of crown diameter to the nearest 1 foot.

8. **Condition** – the condition (1-4) of each inventoried tree will be recorded as number that corresponds with the following condition classes:

   1 - Good = Healthy vigorous tree. No signs of insect, disease, or mechanical injury. Little or no corrective work required. Form representative of species.
   2 - Fair = Average condition and vigor for area. May need corrective pruning or repair. May lack desirable form characteristic of species. May show minor insect injury, disease, or physiological problem.
   3 - Poor = General state of decline. May show severe mechanical, insect, or disease amage, but death not imminent. May require major repair or renovation.
   4 - Dead or Dying = Dead or death imminent from disease or other causes.

9. **Needs Pruning** – adequacy of pruning is determined by visually estimating whether or not pruning is needed. "Yes" (1) will be recorded for each tree that has dead-wood present in diameters >1 inch, needs crown cleaning, thinning, reduction, raising, or restoration. "No" (0) will be entered if the tree does not exhibit or require the above conditions. Look at the tree and think, "If I could only prune ½ of the street trees in the City, would I choose this one?" This data is worthless if all the trees we survey 'need pruning'. We 'tree people' can almost find something to prune on any tree we see!

10. **Sidewalk Heave** – using the categories on the bottom of the data sheet, enter the appropriate range. You are likely to find that a tree was removed that caused the damage and a new tree was planted. Where the damage appears to be unrelated to the existing tree, enter'0' for no damage.

11. **Traffic Signals, Traffic Signage or Storefront Signage** – the signage relating to 'traffic' signage is only looking at the signs dealing with moving traffic safety, not "No Parking, Street Cleaning, Mon. Noon-4pm" signs. These include, "One Way", "25 MPH," "School Crossing" etc. The traffic lights are just that, the red, yellow and green signal lights. The 'storefront' signs are signs that business put up to attract/inform the passer by that they exist, like "Bill's Bar'n Grill". When trees are in conflict with these signs and signals when clear views to them are obstructed by the tree. The following two scenarios are possible: 1) signage is blocked by the tree; 2) tree has been lifted (pruned) and is not in the way/blocking. In either case, if there is a sign and the tree may or may not be in conflict with it- enter "1" for 'yes'.

12. **Overhead Lines** – where there are overhead lines running parallel to the curb (not the lines that drop in from lines across the street) these trees have the potential to obstruct or interfere in the future with overhead utility lines. If they are present on one side of the block, it is likely that they continue down that one side of the street and not the other. However, in some cases they will be present on both sides of the street. Again, these are the lines that are supported by your typical telephone pole and may have both a high 'rack' (high voltage) and a lower 'rack' (low voltage, cable, and phone lines). Simply enter "1" for 'yes' if they are present.

13. **Tree Been Topped** – where the tree has clear recent pruning that is of the extreme severity that tree lovers see far too much of in our City. The word topping is typically used to describe a pruning that limits the height of a tree to perhaps allow for views to the downtown, views to business signage and clearance of utility lines above the tree. Remember that trees like the London Plane Tree and Siberian Elm and the Linden can be pollarded (cut annually to the same point) without injury to the tree and this is not topping. Where the tree has been topped years ago yet the tree has recovered from this 'hard pruning' (topping!) with sound branching and recovery, enter '0' for no topping.

14. **Potential for What Sized Tree?** – where "Void" (for no tree) or "EMBA" (for Empty Basin) has been entered in column number 2, enter the appropriate size of tree that could be planted in this location using the following size classes:

    "S" = 0' – 20' (Small tree, e.g, Strawberry tree or Australian tea tree)
    "M" =20' – 35' (Medium tree, e.g. Pittosporum or carob)
    "L" = >35' (Large tree, e.g., London plane or Brisbane Box)

    Note: where there are overhead wires, a medium size tree is the largest potential tree for the site. Based on the type of trees that may be on either side of this location, you may choose a smaller species given that the canopies of these neighboring trees will for certain over shadow this potential tree.

15. **Other Needs/Comments** – additional notes not included or pertaining to the above fields are to be noted where applicable. Some examples would be a pollarded tree, a street with no curb or sidewalk, a block with only three sides due to the forth side backing up to a reservoir are just a few comments. While these comments will not be entered as data per say, they may help bring additional clarity to that particular tree site or to the block itself.

Appendix B:

Resident/Owner Street Tree Care Survey

FRIENDS OF THE URBAN FOREST

S.F. DEPARTMENT OF PUBLIC WORKS-BUREAU OF URBAN FORESTRY

RESIDENT/OWNER
STREET TREE CARE SURVEY

San Francisco, CA
-November 2002-

Name of contact person: ______________________ Are you the property owner? Yes___ No___
Address: ______________________
____
____
Phone number: ______________________
E-Mail address: ______________________

Are you responsible for the care of a planted street tree (in the sidewalk) adjacent to your property?
Yes___ No______
If so, indicate the species and tree height:
Species______________ Height:_<10 ft.________ 10-20 ft._20-40 ft._40-60 ft._

How many years have you been responsible for this tree?________ Yrs.

Did you purchase the house with the tree already planted? Yes________ No______

What year was this tree planted? ____________

On average, how many hours do you spend on caring (pruning, watering, leaf clean-up, etc.) for this tree?__________ hours per year

Has your tree been pruned? Yes______ No______

If so, do you prune it yourself, or is it pruned by FUF or a Commercial service?
Yourself:______________ FUF:__________ Commercial arborist:____________ Other:__________

On average, how often does your tree get pruned (please circle)?
Once a yr.; Once every 2 yrs.; Once every 3 yrs.; Once every 5 yrs.; Once every 10 yrs.; other______ __________.

How many times has it been pruned by yourself?______________________

How many times has it been professionally pruned?______________________

How large was the tree when you decided to have it pruned professionally instead of pruning it yourself?___ ______________ feet tall

Do you have your tree sprayed or otherwise treated for insects or disease? Yes___ No______

If so, do you treat it yourself or have it done by a professional service? Self______ Professional____________

On average, how often does your tree get treated?
Once a yr.; Once every 2 yrs.; Once every 3 yrs.; Once every 5 yrs.; Once every 10 yrs.; other______

Since you have been responsible for this tree's care, how many times has your tree been treated for pests/disease?___ ________

What has been the typical cost for a single treatment? $______________

Do you water this tree?____________

If so, during what months do you typically water?____________

During these months, how many times per week do you water?______________

Have you had to make sidewalk, sewer-line, or other repairs due to known conflicts with this tree's roots? Yes___ ________ No ____________

If yes, what were the costs and type of repair?

$ ______________ *for* Type of repair:______________________
$ ______________ *for* Type of repair:______________________
$ ______________ *for* Type of repair:______________________
$ ______________ *for* Type of repair:______________________

Thank you for your participation!

☐ Yes, I would like a summary copy of this report.

Doug Wildman,

Program Director
Friends of the Urban Forest

Appendix C:

Species Code Reference List

Species Code	Scientific Name	Common Name	Tree Type	Species Value Assignment
ACBA	*Acacia baileyana*	Bailey's acacia	BEM	BEM OTHER
ACBA P	*Acacia baileyana* 'Purpurea'	purple-leaf acacia	BEM	BEM OTHER
ACBU	*Acer buergeranum*	trident maple	DS	DS OTHER
ACCI	*Acer circinatum*	vine maple	DS	DS OTHER
ACGI	*Acer ginnala*	amur maple	DS	DS OTHER
ACLO	*Acacia longifolia*	Sydney golden wattle	BEM	BEM OTHER
ACMA	*Acer macrophyllum*	bigleaf maple	DL	DL OTHER
ACME	*Acacia melanoxylon*	blackwood acacia	BEL	ACME
ACPA	*Acer palmatum*	Japanese maple	DS	DS OTHER
ACRU	*Acer rubrum* 'Red Sunset'	scarlet maple, red maple	DL	DL OTHER
ACST	*Acacia stenophylla*	shoestring acacia	BEM	BEM OTHER
ACSU	*Acacia subporosa*	bower wattle, river Wattle	BEM	BEM OTHER
AECA	*Aesculus carnea*	red horsechestnut	DM	DM OTHER
AESC	*Aesculus californica*	California buckeye	DM	DM OTHER
AGFL	*Agonis flexuosa*	Australian peppermint willow	BEM	MABO
ALCO	*Alnus cordata*	Italian alder	DM	DM OTHER
ALDI	*Albizia distachya*	plume albisia	DS	DS OTHER
ALJU	*Albizia julibrissin*	silk tree	DM	DM OTHER
ALRH	*Alnus rhombifolia*	white alder	DL	DL OTHER
ARCU	*Archontophoenix cunninghamiana*	king palm	PS	PS OTHER
ARMA	*Arbutus* 'Marina'	Arbutus 'Marina'	BES	TRLA
ARRO	*Arecastrum romanzoffianum*	queen palm	PM	PM OTHER
ARUN	*Arbutus unedo*	strawberry tree	BES	BES OTHER
AZMI	*Azara microphylla*	boxleaf azara	BES	BES OTHER
BRAC	*Brachychiton acerifolius*	Autralian flame tree	DL	DL OTHER
BENI	*Betula nigra*	river birch	DL	DL OTHER
BEPE	*Betula pendula*	European white birch	DM	DM OTHER
BRED	*Brahea edulis*	Guadalupe palm	PS	PS OTHER
BRPO	*Brachychiton populneus*	bottle tree	BEM	BEM OTHER
BUCA	*Butia capitata*	pindo palm	PS	PS OTHER
CABE	*Carpinus betulus*	European hornbeam	DM	DM OTHER
CACI	*Callistemon citrinus*	lemon bottlebrush	BES	CACI
CAST	*Casuarina stricta*	coast beefwood	CL	CL OTHER
CAVI	*Callistemon viminalis*	weeping bottlebrush	BES	CAVI
CEAN	*Ceanothus* 'Ray Hartman'	wild lilac	BES	BES OTHER
CECA	*Cercis canadensis*	eastern redbud	DS	DS OTHER
CEOC	*Celtis occidentalis*	common hackberry	DL	DL OTHER
CEOC	*Cercis occidentalis*	western redbud	DS	DS OTHER
CESI	*Ceratonia siliqua*	carob tree	BEM	CESI
CESI1	*Celtis sinensis*	Chinese hackberry	DL	DL OTHER
CHHU	*Chamaerops humilis*	Mediterranean fan palm	PS	PS OTHER
CHSP M	*Chorisia speciosa* 'Majestic Beauty'	floss silk tree	DL	DL OTHER
CICA	*Cinnamomum camphora*	camphor tree	BEM	BEM OTHER
COAU	*Cordyline australis*	cordyline	PS	PS OTHER
COLA	*Corynocarpus laevigata*	New Zealand laurel	BEM	BEM OTHER
CRAT	*Crataegus spp.*	hawthorn	DS	DS OTHER
CRLA	*Crataegus laevigata*	English hawthorn	DS	DS OTHER
CRLA P	*Crataegus laevigata* 'Paul Scarlet'	Paul Scarlet hawthorn	DS	DS OTHER
CRPH	*Crataegus phaenopyrum*	Washington hawthorn	DS	DS OTHER
CUAN	*Cupaniopsis anacardioides*	carrotwood	BEM	BEM OTHER
CUMA	*Cupressus macrocarpa*	Monterey cypress	CL	CUMA
DOVI	*Dodonaea viscosa*	hop bush	BES	BES OTHER
DOVI P	*Dodonaea viscosa* 'Purpurea'	purple hop bush	BES	BES OTHER
DRDR	*Dracaena draco*	dragon tree	PS	PS OTHER
EMBA	NA	empty basin	NA	NA
ERDE	*Eriobotrya deflexa*	bronze loquat	BEM	BEM OTHER
ERJA	*Eriobotrya japonica*	loquat	BEM	BEM OTHER
EUCA	*Eucalyptus spp.*	eucalyptus	BEL	BEL OTHER
EUCI	*Eucalyptus citriodora*	lemon-scented gum	BEM	BEM OTHER
EUFI	*Eucalyptus ficifolia*	red-flowering gum	BEL	EUFI
EUGL	*Eucalyptus globulus*	blue gum	BEL	BEL OTHER
EUNI	*Eucalyptus nicholii*	Nichol's willow-leafed peppermint	BEM	BEM OTHER
EUPO	*Eucalyptus polyanthemos*	silver dollar gum	BEL	BEL OTHER
EURU	*Eucalyptus rudis*	flooded gum	BEL	BEL OTHER
EUSI	*Eucalyptus sideroxylon*	red ironbark gum	BEL	EUSI
FASY	*Fagus sylvatica*	European beech	DL	DL OTHER
FIMI	*Ficus microcarpa*	Indian laurel, ficus	BEM	FINI
FRLA	*Fraxinus latifolia*	Oregon ash	DL	DL OTHER
FROX	*Fraxinus oxycarpa*	raywood Ash	DL	DL OTHER
FROX R	*Fraxinus oxycarpa* 'Raywood'	raywood ash	DL	DL OTHER
FRUH	*Fraxinus uhdei*	evergreen ash, shamel ash	DL	DL OTHER
FRVE M	*Fraxinus velutina* 'Modesto'	Modesto ash	DL	DL OTHER
GEPA	*Geijera parviflora*	Autralian willow, wilga	BEM	BEM OTHER
GIBI	*Ginkgo biloba*	maiden hair tree	DL	ULPU

Species Code	Scientific Name	Common Name	Tree Type	Species Value Assignment
GLTR	*Gleditsia triacanthos*	honey locust	DM	DM OTHER
GRLI	*Griselinia literalis*	griselinia	BES	BES OTHER
GRRO	*Grevillea robusta*	silk oak	BEL	BEL OTHER
HALA	*Hakea laurina*	sea urchin, pincushion tree	BES	BES OTHER
HASU	*Hakea suaveolens*	sweet hakea	BES	BES OTHER
HYFL	*Hymenosporum flavum*	sweetshade	BEM	BEM OTHER
ILAL W	*Ilex altaclarensis* 'Wilsonii'	Wilson's holly	BEM	BEM OTHER
ILAQ	*Ilex aquifolium*	English holly	BEM	BEM OTHER
JAMI	*Jacaranda mimosifolia*	jacaranda	DM	DM OTHER
KOBI	*Koelreuteria bipinnata*	Chinese flame tree	DM	DM OTHER
KOPA	*Koelreuteria paniculata*	goldenrain tree	DM	DM OTHER
LAAN	*Laburnum anagyroides*	common goldenchain	DM	DM OTHER
LANO	*Laurus nobilis*	sweet bay, Grecian laurel	BEM	BEM OTHER
LANO S	*Laurus nobilis* 'Saratoga'	NA	BEM	BEM OTHER
LAPA	*Lagunaria patersonii*	primrose tree, cow itch tree	BEM	BEM OTHER
LEAR	*Leucodendron argenteum*	silver tree	BEM	BEM OTHER
LELA	*Leptospermum laevigatum*	Autralian tea tree	BES	BES OTHER
LESC	*Leptospermum scoparium*	New Zealand tea tree	BES	BES OTHER
LIDE	*Lithocarpus densiflorus*	tanbark oak	BEL	BEL OTHER
LILU	*Ligustrum lucidum*	glossy privet	BEM	LILU
LIST	*Liquidambar styraciflua*	American sweet gum	DM	DM OTHER
LITU	*Liriodendron tulipifera*	tulip tree	DL	DL OTHER
LYFL	*Lyonothamnus floribundus*	Catalina ironwood	BEM	BEM OTHER
MABO	*Maytenus boaria*	mayten tree	BEM	MABO
MAGR	*Magnolia grandiflora*	southern magnolia	BEM	MAGR
MALU	*Malus spp.*	crabapple	DS	DS OTHER
MASO	*Magnolia soulangiana*	saucer magnolia	DS	DS OTHER
MEER	*Melaleuca ericifolia*	heath melalueca	BES	BES OTHER
MEEX	*Metrosideros excelsus*	New Zealand Christmas tree	BEM	MEEX
MELI	*Melaleuca linarifolia*	flaxleaf paperbark	BEM	BEM OTHER
MENE	*Melaleuca nesophila*	pink melalueca	BES	BES OTHER
MEQU	*Melaleuca quinquenervia*	cajeput tree	BEM	MEQU
MEST	*Melaleuca styphelioides*	NA	BEM	BEM OTHER
MIDO	*Michelia doltsopa*	sweet michelia	BES	BES OTHER
MOAL	*Morus alba*	white mulberry	DL	DL OTHER
MYLA	*Myoporum laetum*	myoporum	BEM	LILU
OLEU	*Olea europaea*	olive	BEM	OLEU
PHCA	*Phoenix canariensis*	Canary Island date palm	PL	PHCA
PHFR	*Photinia fraseri*	Chinese photinia	BES	BES OTHER
PICA	*Pinus canariensis*	Canary Island pine	CL	CL OTHER
PICH	*Pistacia chinensis*	Chinese pistache	DM	DM OTHER
PICR	*Pittosporum crassifolium*	karo	BEM	PIUN
PIEU	*Pittosporum eugenioides*	pittosporum	BEM	PIUN
PIPI	*Pinus pinea*	Italian stone pine	CL	CL OTHER
PIRA	*Pinus radiata*	Monterey pine	CL	PIRA
PITO	*Pittosporum tobira*	tobira	BES	BES OTHER
PIUN	*Pittosporum undulatum*	Victorian box	BEM	PIUN
PLAC	*Platanus acerfolia*	London plane tree	DL	PLAC
POGR	*Podocarpus gracilior*	fern pine	BEM	BEM OTHER
POMA	*Podocarpus macrophyllus*	yew pine	BES	BES OTHER
PONI I	*Populus nigra* 'Italica'	Lombardy poplar	DL	DL OTHER
PRBL	*Prunus blireiana*	flowering plum	DS	DS OTHER
PRCE	*Prunus cerasifera*	cherry plum	DS	DS OTHER
PRLA	*Prunus laurocerasus*	English laurel	BES	BES OTHER
PRSE	*Prunus serrulata*	Japaneses flowering cherry	DS	DS OTHER
PYCA	*Pyrus calleryana*	callery pear	DM	DM OTHER
PYKA	*Pyrus kawakamii*	evergreen pear	BES	PYKA
QUAG	*Quercus agrifolia*	coast live oak	BEL	BEL OTHER
QUCO	*Quercus coccinea*	scarlet oak	DL	DL OTHER
QUIL	*Quercus ilex*	holly oak	BEL	BEL OTHER
QULO	*Quercus lobata*	valley oak	DL	DL OTHER
QUKE	*Quercus kelloggii*	California black oak	DL	DL OTHER
QUSU	*Quercus suber*	cork oak	BEL	BEL OTHER
RHAL	*Rhamnus alaternus*	Italian buckthorn	BEM	BEM OTHER
RHAP	*Rhaphiolepis* 'Majestic Beauty'	Indian hawthorn	BES	TRLA
RHLA	*Rhus lancea*	African sumac	BEM	BEM OTHER
ROAM	*Robinia ambigua*	locust	DM	DM OTHER
SABA	*Salix babylonica*	weeping willow	DL	DL OTHER
SASE	*Sapium sebiferum*	Chinese tallow tree	DL	DL OTHER
SCMO	*Schinus molle*	California pepper tree	BEM	BEM OTHER
SCTE	*Schinus terebinthifolius*	Brazilian pepper	BEM	BEM OTHER
SEGI	*Sequoiadendron giganteum*	giant sequoia	CL	CL OTHER
SESE	*Sequoia sempervirens*	coast redwood	CL	CL OTHER
SOJA	*Sophora japonica*	Japanese pagoda tree	DL	DL OTHER

Species Code	Scientific Name	Common Name	Tree Type	Species Value Assignment
SYPA	*Syzigium paniculatum*	brush cherry	BEM	BEM OTHER
TICO	*Tilia cordata*	little-leaf linden	DM	DM OTHER
TRCO	*Tristania conferta*	Brisbane box	BEL	TRCO
TRFO	*Trachycarpus fortunei*	windmill palm	PS	PS OTHER
TRLA	*Tristania laurina*	small-leaf tristania	BES	TRLA
ULPA	*Ulmus parvifolia*	Chinese elm	DM	ULPA
ULPU	*Ulmus pumila*	Siberian elm	DL	ULPU
UMCA	*Umbellularia californica*	California laurel	BEL	BEL OTHER
VOID	NA	available planting site	NA	NA
WAFI	*Washingtonia filifera*	California fan palm	PM	PM OTHER
WARO	*Washingtonia robusta*	Mexican fan palm	PM	WARO

Appendix D:

Total Citywide and District Street Tree Numbers

Citywide

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	159	235	885	1,188	653	192	116	3,429
BEL OTHER	149	273	385	473	298	183	331	2,091
EUFI	185	127	390	1,700	833	38	235	3,508
TRCO	253	888	1,891	298	36	0	0	3,366
Total	746	1,523	3,551	3,660	1,819	413	681	12,394
Med. Broadleaf Evergreen								
AGFL	34	658	733	220	0	0	0	1,645
BEM OTHER	869	1,157	2,414	455	205	77	0	5,177
FIMI	747	254	3,396	1,515	130	0	0	6,042
LILU	99	405	571	183	0	0	0	1,258
MABO	428	1,038	1,173	183	68	0	0	2,890
MAGR	469	935	509	0	0	0	0	1,914
MEEX	158	714	2,730	1,155	115	0	0	4,873
MEQU	429	1,012	108	0	0	0	0	1,549
MYLA	122	131	851	709	142	37	0	1,992
OLEU	360	361	462	78	124	39	0	1,423
PICR	234	147	517	115	76	117	0	1,206
PIUN	1,132	1,888	4,191	1,133	74	84	0	8,500
Total	5,082	8,701	17,654	5,746	934	354	0	38,470
Sm. Broadleaf Evergreen								
ARMA	2,327	328	75	0	0	0	0	2,731
BES OTHER	2,598	1,416	1,039	647	156	75	80	6,013
CACI	113	575	1,361	108	0	0	0	2,157
PYKA	398	493	1,039	185	36	0	0	2,151
RHAP	1,415	0	0	0	0	0	0	1,415
TRLA	1,715	883	66	113	0	38	38	2,852
Total	8,567	3,696	3,581	1,053	192	113	117	17,320
Lg. Conifer								
CL OTHER	34	145	145	112	113	0	36	585
CUMA	36	108	391	197	36	0	524	1,292
PIRA	34	76	476	414	322	138	575	2,035
Total	103	329	1,012	723	471	138	1,135	3,911
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	310	216	231	250	221	264	190	1,683
GIBI	1,311	592	195	43	0	0	0	2,140
PLAC	315	1,099	3,583	1,077	346	47	47	6,514
Total	1,935	1,907	4,009	1,371	567	310	237	10,337
Med. Deciduous								
DM OTHER	927	966	643	0	67	0	47	2,650
ULPA	69	43	790	1,102	36	0	0	2,040
Total	997	1,009	1,433	1,102	103	0	47	4,691
Sm. Deciduous								
DS OTHER	704	740	288	0	0	0	0	1,732
PRCE	2,315	1,435	720	67	0	0	0	4,537
PRSE	1,491	993	813	116	0	0	0	3,413
Total	4,510	3,168	1,821	184	0	0	0	9,682
Lg. Palm								
PL OTHER	0	0	0	0	0	67	40	107
Total	0	0	0	0	0	67	40	107
Med. Palm								
PM OTHER	69	116	75	70	106	72	36	543
Total	69	116	75	70	106	72	36	543
Sm. Palm								
PS OTHER	36	284	431	217	71	0	40	1,079
Total	36	284	431	217	71	0	40	1,079
Citywide Total	22,046	20,733	33,566	14,125	4,264	1,467	2,333	98,534

District 1

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	0	37	37	184	74	0	0	331
BEL OTHER	0	0	0	0	0	0	0	0
EUFI	0	0	37	147	37	0	0	221
EUGL	0	0	37	0	74	0	331	441
TRCO	0	37	74	0	0	0	0	110
Total	0	74	184	331	184	0	331	1,103
Med. Broadleaf Evergreen								
ACLO	0	0	147	110	0	0	0	257
BEM OTHER	0	0	74	0	37	0	0	110
ERDE	0	74	0	0	0	0	0	74
FIMI	0	0	37	37	0	0	0	74
MABO	37	0	37	0	0	0	0	74
MAGR	74	37	0	0	0	0	0	110
MEEX	37	0	294	110	37	0	0	478
MYLA	0	0	147	221	37	37	0	441
PIEU	0	0	184	0	37	0	0	221
PIUN	74	147	331	184	37	37	0	809
SYPA	0	0	74	0	0	0	0	74
Total	221	257	1,324	662	184	74	0	2,722
Sm. Broadleaf Evergreen								
ARMA	74	37	0	0	0	0	0	110
BES OTHER	0	0	0	37	0	0	0	37
CAVI	184	0	37	0	37	0	0	257
DOVI	0	74	37	0	0	0	0	110
PYKA	37	0	37	0	0	0	0	74
Total	294	110	110	37	37	0	0	588
Lg. Conifer								
CL OTHER	0	0	0	0	0	0	0	0
CUMA	0	0	0	37	0	0	147	184
PIRA	0	0	0	0	74	0	74	147
SEGI	0	0	37	37	74	0	0	147
Total	0	0	37	74	147	0	221	478
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	0	0	0	0	0	0	0	0
GIBI	74	0	37	0	0	0	0	110
PLAC	0	0	294	294	37	0	0	625
ULPU	0	110	37	110	110	221	147	736
Total	74	110	368	405	147	221	147	1,471
Med. Deciduous								
DM OTHER	37	37	37	0	0	0	0	110
Total	37	37	37	0	0	0	0	110
Sm. Deciduous								
CRPH	74	37	0	0	0	0	0	110
DS OTHER	37	0	37	0	0	0	0	74
PRCE	74	221	37	0	0	0	0	331
Total	184	257	74	0	0	0	0	515
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Palm								
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
District 1 Total	809	846	2,133	1,508	699	294	699	6,988

District 2

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	0	47	234	140	234	47	0	702
BEL OTHER	0	0	0	0	0	0	0	0
EUFI	0	47	0	47	47	0	47	187
TRCO	0	234	0	0	0	0	0	234
Total	0	328	234	187	281	47	47	1,123
Med. Broadleaf Evergreen								
BEM OTHER	140	140	187	94	47	0	0	608
CESI	0	0	187	0	47	0	0	234
FIMI	234	47	702	515	94	0	0	1,591
LILU	0	47	94	0	0	0	0	140
MABO	94	94	94	0	0	0	0	281
MAGR	94	421	94	0	0	0	0	608
MEEX	47	140	140	0	0	0	0	328
MYLA	47	94	94	140	0	0	0	374
OLEU	140	140	140	0	47	0	0	468
PIUN	328	328	749	47	0	47	0	1,498
Total	1,123	1,451	2,480	796	234	47	0	6,131
Sm. Broadleaf Evergreen								
BES OTHER	140	47	94	0	0	0	0	281
PYKA	0	47	187	0	0	0	0	234
RHAP	328	0	0	0	0	0	0	328
TRLA	187	94	0	0	0	0	0	281
Total	655	187	281	0	0	0	0	1,123
Lg. Conifer								
CL OTHER	0	0	0	0	0	0	0	0
CUMA	0	0	94	47	0	0	0	140
Total	0	0	94	47	0	0	0	140
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	47	0	0	0	47	0	0	94
GIBI	468	0	0	0	0	0	0	468
PLAC	0	47	796	328	0	47	47	1,264
Total	515	47	796	328	47	47	47	1,825
Med. Deciduous								
DM OTHER	0	0	47	0	0	0	47	94
Total	0	0	47	0	0	0	47	94
Sm. Deciduous								
DS OTHER	47	0	0	0	0	0	0	47
Total	47	0	0	0	0	0	0	47
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Palm								
COAU	0	0	140	0	0	0	0	140
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	140	0	0	0	0	140
District 2 Total	2,340	2,012	4,072	1,357	562	140	140	10,624

District 3

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	0	0	28	168	84	0	0	281
BEL OTHER	0	0	28	0	0	0	0	28
EUFI	0	0	28	28	0	0	0	56
QUIL	0	28	28	28	0	0	0	84
TRCO	0	28	56	0	0	0	0	84
Total	0	56	168	225	84	0	0	534
Med. Broadleaf Evergreen								
BEM OTHER	0	28	84	0	0	0	0	112
FIMI	28	28	562	281	0	0	0	899
LANO	0	0	84	0	0	0	0	84
LILU	56	28	28	0	0	0	0	112
MABO	0	0	0	28	28	0	0	56
MEEX	0	112	309	0	0	0	0	421
PIUN	0	0	197	56	0	0	0	253
Total	84	197	1,264	365	28	0	0	1,938
Sm. Broadleaf Evergreen								
BES OTHER	0	0	28	0	0	0	0	28
PYKA	28	112	0	0	0	0	0	140
Total	28	112	28	0	0	0	0	168
Lg. Conifer								
CL OTHER	0	0	0	0	0	0	0	0
PIRA	0	0	0	28	56	28	28	140
Total	0	0	0	28	56	28	28	140
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	0	0	0	0	0	0	0	0
PLAC	0	28	618	56	28	0	0	730
PONI I	0	0	0	28	28	0	0	56
Total	0	28	618	84	56	0	0	786
Med. Deciduous								
DM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Deciduous								
DS OTHER	0	0	0	0	0	0	0	0
PRCE	28	28	0	0	0	0	0	56
Total	28	28	0	0	0	0	0	56
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Palm								
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
District 3 Total	140	421	2,078	702	225	28	28	3,623

District 4

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	159	0	0	40	40	0	0	238
BEL OTHER	40	0	0	0	0	0	0	40
EUSI	0	0	0	80	40	0	0	119
Total	199	0	0	119	80	0	0	398
Med. Broadleaf Evergreen								
ACBA	40	159	40	0	0	0	0	238
ACLO	0	0	80	0	0	40	0	119
AGFL	0	0	40	40	0	0	0	80
BEM OTHER	0	40	40	0	0	0	0	80
LILU	0	0	80	0	0	0	0	80
MAGR	80	0	0	0	0	0	0	80
MEEX	0	40	119	40	40	0	0	238
MELI	0	40	80	0	0	0	0	119
MYLA	40	0	358	238	0	0	0	636
PICR	199	80	199	80	40	80	0	676
PIUN	80	40	0	40	0	0	0	159
SYPA	40	0	199	0	0	0	0	238
Total	477	398	1,232	437	80	119	0	2,743
Sm. Broadleaf Evergreen								
ARMA	40	40	0	0	0	0	0	80
ARUN	80	80	0	0	0	0	0	159
BES OTHER	40	0	0	80	0	0	0	119
CACI	40	40	80	0	0	0	0	159
GRLI	119	40	40	238	80	0	80	596
LELA	0	80	358	119	40	40	0	636
PITO	40	40	0	40	0	0	0	119
RHAP	119	0	0	0	0	0	0	119
Total	477	318	477	477	119	40	80	1,988
Lg. Conifer								
CL OTHER	0	0	0	0	40	0	0	40
CUMA	0	0	40	0	0	0	80	119
PIRA	0	40	159	119	80	0	398	795
Total	0	40	199	119	119	0	477	954
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Deciduous								
DM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Deciduous								
DS OTHER	0	0	0	0	0	0	0	0
PRCE	238	0	0	0	0	0	0	238
PRSE	716	0	0	0	0	0	0	716
Total	954	0	0	0	0	0	0	954
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Palm								
COAU	0	0	40	0	0	0	40	80
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	40	0	0	0	40	80
District 4 Total	2,107	755	1,948	1,153	398	159	596	7,115

District 5

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	0	0	39	0	78	0	0	116
BEL OTHER	0	0	0	0	0	0	0	0
EUFI	39	0	0	155	39	0	0	233
EUPO	0	0	116	0	0	0	0	116
EUSI	0	0	0	78	39	0	0	116
TRCO	0	0	39	78	0	0	0	116
Total	39	0	194	310	155	0	0	698
Med. Broadleaf Evergreen								
BEM OTHER	39	116	0	0	0	0	0	155
FIMI	39	0	620	427	0	0	0	1,086
LILU	0	39	78	39	0	0	0	155
MABO	116	233	543	155	0	0	0	1,047
MAGR	39	78	0	0	0	0	0	116
MEEX	39	78	233	233	39	0	0	620
MYLA	0	0	116	0	0	0	0	116
OLEU	0	0	39	78	78	39	0	233
PIUN	349	233	776	233	0	0	0	1,590
Total	620	776	2,404	1,163	116	39	0	5,119
Sm. Broadleaf Evergreen								
BES OTHER	39	78	0	0	0	0	0	116
CACI	0	0	194	0	0	0	0	194
Total	39	78	194	0	0	0	0	310
Lg. Conifer								
CL OTHER	0	78	0	0	0	0	0	78
Total	0	78	0	0	0	0	0	78
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	0	39	39	0	0	0	0	78
GIBI	194	39	78	0	0	0	0	310
PLAC	0	194	271	116	116	0	0	698
Total	194	271	388	116	116	0	0	1,086
Med. Deciduous								
DM OTHER	0	39	39	0	0	0	0	78
ULPA	0	0	233	39	0	0	0	271
Total	0	39	271	39	0	0	0	349
Sm. Deciduous								
DS OTHER	78	116	39	0	0	0	0	233
MALU	39	78	0	0	0	0	0	116
PRCE	39	194	0	0	0	0	0	233
PRSE	78	155	233	116	0	0	0	582
Total	233	543	271	116	0	0	0	1,163
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Palm								
PS OTHER	0	0	0	39	0	0	0	39
Total	0	0	0	39	0	0	0	39
District 5 Total	1,125	1,784	3,723	1,784	388	39	0	8,841

District 6

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
BEL OTHER	0	0	0	75	0	0	0	75
EUFI	37	37	37	0	0	0	0	112
TRCO	150	374	1,308	150	0	0	0	1,981
Total	187	411	1,346	224	0	0	0	2,168
Med. Broadleaf Evergreen								
AGFL	0	37	75	0	0	0	0	112
BEM OTHER	0	0	0	0	0	0	0	0
EUNI	37	37	75	0	0	0	0	150
FIMI	75	37	785	75	0	0	0	972
MAGR	112	187	0	0	0	0	0	299
MEEX	0	0	299	0	0	0	0	299
MEQU	0	224	0	0	0	0	0	224
OLEU	112	150	0	0	0	0	0	262
PIUN	187	561	299	0	0	0	0	1,047
Total	523	1,234	1,533	75	0	0	0	3,365
Sm. Broadleaf Evergreen								
BES OTHER	0	37	0	0	0	0	0	37
CAVI	0	112	0	0	0	0	0	112
PHFR	187	150	0	0	0	0	0	336
PYKA	75	187	224	37	0	0	0	523
TRLA	112	150	0	0	0	0	0	262
Total	374	636	224	37	0	0	0	1,271
Lg. Conifer								
CL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	0	0	0	0	0	0	0	0
GIBI	75	374	37	0	0	0	0	486
PLAC	112	486	150	0	0	0	0	748
Total	187	860	187	0	0	0	0	1,234
Med. Deciduous								
DM OTHER	0	0	0	0	0	0	0	0
GLTR	262	0	0	0	0	0	0	262
PYCA	224	0	0	0	0	0	0	224
ROAM	0	187	0	0	0	0	0	187
Total	486	187	0	0	0	0	0	673
Sm. Deciduous								
DS OTHER	75	0	0	0	0	0	0	75
PRCE	262	37	0	0	0	0	0	299
PRSE	187	112	0	0	0	0	0	299
Total	523	150	0	0	0	0	0	673
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	37	75	0	0	0	0	112
Total	0	37	75	0	0	0	0	112
Sm. Palm								
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
District 6 Total	2,280	3,514	3,365	336	0	0	0	9,496

District 7

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	0	0	0	188	0	38	0	225
BEL OTHER	38	0	0	38	38	75	0	188
EUFI	38	0	0	676	601	38	188	1,540
TRCO	0	38	75	38	0	0	0	150
Total	75	38	75	939	639	150	188	2,104
Med. Broadleaf Evergreen								
ACBA	38	0	113	0	0	0	0	150
AGFL	0	75	38	38	0	0	0	150
BEM OTHER	75	150	188	38	38	75	0	563
FIMI	338	0	0	0	0	0	0	338
LILU	0	113	150	0	0	0	0	263
MABO	75	75	75	0	0	0	0	225
MEEX	0	75	376	413	0	0	0	864
PIUN	0	263	526	113	38	0	0	939
Total	526	751	1,465	601	75	75	0	3,493
Sm. Broadleaf Evergreen								
ARMA	38	38	75	0	0	0	0	150
ARUN	300	38	0	0	0	0	0	338
BES OTHER	113	38	0	0	0	0	0	150
CACI	38	263	338	38	0	0	0	676
DOVI P	38	150	0	0	0	0	0	188
LESC	150	38	0	0	0	0	0	188
PYKA	150	75	38	0	0	0	0	263
RHAP	263	0	0	0	0	0	0	263
TRLA	338	0	38	113	0	38	38	563
Total	1,427	639	488	150	0	38	38	2,780
Lg. Conifer								
CL OTHER	0	0	0	75	0	0	0	75
CUMA	0	0	0	0	0	0	225	225
PIRA	0	0	75	75	0	38	0	188
Total	0	0	75	150	0	38	225	488
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	38	0	0	0	0	0	0	38
PLAC	0	0	451	75	0	0	0	526
Total	38	0	451	75	0	0	0	563
Med. Deciduous								
DM OTHER	38	0	75	0	0	0	0	113
PYCA	113	113	0	0	0	0	0	225
Total	150	113	75	0	0	0	0	338
Sm. Deciduous								
DS OTHER	38	38	0	0	0	0	0	75
PRCE	526	263	0	0	0	0	0	789
PRSE	263	338	225	0	0	0	0	826
Total	826	639	225	0	0	0	0	1,690
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Palm								
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
District 7 Total	3,043	2,179	2,855	1,916	714	300	451	11,457

District 8

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	0	72	468	468	108	72	36	1,224
BEL OTHER	72	36	0	0	36	0	0	144
EUCA	0	72	108	36	0	36	0	252
EUFI	36	0	144	360	36	0	0	576
EUGL	0	0	0	36	72	72	0	180
Total	108	180	720	900	252	180	36	2,376
Med. Broadleaf Evergreen								
BEM OTHER	288	144	216	108	36	0	0	792
FIMI	0	108	396	72	36	0	0	612
LILU	0	72	108	144	0	0	0	324
MABO	72	180	288	0	0	0	0	540
MAGR	0	108	180	0	0	0	0	288
MEEX	36	72	324	216	0	0	0	648
MEQU	108	0	72	0	0	0	0	180
MYLA	0	0	108	36	0	0	0	144
PIUN	72	180	648	324	0	0	0	1,224
SCTE	0	72	144	72	0	0	0	288
Total	576	936	2,484	972	72	0	0	5,040
Sm. Broadleaf Evergreen								
BES OTHER	324	144	108	0	0	0	0	576
CACI	0	72	360	0	0	0	0	432
CEAN	108	0	144	0	0	0	0	252
PRLA	36	0	108	0	0	0	0	144
PYKA	108	72	72	108	36	0	0	396
Total	576	288	792	108	36	0	0	1,800
Lg. Conifer								
CL OTHER	0	0	108	0	0	0	36	144
CUMA	36	108	108	0	36	0	72	360
PIRA	0	36	36	72	36	72	36	288
Total	36	144	252	72	72	72	144	792
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	36	0	36	108	72	0	0	252
GIBI	360	72	0	0	0	0	0	432
Total	396	72	36	108	72	0	0	684
Med. Deciduous								
DM OTHER	36	36	144	0	0	0	0	216
LIST	72	108	72	0	0	0	0	252
ULPA	0	0	144	72	0	0	0	216
Total	108	144	360	72	0	0	0	684
Sm. Deciduous								
DS OTHER	108	0	0	0	0	0	0	108
PRBL	0	0	180	0	0	0	0	180
PRCE	504	360	108	0	0	0	0	972
PRSE	0	72	108	0	0	0	0	180
Total	612	432	396	0	0	0	0	1,440
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	0	0	0	0	0	0	36	36
WAFI	0	0	0	36	72	36	0	144
Total	0	0	0	36	72	36	36	180
Sm. Palm								
COAU	0	36	108	0	0	0	0	144
PS OTHER	0	0	0	0	0	0	0	0
Total	0	36	108	0	0	0	0	144
District 8 Total	2,412	2,232	5,148	2,268	576	288	216	13,140

District 9

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
BEL OTHER	0	101	67	67	0	0	0	236
EUFI	0	0	101	168	34	0	0	303
TRCO	67	135	303	34	0	0	0	539
Total	67	236	472	270	34	0	0	1,078
Med. Broadleaf Evergreen								
AGFL	34	505	438	0	0	0	0	977
BEM OTHER	135	135	202	0	34	0	0	505
ERDE	0	67	135	0	0	0	0	202
FIMI	34	34	135	34	0	0	0	236
MABO	34	371	101	0	0	0	0	505
MAGR	34	67	236	0	0	0	0	337
MEEX	0	0	135	0	0	0	0	135
MEQU	0	337	0	0	0	0	0	337
PIUN	0	101	337	101	0	0	0	539
Total	270	1,617	1,718	135	34	0	0	3,774
Sm. Broadleaf Evergreen								
BES OTHER	202	67	168	101	0	0	0	539
PYKA	0	0	202	0	0	0	0	202
TRLA	168	168	0	0	0	0	0	337
Total	371	236	371	101	0	0	0	1,078
Lg. Conifer								
CL OTHER	34	67	34	34	0	0	0	168
PIRA	34	0	135	34	34	0	0	236
Total	67	67	168	67	34	0	0	404
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	168	67	135	0	0	0	0	371
Total	168	67	135	0	0	0	0	371
Med. Deciduous								
DM OTHER	34	34	101	0	67	0	0	236
JAMI	34	202	101	0	0	0	0	337
PYCA	0	168	67	0	0	0	0	236
ULPA	34	0	101	741	0	0	0	876
Total	101	404	371	741	67	0	0	1,685
Sm. Deciduous								
CRLA	0	236	34	0	0	0	0	270
CRPH	67	101	0	0	0	0	0	168
DS OTHER	67	135	0	0	0	0	0	202
PRCE	371	135	539	67	0	0	0	1,112
PRSE	34	101	67	0	0	0	0	202
Total	539	708	640	67	0	0	0	1,954
Lg. Palm								
PL OTHER	0	0	0	0	0	67	0	67
Total	0	0	0	0	0	67	0	67
Med. Palm								
PM OTHER	34	0	0	34	34	0	0	101
Total	34	0	0	34	34	0	0	101
Sm. Palm								
PS OTHER	0	34	0	0	0	0	0	34
Total	0	34	0	0	0	0	0	34
District 9 Total	1,617	3,369	3,875	1,415	202	67	0	10,546

District 10A

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
BEL OTHER	0	0	0	0	0	0	0	0
EUFI	0	43	43	43	0	0	0	129
TRCO	0	43	0	0	0	0	0	43
Total	0	86	43	43	0	0	0	172
Med. Broadleaf Evergreen								
ACBA	0	43	129	0	0	0	0	172
BEM OTHER	0	0	0	0	0	0	0	0
CICA	0	0	43	0	0	0	0	43
LILU	43	0	0	0	0	0	0	43
MABO	0	86	0	0	0	0	0	86
MEEX	0	86	215	0	0	0	0	301
PIUN	43	0	43	0	0	0	0	86
Total	86	215	430	0	0	0	0	731
Sm. Broadleaf Evergreen								
ARUN	86	43	0	0	0	0	0	129
BES OTHER	0	0	0	0	0	0	0	0
CACI	0	129	86	0	0	0	0	215
CAVI	0	43	0	0	0	0	0	43
MENE	43	0	0	0	0	0	0	43
Total	129	215	86	0	0	0	0	430
Lg. Conifer								
CL OTHER	0	0	0	0	0	0	0	0
PIRA	0	0	0	86	43	0	0	129
Total	0	0	0	86	43	0	0	129
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	0	0	0	0	0	0	0	0
GIBI	0	0	43	43	0	0	0	86
LITU	86	0	86	0	0	0	0	172
PLAC	43	344	903	172	129	0	0	1,591
PONI I	0	0	0	0	0	43	43	86
Total	129	344	1,032	215	129	43	43	1,935
Med. Deciduous								
DM OTHER	0	0	0	0	0	0	0	0
LIST	43	43	0	0	0	0	0	86
ULPA	0	43	129	0	0	0	0	172
Total	43	86	129	0	0	0	0	258
Sm. Deciduous								
DS OTHER	0	0	0	0	0	0	0	0
PRCE	43	86	0	0	0	0	0	129
Total	43	86	0	0	0	0	0	129
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
ARRO	0	43	0	0	0	0	0	43
PM OTHER	0	0	0	0	0	0	0	0
Total	0	43	0	0	0	0	0	43
Sm. Palm								
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
District 10a Total	430	1,075	1,720	344	172	43	43	3,827

District 10B

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
ACME	0	80	80	0	0	0	80	239
BEL OTHER	0	0	0	0	0	0	0	0
EUFI	0	0	0	40	40	0	0	80
Total	0	80	80	40	40	0	80	319
Med. Broadleaf Evergreen								
BEM OTHER	40	120	0	0	40	0	0	199
FIMI	0	0	160	40	0	0	0	199
GEPA	0	0	80	0	0	0	0	80
PICR	0	0	80	0	0	0	0	80
Total	40	120	319	40	40	0	0	558
Sm. Broadleaf Evergreen								
ARMA	1,955	0	0	0	0	0	0	1,955
BES OTHER	40	0	0	0	0	0	0	40
PHFR	120	160	0	0	0	0	0	279
PYKA	0	0	279	0	0	0	0	279
RHAP	638	0	0	0	0	0	0	638
TRLA	838	40	0	0	0	0	0	878
Total	3,590	199	279	0	0	0	0	4,069
Lg. Conifer								
CL OTHER	0	0	0	0	0	0	40	40
CUMA	0	0	80	80	0	0	0	160
Total	0	0	80	80	0	0	40	199
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	40	0	0	40	0	0	0	80
PLAC	160	0	0	0	0	0	0	160
Total	199	0	0	40	0	0	0	239
Med. Deciduous								
DM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Deciduous								
DS OTHER	40	0	0	0	0	0	0	40
PRCE	160	40	0	0	0	0	0	199
Total	199	40	0	0	0	0	0	239
Lg. Palm								
PL OTHER	0	0	0	0	0	0	40	40
Total	0	0	0	0	0	0	40	40
Med. Palm								
PM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Palm								
PS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
District 10b Total	4,029	439	758	199	80	0	160	5,664

District 11

Species	DBH Class (in)							
	0-3	3-6	6-12	12-18	18-24	24-30	>30	Total
Lg. Broadleaf Evergreen								
BEL OTHER	36	36	0	71	36	36	0	214
TRCO	36	0	36	0	36	0	0	107
Total	71	36	36	71	71	36	0	321
Med. Broadleaf Evergreen								
AGFL	0	0	107	143	0	0	0	250
BEM OTHER	143	107	71	107	0	0	0	429
LILU	0	107	0	0	0	0	0	107
MEEX	0	71	286	143	0	0	0	500
MEQU	321	357	36	0	0	0	0	714
MYLA	36	0	0	36	71	0	0	143
OLEU	0	71	107	0	0	0	0	179
PICR	36	0	107	36	0	0	0	179
PIUN	0	36	286	36	0	0	0	357
Total	536	750	1,000	500	71	0	0	2,857
Sm. Broadleaf Evergreen								
ARMA	36	107	0	0	0	0	0	143
BES OTHER	0	0	0	0	0	0	0	0
CACI	36	71	143	0	0	0	0	250
LESC	393	107	107	0	0	0	0	607
MEER	107	0	0	0	0	36	0	143
MENE	0	36	0	143	0	0	0	179
TRLA	36	357	0	0	0	0	0	393
Total	607	679	250	143	0	36	0	1,714
Lg. Conifer								
CL OTHER	0	0	107	0	0	0	0	107
Total	0	0	107	0	0	0	0	107
Med. Conifer								
CM OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Sm. Conifer								
CS OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Lg. Deciduous								
DL OTHER	0	0	0	0	0	0	0	0
GIBI	36	107	0	0	0	0	0	143
Total	36	107	0	0	0	0	0	143
Med. Deciduous								
DM OTHER	36	0	71	0	0	0	0	107
ULPA	36	0	71	250	36	0	0	393
Total	71	0	143	250	36	0	0	500
Sm. Deciduous								
DS OTHER	36	0	36	0	0	0	0	71
PRCE	71	71	36	0	0	0	0	179
PRSE	214	214	143	0	0	0	0	571
Total	321	286	214	0	0	0	0	821
Lg. Palm								
PL OTHER	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0
Med. Palm								
PM OTHER	36	36	0	0	0	36	0	107
Total	36	36	0	0	0	36	0	107
Sm. Palm								
DRDR	36	107	71	0	0	0	0	214
PS OTHER	0	0	0	0	0	0	0	0
TRFO	0	107	71	179	71	0	0	429
Total	36	214	143	179	71	0	0	643
District 11 Total	1,714	2,107	1,893	1,143	250	107	0	7,214

Center for
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Center for Urban Forest Research
Pacific Southwest Research Station, USDA Forest Service
1 Shields Avenue, Suite 1103 • Davis, CA 95616-8587
(530) 752-7636 • Fax (530) 752-6634 • http://cufr.ucdavis.edu/