PORTLAND PARKS & RECREATION

Healthy Parks, Healthy Portland

# Portland's Urban Forest Canopy

## Assessment and Public Tree Evaluation

October 2007

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Heritage tree photos courtesy of Phyllis Reynolds.

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*Portland's South Waterfront*

# Executive Summary

Portland's urban trees are the soul of a city known for its progressive land-use planning and extensive green infrastructure. Trees are a crucial part of the cityscape, softening and beautifying the built environment, improving neighborhood safety and livability, and providing vital ecosystem services such as air purification, temperature mitigation, and stormwater interception. Effective and efficient management of the urban forest relies on an understanding of the structure and function of the resource, as well as the benefits it provides.

This report describes the benefits provided by Portland's urban forest canopy, focusing on a study of publicly owned street and park trees. The structure and function of these public tree resources are used to calculate the value of the environmental and aesthetic benefits the trees provide. Maintenance costs are tallied and deducted from gross benefits to determine annualized net returns on the street and park tree investments.

## Resource Structure

- The street tree population is estimated at 236,000 trees of 171 different types, and roughly 1.2 million trees of 41 types are found in parks and natural spaces. Broadleaf deciduous trees dominate the landscape, accounting for 85% of street trees and 77% of park trees. Relative age within these multi-aged populations varies with tree type and area of town. Greater than 90% of street and park trees are in fair to good condition.

- Maples are ubiquitous in Portland. The native bigleaf maple (*Acer macrophyllum*) is the most abundant tree in natural areas; Norway maple (*Acer platanus*), red maple (*Acer rubrum*), and bigleaf maple (*Acer macrophyllum*) are among the five most common street tree types. With the greatest dominance and biomass, Norway maple is the most important street tree type.

- Roughly half of Portland's public trees are smaller than 6" DBH, and fewer than 10% are greater than 30" DBH.

- The majority of street trees (60%) are native to places outside of the United States, mainly Europe and Asia, and the majority of park trees (86%) are native to the Portland area.

- Street tree stocking levels range from 37% in Southeast Portland to 64% in Northwest Portland, averaging 45% citywide.
- At least 87,000 street trees (37%) grow in rights-of-way that are either too small or too large to accommodate them optimally. At least 51,000 large trees would perform better in a more spacious location, and at least 35,000 street trees are better suited to a smaller planting area.
- Tree canopy covers 26% of the city.

## Resource Function and Value

- The replacement value of Portland's public tree resource is over $2.3 billion. The structural value of the entire urban forest canopy is estimated at nearly $5 billion.
- Each year, Portland's street and park trees cost the city and private property owners just over $6.5 million to manage while providing nearly $27 million worth of environmental and aesthetic benefits. For every dollar invested, $3.80 worth of benefits is returned.
- Portland's street and park trees provide $980,000 worth of air cleaning and carbon fixing services annually, removing 25 million pounds of pollutants from Portland's air supply each year. The entire urban forest canopy provides more than $3 million worth of annual air cleaning and carbon fixing services by removing almost 2 million pounds of pollutants and nearly 53 million pounds of carbon. Portland's urban tree infrastructure stores roughly 1.5 billion pounds of carbon.
- Portland's street and park trees save the city over $11 million in stormwater processing by intercepting nearly half a billion gallons of stormwater annually. Citywide, the urban forest canopy intercepts 1.3 billion gallons of stormwater each year, saving almost $36 million in processing costs.
- Portland's street trees are responsible for almost $750,000 in avoided energy costs, and over $13 million in property resale value is attributable to the presence of street trees.
- Annual environmental benefits provided by the entire urban forest canopy exceed $38 million and will exceed $43 million when the goal of 7% more land covered by tree canopy (25% increase) is met.

## Resource Management

- This report provides a powerful tool for use in achieving *Urban Forestry Management Plan* implementation goals.
- For benefit maximization, efforts should focus on retaining existing canopy, planting the right tree in the right place, planting large-species trees where appropriate, and keeping trees healthy.
- A proactive, wellness-based strategy consisting of regular care and maintenance is a wise investment of limited resources that can increase longevity and reduce the need for costly emergency care.

*Foley-Balmer Natural Area*

*Columbia Park in northeast Portland*

# Introduction

## The Value of the Urban Forest

Urban trees are an invaluable resource whose merits may be underappreciated. Not only do trees soften and beautify the cityscape and improve neighborhood safety and livability, they provide vital—and quantifiable—ecosystem services such as air purification, temperature mitigation, and stormwater interception. Yet trees defy classic valuation models. Unlike the grey infrastructure of buildings, roads, and the like, trees appreciate in value as they age, mature, and approach senescence. Assessing the structural value of urban trees and of the benefits they provide reveals a more holistic picture of the importance of the green infrastructure.

Urban trees improve air quality passively and actively. Shade provided by trees over paved surfaces and cars reduces evaporative hydrocarbon emissions and ozone formation (Scott *et al*. 1999). The reduction in VOC emissions extends the lifetime of paved surfaces, resulting in lower maintenance and repair costs. In addition, trees physically and chemically remove gaseous and particulate pollutants from the atmosphere (McPherson *et al*. 2000). Small particulate matter adheres to plant surfaces, and gaseous pollutants are absorbed and may be incorporated into plant tissue.

Trees improve ambient air quality by absorbing atmospheric pollutants and lower atmospheric $CO_2$ levels by transforming atmospheric carbon into plant tissues. Trees intercept and calm winds channelized by the urban landscape, and their transpiration and shading mitigate the urban heat island effect. Reduced demand for heating and cooling results in a net decrease of $CO_2$ and other pollutants introduced into the atmosphere as a result of avoided emissions. In addition, trees act as carbon reservoirs by removing $CO_2$ from the atmosphere, releasing the $O_2$, and retaining the carbon in their tissues. All photosynthesizers fix inorganic carbon ($CO_2$) into organic molecules (sugars), but in terrestrial systems, only long-lived, woody tissues retain the carbon long enough to effectively reduce the concentration of $CO_2$ in the atmosphere. In this way, trees are a big help in managing greenhouse gases.

Trees also intercept precipitation that would otherwise run off impermeable urban surfaces into stormwater conveyance and treatment facilities. Processing stormwater mechanically requires large investments in infrastructure and energy. Urban trees reduce total stormwater volume, thereby reducing the burden on conveyance and treatment facilities.

A major goal of this project is to describe and quantify the benefits trees provide that are integral to Portland's high quality of life. Detailing the costs involved in growing and maintaining the urban forest—and describing how those costs compare with the environmental and aesthetic benefits the trees provide—justifies the public investment in our green infrastructure. Beyond that, benefit valuation also increases our understanding of the value of the suite of essential ecosystem services urban trees provide.

This analysis of Portland's urban canopy focuses primarily on the public tree asset. The assessment quantifies the structure, function, value, and management needs of the city's trees. Forest structure—the number, type, and relative age and health of the population—determines the functionality of the forest. Forest functionality translates to the magnitude of environmental and aesthetic benefits the trees provide. This metric allows the valuation of forest benefits and the ability to plan a management strategy for future growth and benefit maximization of the urban forest.

## Study Area

The city of Portland, Oregon, lies just south of the Columbia River and the Oregon-Washington state border, straddling the Willamette River at the north end of the Willamette Valley. Home to more than 550,000 people, Portland is the state's largest city and the third largest city in the Pacific Northwest behind Seattle, WA, and Vancouver, B.C. Strongly seasonal precipitation, 40-45 in. annually, falls mostly as rain in the winter months (November through April) in Portland's Mediterranean climate. Average temperatures range from 37°F during the cool, wet winters to 81°F during the hot, dry summers. Weather conditions determine the types of trees that can grow in the city as long as irrigation is provided at establishment during the dry summer months.

Portland is known for its progressive land-use planning and extensive green infrastructure. The livability and popularity of Oregon's largest city rely on the network of urban parks and natural spaces interconnected with the green landscapes that line streets and accent homes and businesses. Although all components of this urban forest contribute to softening and beautifying the cityscape, trees are special by virtue of their stature, their longevity, and the significant environmental and aesthetic benefits they provide.

Street trees are those that grow in the rights-of-way between the street and either the sidewalk or adjacent taxlot. Unimproved rights-of-way are predominantly undeveloped and are often indistinguishable from the adjacent property. The majority of Portland's rights-of-way are improved with sidewalks, curbs, and either planting strips or cutouts for trees and other landscaping elements. The pervious spaces available for trees vary in width from roughly 18 in. to over 10 ft. Park trees grow on property owned by Portland Parks & Recreation (PP&R). PP&R properties are comprised of a matrix of developed, undeveloped, and natural areas. Developed areas contain built structures such as restrooms, tennis courts, and playgrounds; undeveloped areas are those portions of developed parks without built structures; and natural areas have few to no built structures and are maintained predominantly for habitat values. For the purposes of this analysis, 'park' trees refers to all PP&R-owned trees except where otherwise noted. Collectively, street and park trees comprise the majority of Portland's publicly owned trees.

Because urban trees grow within the matrix of the built environment, they face special challenges of poor and limiting resources, including air and soil pollutants, limited soil and space resources, and inconsistent maintenance. Air pollutants from vehicle exhaust and industrial activities may weaken trees' hardiness, and the limitations imposed by small growing spaces prevent trees from reaching their full potential. Poor maintenance practices such as incorrect or insufficient pruning also limits trees' potential and can weaken the trees, creating safety hazards to people and property.

Although all urban trees endure reduced air quality, relative to parks and natural areas, the street environment provides the most severe growing conditions. Street trees must contend with the most polluted air, the most compacted and contaminated soil, and the most restricted space both below and above ground. Trees in developed parks may grow in relatively unrestricted fashion, but they are still subject to soil compaction and pollution from maintenance activities. Natural areas, the closest urban analogue to non-urban forests, are managed to preserve the native ecosystem. Natural area trees are limited primarily by competition for limited resources by neighboring vegetation.

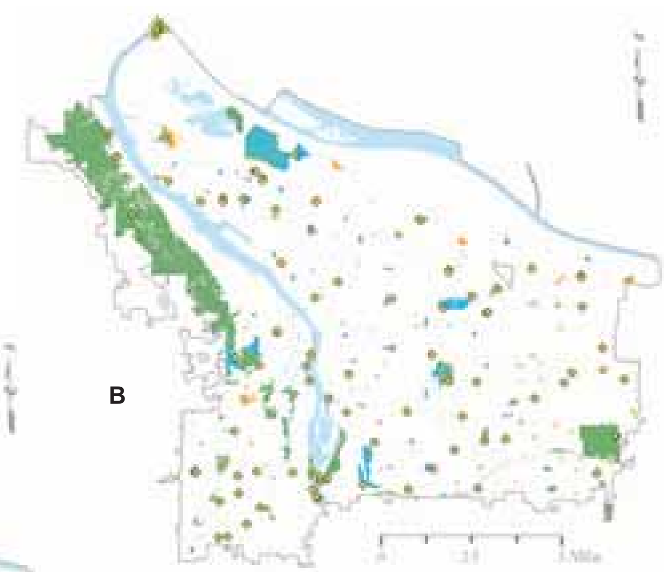
Responsibility for the regular care and maintenance of Portland's trees is shared among the public and private sectors depending on tree location and ownership. With a few exceptions in specially landscaped areas, street trees are the responsibility of the adjacent property owner. PP&R's City Nature group manages park and natural area trees. Trees growing on private property are the responsibility of the respective property owners.

*Westmoreland Park in southeast Portland*

# Methods

*Please see Appendix A for detailed methods*

Four field technicians conducted field sampling during the leaf-on season from mid-June through mid-October 2006. Sample street segments and study plots were generated randomly within a geographic database to assure unbiased coverage of the citywide street tree resource and park properties, respectively (Figure 2-1). Field data were analyzed along with hourly meteorological data, resource management costs, and the rates of accrual of the environmental and aesthetic benefits trees provide using a suite of algorithms based on 20+ years of urban forestry research (*e.g.*, McPherson et al. 2000). In addition, satellite image analysis revealed current canopy cover for public and private property, a hypothetical future canopy target, and the environmental benefits of both (American Forests 2004). The resulting analysis of the structure and function of the urban canopy, along with associated net benefits, may provide a framework for making strategic management decisions.



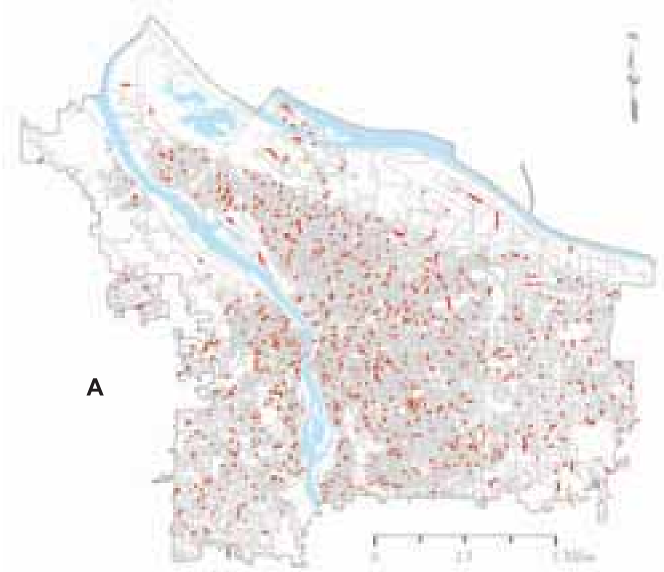




**Figure 2-1.** *Sample data collection sites for (a) street trees and (b) park trees. Red lines (a) indicate randomly selected sample street segments; yellow circles (b) indicate randomly selected sample plots on Parks-owned properties.*

*Flowering dogwood*

# Urban Forest Structure

## Forest Structure

Portland's public streets, parks, and natural areas host a diverse array of tree types (Tables B-1 and B-2, Appendix B). Nearly 1.5 million trees grow in these public spaces. The street tree population is estimated at 236,000 trees of 171 different types, and over 1.2 million trees of 41 types are found in developed parks (39,000) and natural areas (1.2 million). For the purposes of this analysis, 'park' trees refers to all PP&R-owned trees growing in developed, undeveloped, and natural areas except where otherwise noted. Even though Portland's streets host a diversity of trees, ten types (6%) comprise nearly half (45%) of the resource, leaving the vast majority of tree types (94%) relatively poorly represented. Similarly in parks, over half (54%) of all trees belong to one of three tree types (7%).

**Table 3-1.** *Relative dominance and distribution of the five most abundant tree types on Portland's streets and in Portland's parks and natural areas. Numbers in parentheses show the percent of all trees of a given type.*

| Rank | North | Northeast | Northwest | Southeast | Southwest | All Street Trees | Park Trees |
|---|---|---|---|---|---|---|---|
| **1st** | Norway maple | Norway maple | Bigleaf maple | Norway maple | Arborvitae | Norway maple | *Bigleaf maple* |
| **(%)** | (11.3) | (8.7) | (15.5) | (11.4) | (16.3) | (8.7) | *(20.8)* |
| **2nd** | Red maple | Flowering cherry | Red maple | Flowering cherry | Bigleaf maple | Flowering cherry | *Black cottonwood* |
| **(%)** | (6.7) | (8.5) | (10.7) | (7) | (9) | (6.5) | *(17.8)* |
| **3rd** | Flowering cherry | Purple-leaf plum | Norway maple | Pear | Western redcedar | Red maple | *Douglas-fir* |
| **(%)** | (5.9) | (5.6) | (8.1) | (5.4) | (7.3) | (5.7) | *(15.2)* |
| **4th** | Scarlet oak | Red maple | Flowering cherry | Red maple | Red maple | Arborvitae | *Vine maple* |
| **(%)** | (4.9) | (4.2) | (5.1) | (5.3) | (5.4) | (5.2) | *(5.9)* |
| **5th** | Crabapple | Arborvitae | Western redcedar | Purple-leaf plum | Douglas fir | Bigleaf maple | *Red alder* |
| **(%)** | (3.4) | (4.2) | (4.4) | (3.4) | (4.9) | (4.6) | *(5.8)* |
| **TOTAL Trees** | **39,867** | **69,751** | **19,288** | **64,216** | **43,399** | **236,521** | ***1,233,790*** |

The dominant tree types growing along Portland's streets vary by area of town (Table 3-1). While Norway maple (*Acer platanus*) is the most abundant street tree species citywide, bigleaf maple (*Acer macrophyllum*) and arborvitae (*Thuja occidentalis*) are the most prevalent in northwest and southwest Portland, respectively. Of the city's five most abundant species, only red maple (*Acer rubrum*) is widespread enough to make it into the top five species for all five areas of town.

Maples are ubiquitous in Portland (Table 3-1). The native bigleaf maple (*Acer macrophyllum*) is the most abundant tree in natural areas; Norway maple, red maple, and bigleaf maple are among the five most common street tree types. Flowering cherry (*Prunus spp*.) and arborvitae are also popular street trees.

Broadleaf deciduous trees dominate the landscape, accounting for 85% of street trees and 77% of park trees (Table 3-2). Tree size designations (small, medium, and large) are determined by both the functional type and mature size of the tree. Parks contain more large-at-maturity trees (64%) and more conifers (23%) than do street rights-of-way. Streets host four times the diversity of tree types than parks, one-third of which are small when mature.

**Table 3-2.** *Distribution of street trees and parks and natural area trees by functional tree type (broadleaf, coniferous, deciduous, and evergreen) and mature tree size (small, medium, and large).*

| Functional | Street Trees (%) | | | | Park Trees (%) | | | |
|---|---|---|---|---|---|---|---|---|
| Tree Type | Sm. | Med. | Lg. | Total | Sm. | Med. | Lg. | Total |
| Broadleaf Deciduous | 32 | 28 | 25 | **85** | 24 | 12 | 41 | **77** |
| Broadleaf Evergreen | 1 | 1 | <0.1 | **2** | 1 | 0 | 0 | **1** |
| Coniferous Evergreen | <0.1 | 1 | 12 | **12** | 0 | 0 | 23 | **23** |
| Palm Evergreen | <0.01 | 0 | 0 | **<0.01** | 0 | 0 | 0 | **0** |
| **TOTAL** | **33** | **30** | **37** | | **25** | **12** | **64** | |

## Tree Dimensions and Characteristics

RELATIVE TREE AGE

Tree size—a function of height, diameter, canopy spread, and leaf area—varies with species and planting conditions. That is, the size of a tree is determined by its genetic predisposition tempered by the resource limitations, pathogen interactions, and management it experiences throughout its lifetime. Generally within a species, age and photosynthetic capacity increase with tree size, so the value of the tree—and the magnitude of the benefits it provides—increase throughout the life of the tree up to senescence.

Because actively growing trees increase in girth as they age, the relative ages of trees within taxa may be approximated using diameter at breast height (DBH). Relative age diagrams show the proportion of trees in each diameter class, providing information about the proportion of young, maturing, and mature trees in the population (Figure 3-1). An uneven-aged population contains trees at various stages of maturity and is desirable for managing maintenance costs over time. In

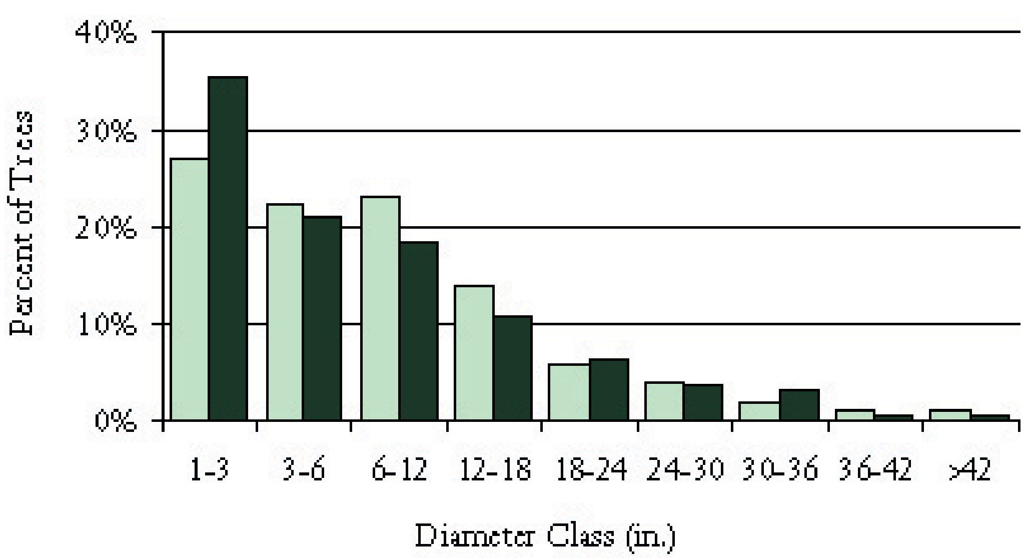



**Figure 3-1.** *Percentage of street trees (light green) and park trees (dark green) in each diameter class.*

addition, age diversity ensures that canopy coverage and community complexity are not reduced with mortality.

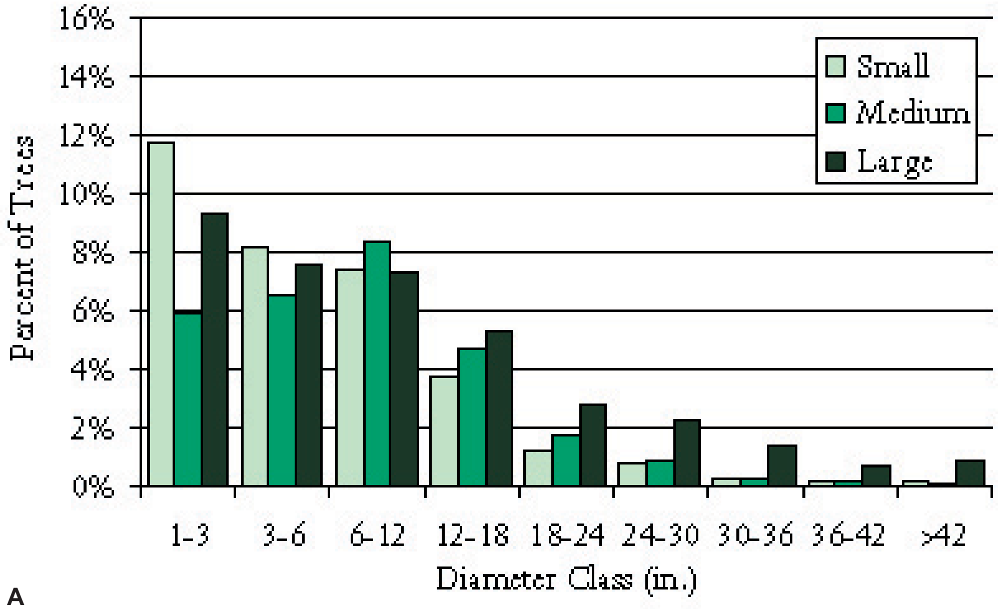
Portland's streets and parks host a diversity of tree sizes from the smallest one-inch saplings to the majestic, mature specimen trees that exceed 3½ feet in diameter (Figure 3-1 and Tables B-1 and B-2, Appendix B). Roughly half of these public trees are smaller than 6" DBH, and fewer than 10% are greater than 30" DBH. Although larger trees are generally older than smaller trees within specific taxa, for trees of similar DBH, individual tree age varies depending on mature tree size. For example, a 6" diameter vine maple may be fully mature, but a 6" diameter Douglas-fir is likely less than ten years old.

Three qualitative categories – small, medium, and large – define the potential mature size for each tree type and allow relative age comparisons within each diameter class (Figure 3-2 and Tables B-1 and B-2, Appendix B). Large trees such as Douglas-fir, bigleaf maple, and most elm species have the potential to attain the greatest heights, diameters, and longevity. By comparison, ornamentals like dogwoods, hawthorns, and many flowering cherries are among the smallest and shortest lived species growing in Portland. Species like birch, ash, and tupelo have intermediate attributes.

*Marquam Nature Trail near Council Crest*

Parks host more large-growing species than streets do in all size categories (Figure 3-2). Because large-growing species are likely younger than small-growing species within each diameter class, the park tree population may be younger than the street tree population. A greater variety of mature tree sizes grows on Portland's streets where small, medium, and large-growing trees are represented in each diameter class.

The amount of environmental and aesthetic benefits a tree may provide over its lifetime is a function of mature tree size and longevity, so the larger the mature size of the tree and the longer the tree lives, the greater the potential environmental and aesthetic benefits the tree will provide. Parks host 27% more large-tree types, 17% fewer medium-tree types, and 10% fewer small-tree types than do streets (Table 3-2), suggesting that park trees represent a greater potential source of environmental benefits per tree than street trees. To

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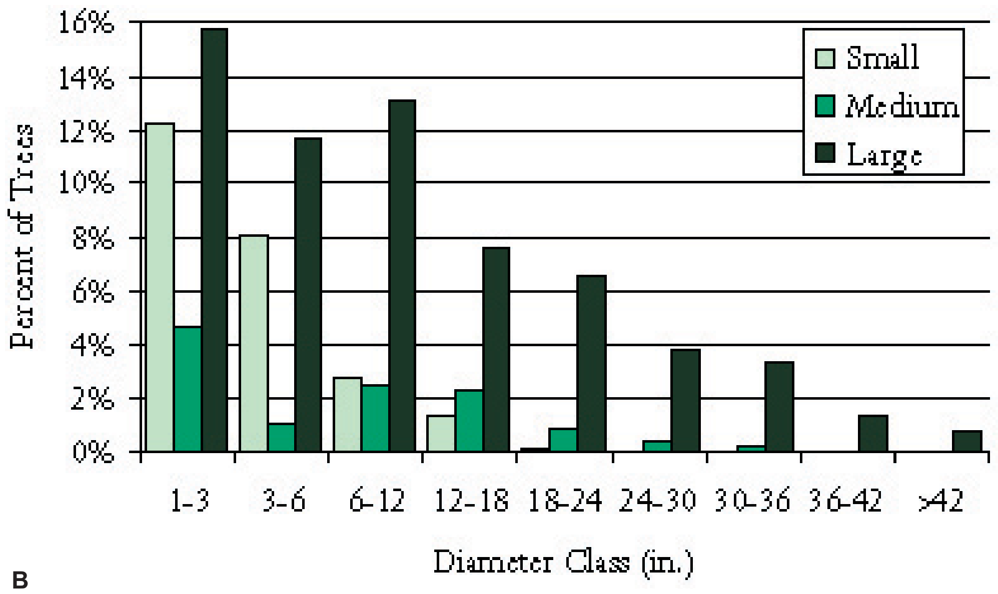



B

**Figure 3-2.** *Proportion of small, medium, and large at maturity (a) street tree and (b) park tree species by diameter class.*

compare net environmental benefits among the populations, however, requires relative mortality and longevity rates which this study does not address.

### TREE HEIGHT

In general, park trees overtop street trees. The majority of street trees are shorter than 30 feet, and the majority of park trees are taller than 30 feet (Figure 3-3). Tree height is a function of species, location, and maintenance history. While most park trees are fettered only by competition from adjacent vegetation, street trees must contend with small growing spaces, limited soil resources, and poor maintenance practices such as topping. The comparatively large proportion of short street trees and tall park trees may be indicative of the relatively hostile street environment.

### LEAF AREA, CANOPY COVERAGE, AND IMPORTANCE VALUES

Leaf surface area is the tree's fundamental unit of production. Generally speaking, the greater the leaf surface area, the greater the photosynthetic capacity of the tree and the greater the benefits the tree

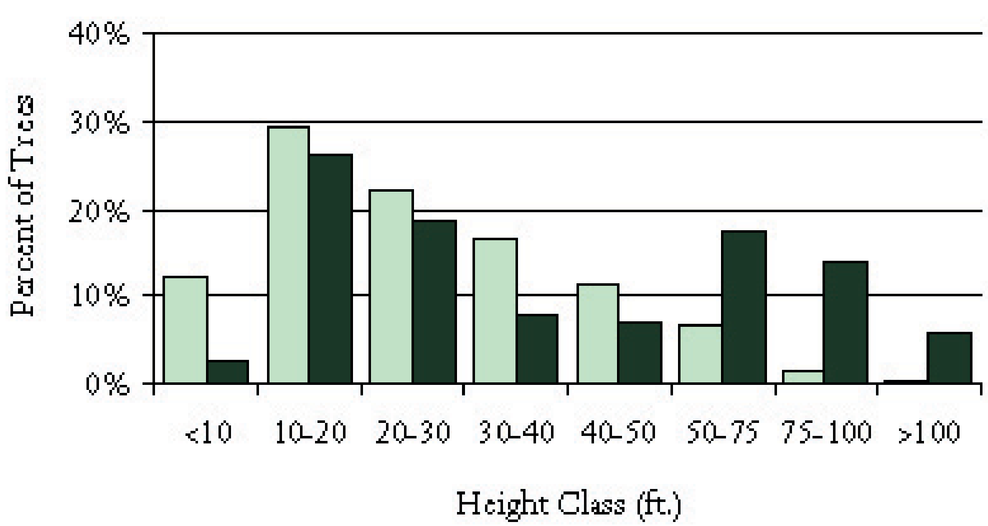



**Figure 3-3.** *Relative height of street trees (light green) and park trees (dark green).*

provides. Canopy coverage is the amount of ground surface covered by tree canopy. Along with the total number of trees, leaf area and canopy coverage combine to show the amount of biomass present in the population for each tree type. In ecological terms, the greater the biomass, the more important the tree type.

Relative importance considers the number of individuals, leaf area, and canopy coverage, normalized by percent of total, for each tree type. Because the metric is standardized, importance values allow for comparisons of relative dominance among tree types in a population. The concentration of large importance values in a small number of taxa indicates the extent to which the population relies on a small number of tree types.

Of Portland's ten most important street tree types, Norway maple is the most important and is more than twice as important as the

**Table 3-3.** *Relative dominance of Portland's ten most important types of street and park trees.*

| Tree Type | Trees (#) | Trees (%) | Leaf Area (%) | Canopy Cover (%) | Importance Value |
|---|---|---|---|---|---|
| **Street Trees** | | | | | |
| Norway maple | 20,681 | 8.74 | 14.26 | 12.61 | **11.87** |
| Red maple | 13,482 | 5.70 | 5.25 | 4.89 | **5.28** |
| Douglas fir | 5,501 | 2.33 | 7.46 | 5.80 | **5.20** |
| Flowering cherry | 15,315 | 6.48 | 2.75 | 4.89 | **4.71** |
| Bigleaf maple | 10,799 | 4.57 | 4.41 | 4.04 | **4.34** |
| European white birch | 5,705 | 2.41 | 4.96 | 4.57 | **3.98** |
| Elm | 2,513 | 1.06 | 6.08 | 4.79 | **3.98** |
| Sweetgum | 4,550 | 1.92 | 4.98 | 3.76 | **3.55** |
| Western redcedar | 5,569 | 2.35 | 3.43 | 2.88 | **2.89** |
| Scarlet oak | 4,177 | 1.77 | 2.64 | 4.09 | **2.83** |
| **Park Trees** | | | | | |
| Douglas fir | 149,413 | 12.11 | 34.22 | 25.13 | **23.82** |
| Bigleaf maple | 297,734 | 24.13 | 20.93 | 24.72 | **23.26** |
| Black cottonwood | 224,421 | 18.19 | 9.94 | 13.31 | **13.81** |
| Red alder | 79,588 | 6.45 | 8.44 | 9.08 | **7.99** |
| Western redcedar | 71,675 | 5.81 | 6.90 | 4.68 | **5.80** |
| Vine maple | 81,488 | 6.60 | 2.66 | 3.56 | **4.28** |
| Oregon ash | 63,186 | 5.12 | 2.55 | 3.77 | **3.81** |
| European bird cherry | 64,713 | 5.25 | 2.83 | 2.08 | **3.39** |
| Beaked hazelnut | 35,493 | 2.88 | 2.12 | 2.85 | **2.61** |
| Shining willow | 41,772 | 3.39 | 0.93 | 0.93 | **1.75** |

next tree type (Table 3-3). The ten most important street tree types account for roughly one-third of the population. In parks, roughly one-third of the trees are either Douglas-fir or bigleaf maple, and the ten most important park trees account for 90% of the population.

### TREE CONDITION

In this analysis, tree condition is the health of the tree as manifest in the condition of its bark and leaves, assessed using a four-point scale: 1 = good, 2 = fair, 3 = poor, and 4 = dead/dying. The condition of urban trees reflects species hardiness, site conditions, and maintenance history. Trees that are well suited to Portland's climate, that can adapt to the challenges of growing in an urban environment, and that have been maintained using proper arboricultural techniques (*e.g.*, not topped) are generally the most successful.

**Table 3-4.** *Proportion of street and park trees in each of four condition classes: good, fair, poor, and dead/dying.*

| Condition | Street Trees | Park Trees |
|---|---|---|
| Good | 63.9% | 87.8% |
| Fair | 28.2% | 6.6% |
| Poor | 6.5% | 4.6% |
| Dead/Dying | 1.3% | 0.9% |

Portland's park trees are in generally better health than its street trees (Table 3-4). While roughly the same proportion of park (94%) and street (91%) trees are in fair to good condition, 24% more park trees are classified in good condition. Location may affect tree condition. Compared with parks and natural spaces, the street environment—where growing space is limited, soils are generally poor, and automobile exhaust reduces local air quality—is far less hospitable to trees.

### NATIVE ORIGIN

The native origin of species is increasingly important to managers who seek to preserve native ecosystems. Non-native species can reduce the quality and quantity of habitat for native species. Invasive non-

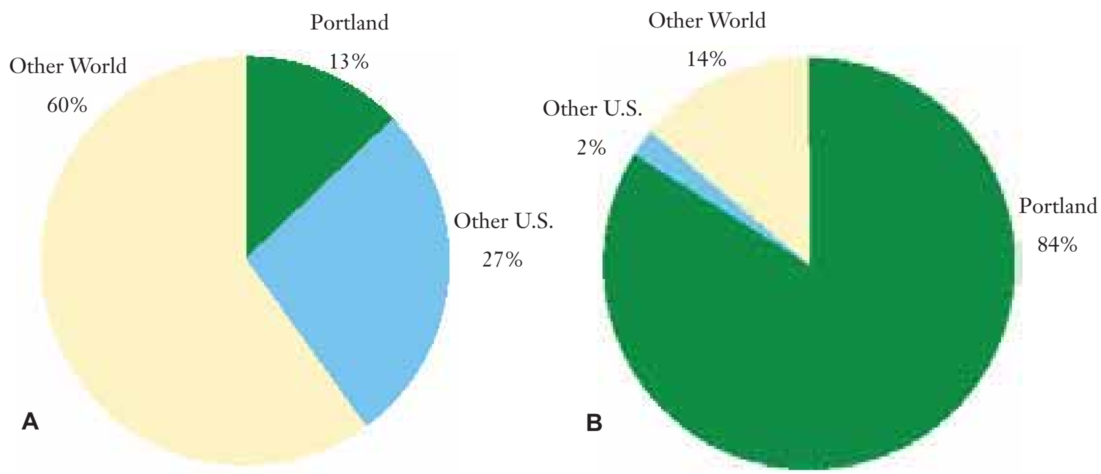



**Figure 3-4.** *Native origin of Portland's (a) street and (b) park trees (% of tree total).*

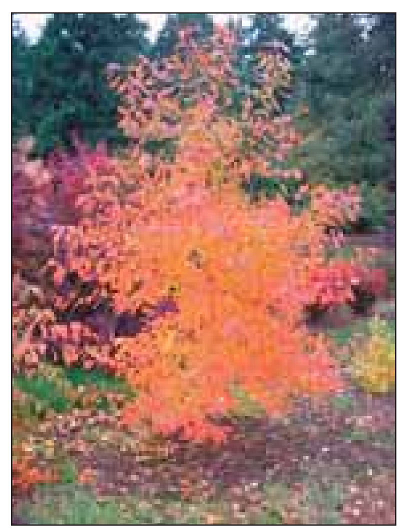
natives can outcompete native species because the natural "checks and balances" with which they evolved may be absent outside of their own native habitats.

The majority of Portland's street trees (60%) are native to places outside of the United States, mainly Europe and Asia, with only 13% native to the Portland area. Conversely, the majority of park trees (84%) have genetic origins in the Willamette Valley (Figure 3-4).

## Street Tree Distribution and Placement

### STOCKING LEVEL

Street tree stocking level reflects the percentage of potential planting spaces within the street rights-of-way that are currently occupied by trees. Planting space availability on Portland's street rights-of-way is subject to a number of guidelines. For example, the potential planting space must be large enough so that the tree does not block signs, signals, intersections, and lines-of-sight (for more information, request the "Street Tree Planting and Establishment Guidelines" from Urban Forestry, (503) 823-4489).



Cornus florida *in glorious autumn color*

Stocking levels range from 37% in Southeast Portland to 64% in northwest Portland, averaging 45% citywide (Figure 3-5). The total number of street trees varies from roughly 19,000 in northwest

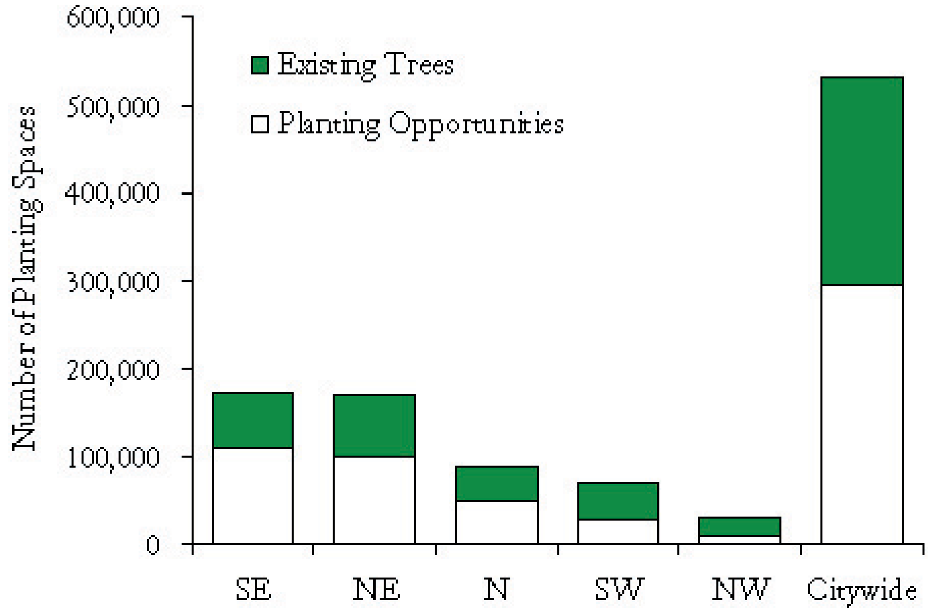



**Figure 3-5.** *Estimated street tree stocking levels for southeast (SE), northeast (NE), north (N), southwest (SW), and northwest (NW), Portland and the City of Portland as a whole.*

Portland to more than 69,000 in northeast Portland (Table 3-5). Differences in the stocking potential in each zone reflect differences in zone size (Figure 3-6). Because the east side zones are larger than the west side zones, east side stocking levels are lowest even though east side street tree populations are highest.

**Table 3-5.** *Distribution of street trees and right-of-way (ROW) planting spaces per square mile by area of town. Numbers in parentheses indicate percent of total.*

| | North | Northeast | Northwest | Southeast | Southwest | Citywide |
|---|---|---|---|---|---|---|
| Trees | 39,900 (17%) | 69,800 (30%) | 19,300 (8%) | 64,200 (27%) | 43,400 (18%) | **236,500** |
| ROW Planting Spaces | 88,900 (17%) | 168,300 (32%) | 30,300 (6%) | 173,300 (33%) | 70,400 (13%) | **531,100** |
| Land Area ($mi^2$) | 27 (19%) | 37 (26%) | 19 (13%) | 37 (26%) | 21 (15%) | **141** |
| Planting Spaces/$mi^2$ | 3,352 | 4,535 | 1,606 | 4,632 | 3,305 | **3,762** |
| Trees/$mi^2$ | 1,504 | 1,880 | 1,024 | 1,717 | 2,036 | **1,675** |

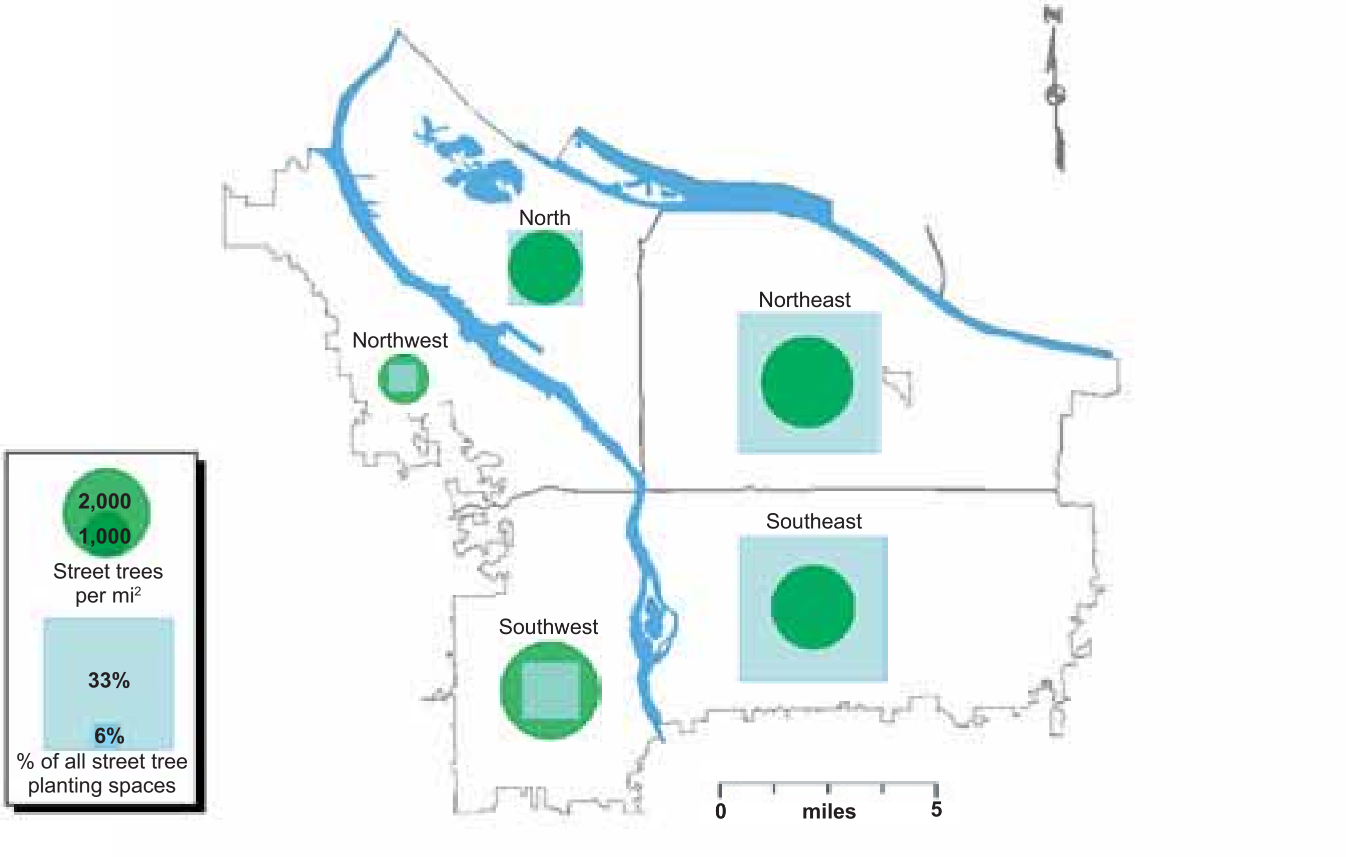



**Figure 3-6.** *Relative stocking potential by area of town. Proportional green circles and blue squares indicate (1) the current number of street trees per square mile, and (2) the percentage of all street tree planting opportunities in each of Portland's five major zones.*

Southeast and northeast Portland have the lowest stocking levels (37% and 41%) but the largest numbers of right-of-way planting spaces (173,000 and 168,000) in the city (Table 3-5). Although northwest Portland has the highest stocking rate of all the zones (64%), it houses only 6% of the city's right-of-way planting spaces and has the fewest street trees per square mile (Figure 3-6). By comparison, north Portland has twice the number of planting spaces per square mile, 1½ times the number of trees per square mile, and a stocking level equal to that of the city as a whole. Southwest Portland has the second highest stocking level (62%) and the greatest density of street trees (2,036 /$mi^2$).

### STREET TREE PLACEMENT

The urban forester's guiding adage is, "the right tree in the right place." Tree placement is important for maximizing the benefits trees provide and minimizing avoidable costs. A tree that is well suited to its location experiences fewer obstacles to reaching maturity and providing a maximum of environmental and aesthetic benefits over its lifetime. An inappropriately placed tree, however, may cost more to maintain, experience reduced health and a shorter life span, and thereby provide fewer benefits.

Mature tree size is a decisive factor in determining an appropriate species for a location. A large-growing tree planted in an undersized space will be increasingly stressed as it ages and its roots reach the limits of the available soil resource. Limited water and nutrient availability negatively affect the tree's growth and health, shortening life span and reducing the benefits the tree can provide. In addition, recurrent infrastructure damage, more frequent pruning, and the increased likelihood of disease and pathogen infection increase maintenance costs.

Space for planting street trees is a valuable commodity. A small-at-maturity tree in a space that could house a larger species represents a missed opportunity to increase environmental benefits. Small-growing species will likely not grow as large or live as long as large-growing species. Roughly 87,500 of Portland's street trees (37%) grow in rights-of-way that are either too small or too large to accommodate them optimally (Table 3-6). Almost 52,700 large trees would perform better in a more spacious location, and at least 35,800 could tolerate a smaller planting area.

## Citywide Forest Canopy Coverage

Total forest canopy coverage for the City of Portland exceeds 24,000 acres or 26% of the city's landcover (Table 3-7). Just over half (54%) of the property in Portland is privately owned, and 53% of the city's tree canopy shades private property. While public property hosts less canopy cover (47%) overall, canopy density is slightly greater on public (27%) than private (26%) property.

**Table 3-6.** *Number and percent of trees growing in undersized and oversized rights-of-way (ROW) by tree type for the 27 most abundant street tree types. Letters in parentheses denote mature tree size: L = large, M = medium, and S = small.*

| Tree Type | Trees Growing in an Undersized ROW | | Trees Growing in an Oversized ROW | |
|---|---|---|---|---|
| | (#) | (%) | (#) | (%) |
| Littleleaf linden (M) | 2,291 | 82 | 0 | 0 |
| Sweetgum (M) | 3,169 | 70 | 0 | 0 |
| Red maple (M) | 9,207 | 68 | 0 | 0 |
| Scarlet oak (L) | 2,743 | 66 | 0 | 0 |
| Western redcedar (L) | 3,548 | 64 | 0 | 0 |
| Douglas-fir (L) | 3,348 | 61 | 0 | 0 |
| Bigleaf maple (L) | 5,824 | 54 | 0 | 0 |
| Silver maple (L) | 1,298 | 54 | 0 | 0 |
| Horsechestnut (L) | 1,336 | 49 | 0 | 0 |
| Flame ash (M) | 1,664 | 46 | 0 | 0 |
| Sugar maple (L) | 1,281 | 41 | 0 | 0 |
| Ash (M) | 1,084 | 38 | 0 | 0 |
| Elm (L) | 965 | 38 | 0 | 0 |
| Norway maple (L) | 7,200 | 35 | 0 | 0 |
| European white birch (L) | 1,125 | 20 | 0 | 0 |
| Sycamore maple (M) | 348 | 12 | 0 | 0 |
| Flowering cherry (S) | 662 | 4 | 0 | 0 |
| Kousa dogwood (S) | 982 | 36 | 567 | 21 |
| Flowering dogwood (S) | 948 | 36 | 668 | 25 |
| Japanese snowbell (S) | 0 | 0 | 680 | 25 |
| English hawthorn (S) | 1,678 | 30 | 2,080 | 37 |
| Pear (S) | 629 | 8 | 3,670 | 44 |
| Plum (S) | 0 | 0 | 1,920 | 46 |
| Arborvitae (S) | 347 | 3 | 9,214 | 75 |
| Japanese maple (S) | 0 | 0 | 4,006 | 80 |
| Crabapple (S) | 0 | 0 | 5,050 | 88 |
| Purple-leaf plum (S) | 0 | 0 | 7,999 | 99 |
| **TOTAL** | **51,677** | | **35,854** | |

Portland's *Urban Forestry Management Plan* (2004) contains forest canopy coverage goals for four major Urban Land Environments (ULEs) within the urban forest: residential, commercial/ industrial, developed parks/open space, and rights-of-way (Table 3-8). Based on the acreage of each ULE, citywide forest canopy coverage must increase by one-fourth—covering additional 7% of the city—to fulfill these goals. This hypothetical future condition would increase canopy coverage to over 30,000 acres which is roughly one-third of the city.

**Table 3-7.** *Citywide landcover and forest canopy coverage for the 2002 urban forest canopy and desired target forest canopy cover.*

| Canopy Extent | Public Property | Private Property | Citywide | Target Canopy |
|---|---|---|---|---|
| Total Landcover (acres) | 42,785 | 49,845 | 92,630 | *92,630* |
| Total Canopy Coverage (acres) | 11,404 | 12,714 | 24,118 | *30,566* |
| Canopy % of Landcover | 27 | 26 | 26 | *33* |

**Table 3-8.** *Current (2002) and target firest canopy coverage for four of Portland's Urban Land Environments.*

| Urban Land Environment | Current Canopy (2002) (%) | Target Canopy (%) |
|---|---|---|
| Residential | 30 | 35-40 |
| Commercial/Industrial | 7 | 15 |
| Developed Parks and Open Spaces | 28 | 30 |
| Rights-of-way | 17 | 35 |

*A lovely autumn day at Columbia Park*

# Asset Management

## Tree Replacement Values

While urban trees provide quantifiable environmental and aesthetic benefits, the biological legacy in the tree infrastructure itself may also be appraised. The value of a tree is a function of its size, species, health, and location (CTLA 1992). Portland's street tree resource is valued at just under $500 million (Table 4-1) or roughly $2,050 per tree. The replacement value of the tree infrastructure in Portland's parks and natural areas exceeds $1.8 billion (Table 4-2).

**Table 4-1.** *Replacement value of Portland's street tree resource by DBH class and area of town.*

| DBH (in) | North | Northeast | Northwest | Southeast | Southwest | Citywide |
|---|---|---|---|---|---|---|
| 0-3 | $1,960,606 | $3,211,467 | $977,481 | $2,589,176 | $2,522,081 | *$11,260,811* |
| 3-6 | $2,216,089 | $5,147,032 | $1,438,693 | $5,673,111 | $4,249,767 | *$18,724,691* |
| 6-12 | $7,841,720 | $14,576,751 | $5,795,344 | $16,536,142 | $11,571,980 | *$56,321,937* |
| 12-18 | $18,628,916 | $24,709,645 | $6,766,463 | $27,711,578 | $12,061,154 | *$89,877,756* |
| 18-24 | $16,203,692 | $24,073,332 | $4,560,285 | $18,518,995 | $6,544,193 | *$69,900,495* |
| 24-30 | $13,230,828 | $28,722,012 | $5,400,757 | $25,152,732 | $8,254,217 | *$80,760,547* |
| 30-36 | $9,800,059 | $22,220,207 | $1,628,351 | $26,422,821 | $4,538,524 | *$64,609,962* |
| 36-42 | $12,312,079 | $17,621,721 | $887,650 | $11,907,247 | $2,993,732 | *$45,722,428* |
| >42 | $16,387,569 | $7,341,228 | $791,143 | $18,298,692 | $4,764,893 | *$47,583,525* |
| **ALL** | **$98,581,559** | **$147,623,395** | **$28,246,166** | **$152,810,495** | **$57,500,539** | ***$484,762,153*** |

Assuming that the privately owned tree infrastructure is comparable in size, species, and health to that of the public trees, the structural value of the entire urban canopy may be approximated from the ratio of public to private canopy. Just over half (53%) of the urban forest canopy is privately owned (Table 3-7), so the replacement value of the private tree asset is roughly $2.6 billion, and the value of the entire urban canopy exceeds $4.9 billion.

**Table 4-2.** *Replacement value and unit cost for trees in Portland's developed, undeveloped, and natural parks.*

| Park Type | Replacement Value | Cost/Tree |
|---|---|---|
| Developed | $126,869,306 | $5,976 |
| Undeveloped | $91,804,652 | $5,275 |
| Natural Areas | $1,597,189,981 | $1,336 |
| ***ALL*** | ***$1,815,863,938*** | ***$1,472*** |

## Annualized Costs

The costs of maintaining Portland's street and park trees include one-time planting and removal expenses as well as ongoing care and maintenance responsibilities that vary depending on tree species, age, location, and ownership. City Nature Urban Forestry is responsible for all tree work on Parks-owned properties. Planting, removal, and ongoing maintenance of street trees are the responsibility of the adjacent property owners. Urban Forestry assists landowners through professional consultation and permitting services for street tree planting and cutting as well as emergency response for trees and branches blocking rights-of-way.

In 2006, the total annual cost of managing and maintaining Portland's street and park trees just exceeded $6.5 million (Table 4-3). Pest and disease control was the largest expense for street trees, accounting for 39% of all costs incurred. In Portland's parks, Urban Forestry spent 46% of the tree maintenance budget on pruning. Compared with the park tree resource, more than twice as much was spent on street trees. Two general factors may explain much of the variance: differing maintenance needs and the economies of scale recognized by larger park tree maintenance projects.

Portland's street tree expenditures compare favorably with other cities. Each year, an average of $19.50 is spent for each street tree and $1.60 for each park tree. Other municipalities have found annual costs per street tree range from $18.00 in Bismarck, ND, to $65.00 in Berkeley, CA (McPherson *et al.* 2005).

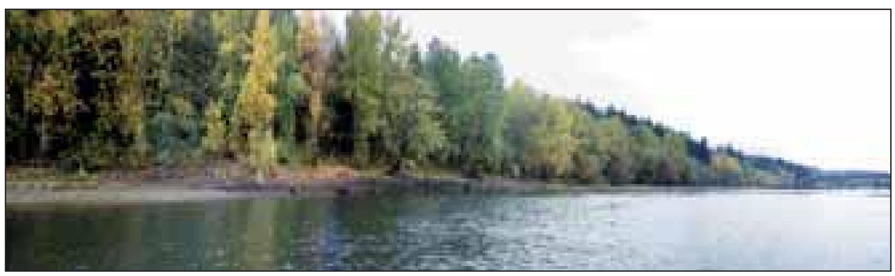
**Table 4-3.** *Annual expenses incurred in managing and maintaining Portland's street and park trees. Expenses incurred by private property owners are shown in italics.*

| Costs | Street Trees | | Park Trees | Total Costs |
|---|---|---|---|---|
| | (private) | (public) | | |
| Planting | *$233,928* | $574,600 | $361,800 | **$1,170,328** |
| Pruning | *$469,517* | | $904,567 | **$1,374,084** |
| Removal & Disposal | *$488,320* | $34,678 | $308,880 | **$831,878** |
| Pest & Disease Control | *$1,800,283* | $4,567 | $13,238 | **$1,818,088** |
| Establishment | *$1,020* | $34,243 | $180,900 | **$216,163** |
| Infrastructure Damage | *$333,445* | | | **$333,445** |
| Emergency Response | | $126,168 | $39,487 | **$165,655** |
| Litigation | | $4,500 | | **$4,500** |
| Program Administration | | $105,411 | $105,411 | **$210,822** |
| Inspections | | $401,893 | $55,266 | **$457,159** |
| **Total Annual Costs** | ***$3,326,513*** | **$1,286,060** | **$1,969,549** | **$6,582,122** |
| **Total Street Tree Costs** | | | | **$4,612,573** |
| **Total Public Costs** | | | | **$3,255,609** |

# The Benefits of Trees

## Environmental Services and Aesthetic Benefits from Public Trees

Portland's green infrastructure provides numerous quantifiable environmental and aesthetic benefits that enhance the quality of life and reduce the burden on the grey infrastructure. Environmental benefits are quantified based on the market value of the service provided or the cost avoided. Aesthetic benefits such as landscape beautification, sense of calm and well-being, and wildlife habitat, however, are intangible and difficult to quantify. Therefore, the increase in property values attributable to the presence of trees is used to approximate the value of this suite of intangibles.



*Powers Marine Park stretches along the west bank of the Willamette River*

Through the process of photosynthesis, trees improve air quality, lower atmospheric $CO_2$ levels, and reduce stormwater runoff. Shading of buildings by tree canopies reduces overall energy demand, thereby decreasing energy consumption and pollutant emissions (McPherson *et al*. 2002). The monetary value of the environmental and aesthetic benefits Portland's public trees provide equals nearly $27 million each year (Table 5-1).

**Table 5-1.** *Valuation of the environmental and aesthetic benefits provided annually by Portland's street and park trees.*

| Benefits | Street Trees | | Park Trees | | Street and Park | |
|---|---|---|---|---|---|---|
| | Total ($) | $/tree | Total ($) | $/tree | Total ($) | $/person |
| Energy Savings | $750,650 | $3 | | | $750,650 | $1 |
| Carbon Sequestration | $132,599 | <$1 | $171,592 | <$1 | $304,190 | <$1 |
| Air Quality Improvement | $257,699 | $1 | $512,451 | <$1 | $770,150 | $1 |
| Stormwater Processing | $3,757,727 | $16 | $7,738,608 | $6 | $11,496,335 | $21 |
| Aesthetics | $13,692,429 | $58 | | | $13,692,429 | $25 |
| **Total Benefits** | **$18,591,104** | **$79** | **$8,422,651** | **$7** | **$27,013,755** | **$49** |

Portland's street and park trees provide over $1 million worth of air cleaning and carbon fixing services annually. This equates to more than 25 million pounds of carbon dioxide, nitrogen dioxide, ozone, $PM_{10}$ (particulate matter ≤10 microns) and sulfur dioxide removed from Portland's air supply each year (Table 5-2). In addition to removing harmful air pollutants, trees contribute biogenic volatile organic compounds (BVOCs) to the atmosphere. BVOCs reduce air quality by contributing to low-level ozone production—a precursor to smog. BVOC production varies with tree type; some trees (*e.g.*, Sweetgums) produce high enough levels of BVOCs that their net contribution to air quality is relatively low (Table 5-3).

**Table 5-2.** *Annual environmental benefits and total carbon storage provided by Portland's street and park trees.*

| Benefits | Street Trees | | Park Trees | | Street and Park | |
|---|---|---|---|---|---|---|
| | Total | per tree | Total | per tree | Total | per person |
| Electricity (MWh) | 6,105 | <1 | | | 6,105 | <1 |
| Natural Gas (therms) | 198,761 | <1 | | | 198,761 | <1 |
| Stormwater (gallons) | 135,209,280 | 572 | 278,467,356 | 226 | 413,676,636 | 744 |
| Annual Carbon (lbs) | 10,834,169 | 46 | 14,020,187 | 11 | 24,854,356 | 45 |
| Air Pollutants (lbs) | 136,361 | 1 | 462,662 | <1 | 599,023 | 1 |
| Stored Carbon (lbs) | 158,438,439 | 670 | 562,639,777 | 456 | 721,078,216 | 1,296 |

*Stately elm trees in the South Park Blocks*

**Table 5-3.** *Average annual environmental and aesthetic benefits accrued ($/tree) by Portland's 27 most abundant street tree types. Letters in parentheses denote mature tree size: L = large, M = medium, and S = small.*

| Tree Type | Energy | $CO_2$ | Air Quality | Stormwater | Aesthetics | Total |
|---|---|---|---|---|---|---|
| Elm (L) | $13.36 | $1.94 | $5.16 | $78.52 | $98.72 | **$197.69** |
| Douglas-fir (L) | $7.24 | $0.98 | $2.84 | $63.68 | $119.41 | **$194.15** |
| Sweetgum (M) | $6.90 | $0.78 | $0.94 | $33.06 | $135.20 | **$176.87** |
| European white birch (M) | $6.26 | $0.96 | $1.63 | $28.56 | $101.95 | **$139.36** |
| Sugar maple (L) | $6.49 | $1.25 | $2.44 | $33.60 | $94.23 | **$138.01** |
| Littleleaf linden (M) | $5.15 | $0.77 | $1.34 | $22.86 | $97.27 | **$127.38** |
| Silver maple (L) | $6.30 | $1.14 | $2.40 | $34.36 | $82.61 | **$126.81** |
| Western redcedar (L) | $3.57 | $0.50 | $1.46 | $29.49 | $86.87 | **$121.90** |
| Norway maple (L) | $4.90 | $1.01 | $1.81 | $23.21 | $88.66 | **$119.59** |
| Sycamore maple (M) | $4.42 | $0.63 | $1.15 | $19.54 | $89.17 | **$114.91** |
| Scarlet oak (L) | $6.30 | $1.22 | $2.30 | $37.00 | $61.80 | **$108.63** |
| Horsechestnut (M) | $8.06 | $1.26 | $4.07 | $46.18 | $34.99 | **$94.57** |
| Ash (M) | $3.68 | $0.56 | $0.97 | $17.06 | $66.40 | **$88.66** |
| Red maple (M) | $2.92 | $0.43 | $0.76 | $12.82 | $68.90 | **$85.83** |
| Bigleaf maple (L) | $3.05 | $0.63 | $1.12 | $13.89 | $65.94 | **$84.64** |
| Pear (M) | $2.24 | $0.32 | $0.58 | $9.51 | $61.88 | **$74.53** |
| Flame ash (M) | $2.05 | $0.30 | $0.53 | $8.70 | $56.87 | **$68.45** |
| English hawthorn (S) | $2.31 | $1.24 | $0.93 | $7.36 | $42.16 | **$54.00** |
| Flowering cherry (S) | $2.30 | $1.28 | $0.93 | $7.55 | $41.60 | **$53.66** |
| Arborvitae (S) | $0.37 | $0.04 | $0.14 | $2.19 | $38.59 | **$41.34** |
| Blieriana plum (S) | $1.71 | $0.79 | $0.67 | $5.05 | $32.20 | **$40.43** |
| Plum (S) | $1.53 | $0.69 | $0.60 | $4.47 | $29.20 | **$36.49** |
| Crabapple (S) | $1.34 | $0.61 | $0.52 | $3.91 | $26.13 | **$32.50** |
| Flowering dogwood (S) | $0.87 | $0.36 | $0.33 | $2.41 | $17.38 | **$21.34** |
| Kousa dogwood (S) | $0.86 | $0.36 | $0.33 | $2.40 | $16.96 | **$20.90** |
| Japanese maple (S) | $0.40 | $0.13 | $0.15 | $1.00 | $8.81 | **$10.49** |
| Japanese snowbell (S) | $0.19 | $0.04 | $0.06 | $0.38 | $4.53 | **$5.21** |

Urban trees intercept and retain precipitation that would otherwise enter stormwater conveyance and treatment systems (McPherson *et al*. 2002). In this way, trees reduce the burden on a city's stormwater processing infrastructure. Portland's public trees save the city over $11 million in stormwater processing costs by intercepting nearly half a billion gallons of stormwater annually.

Trees also reduce temperature extremes and calm winds, reducing total electricity and natural gas needs (McPherson *et al*. 2002). Over 6,000 MWh of electricity and nearly 200,000 therms of natural gas are saved each year because of the mitigating effects of street trees. As a result, Portlanders save an annual $750,000 in avoided energy costs.

Trees increase the average resale value of residential properties, increase building rental rates, reduce the incidence of crime in innercity environments, and encourage more shopping and increased spending in business districts (Anderson and Cordell 1988, Wolf 1999, Kuo and Sullivan 2001, Laverne and Winson-Geideman 2003). Portland's street trees provide nearly three times more aesthetic benefits than environmental benefits. Over $13 million in property resale value is attributable to the presence of trees in the adjacent rights-of-way.

The level of benefits provided by each tree type depends on the importance of that tree type to the forest. The value of per tree benefits depends on the type and relative age of the trees. Large trees have greater surface area and photosynthetic capacity than small trees, so they provide more benefits. In this way, the larger a tree grows and the longer it lives, the greater the total amount of environmental benefits it provides. For example, each of Portland's elms provides roughly $200 in benefits each year—nearly forty times more than the least valuable tree type (Table 5-3).

## Benefit-Cost Ratio and Net Benefits

Portland's street and park trees provide nearly four times more in benefits than they cost to manage (Figure 5-1). Net annual benefits average $13.50 per tree and $36.00 per Portland resident. Considered separately, street trees provide greater net benefits ($57.00 per tree and $24.00 per person) than park trees ($5.00 per tree and $11.50 per person). Park trees do not provide the energy savings to buildings that street trees do, and this analysis does not attempt to quantify the aesthetic value of park trees. For the latter reason, the net benefits provided by park trees may be undervalued.

For every dollar spent managing Portland's street and park trees, $3.81 is returned in environmental and aesthetic benefits (Figure 5-1). On average, street trees return $3.61 for each dollar invested, and park trees return $4.28. Portland's street tree benefit-to-cost ratio compares favorably with those of other U.S. cities (*cf.* McPherson *et al.* 2005 and Vargas *et al.* 2006). Benefit-to-cost ratios for the street tree resource in 11 U.S. cities derived using the same methods vary from

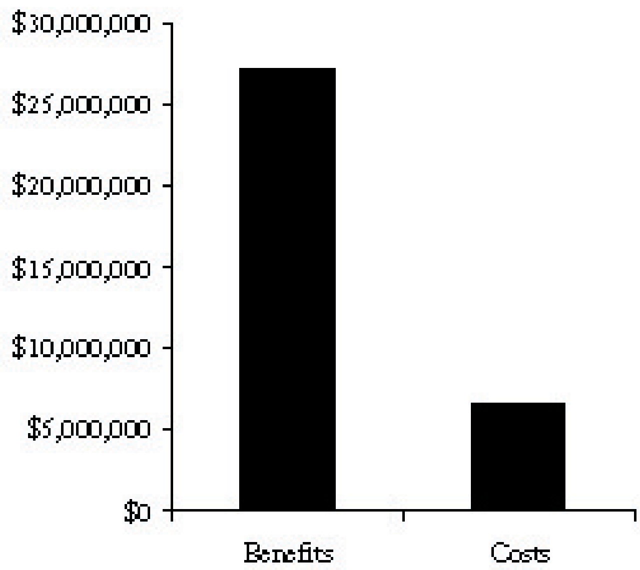



**Figure 5-1.** *Total annual costs incurred and benefits realized by Portland's street and park trees. Benefits exceed costs by 3.8 to 1.*

**Table 5-4.** *Benefit-to-cost ratios (BCR) for street tree assets in 11 U.S. cities.*

| City | BCR | Reference |
|---|---|---|
| San Francisco, CA | 1.00 | Vargas *et al*. 2006 |
| Albuquerque, NM | 1.31 | Vargas *et al*. 2006 |
| Charleston, SC | 1.34 | Vargas *et al*. 2006 |
| Berkeley, CA | 1.37 | McPherson *et al*. 2005 |
| Minneapolis, MN | 1.57 | Vargas *et al*. 2006 |
| Cheyenne, WY | 2.09 | McPherson *et al*. 2005 |
| Fort Collins, CO | 2.18 | McPherson *et al*. 2005 |
| Glendale, AZ | 2.41 | McPherson *et al*. 2005 |
| Bismarck, ND | 3.09 | McPherson *et al*. 2005 |
| Charlotte, NC | 3.25 | Vargas *et al*. 2006 |
| Portland, OR | 3.61 | current analysis |

1.00 in San Francisco, CA to 3.25 in Charlotte, NC, with Portland ranking first overall (Table 5-4).

The relatively high benefit-to-cost ratio in Portland may be a function of benefit pricing and the use of cost management strategies. Portland's stringent stormwater processing standards and robust real estate market make the stormwater interception and property resale value benefits exceptionally valuable (Table 5-1). In addition, many of the tree planting and establishment projects in Portland are undertaken by volunteers, effectively reducing overall costs.

## Benefits of the Citywide Urban Forest Canopy

Urban forest canopy coverage derived from satellite imagery provides the basis for estimating the environmental benefits provided by the entire urban forest canopy. A model determines the magnitude of environmental benefits provided annually by the existing forest canopy and predicts how benefits will increase with increasing canopy. Portland's urban forest canopy stores about 1.5 billion pounds of carbon and produces almost $40 million worth of carbon sequestration, air cleaning, and stormwater processing benefits each year (Table 5-5). Meeting the *Urban Forestry Management Plan* canopy goals of increasing tree canopy coverage by one-fourth to cover 7% more land would boost carbon storage to nearly 2 billion pounds and increase the annual value of carbon, air pollutant, and stormwater reductions to almost $44 million.

**Table 5-5.** *Quantity and value of annual environmental benefits and total carbon storage provided by Portland's urban forest at present and with an additional 7% of land covered by tree canopy.*

| | Canopy Extent | | |
|---|---|---|---|
| | Current (26%) | 7% Increase | Future (33%) |
| **Canopy Extent** | | | |
| Total Land Area (acres) | 92,630 | 92,630 | 92,630 |
| Canopy Coverage (acres) | 24,118 | 6,448 | 30,566 |
| Canopy % of Landcover | 26 | 7 | 33 |
| **Infrastructure Storage** | | | |
| Total Carbon Storage (lbs) | 1,534,208,970 | 413,056,261 | 1,947,265,232 |
| | $18,777,057 | $5,055,362 | $23,832,419 |
| **Environmental Benefits** | | | |
| Carbon Sequestration (lbs) | 52,881,610 | 14,237,356 | 67,118,966 |
| | $647,214 | $174,250 | $821,463 |
| Air Pollutant Removal (lbs) | 1,848,886 | 494,349 | 2,343,235 |
| | $2,426,556 | $648,805 | $3,075,361 |
| Stormwater Control (gallons) | 1,282,799,204 | 150,917,553 | 1,433,716,757 |
| | $35,648,990 | $4,193,999 | $39,842,989 |
| **Annual Environmental Benefits** | **$38,722,760** | **$5,017,054** | **$43,739,813** |

# Implications for Urban Forest Management

## Urban Forest Canopy Composition

Portland's urban forest canopy is a complex, multi-species, multi-aged resource valued at roughly $5 billion that produces over $52 million in environmental and aesthetic benefits annually. Roughly 1.5 million trees grow on publicly owned property, comprising just under half of the urban forest canopy. These publicly owned trees cost the City and private property owners over $6.5 million annually to maintain and return $3.80 in benefits for each dollar invested in their care and maintenance.

A diversity of tree types—171 on streets and 41 in parks and natural areas—thrive in Portland's moderate Mediterranean climate. Although a large number of species are present in the urban forest canopy, relatively few species constitute the majority of the resource. One-third of all street trees belong to 3% of tree types, and over 50% of park trees are bigleaf maple, black cottonwood, and Douglas-fir.

Managed for habitat value, the majority of trees in natural areas are native canopy dominants (Douglas-fir) and sub-dominants (bigleaf maple and black cottonwood). The greater diversity of tree types in developed parks and along streets reflects different management strategies. When managing a system dominated by non-native species, diversity is a good strategy. Overplanting of just a few tree types has proven risky. Pests and pathogens can cause widespread and expensive damage, especially when host trees are plentiful and grow in close proximity to one another. The decimation of elm trees in eastern and midwestern North America in the 1900s by Dutch elm disease (DED) provides a classic example of the costly and catastrophic loss that can befall a monoculture. To retard the spread of DED in Portland, the City, non-profit elm protection groups, and elm owners spend roughly $125,000 each year for elm monitoring, DED-infected tree removal and replanting, and prophylactic inoculations.

The vast majority of Portland's public trees are in fair to good condition. A greater percentage of park trees are in better condition than street trees, possibly a function of the relatively hostile street environment, improper arboricultural practices, and the relative hardiness of non-native species. In addition, improperly sited trees that outgrow the spaces afforded them experience resource limitations that can exacerbate health issues. Over one-third of all street trees are poorly matched to the size of their locations—50,000 in undersized spaces and 35,000 in oversized spaces—representing a decrease in canopy health, the potential for recurring infrastructure damage, and a loss of productivity and thereby the level of benefits the population can provide.

While natural areas and developed parks are managed for habitat and recreation values, stocking level provides a metric for judging the extent of the street tree resource. Citywide, close to half of all street planting opportunities house trees. The west side has stocking levels in excess of 62%; the east side has over three times more right-of-way planting spaces than the west side and the lowest stocking levels (to 37%). A spatial analysis beyond the scope of this work may reveal that differences in zoning and land use contribute to differences in stocking level.

## IT PAYS TO GROW AN URBAN FOREST

Investing in urban trees provides a number of benefits. The presence of trees enhances one's sense of place and creates a more beautiful and inviting cityscape. Unlike elements of the built environment, as trees grow to maturity, they appreciate in structural value while providing an increasing level of environmental and aesthetic benefits. A nearly four-fold return in environmental and aesthetic benefits is recognized on the nominal investment made in planting, establishing, and maintaining a public tree in Portland.

The varied origins of Portland's urban canopy range from relict second-growth Douglas-fir stands to hand-planted and highly maintained landscape ornamentals interspersed with back alley volunteers and wild-sown, natural area natives. While a wide range of ages and sizes are represented, the majority of public trees measure fewer than 6" DBH. At present, these many small, young trees require limited maintenance and care and provide minimal net environmental benefits for the city. As they age and require more frequent care and maintenance, however, these trees will grow larger and provide greater net environmental benefits. In this way, young trees represent potential future environmental and aesthetic benefits.

In addition to softening and beautifying the built environment, Portland's trees reduce energy demand, improve ambient air quality, reduce the burden on stormwater processing infrastructure, and reduce levels of atmospheric $CO_2$. These ecosystem services help to make Portland a livable, sustainable community. A 2007 study of the environmental health of the 72 largest U.S. cities determined Portland's environmental quality of life to be the highest for its size category and the third highest overall (Earth Day Network). By removing and storing 2.3 billion pounds of carbon from the atmosphere, Portland's urban forest assisted in reducing net carbon emissions by more than 12% per Multnomah County resident over the 12-year period from 1993-2005 (Global Warming Progress Report 2005).

Urban trees also provide quantifiable aesthetic benefits. The presence of trees increases property resale values (Anderson and Cordell 1988). Portland's street trees alone increase property values by more than $13 million each year, benefiting the seller with greater revenue and benefiting the city with higher property tax income. As with ecosystem services, larger trees provide greater aesthetic benefits (Table 5-3). Where practicable, planting large-growing, long-lived shade trees provides the greatest investment return.

Recognition of the asset value of the green infrastructure along with the familiar grey infrastructure of buildings, bridges, and structures, however, remains an accounting challenge. Public entities use accrual accounting methods per guidelines established and overseen by the Government Accounting Standards Board (GASB). GASB allows capital asset recognition for depreciating assets (Hartel 2003). Since trees *appreciate* in value as they age, however, the standard accounting system is not equipped to accurately reflect the urban forest's true value. Because the City's bond rating is a function of the level at which capital assets are maintained, the benefit of capitalizing the urban forest asset may be reflected in improved and standardized tree care and maintenance. In this way, formally recognizing the infrastructure value of the urban forest may be an effective means to ensure that Portland's trees receive the care and maintenance they need to be a fully functional urban forest.

## MANAGEMENT RECOMMENDATIONS

Sound forest management is vital to maximizing the extent and health of the urban forest canopy—and thereby maximizing the environmental and aesthetic benefits the trees provide. Portland's street and park trees are a sustainable resource vital to the city's beauty and livability. Although these public trees provide a large return for the investment, opportunities exist to increase realized benefits by improving urban forest management. For benefit maximization, management should focus on retaining existing canopy, planting the right tree in the right place, planting large-growing species where appropriate, and keeping trees healthy.

Decisions regarding tree selection and placement affect the composition and function of the urban forest. A large planting space occupied by a small-species tree represents a significant loss of benefits over the life of the tree. The larger the tree, the greater the photosynthetic capacity and, thereby, the greater the environmental benefits produced. A small tree planted in a location better suited to a larger species saves less energy, removes fewer inorganic air pollutants, sequesters less carbon, and intercepts less stormwater. For Portland's street trees, these material losses translate into real losses of up to $190 per tree each year (Table 5-3).

**To Do List**

- ✓ Maintain existing trees
- ✓ Plant more trees
- ✓ Plant the right tree in the right place
- ✓ Plant large-species trees where appropriate
- ✓ Make more room for trees
- ✓ Keep trees healthy

Sound urban forest management includes planning for efficient use of limited resources. Urban trees endure harsh growing conditions, including poor air, soil, and water quality. Inadequate, improper, and crisis-driven maintenance practices exacerbate the negative effects of these environmental factors, reducing tree vigor and ultimately shortening life expectancy. Unfortunately, urban tree management is rarely proactive. A proactive, wellness-based strategy consisting of regular care and maintenance is a wise investment of limited resources that can increase longevity and reduce the need for costly emergency care.

## URBAN FORESTRY MANAGEMENT PLAN: GOALS AND IMPLEMENTATION

The importance of preserving and growing the urban forest canopy is evidenced in the City's tree preservation and management regulations. At present, public tree planting, pruning, and removal activities are regulated by permitting programs. Issuance of street tree removal permits is contingent on replanting where practicable, and commercial and residential development and redevelopment projects require tree preservation and/or mitigation. Beyond mitigation planting, neighborhood tree planting activities are bolstered by the volunteer efforts of neighborhood and non-profit groups.

The 2004 *Urban Forestry Management Plan* provides direction for the management and administration of Portland's urban forest. The *Urban Forest Action Plan* (both documents available at www.PortlandParks.org) was adopted by City Council in March 2007 and serves as the roadmap for the *Management Plan*. The plans consist of three major goals: (1) to protect, preserve, restore, and expand Portland's urban forest; (2) to develop and maintain support for the urban forest, and (3) to manage the urban forest to maximize community benefits for all residents of the city. Conducting an inventory and assessment of Portland's public trees is a current action recognized by the *Action Plan*. In turn, the findings of this study substantiate the *Plan's* framework and direction, and goal implementation will benefit from this detailed analysis of Portland's public trees and benefit analysis of Portland's urban forest canopy.

*Ainsworth Blocks, northeast Portland*

To meet the first goal—the protection, preservation, restoration, and expansion of Portland's urban forest—requires a baseline from which to plan projects and by which to measure progress. This analysis quantifies the structure and function of the majority of Portland's public tree asset. Using this tool as a baseline, managers can determine the differences between current and ideal conditions, and can plan strategies for meeting forest canopy cover and equity goals. In addition, the benefit-cost analysis provides a powerful tool for developing, enhancing, and maintaining public and private support for the urban forest.

The logistics of goal implementation must consider the heterogeneous nature of the urban environment. The extent and character of Portland's urban forest canopy vary with zoning and land use throughout the city. Although many exceptions exist, parks, natural areas, and residential areas tend to be well-treed while larger arterial roadways and industrial zones tend to have fewer trees. Recommendations for enhancing the urban forest canopy follow:

- A more comprehensive public tree inventory will provide a guide for prioritizing maintenance activities and a baseline against which urban canopy growth and enhancement may be measured,
- Increasing the level of maintenance of large, old trees will maximize the ecosystem services provided by these high value members of the urban forest,
- Increasing tree planting efforts will increase stocking levels and help to meet canopy coverage goals more rapidly,
- Increasing outreach in the forms of technical assistance and education to encourage private citizens to plant and care for trees on their own property,
- Increasing the general knowledge of the city's tree codes and of proper arboricultural techniques within the arboricultural community as well as the general public will improve code compliance and urban forest canopy condition, and
- Increasing the size of street tree rights-of-way in new development and redevelopment where practicable will provide more opportunities for planting high value, large growing species.

*Action Plan* implementation is a citywide, public-private endeavor involving multiple city bureaus, non-profit organizations, businesses, and the public. Current efforts are underway to develop performance measures and monitor progress for goal implementation. Through individual action and partnerships, Portlanders are committed to the protection and betterment of their urban forest.

# Conclusions

Portland's urban forest canopy—a diverse, sustainable, and valuable part of the city's green infrastructure—provides a multitude of aesthetic and environmental benefits to the city for a nominal investment. Portlanders today enjoy a city whose streets and parks are stocked with large, mature trees because previous generations valued trees and had the foresight to plant and care for them. In this way, the urban forest canopy is our legacy from the past and our obligation to the future.

The value of the urban tree infrastructure and the benefits it offers relies on management practices through time. Investments made in planting trees in appropriate locations and providing regular care and maintenance return robust benefits. Opportunities to increase benefit returns exist in planting more trees, planting the right tree in the right place, planting large-species trees where appropriate, and keeping trees healthy. Costs may be reduced by focusing on forest health through proactive maintenance rather than crisis-driven emergency management.

This analysis provides a baseline of current forest conditions. As such, it is a powerful tool for use in realizing urban forest canopy growth and enhancement goals. Growing the urban canopy will require additional resources. Quantifying the value of the urban tree asset—and considering that value as part of the city's infrastructure investment—provides a compelling case for greater public investment in the urban forest.

*Black tupelo showing brilliant fall color*

*Plaza Blocks, downtown Portland*

# Glossary

**Diameter at breast height (DBH)** – the diameter of the tree when measured at 4.5 ft. (1.38 m) above the forest floor. Breast height of 4.5 ft. is the convention for tree diameter measurement in the United States.

**Green infrastructure ("greenfrastructure")** – the network of urban parks and natural spaces interconnected with the green landscapes along street rights-of-way and around homes and businesses. Trees are a special component of the green infrastructure by virtue of their stature, their longevity, and the significant environmental and aesthetic benefits they provide.

**Invasive species** – An alien plant species whose introduction causes or is likely to cause economic, environmental, and/or human health harm. In the absence of their natural predators and pathogens, invasive species may often outcompete native species, reducing species diversity and habitat quality.

**Native species** – originating or occurring naturally in a particular region, *i.e.*, not introduced from elsewhere.

**Non-native species** – introduced from outside the region. The detrimental effects of non-natives on natural systems vary with habitat type and the invasive nature of the exogenous species.

**Senescence –** the portion of a tree's life span from full maturity to death.

**Stocking level** – for a discrete geographic area, the total number of street trees divided by the total number of street tree planting opportunities, represented as percent of total.

**Tree condition** – the health of the tree as manifest in the condition of its bark and leaves, assessed using a four-point scale: 1 = good, 2 = fair, 3 = poor, and 4 = dead/dying.

**Tree replacement value** – the theoretical cost of replacing a tree in the same location with another tree of equivalent size, species, and condition. Tree replacement value is calculated based on cross-sectional trunk area, species, condition, and location.

# Glossary

**Urban forest** – the complex system of trees, shrubs, and herbaceous plants, associated organisms, soil, water, air, and people in and around human settlements ranging in size from modest rural communities to densely populated metropolitan areas.

**Urban forest canopy** – the collection of trees in and around human settlements ranging in size from modest rural communities to densely populated metropolitan areas.

*Tree planting at Arbor Day 2007 celebration*

# References

American Forests. 2004. *CITYgreen for ArcGIS* (ArcView for Windows extension). www.americanforests.org

Anderson, L.M., and H.K. Cordell. 1988. Residential property values improve by landscaping with trees. *Southern Journal of Applied Forestry* 9:162–166.

Ares, R. 2006. *Portland Real Estate Market Activity for September 2006* http://www.repdx.com/2006/09/15/portland-real-estate-market-activity-for-september-2006/.

CO2e.com. 2005. The global hub for carbon commerce. www.co2e.com.

(CTLA) Council of Tree and Landscape Appraisers. 1992. *Guide for plant appraisal* Savoy, IL: International Society of Arboriculture. 103 p.

(CUFR) Center for Urban Forest Research. 2007. *STRATUM 3.0; Street Tree Resource Analysis Tool for Urban Forest Managers* USDA Forest Service, Pacific Northwest Research Station, Davis, CA.

Earth Day Network. 2007. *Urban Environment Report* http://www.earthday.org/UER/report/

Global Warming Progress Report. 2005. *A Progress Report on the City of Portland and Multnomah County Local Action Plan on Global Warming* Multnomah County Finance, Budget, and Tax Office and City of Portland Office of Sustainable Development.

Gronowski, N., R. Crouch, J. Curkendall, and C. Trevor. 2004. *Portland Urban Forestry Management Plan* City of Portland Parks and Recreation Department, Portland, OR. 115 p.

Hartel, D.R. 2003. *GASB 34: Urban Natural Resources as Capital Assets*. National Urban Forest Conference, San Antonio, TX, September 17-20, 2003.

Jenness, J. 2005. Random point generator (randpts.avx) extension for ArcView 3.x, v. 1.3. Jenness Enterprises. Available at: http://www.jennessent.com/arcview/random_points.htm.

Kuo, F.E., and W.C. Sullivan. 2001. Environment and crime in the inner city: does vegetation reduce crime? *Environment and Behavior* 33:343-367.

Laverne, R.J., and Winson-Geideman, K. 2003. The influence of trees and landscaping on rental rates at office buildings. *Journal of Arboriculture* 29:281-290.

McPherson, E.G., and J.R. Simpson. 1999. *Carbon dioxide reductions through urban forestry.* General Technical Report PSW-171, USDA Forest Service, Pacific Southwest Research Station, Albany, CA. 237 p.

McPherson, E.G., J.R. Simpson, P.J. Peper, S. Maco, and Q. Xiao. 2000. *Benefit-cost analysis of Fort Collins' municipal forest*. Internal technical report, Center for Urban Forest Research, USDA Forest Service, Pacific Northwest Research Station, Davis, CA. 38 p.

McPherson, E.G., J.R. Simpson, P.J. Peper, S. Maco, and Q. Xiao. 2005. Municipal forest benefits and costs in five U.S. cities. *Journal of Forestry* 103(8):411-416.

McPherson, E.G., S.E. Maco, J.R. Simpson, P.J. Peper, Q. Xiao, A.M. VanDerZanden, and N. Bell. 2002. *Western Washington and Oregon Community Tree Guide: Benefits, Costs, and Strategic Planning* International Society of Arboriculture, Pacific Northwest Chapter, Silverton, OR. 78 p.

McPherson, E.G., and J. Muchnick. 2005. Effects of street tree shade on asphalt concrete paving performance. *Journal of Arboriculture* 31(6):303-310.

Nowak, D.J. 1994. *Atmospheric carbon dioxide reduction by Chicago's urban forest* In: McPherson, E.G., Nowak, D.J., and Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. General Technical Report NE-186, Radnor, PA. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 63-81.

Nowak, D.J., and D.E. Crane. 2000. The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions In: M. Hansen and T. Burk [eds.], Proceedings: *Integrated tools for natural resources inventories in the 21st century*. IUFRO Conference, 16-20 August 1998, Boise, ID. General Technical Report NC-212, U.S. Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN. pp. 714-720.

(NRS) Northeastern Research Station. 2006. *UFORE 1.0; Urban Forest Effects Model* USDA Forest Service, Syracuse, NY.

NW Natural. 2005. Summary of monthly sales service billing rates. Effective October 1, 2005.

(PGE) Pacific General Electric Company. 2006. Rate Schedules 7 and 32: residential and small nonresidential standard service. Effective April 15, 2006.

Pillsbury, N.H., Reimer, J.L., and R.P. Thompson. 1998. *Tree volume equations for fifteen urban species in California*. Tech. Rep. 7, Urban Forest Ecosystems Institute, California Polytechnic State University, San Luis Obispo, CA. 56 p.

Scott, K.I., E.G. McPherson, and J.R. Simpson. 1998. Air pollutant uptake by Sacramento's urban forest. *Journal of Arboriculture* 24(4):224-234.

Scott, K.I., J.R. Simpson, and E.G. McPherson. 1999. Effects of tree cover on parking lot microclimate and vehicle emissions. *Journal of Arboriculture* 25(3):129-142.

Vargas, K.E., E.G. McPherson, J.R. Simpson, P.J. Peper, S.L. Gardner, J. Ho, and Q. Xiao. 2006. *City of Albuquerque, New Mexico Municipal Forest Resource Analysis*. Center for Urban Forest Research, Pacific Southwest Research Station, USDA Forest Service.

Wang, M.Q., and D.J. Santini. 1995. Monetary values of air pollutant emissions in various U.S. regions. *Transportation Research Record* 1475:33– 41.

Wolf, K.L. 1999. Nature and commerce: human ecology in business districts. In C. Kollin (Ed.), *Building Cities of Green*. Proceedings of the 1999 National Urban Forest Conference. Washington D.C. American Forests; 56-59.

Xiao, Q., E.G. McPherson, S.L. Ustin, and M.E. Grismer. 2000. A new approach to modeling tree rainfall interception. *Journal of Geophysical Research* 105(D23):29173-29188.

*Sellwood Park in southeast Portland*

# Appendix A

## Methods and Procedures

The study design, field data collection, and data analysis methods used are part of the iTree Tools protocol developed and disseminated by the U.S. Forest Service in cooperation with private and non-profit organizations. Based on more than 20 years of urban forest research, the iTree Tools include guidelines and extensions for use in designing the study, utility programs that allow the user to collect field data electronically, and software applications that analyze field data vis-à-vis cost-benefit data and provide outputs that describe the structure, function, and net benefits provided by the urban forest.

### STUDY DESIGN AND FIELD DATA COLLECTION

#### STREET TREE INVENTORY

To ensure the sample street tree inventory faithfully represents the entire street tree population, inventory data were collected along a geographically random selection of 3% of all sampleable street segments within the City of Portland (Figure 2-1). Street segments were randomly selected using a random segment generator in a geographic database (Jenness 2005). Two, two-person teams detailed the dimensions and attributes of all street trees and planting opportunities located along the selected street segments (Table A-1). Data were collected on handheld PCs using the iTree Tools PDA Utility for STRATUM (version 20051231).

#### PARK ECOSYSTEMS ASSESSMENT

To ensure the ecosystem assessment of Parks-owned properties adequately describes the diversity of the resource, sample plots were sited using a random point generator in a geographic database (Jenness 2005) (Figure 2-1). Two, two-person teams collected data describing the land use, land cover, shrubs, and trees within 90 tenth-acre plots randomly located to capture three functional categories of park type: developed, undeveloped, and natural (Table A-1). Data were collected on handheld PCs using the iTree Tools PDA Utility for UFORE (version 20060220) and paper forms.

**Table A-1.** *Data collected to describe the structure and function and evaluate the costs and benefits of Portland's street and park trees.*

| | Street Tree Inventory | Parks Properties Ecosystem Assessment |
|---|---|---|
| **Field Data** | Tree species, height, DBH<br>Tree location<br>Tree topped?<br>Condition of wood and leaves<br>Maintenance recommendations<br>Priority task<br>Wire conflict<br>Sidewalk damage<br>Adjacent real land use<br>Right-of-way width | Tree species, height, DBH<br>Tree live crown height, crown width, and crown light exposure<br>% canopy missing and dieback<br>% tree, shrub, and ground cover<br>% plantable space<br>Shrub species, dimensions<br>Land use |
| **Environmental Data** | Hourly air pollution and meteorological data (BVOC, $CO_2$, $NO_2$, $PM_{10}$, $SO_2$) | Hourly air pollution and meteorological data (BVOC, CO, $NO_2$, $O_3$, $PM_{10}$, $SO_2$) |
| **Annualized Cost Data** | Planting<br>Pruning<br>Tree and Stump Removal and Disposal<br>Pest and Disease Control<br>Establishment and Irrigation<br>Repair/Mitigation of Infrastructure Damage<br>Litter/Storm Cleanup<br>Litigation and Settlements from Tree-Related Claims<br>Program Administration<br>Inspections and Service Requests | Planting<br>Pruning<br>Tree and Stump Removal and Disposal<br>Pest and Disease Control Costs<br>Establishment and Irrigation<br>Litter/Storm Cleanup<br>Program Administration<br>Inspections and Service Requests |
| **Benefit Savings** | Electricity ($/Kwh)<br>Natural gas ($/therm)<br>BVOC ($/lb)<br>$CO_2$ ($/lb)<br>$NO_2$ ($/lb)<br>$PM_{10}$ ($/lb)<br>$SO_2$ ($/lb)<br>Stormwater interception ($/gallon)<br>Average home resale value ($) | BVOC ($/lb)<br>$CO_2$ ($/lb)<br>$NO_2$ ($/lb)<br>$PM_{10}$ ($/lb)<br>$SO_2$ ($/lb)<br>Stormwater retention* ($/gallon) |
| **City Data** | Total Municipal Budget<br>Population<br>Total Land Area<br>Average Street Width (curb to curb)<br>Average Sidewalk Width<br>Total Linear Miles of Street | Total area by park type<br>Population |

**Stormwater retention data derived from CITYgreen analysis*

As the UFORE program does not quantify stormwater retention, CITYgreen software provided annual stormwater retention estimates for parks and natural spaces (American Forests 2004). CITYgreen acts as an extension for ArcGIS, estimating tree canopy functionality from classified aerial imagery. This analysis used the Bureau of Planning's land use and canopy classification derived from 2002 multi-spectral imagery.

## DATA ANALYSES: FOREST STRUCTURE AND FUNCTION

### STREET TREE INVENTORY

The STRATUM 3.0 (CUFR 2007) program produces structural and population data describing the street tree resource (Table A-2). STRATUM calculates a one-year change in street tree biomass using climate zone specific growth models. The additional biomass provides the basis for quantifying forest functionality. Detailed methods are available from the Center for Urban Forest Research (*e.g.*, McPherson *et al*. 2000)

### PARK ECOSYSTEMS ASSESSMENT

The UFORE 1.0 program (NRS 2006) produces a series of tables describing the structure and function of Portland's park ecosystems (Table A-2). UFORE calculates tree biomass from field data and uses local environmental data along with these structural characteristics to model ecosystem function. Detailed methods are available from the U. S. Forest Service, Northeastern Research Station in Syracuse, NY and the manual for UFORE methods (Nowak and Crane 2000).

## DATA ANALYSES: CALCULATING COSTS AND BENEFITS

Costs incurred in managing street, park, and natural area trees were calculated based on operations data tracked by Portland Parks and Recreation's City Nature Urban Forestry (Urban Forestry) as well as interviews with tree service providers and the non-profit organization Friends of Trees. The costs of tree services such as pruning, pest management, and removal vary widely depending on the type, size, and location of the tree. In most cases, annual costs incurred are estimated based on average values.

**Table A-2.** *Street and park tree structure and function outputs from street tree inventory (STRATUM) and Parks' properties ecosystem assessment (UFORE) analyses.*

| | Street Tree Inventory | Parks Properties Ecosystem Assessment |
|---|---|---|
| **Forest Structure** | **By Area of Town:**<br>• Tree types in functional categories<br>• Relative distribution of ten most abundant tree types<br>• Relative age of ten most abundant tree types<br>• Condition<br>• Stocking level<br>• Priority maintenance task needed<br>• Recommended maintenance task<br>• Adjacent land use<br>• Tree location<br>• Canopy cover<br>**By DBH Class:**<br>• Tree types in functional categories<br>• Priority maintenance task needed<br>**For 27 Most Abundant Tree Types:**<br>• Importance value<br>• Condition<br>• Relative performance by tree type<br>• Overhead utility line conflicts<br>• Sidewalk heave conflicts<br>• Tree height conflict<br>• Topping condition<br>• Planting strip width | • Percent of tree species population by land use and DBH<br>• Percent of tree condition by tree type, land use, and DBH<br>• Origin of live trees, percent by land use<br>• Susceptibility of trees to Gypsy Moth by land use<br>• Susceptibility of trees to Asian long-horned beetle by land use<br>• Percent of predicted land use in actual land use<br>• Species richness and diversity<br>• Percent ground cover by land use |
| **Forest Function** | **For 27 Most Abundant Tree Types, Quantity and Value:**<br>• Annual avoided electricity and natural gas<br>• Carbon storage and annual carbon sequestration<br>• Annual air pollutant removal<br>• Annual stormwater interception<br>• Annual property resale value increase | **By Month:**<br>• Tree/shrub pollutant removal<br>**By Tree Type and Land Use:**<br>• Carbon storage and sequestration<br>• Leaf area and leaf biomass<br>• Leaf area and leaf biomass<br>• Per area carbon storage, carbon sequestration, leaf area and leaf biomass |
| **Valuation** | • Tree replacement value | • Tree compensatory value |

Annual benefit accrual for street and park trees was based on the change in tree biomass (leaf area and diameter) over a one year period using growth modeling techniques developed by the U.S. Forest Service for each of 19 United States climate zones. All street tree benefit calculations were based on algorithms designed for the Pacific Northwest climate zone and were performed using the computer program STRATUM (McPherson *et al.* 2000).

Environmental benefit valuation considered the cost savings of avoided electricity and natural gas use, air pollutant removal, and avoided stormwater processing. Market rate prices vary by climate zone. Aesthetic benefits were valued based on Anderson and Cordell's (1988) finding that the presence of trees increases property values. Average home resale price (Ares 2006), tree size, and adjacent land use were factored into a model that calculates the increase in property value attributable to the presence of street trees.

### TREE REPLACEMENT VALUES

The theoretical replacement value of Portland's public trees was calculated as the cost of replacing the asset with trees of equivalent species, size, and condition in the same locations (CTLA 1992). The dollar value for each tree is derived from its cross-sectional trunk area, species, condition, and location. Species and area determine the basic value of the tree; condition and location ratings range from 0-1 and determine the compensatory value for each individual tree. The detailed methods are available from the Council of Tree and Landscape Appraisers.

### TREE PLANTING AND ESTABLISHMENT COSTS

The expenses involved with procuring, planting, and establishing a sapling vary with species, size, and establishment method. Saplings are priced based on size and species. Exotic, uncommon, and slow-growing species may fetch a higher price to compensate for increased nursery expenses. Smaller saplings (1" to 2 ½" caliper) are less expensive and easily planted by homeowners and volunteers. Larger saplings (3" caliper) are more expensive and can require heavy machinery to plant. The annual cost of planting street and park trees was calculated based on the number of trees planted, the size of trees planted, and the cost of planting.

Although Portland receives 40-45" of precipitation annually, the majority falls from October to April, and the summer months are relatively dry. This seasonal drought necessitates watering for the first two years after planting. To alleviate drought stress, a new tree requires 15 gallons of water weekly throughout the growing season (May through September).

Establishment costs vary with tree ownership and location. The least expensive trees to establish are those planted in a landscape with existing irrigation and those watered with a local water source by volunteers. Trees planted far from an existing water source require water delivery, and trees planted in the median of heavily used boulevards require the use of traffic control devices and a watering truck. Total annual establishment costs include the costs of water, labor, and equipment.

### CARE, MAINTENANCE, AND REMOVAL COSTS

Tree care costs include a broad variety of services, including pruning, pest management, emergency response, infrastructure repair costs, liability costs, and removal costs. In the City of Portland, the regular care and maintenance of street trees is generally the responsibility of the adjacent property owner. Urban Forestry's certified arborists provide property owners with permits and guidance for tree pruning, removal, and replanting. In addition, Urban Forestry inspectors and crews provide 24-hour emergency response to tree-related hazards in public rights-of-way. Park and natural area trees are the sole responsibility of Urban Forestry.

Total annual pruning and removal costs were calculated based on the number of permits issued by Urban Forestry and the average per tree cost of the service. Average cost per tree was derived from average job length in hours and cost per hour using private arborists' rates for street trees and Urban Forestry rates for park trees. Infrastructure repair costs were based on the number of root inspections conducted by Urban Forestry inspectors and the average cost of sidewalk repair per job. Average cost per job was derived from the average price, including removal, replacement, and labor, per square foot of infrastructure and the average dimensions of a tree-related replacement job.

Most street tree pest management work is not regulated nor tracked by Urban Forestry, so the bulk of these costs were based on estimates provided by private tree care providers.  Urban Forestry consults with local groups in Ladd's Addition and Eastmoreland, assisting volunteers to inoculate neighborhood elm trees against the spread of Dutch elm disease (DED).  In addition, Urban Forestry inoculates ~125 park and public elm trees annually to decrease the likelihood of the loss of significant elms to DED.  The costs of the DED program include the fungicide, crew, and equipment costs calculated on a per tree basis.

### URBAN FORESTRY PERMIT PROGRAM COSTS

Urban Forestry staffs certified arborists who provide professional consulting services for property owners, non-for-profit organizations, and city and state agencies.  Total costs for the permit program include intake staff, arborists' inspection and permit issuance time, and program administration.

### ENVIRONMENTAL AND AESTHETIC BENEFITS

The quantification of environmental and aesthetic benefits was conducted using algorithms developed by the U. S. Forest Service, Center for Urban Forest Research (see McPherson *et al*. 2000) and the U. S. Forest Service, Northeastern Research Station in Syracuse, NY (see Nowak and Crane 2000).  Street trees were analyzed using the STRATUM model.  The park trees assessment used the Urban Forest Effects (UFORE) model.  Some park tree benefits were valued using rates from the STRATUM model.  Detailed methods are available from the Forest Service and in the aforementioned references.

#### ENERGY SAVINGS

Changes in energy use from tree shading were quantified by modeling shading effects on buildings as influenced by climate (McPherson and Simpson 1999).  The model incorporates typical urban building characteristics and local weather data.  Cost savings of avoided energy use were quantified using average local energy rates: $0.08/kWh for electricity (PGE 2006) and $1.29/therm for natural gas (NW Natural 2006).

## CARBON SEQUESTRATION BENEFITS

Trees act as carbon reservoirs by removing $CO_2$ from the atmosphere, releasing the $O_2$, and retaining the carbon in their tissues. The calculation of the total amount of carbon fixed in street tree biomass annually includes tree-related atmospheric $CO_2$ fluctuations as follows: total carbon fixed by all street trees, total avoided $CO_2$ emissions as a result of decreased building energy use, and total $CO_2$ released into the atmosphere from tree tissue decomposition and tree maintenance activities.

Total carbon storage and the rate of carbon sequestration into biomass were calculated using tree biomass equations and tree growth models (Nowak 1994, Pillsbury *et al*. 1998). Tree biomass equations calculate the amount of above- and below-ground biomass in each tree based on species and DBH; tree growth models predict the amount of additional biomass each tree gains per year based on species, DBH, and climate zone. The net amount of carbon dioxide removed from the atmosphere was valued at $0.00334/lb based on the market rate for carbon (CO2e.com 2005).

## AIR QUALITY IMPROVEMENT BENEFITS

The removal of criteria air pollutants—$PM_{10}$, $NO_2$, $O_3$, $SO_2$, and VOC—by trees was calculated using hourly dry deposition rates (Scott *et al*. 1998). Dry deposition rates are a function of ambient pollutant concentration, deposition velocity, and the amount of tree surface available for pollutant capture over time. Pollutant concentration and deposition velocities were calculated using reference city (Longview, WA, for the Pacific Northwest climate zone) meteorological data for an average year. Tree surface was calculated from tree type and DBH. Total air quality improvement included avoided emissions as a result of tree-related energy savings and the emission of biogenic volatile organic compounds—precursors to atmospheric ozone production. Net avoided or contributed emissions were valued using market costs of controlling air pollutants as follows: $PM_{10}$ = $1.67/lb, $NO_2$ = $0.94/lb, $O_3$ = $0.94/lb, $SO_2$ = $1.88/lb, and VOC = $0.35/lb (Wang and Santini 1995).

### STORMWATER INTERCEPTION AND RETENTION BENEFITS

Stormwater interception by street trees was calculated as the volume of water intercepted by the tree within the drip line using canopy area, leaf area, and water depth on canopy surfaces (Xiao *et al*. 2000). Stormwater retention by park trees was calculated using the Natural Resources Conservation Service TR-55 hydrology model within the CITYgreen for ArcGIS program. The volume of intercepted and retained water was valued at $0.02779 per gallon based on the avoided cost of processing the runoff using stormwater conveyance infrastructure (see McPherson *et al*. 2005).

### AESTHETIC BENEFITS

Lacking a model for evaluating park trees, aesthetic benefits were quantified for street trees only. The increase in property resale value attributable to the presence of street trees was calculated based on the amount of leaf surface area adjacent to each property, the adjacent property land use, and the average median home sale price (see McPherson *et al*. 2002).

### BENEFIT-COST RATIO AND NET BENEFITS

The benefit return on the investment in street and park trees was summarized in the benefit-cost ratio and net benefits. The benefit-cost ratio compares the yearly sum of the values of all environmental and aesthetic benefits ($B_{TOT}$) provided by street and park trees with the sum of all expenses ($C_{TOT}$) incurred in managing them:

$$B_{TOT}:C_{TOT} = \frac{(E + AQ + CO_2 + SW + A)}{(PL + ES + PR + RE + PD + ID + ER + LI + AD + IN)}$$

where,

E = energy savings,
A = air quality improvement,
$CO_2$ = $CO_2$ reduction,
SW = stormwater interception,
A = aesthetics,

PE = planting costs,
ES = establishment costs,
PR = pruning costs,
RE = removal and disposal costs,
PD = pest and disease control costs,
ID = infrastructure damage costs,
ER = emergency response costs,
LI = litigation costs,
AD = program administration costs, and
IN = inspection costs.

The amount of the net benefits ($B_{NET}$) provided by street and park trees is the total benefits less the total costs:

$$B_{NET} = B_{TOT} - C_{TOT}$$

where,

$B_{TOT}$ = total environmental and aesthetic benefits, and
$C_{TOT}$ = total costs incurred.

CITYWIDE FOREST CANOPY COVERAGE

Citywide forest canopy coverage and the environmental benefits provided by the urban forest canopy were assessed using CITYgreen, an imagery-based software (American Forests 2004). CITYgreen calculates existing canopy coverage from aerial imagery and provides a modeling interface to show how environmental benefits relate to existing canopy cover as well as hypothetical coverage levels. With this tool, one can predict the magnitude and value of environmental benefits for current and desired future canopy coverage.

# Appendix B

## STREET AND PARK TREE POPULATION STRUCTURES

**Table B-1.** *Relative number of street trees by functional type, species, and diameter at breast height (DBH) class.*

| | DBH Class (in) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tree Type | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
| **Broadleaf Deciduous Large (BDL)** | | | | | | | | | | | |
| *Acer macrophyllum* Bigleaf maple | 2,513 | 3,124 | 2,683 | 1,324 | 543 | 272 | 34 | 102 | 204 | 10,799 | (±2,460) |
| *Acer negundo* Boxelder | 0 | 136 | 68 | 68 | 0 | 0 | 0 | 0 | 0 | 272 | (±141) |
| *Acer platanoides* Norway maple | 2,717 | 3,634 | 5,230 | 4,686 | 2,038 | 985 | 883 | 272 | 238 | 20,681 | (±2,206) |
| *Acer saccharinum* Silver maple | 374 | 238 | 883 | 102 | 136 | 102 | 340 | 102 | 136 | 2,411 | (±704) |
| *Acer saccharum* Sugar maple | 204 | 509 | 781 | 577 | 306 | 238 | 170 | 204 | 102 | 3,090 | (±680) |
| BDL other | 34 | 34 | 34 | 34 | 68 | 68 | 34 | 0 | 0 | 306 | (±129) |
| *Betula papyrifera* Paper birch | 577 | 272 | 204 | 0 | 0 | 0 | 0 | 0 | 0 | 1,053 | (±365) |
| *Castanea dentate* American chestnut | 0 | 34 | 68 | 0 | 0 | 0 | 34 | 0 | 136 | 272 | (±149) |
| *Catalpa spp.* Catalpa species | 34 | 34 | 0 | 102 | 68 | 68 | 0 | 68 | 34 | 408 | (±156) |
| *Fagus spp.* Beech species | 102 | 306 | 238 | 0 | 0 | 34 | 0 | 0 | 0 | 679 | (±262) |
| *Fagus sylvatica* European beech | 68 | 340 | 238 | 102 | 0 | 0 | 0 | 34 | 0 | 781 | (±310) |
| *Fraxinus americana* American ash | 34 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 68 | (±47) |
| *Fraxinus excelsior* Golden desert ash | 102 | 204 | 238 | 340 | 0 | 0 | 0 | 0 | 0 | 883 | (±346) |

| Tree Type | DBH Class (in) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
| *Fraxinus pennsylvanica* Green ash | 34 | 543 | 34 | 136 | 0 | 0 | 0 | 0 | 0 | 747 | (±326) |
| *Juglans nigra* Black walnut | 34 | 0 | 68 | 136 | 136 | 68 | 34 | 0 | 34 | 509 | (±166) |
| *Liriodendron tulipifera* Tulip tree | 68 | 0 | 0 | 0 | 0 | 68 | 68 | 68 | 68 | 340 | (±149) |
| *Platanus hybrida* London plane tree | 102 | 0 | 238 | 679 | 340 | 238 | 0 | 0 | 0 | 1,596 | (±878) |
| *Platanus occidentalis* American sycamore | 0 | 34 | 0 | 102 | 34 | 136 | 0 | 0 | 0 | 306 | (±156) |
| *Populus nigra* Lombardy poplar | 0 | 34 | 68 | 0 | 34 | 0 | 0 | 0 | 34 | 170 | (±74) |
| *Populus spp.* Cottonwood species | 475 | 238 | 68 | 170 | 34 | 0 | 0 | 0 | 0 | 985 | (±579) |
| *Populus trichocarpa* Black cottonwood | 34 | 408 | 170 | 68 | 34 | 34 | 0 | 0 | 68 | 815 | (±400) |
| *Quercus coccinea* Scarlet oak | 408 | 374 | 883 | 1,019 | 883 | 374 | 102 | 136 | 0 | 4,177 | (±1,836) |
| *Quercus frainetto* Forest green oak | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Quercus garryana* Oregon oak | 374 | 102 | 68 | 0 | 34 | 34 | 34 | 0 | 0 | 645 | (±190) |
| *Quercus palustris* Pin oak | 102 | 238 | 68 | 68 | 136 | 170 | 34 | 34 | 0 | 849 | (±267) |
| *Quercus robur* English oak | 0 | 0 | 0 | 0 | 34 | 0 | 34 | 0 | 0 | 68 | (±47) |
| *Quercus rubra* Northern red oak | 136 | 34 | 475 | 408 | 68 | 102 | 102 | 0 | 68 | 1,392 | (±570) |

| Tree Type | DBH Class (in) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
| *Tilia americana* American basswood | 68 | 0 | 0 | 0 | 136 | 102 | 102 | 0 | 0 | 408 | (±254) |
| *Ulmus pumila* Siberian elm | 102 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | (±111) |
| *Ulmus spp.* Elm species | 102 | 34 | 34 | 102 | 340 | 509 | 577 | 238 | 577 | 2,513 | (±767) |
| *Ulmus x hybrid* Hybrid elm | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | (±75) |
| *Zelkova spp.* Zelkova species | 170 | 340 | 102 | 68 | 0 | 0 | 0 | 0 | 0 | 679 | (±253) |
| **BDL Total** | **9,101** | **11,274** | **12,972** | **10,323** | **5,399** | **3,600** | **2,581** | **1,256** | **1,698** | **58,205** | **(±4,218)** |
| | | | | | | | | | | | |
| **Broadleaf Deciduous Medium (BDM)** | | | | | | | | | | | |
| *Acer pseudoplatanus* Sycamore maple | 68 | 340 | 1,494 | 781 | 68 | 68 | 0 | 34 | 0 | 2,853 | (±672) |
| *Acer rubrum* Red maple | 1,800 | 4,584 | 4,483 | 1,936 | 509 | 102 | 34 | 34 | 0 | 13,482 | (±1,961) |
| *Acer spp.* Maple species | 340 | 204 | 34 | 0 | 34 | 0 | 34 | 0 | 0 | 645 | (±212) |
| *Aesculus spp.* Buckeye species | 0 | 0 | 0 | 68 | 68 | 170 | 102 | 102 | 68 | 577 | (±223) |
| *Ailanthus altissima* Tree of heaven | 0 | 0 | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | (±100) |
| *Albizia julibrissin* Silktree mimosa | 102 | 0 | 170 | 102 | 34 | 68 | 0 | 0 | 0 | 475 | (±148) |
| *Alnus rubra* Red alder | 747 | 543 | 611 | 136 | 68 | 0 | 0 | 0 | 0 | 2,105 | (±868) |

| Tree Type | DBH Class (in) | | | | | | | | | Total | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | | |
| *Alnus spp.* Alder species | 204 | 340 | 475 | 34 | 34 | 0 | 0 | 0 | 0 | 1,087 | (±508) |
| BDM other | 238 | 306 | 68 | 0 | 34 | 0 | 0 | 0 | 0 | 645 | (±178) |
| *Betula jacquemontii* Jacquemonti birch | 0 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±47) |
| *Betula nigra* River birch | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | (±88) |
| *Betula pendula* European white birch | 543 | 238 | 1,324 | 2,309 | 1,019 | 238 | 34 | 0 | 0 | 5,705 | (±747) |
| *Betula spp.* Birch species | 136 | 0 | 0 | 34 | 34 | 0 | 0 | 0 | 0 | 204 | (±94) |
| *Carpinus betulus* European hornbeam | 170 | 34 | 238 | 0 | 0 | 0 | 0 | 0 | 0 | 441 | (±285) |
| *Cercidiphyllum japonicum* Katsuratree | 747 | 985 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 1,766 | |
| *Cladrastis lutea* Yellowwood | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | (±58) |
| *Cornus nuttallii* Pacific dogwood | 645 | 170 | 34 | 68 | 34 | 0 | 0 | 0 | 0 | 951 | (±275) |
| *Frangula purshiana* Cascara buckthorn | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | (±100) |
| *Fraxinus spp.* Ash species | 815 | 543 | 645 | 441 | 204 | 102 | 34 | 34 | 0 | 2,819 | (±541) |
| *Fraxinus angustifolia* Narrowleaf ash | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±67) |
| *Fraxinus oregana* Oregon ash | 747 | 441 | 204 | 34 | 0 | 0 | 68 | 0 | 0 | 1,494 | (±454) |
| *Fraxinus ornus* Flowering ash | 34 | 136 | 68 | 0 | 34 | 0 | 0 | 34 | 0 | 306 | (±129) |

| Tree Type | DBH Class (in) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
| *Fraxinus oxycarpa* Flame ash | 1,223 | 781 | 1,155 | 441 | 0 | 0 | 0 | 0 | 0 | 3,600 | (±923) |
| *Ginkgo biloba* Maidenhair tree | 713 | 136 | 272 | 68 | 34 | 0 | 0 | 0 | 0 | 1,223 | (±287) |
| *Gleditsia triacanthos* Honeylocust | 102 | 204 | 102 | 102 | 68 | 0 | 0 | 0 | 0 | 577 | (±191) |
| *Juglans regia* English walnut | 102 | 170 | 408 | 441 | 611 | 306 | 68 | 0 | 34 | 2,139 | (±368) |
| *Koelreuteria paniculata* Goldenrain tree | 68 | 68 | 170 | 68 | 0 | 0 | 0 | 0 | 0 | 374 | (±186) |
| *Larix spp.* Larch species | 0 | 136 | 34 | 68 | 0 | 0 | 0 | 0 | 0 | 238 | (±120) |
| *Larix x marschlinsii* Dunkeld larch | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Liquidambar styraciflua* Sweetgum | 0 | 340 | 1,290 | 1,528 | 713 | 543 | 68 | 68 | 0 | 4,550 | (±788) |
| *Morus spp.* Mulberry | 34 | 0 | 0 | 170 | 34 | 0 | 0 | 0 | 0 | 238 | (±174) |
| *Nyssa sinensis* Chinese tupelo | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±67) |
| *Nyssa sylvatica* Black tupelo | 509 | 136 | 272 | 68 | 0 | 0 | 0 | 0 | 0 | 985 | (±347) |
| *Ostrya virginiana* Eastern hophornbeam | 204 | 136 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 374 | (±186) |
| *Oxydendrum arboretum* Sourwood | 272 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 306 | (±209) |
| *Parrotia persica* Persian ironwood | 170 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 204 | (±116) |

| Tree Type | DBH Class (in) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
| *Paulownia tomentosa* Empress tree | 0 | 34 | 0 | 34 | 0 | 0 | 0 | 34 | 0 | 102 | (±75) |
| *Populus tremuloides* Quaking aspen | 0 | 34 | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 136 | (±67) |
| *Prunus serrula* Tibetan cherry | 102 | 68 | 68 | 0 | 34 | 0 | 0 | 0 | 0 | 272 | (±133) |
| *Pyrus spp.* Pear | 1,732 | 2,649 | 3,056 | 849 | 102 | 0 | 0 | 0 | 0 | 8,388 | (±914) |
| *Quercus stellata* Post oak | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 0 | 0 | 34 | (±33) |
| *Robinia pseudoacacia* Black locust | 204 | 340 | 272 | 136 | 136 | 102 | 68 | 0 | 0 | 1,256 | (±376) |
| *Salix spp.* Willow species | 238 | 204 | 441 | 68 | 34 | 0 | 0 | 0 | 0 | 985 | (±475) |
| *Salix matsudana* Corkscrew willow | 102 | 0 | 102 | 68 | 0 | 0 | 0 | 0 | 0 | 272 | (±157) |
| *Sophora japonica* Japanese pagoda tree | 68 | 0 | 102 | 0 | 0 | 34 | 0 | 0 | 0 | 204 | (±94) |
| *Stewartia pseudocamillia* Japanese stewartia | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±67) |
| *Tilia cordata* Littleleaf linden | 34 | 272 | 1,189 | 1,019 | 204 | 34 | 34 | 0 | 0 | 2,785 | (±569) |
| *Tilia spp.* Linden species | 136 | 272 | 306 | 34 | 0 | 170 | 34 | 0 | 0 | 951 | (±322) |
| **BDM Total** | **13,889** | **15,010** | **19,424** | **11,104** | **4,177** | **1,936** | **611** | **340** | **102** | **66,593** | **(±3,140)** |

| Tree Type | DBH Class (in) 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **<u>Broadleaf Deciduous Small (BDS)</u>** | | | | | | | | | | | |
| *Acer buergerianum* Trident maple | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Acer campestre* Hedge maple | 204 | 645 | 170 | 204 | 0 | 34 | 0 | 0 | 0 | 1,256 | (±566) |
| *Acer circinatum* Vine maple | 781 | 306 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 1,121 | (±301) |
| *Acer ginnala* Amur maple | 713 | 577 | 204 | 34 | 0 | 0 | 0 | 0 | 0 | 1,528 | (±362) |
| *Acer griseum* Paperbark maple | 1,324 | 577 | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 2,004 | (±542) |
| *Acer japonicum* Fullmoon maple | 68 | 34 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | (±88) |
| *Acer opalus* Italian maple | 0 | 0 | 0 | 306 | 0 | 0 | 0 | 0 | 0 | 306 | (±180) |
| *Acer palmatum* Japanese maple | 3,464 | 1,121 | 340 | 68 | 0 | 0 | 0 | 0 | 0 | 4,992 | (±595) |
| *Acer tataricum* Tatarian maple | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Acer truncatum* Pacific sunset maple | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| BDS other | 679 | 374 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,053 | (±418) |
| *Carpinus caroliniana* American hornbeam | 102 | 272 | 272 | 306 | 0 | 102 | 0 | 0 | 0 | 1,053 | (±371) |
| *Carpinus japonica* Japanese hornbeam | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | (±120) |
| *Cercis canadensis* Eastern redbud | 509 | 306 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 883 | (±238) |

| Tree Type | DBH Class (in) 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chionanthus retusus* Chinese fringetree | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±75) |
| *Clerodendrum spp.* Glorybower species | 204 | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 374 | (±160) |
| *Clerodendrum trichotomum* Harlequin glorybower | 408 | 136 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 611 | (±172) |
| *Cornus florida* Flowering dogwood | 1,324 | 543 | 645 | 102 | 34 | 0 | 0 | 0 | 0 | 2,649 | (±468) |
| *Cornus kousa* Kousa dogwood | 1,460 | 543 | 475 | 238 | 0 | 0 | 0 | 0 | 0 | 2,717 | (±493) |
| *Cornus sericea* Redosier dogwood | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Cornus spp.* Dogwood species | 577 | 611 | 170 | 136 | 0 | 0 | 0 | 0 | 34 | 1,528 | (±326) |
| *Corylus cornuta* Beaked hazelnut | 408 | 136 | 34 | 0 | 34 | 0 | 0 | 0 | 0 | 611 | (±225) |
| *Cotinus coggygria* Smoke tree | 68 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | (±58) |
| *Crataegus douglasii* Black hawthorn | 136 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 136 | (±82) |
| *Crataegus laevigata* English hawthorn | 951 | 1,087 | 1,766 | 1,256 | 408 | 136 | 34 | 0 | 0 | 5,637 | (±692) |
| *Crataegus monogyna* Common hawthorn | 340 | 238 | 204 | 34 | 0 | 0 | 0 | 0 | 0 | 815 | (±254) |
| *Crataegus phaenopyrum* Washington hawthorn | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | (±100) |
| *Crataegus spp.* Hawthorn species | 340 | 238 | 204 | 34 | 34 | 0 | 0 | 0 | 0 | 849 | (±275) |
| *Diospyros virginiana* Common persimmon | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |

| Tree Type | DBH Class (in) 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ficus carica* Edible fig | 136 | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 204 | (±81) |
| *Ilex spp.* Holly species | 408 | 238 | 68 | 68 | 34 | 0 | 0 | 0 | 0 | 815 | (±252) |
| *Laburnum alpinum* Scotch laburnum | 34 | 102 | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 306 | (±137) |
| *Laburnum spp.* Golden chain tree | 34 | 68 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 136 | (±67) |
| *Lagerstroemia indica* Crapemyrtle | 102 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 136 | (±82) |
| *Magnolia stellata* Star magnolia | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±47) |
| *Malus spp.* Crabapple species | 1,528 | 1,664 | 1,902 | 441 | 204 | 0 | 0 | 0 | 0 | 5,739 | (±729) |
| *Malus sylvestris* European crabapple | 441 | 815 | 441 | 136 | 34 | 34 | 0 | 0 | 0 | 1,902 | (±354) |
| *Malus transitoria* Transitoria crabapple | 34 | 34 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 102 | (±58) |
| *Prunus armeniaca* Apricot species | 204 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 204 | (±125) |
| *Prunus blieriana* Purple-leaf plum | 1,664 | 1,766 | 3,022 | 1,426 | 136 | 0 | 34 | 0 | 0 | 8,048 | (±975) |
| *Prunus cerasifera* Cherry plum | 136 | 136 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 306 | (±120) |
| *Prunus maackii* Amur chokecherry | 0 | 0 | 102 | 34 | 0 | 0 | 0 | 0 | 0 | 136 | (±106) |
| *Prunus padus* European bird cherry | 204 | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 272 | (±115) |
| *Prunus spp.* Flowering cherry | 3,769 | 4,618 | 5,739 | 3,260 | 1,392 | 577 | 68 | 34 | 34 | 19,492 | |

| Tree Type | DBH Class (in) 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Rhus spp.* Sumac species | 543 | 238 | 34 | 68 | 0 | 0 | 0 | 0 | 0 | 883 | (±361) |
| *Rhus typhina* Staghorn sumac | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Sorbus Americana* American mountain ash | 68 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 136 | (±67) |
| *Sorbus spp.* Mountain ash | 306 | 408 | 238 | 340 | 170 | 102 | 0 | 0 | 0 | 1,562 | (±404) |
| *Styrax japonicus* Japanese snowbell | 2,343 | 340 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,683 | (±492) |
| *Styrax obassia* Fragrant snowbell | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±47) |
| *Syringa reticulata* Japanese tree lilac | 238 | 204 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 475 | (±182) |
| **BDS Total** | **26,827** | **18,745** | **16,809** | **8,524** | **2,479** | **985** | **136** | **34** | **68** | **74,607** | **(±3,213)** |
| **Broadleaf Evergreen Large (BEL)** | | | | | | | | | | | |
| BEL other | 68 | 34 | 34 | 34 | 0 | 34 | 0 | 0 | 0 | 204 | (±105) |
| *Eucalyptus spp.* Eucalyptus species | 170 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 238 | (±120) |
| **BEL Total** | **238** | **102** | **34** | **34** | **0** | **34** | **0** | **0** | **0** | **441** | **(±159)** |
| **Broadleaf Evergreen Medium (BEM)** | | | | | | | | | | | |
| *Arbutus menziesii* Pacific madrone | 102 | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | (±120) |
| BEM other | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 170 | (±120) |

| Tree Type | DBH Class (in) 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lyonothamnus floribundus* Catalina ironwood | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Magnolia grandiflora* Southern magnolia | 170 | 68 | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 306 | (±180) |
| *Magnolia spp.* Magnolia species | 509 | 408 | 340 | 0 | 0 | 0 | 0 | 0 | 0 | 1,256 | (±307) |
| **BEM Total** | **985** | **475** | **408** | **68** | **0** | **0** | **0** | **0** | **0** | **1,936** | **(±397)** |
| **Broadleaf Evergreen Small (BES)** | | | | | | | | | | | |
| *Aesculus hippocastanum* Horsechestnut | 272 | 34 | 68 | 170 | 306 | 781 | 509 | 374 | 238 | 2,751 | (±751) |
| BES other | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Camellia japonica* Camellia | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| **BES Total** | **272** | **102** | **68** | **170** | **306** | **781** | **509** | **374** | **238** | **2,819** | **(±752)** |
| **Conifer Evergreen Large (CEL)** | | | | | | | | | | | |
| *Abies grandis* Grand fir | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Abies spp.* True fir species | 34 | 136 | 68 | 68 | 0 | 34 | 0 | 0 | 0 | 340 | (±115) |
| *Calocedrus decurrens* Incense cedar | 577 | 340 | 170 | 136 | 0 | 34 | 34 | 0 | 34 | 1,324 | (±436) |
| *Cedrus deodara* Deodar cedar | 34 | 34 | 34 | 102 | 0 | 0 | 68 | 0 | 34 | 306 | (±110) |
| CEL other | 0 | 34 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 102 | (±58) |

| | DBH Class (in) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tree Type | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
| *Chamaecyparis lawsoniana* Port Orford cedar | 34 | 0 | 34 | 0 | 34 | 0 | 0 | 0 | 0 | 102 | (±58) |
| *Cupressus nootkatensis* Alaska cedar | 0 | 34 | 34 | 34 | 34 | 0 | 0 | 0 | 0 | 136 | (±82) |
| *Juniperus occidentalis* Western juniper | 102 | 272 | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 543 | (±262) |
| *Picea abies* Norway spruce | 34 | 0 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 102 | (±58) |
| *Picea pungens* Blue spruce | 204 | 170 | 441 | 34 | 0 | 34 | 0 | 0 | 0 | 883 | (±191) |
| *Picea spp.* Spruce species | 170 | 306 | 34 | 34 | 34 | 0 | 0 | 0 | 0 | 577 | (±228) |
| *Pinus flexilis* Limber pine | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Pinus monticola* Western white pine | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | (±33) |
| *Pinus palustris* Longleaf pine | 0 | 0 | 0 | 34 | 34 | 0 | 0 | 0 | 0 | 68 | (±47) |
| *Pinus thunbergiana* Japanese black pine | 0 | 0 | 272 | 68 | 0 | 0 | 0 | 0 | 0 | 340 | (±334) |
| *Pseudotsuga menziesii* Douglas-fir | 306 | 543 | 985 | 917 | 815 | 985 | 374 | 441 | 136 | 5,501 | (±1,044) |
| *Sequoia sempervirens* redwood | 0 | 0 | 0 | 34 | 0 | 0 | 34 | 0 | 0 | 68 | (±47) |
| *Thuja occidentalis* Arborvitae | 9,169 | 2,853 | 204 | 34 | 0 | 0 | 0 | 0 | 0 | 12,259 | (±4,635) |
| *Thuja plicata* Western redcedar | 1,121 | 1,426 | 1,358 | 543 | 238 | 611 | 204 | 0 | 68 | 5,569 | (±1,337) |
| *Tsuga spp.* Hemlock species | 68 | 102 | 170 | 68 | 34 | 34 | 0 | 0 | 0 | 475 | (±163) |

| Tree Type | DBH Class (in) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total | SE |
| **CEL Total** | **11,885** | **6,282** | **4,075** | **2,173** | **1,223** | **1,732** | **713** | **441** | **272** | **28,797** | **(±5,095)** |
| **Conifer Evergreen Medium (CEM)** | | | | | | | | | | | |
| CEM other | 0 | 68 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | (±58) |
| *Pinus spp.* Pine species | 204 | 374 | 679 | 238 | 136 | 34 | 34 | 0 | 0 | 1,698 | (±312) |
| *Pinus contorta* Lodgepole pine | 0 | 170 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 238 | (±129) |
| *Pinus nigra* Austrian pine | 0 | 102 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 170 | (±88) |
| *Pinus sylvestris* Scot's pine | 102 | 68 | 170 | 68 | 0 | 34 | 0 | 0 | 0 | 441 | (±219) |
| **CEM Total** | **306** | **781** | **985** | **340** | **136** | **68** | **34** | **0** | **0** | **2,649** | **(±420)** |
| **Conifer Evergreen Small (CES)** | | | | | | | | | | | |
| CES other | 204 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 272 | (±115) |
| *Pinus edulis* Twoneedle pinyon pine | 34 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 102 | (±100) |
| **CES Total** | **238** | **102** | **34** | **0** | **0** | **0** | **0** | **0** | **0** | **374** | **(±192)** |
| **Palm Evergreen Small (PES)** | | | | | | | | | | | |
| *Trachycarpus fortunei* Windmill palm | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | (±67) |
| **PES Total** | **68** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **68** | **(±67)** |
| ***POPULATION TOTAL*** | ***63,842*** | ***52,873*** | ***54,809*** | ***32,736*** | ***13,719*** | ***9,135*** | ***4,584*** | ***2,445*** | ***2,377*** | ***236,521*** | ***(±8,819)*** |

**Table B-2**. *Relative number of park trees by functional type, species, and diameter at breast height (DBH) class.*

| | DBH Class (in) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Tree Type** | **1-3** | **3-6** | **6-12** | **12-18** | **18-24** | **24-30** | **30-36** | **36-42** | **>42** | **Total** |
| **Broadleaf Deciduous Large (BDL)** | | | | | | | | | | |
| *Acer macrophyllum* Bigleaf maple | 91,687 | 47,892 | 61,978 | 34,062 | 12,037 | 2,049 | 5,890 | 512 | 0 | 256,108 |
| *Acer platanoides* Norway maple | 0 | 0 | 0 | 2,033 | 6,098 | 0 | 0 | 0 | 0 | 8,130 |
| *Acer saccharinum* Silver maple | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 | 0 | 2,033 |
| *Acer saccharum* Sugar maple | 0 | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 2,033 |
| *Fagus sylvatica* European beech | 1,130 | 0 | 2,935 | 0 | 0 | 0 | 0 | 0 | 0 | 4,065 |
| *Platanus occidentalis* American sycamore | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 | 0 | 0 | 2,033 |
| *Populus trichocarpa* Black cottonwood | 79,247 | 56,856 | 35,782 | 17,562 | 14,269 | 4,610 | 6,805 | 0 | 4,390 | 219,521 |
| *Quercus garryana* Oregon oak | 0 | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 2,033 |
| *Quercus rubra* Northern red oak | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Tilia platyphyllos* Bigleaf linden | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Ulmus laevis* European white elm | 3,651 | 0 | 0 | 0 | 0 | 415 | 0 | 0 | 0 | 4,065 |
| **BDL Total** | **175,714** | **106,781** | **100,695** | **55,689** | **36,469** | **7,073** | **14,728** | **2,545** | **4,390** | **504,086** |

| | DBH Class (in) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tree Type | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total |
| **<u>Broadleaf Deciduous Medium (BDM)</u>** | | | | | | | | | | |
| *Acer pseudoplatanus* Sycamore maple | 2,884 | 0 | 2,884 | 0 | 329 | 0 | 0 | 0 | 0 | 6,098 |
| *Acer rubrum* Red maple | 3,138 | 0 | 4,992 | 0 | 0 | 0 | 0 | 0 | 0 | 8,130 |
| *Alnus rubra* Red alder | 14,655 | 6,189 | 17,216 | 18,639 | 8,252 | 4,126 | 2,063 | 0 | 0 | 71,141 |
| *Betula pendula* European white birch | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Cornus nuttallii* Pacific dogwood | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Fraxinus oregana* Oregon ash | 39,258 | 6,484 | 6,484 | 6,484 | 0 | 236 | 0 | 0 | 0 | 58,945 |
| *Gleditsia triacanthos* Honeylocust | 0 | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 2,033 |
| **BDM Total** | **57,051** | **12,673** | **30,725** | **27,156** | **10,285** | **4,362** | **2,063** | **0** | **0** | **144,315** |
| **<u>Broadleaf Deciduous Small (BDS)</u>** | | | | | | | | | | |
| *Acer circinatum* Vine maple | 49,978 | 14,854 | 8,342 | 0 | 0 | 0 | 0 | 0 | 0 | 73,174 |
| *Corylus cornuta* Beaked hazelnut | 11,895 | 23,442 | 0 | 3,283 | 0 | 0 | 0 | 0 | 0 | 38,619 |
| *Cotinus coggygria* Smoke tree | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Crataegus douglasii* Black hawthorn | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Crataegus laevigata* English hawthorn | 8,130 | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 10,163 |

| Tree Type | DBH Class (in) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total |
| *Crataegus monogyna*<br>Common hawthorn | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Ilex aquifolium*<br>English holly | 22,342 | 10,179 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32,522 |
| *Magnolia dawsoniana*<br>Dawson's magnolia | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Oemleria cerasiformis*<br>Indian plum | 4,065 | 2,033 | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 8,130 |
| *Prunus amanogawa*<br>Amanogawa cherry | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Prunus avium*<br>Sweet cherry | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| *Prunus domestica*<br>Common plum | 0 | 0 | 4,065 | 0 | 0 | 0 | 0 | 0 | 0 | 4,065 |
| *Prunus padus*<br>European bird cherry | 21,891 | 24,025 | 8,781 | 5,000 | 1,281 | 0 | 0 | 0 | 0 | 60,978 |
| *Salix hookeriana*<br>Hooker willow | 4,065 | 2,033 | 6,098 | 4,065 | 0 | 0 | 0 | 0 | 0 | 16,261 |
| *Salix lucida*<br>Shining willow | 22,355 | 14,232 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36,587 |
| *Toxicodendron diversilobum*<br>Pacific poison oak | 2,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 |
| **BDS Total** | **150,819** | **92,831** | **33,383** | **16,413** | **1,281** | **0** | **0** | **0** | **0** | **294,727** |
| | | | | | | | | | | |
| **Broadleaf Evergreen Small (BES)** | | | | | | | | | | |
| *Rhododendron macrophyllum*<br>Pacific rhododendron | 0 | 6,098 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6,098 |
| **BES Total** | **0** | **6,098** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **6,098** |

| Tree Type | DBH Class (in) 1-3 | 3-6 | 6-12 | 12-18 | 18-24 | 24-30 | 30-36 | 36-42 | >42 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **Conifer Evergreen Large (CEL)** | | | | | | | | | | |
| *Cedrus atlantica* Atlas cedar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,033 | 2,033 | 4,065 |
| *Picea abies* Norway spruce | 0 | 0 | 0 | 0 | 2,033 | 0 | 0 | 0 | 0 | 2,033 |
| *Pseudotsuga menziesii* Douglas-fir | 935 | 17,391 | 49,368 | 26,741 | 33,660 | 27,115 | 20,383 | 8,415 | 2,992 | 186,999 |
| *Sequoia giganteum* Giant sequoia | 0 | 0 | 0 | 0 | 1,130 | 0 | 0 | 2,935 | 0 | 4,065 |
| *Thuja plicata* Western redcedar | 13,013 | 13,013 | 10,866 | 10,866 | 4,964 | 9,994 | 4,360 | 0 | 0 | 67,076 |
| *Tsuga heterophylla* Western hemlock | 2,931 | 5,819 | 0 | 0 | 2,917 | 1,707 | 854 | 0 | 0 | 14,228 |
| **CEL Total** | **16,879** | **36,223** | **60,234** | **37,607** | **44,703** | **38,817** | **25,597** | **13,383** | **5,025** | **278,467** |
| | | | | | | | | | | |
| ***POPULATION TOTAL*** | ***403,348*** | ***254,606*** | ***227,922*** | ***136,865*** | ***93,067*** | ***50,252*** | ***42,388*** | ***15,927*** | ***9,415*** | ***1,233,790*** |