City of Pittsburgh, Pennsylvania Municipal Forest Resource Analysis

April, 2008

DAVEY
RESOURCE GROUP
A Division of The Davey Tree Expert Company

City of Pittsburgh, Pennsylvania Municipal Forest Resource Analysis

April, 2008

Prepared for:
Friends of the Pittsburgh Urban Forest
Liberty Bank Building, Suite 201
6101 Penn Avenue
Pittsburgh, Pennsylvania 15206
412-362-6360

Prepared by:
Davey Resource Group
1500 North Mantua Street
P.O. Box 5193
Kent, Ohio 44240
1-800-828-8312

Acknowledgements

This project was made possible by:

City of Pittsburgh Public Works
Mike Gable, Deputy Director

City of Pittsburgh Forestry Division
David Jahn, City Forester

Friends of the Pittsburgh Urban Forest
Diana Ames, President
Danielle Crumrine, Executive Director
Matthew Erb, Director of Urban Forestry

Pittsburgh Shade Tree Commission
Diana Ames, Chair

Penn State Cooperative Extension
Mark Remcheck, Extension Urban Forester

USDA Forest Service
Pacific Southwest Research Station, Center for Urban Forest Research
Dr. Greg McPherson, Project Leader

With funding from:

Pennsylvania Community Forests
www.dcnr.state.pa.us/forestry/pucfc

While the specific reports and recommendations are unique to this study, the basis for its structure and written content comes from the entire series of *Municipal Forest Resource Analysis* reports prepared and published by the USDA Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research, and credit should be given to those authors. The *Municipal Forest Resource Analysis* reports are companions to the regional *Tree Guides* and i–Tree's STRATUM application developed by the USDA Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research.

Table of Contents

Tables

Figures

Appendices

Executive Summary

Pittsburgh's street trees are a valuable municipal resource and a critical component of the City's infrastructure. While they are an important part of the City's identity and history, in recent years, Pittsburgh has seen a net decrease in tree numbers and the City's Forestry Department has seen decreases in annual tree-related funding and staffing levels. In response to the Pittsburgh Shade Tree Commission's street tree inventory and management plan project in 2005, the City and its partners have realized the need for action. The inventory detailed and prescribed management recommendations resulting in a cost estimate of over $8 million over seven years to perform the necessary maintenance. However, these estimates are beyond the City's current fiscal means. The recent formation of the non-profit Friends of the Pittsburgh Urban Forest offers a partnership to help distribute the financial load of improving the City's municipal tree management program.

The Friends of the Pittsburgh Urban Forest have commissioned an analysis of the City's street tree resource that combines current inventory data with benefit-cost modeling data to produce information on the resource's structure, function, value, and maintenance needs.

Resource Structure

Pittsburgh's street tree inventory includes 29,641 publicly managed street trees. An analysis of the resource composition is the first step towards understanding the benefits that these street trees are providing and their management needs. Looking at species, diversity, age distribution, condition, canopy coverage, and replacement value, the following information characterizes Pittsburgh's street tree resource:

- There are over 130 distinct species growing along the streets of Pittsburgh; the predominant street tree species are Norway maple (*Acer platanoides*, 15.7%); red maple (*Acer rubrum*, 11.4%); callery pear (*Pyrus calleryana*, 11.3%); littleleaf linden (*Tilia cordata*, 10.9%); and London planetree (*Platanus* x *acerifolia*, 8.6%).
- The age structure of Pittsburgh's street trees is not ideal—with an inadequate number of young trees. There is a need to expand street tree plantings to maintain the flow of benefits provided by the resource. In terms of producing benefits, two of Pittsburgh's top performing species, London planetree and pin oak, are lacking numbers of young replacements.
- The majority of Pittsburgh's street trees are only in fair condition (50%), with 27% of trees classified as good, 21% of its street tree resource in poor condition, and almost 2% either critical or dead. There is a need to maintain existing trees to increase their useful lifespan and maintain a flow of benefits, and to remove critical or dead trees as soon as possible.
- In Pittsburgh, the estimated street tree canopy covers only 521 acres, or 1.5%, of the total land area of the City. The street tree canopy cover is less than 10% of that of the total street and sidewalk area (5,461 acres) covered within the City.
- To replace Pittsburgh's 29,641 street trees with trees of similar size, species, and condition would cost approximately $137 million.

Resource Function and Value

Pittsburgh's street trees provide cumulative benefits to the community valued at an average of $81 per tree annually, for a gross total value of $2.4 million annually. They help conserve and reduce energy use, reduce local carbon dioxide levels, improve air quality, mitigate stormwater runoff, and provide other benefits associated with aesthetics, property value increases, and quality of life. The City's street trees are providing the community substantial benefits such as:

- Street trees reduce electricity and natural gas use in Pittsburgh from both shading and climate effects equal to 2,227 MWh and 811,917 therms, for a total savings valued at approximately $1.2 million, with a citywide average of $40.66 per street tree.
- The street trees in Pittsburgh reduce atmospheric CO_2 by a net of 5,303 tons, valued at $35,424 per year, for an average net benefit per tree of $1.20.
- The net air quality improvement provided by the street tree population from the removal and avoidance of air pollutants is valued at $252,935 per year, with an average net benefit per tree of $8.53.
- Pittsburgh's street trees intercept 41.8 million gallons of stormwater annually, for an average of 1,411 gallons per tree. The total value of this benefit to the City is $334,601 per year, with an average value of $11 per tree.
- The estimated total annual benefit associated with property value increases, aesthetics, and other less tangible improvements is $572,882, for an average of $19.33 per tree.
- When the City's annual tree-related expenditures are considered ($816,400), the net annual benefit (benefits minus costs) to the City is $1.6 million. The average net benefit for an individual street tree in Pittsburgh is $53 per year. Pittsburgh receives $2.94 in benefits for every $1 that is spent on its municipal forestry program.

Resource Management

Pittsburgh's street tree resource is a dynamic resource that is worth the investment. The City's street trees improve the quality of life in the community and help mitigate the City's environmental impact. However, this resource is vulnerable to a host of stressors and requires sound management practices in order to sustain the flow of benefits. Achieving resource sustainability requires that Pittsburgh:

- Sustain the benefits of the existing street tree resource through comprehensive tree maintenance, including new tree establishment and cyclical pruning. Develop a replacement plan for the City's most mature trees (and top benefit producers) to replace them with trees of similar stature gradually before they must be removed.
- Implement a citywide tree planting program to expand the extent of the resource, distribute the resource more equitably across wards and neighborhoods, and maintain the flow of benefits over time. Focus on large-stature trees where growing conditions permit to maximize benefits.
- Reduce dependence on Norway maple and London planetree for benefits through careful species selection to achieve greater diversity and guard against catastrophic losses. Achieve an appropriate age distribution by planting new trees to improve long-term resource sustainability.

- Select species and match them to existing site conditions to avoid conflicts with infrastructure. Explore use of structural soils, rerouting sidewalks around root flares, and expanding growing space sizes wherever possible to improve cost-effectiveness associated with existing infrastructure conflicts.
- Strengthen the City's network of partners and urban forest managers to work together towards the common goal of an improved, more functional, and sustainable street tree resource.

The value of Pittsburgh's street tree resource should increase as existing trees mature and new trees are planted. As the resource grows, proactive management is critical to ensuring that residents will continue receiving a high return on investment into the future. It is not enough to simply plant more trees to increase canopy cover and benefits. Planning and funding for care and management must complement planting efforts to ensure the success of new plantings. Existing trees must also be maintained and protected because the greatest benefits will accrue from continued growth of existing canopy. Pittsburgh's street trees are a dynamic resource requiring constant care to maximize and sustain production of benefits into the future. However, the City can take pride in knowing that street trees substantially improve the quality of life in the City and are well worth the investment.

Photograph 1. When the City's annual tree-related expenditures are considered ($816,400), the net annual benefit (benefits minus costs) to the City is $1.6 million. Regular maintenance of existing trees will prolong their useful lives and help to ensure sustained benefits over time.

Chapter 1: Introduction

Pittsburgh has been ranked as the #1 Most Livable City in America by *Places Rated Almanac* (Savageau, 2007), an honor in which the City takes great pride. Once the steel capital of the world, the growth of Pittsburgh and its economy was fueled by heavy industry and the extensive trade of steel—to the detriment of local air and water quality. Successfully adapting to the collapse of the region's steel industry, Pittsburgh has shifted its industry base to health care, education, technology, and financial services, and has been recently named among the top 25 of the World's Cleanest Cities by *Forbes* magazine (2007)—a remarkable transformation. The role Pittsburgh's urban forest has played in this transformation is significant.

Photograph 2. The urban forest makes Pittsburgh a more enjoyable place to live, work, and play while mitigating the City's environmental impact.

Research indicates that healthy city trees can mitigate adverse impacts of the urban environment. Specifically, urban trees can help slow and reduce stormwater runoff, improve poor air quality, reduce energy consumption, and regulate increased temperatures from urban heat islands. Healthy public trees increase real estate values, provide neighborhood residents with a sense of place, and foster psychological health. Park and street trees are also associated with other intangibles, such as increasing community attractiveness for tourism and business and providing wildlife habitat and corridors. The urban forest makes Pittsburgh a more enjoyable place to live, work, and play, while mitigating the City's environmental impact.

Pittsburgh's urban forest—including all trees on public and private lands—softens the industrial landscape and provides a green sanctuary in an otherwise barren hardscape, greatly contributing to the City's "livability". The City's street and park trees play a prominent role in the benefits afforded to the community, and the community relies on a series of partnerships, community groups, and City departments to maintain this resource. Pittsburgh's Forestry Division, a division within the Department of Public Works, is responsible for the care of over 29,000 street trees, wooded rights-of-way, and an extensive network of parks and other greenspaces. Other entities share the responsibility of managing this resource, including the City's Planning Department, the Pittsburgh Shade Tree Commission, the electric utility provider Duquesne Light Company, and non-profit Friends of the Pittsburgh Urban Forest. The Forestry Division, advised by the Shade Tree Commission, primarily deals with the removal and maintenance of existing street trees, while Duquesne Light coordinates with the Forestry Division to provide line clearance where street trees and overhead utilities intersect. Friends of the Pittsburgh Urban Forest advance partnerships with the City and the community-at-large to provide education, advocacy, tree maintenance, and new tree plantings. These partners believe that the public's investment in stewardship of the urban forest produces benefits that far outweigh the costs to the community. Investing in Pittsburgh's green infrastructure makes sense economically, environmentally, and socially.

This report focuses on the City's street trees—the City's most readily quantifiable resource in terms of numbers and benefits provided. This study incorporates data from the City's current street tree inventory into i–Tree's Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM v3.2) to establish baseline information on the value that street trees provide to the community.

In an era of increasing environmental awareness and responsibility, there is a need to establish the ways in which Pittsburgh is addressing its impact on the environment. The City's street tree resource represents a large part of the City's overall effort to improve the environment and the community—an effort solidified by its commitment to the U. S. Mayors Climate Protection Agreement and the reduction of global warming pollution locally. The purpose of this report is to provide information on the structure, function, and value of the street tree resource so managers and citizens alike can make informed decisions about their support and management priorities. Information is provided to do the following:

- Describe the current structure of the street tree resource and establish benchmarks for future management decisions.
- Detail management expenditures for Pittsburgh's publicly managed street trees and provide critical baseline information for evaluating program cost-efficiency.
- Quantify the value of environmental benefits of Pittsburgh's street trees and highlight the relevance and relationship of the resource to local quality of life issues, such as air quality and environmental health, economic development, and psychological health.
- Describe the current management challenges for street tree maintenance and assist decision-makers to assess and justify the level of funding and type of management program appropriate for Pittsburgh's street trees.
- Provide quantifiable data to assist resource managers in developing alternative funding sources through utility purveyors, air quality districts, federal or state agencies, legislative initiatives, or local assessment fees.

Pittsburgh's extensive network of parks and greenways, which account for a large portion of the City's public trees, are not represented in this analysis. Therefore, the full extent and benefit of Pittsburgh's municipal forest may be understated.

Photograph 3. Investing in Pittsburgh's green infrastructure makes sense economically, environmentally, and socially.

Chapter 2: Pittsburgh's Municipal Tree Resource

Street Tree Numbers

Pittsburgh's street tree population is dominated by broadleaf-deciduous trees (96.2% of the total). Broadleaf-deciduous trees usually have larger canopies than coniferous street trees, and because most of the benefits provided by trees are related to leaf surface area, broadleaf trees usually provide the highest level of benefit. There are 16,343 (55%) large-growing, broadleaf-deciduous trees represented in the population, with 7,372 (25%) medium-growing, broadleaf-deciduous trees and 4,808 (16%) small-growing, broadleaf-deciduous contributing to the total street tree numbers. There are 1,118 (4%) evergreen and coniferous street trees rounding out the population.

The majority of this analysis addresses the City's street tree resource as a whole to draw attention to the need for a comprehensive approach to street tree management. However, some insight can be gained from looking at the resource at the neighborhood and ward level. For example, Ward 14 (Squirrel Hill, Point Breeze, and others) is the most densely populated ward in the City and includes 5,726 street trees, 19% of all street trees and 48% of the City's London planetrees. By comparison, Wards 27–28 (Brighton Heights, Fairywood, Windgap, and others) include 1,664 trees or 6% of the population, and Wards 21–22 (Manchester, North Shore, Central North Side, Allegheny Center, and others) include 1,620 trees or 5.5% of the population. Ward 26 (Perry North, Perry South, and others) is the least dense, with only 742 trees, or 2.5% of the total population. More information on Pittsburgh's street tree resource in each ward, including a map of ward locations, can be found in *Appendix C.*

Species Richness and Composition

The street tree population includes a mix of more than 130 species— nearly two and a half times more than that of the mean of 53 species reported by McPherson and Rowntree (1989) in their nationwide survey of street tree populations in 22 U. S. cities. This is unusual for densely urbanized cities of continental climate that typically have a narrow palette of species from which to choose.

However, the top 15 occurring species comprise 85.7% of the total population (*Table 1*; see also *Appendix B*). The predominant street tree species are Norway maple (*Acer platanoides*, 15.7%), red maple (*Acer rubrum*, 11.4%), callery pear (*Pyrus calleryana*, 11.3%), littleleaf linden (*Tilia cordata*, 10.9%), and London planetree (*Platanus acerifolia*, 8.6%). The percentages of Norway maple, red maple, callery pear, and littleleaf linden exceed the widely accepted rule that no single species should represent more than 10% of the total population and no single genus more than 20% (Clark and others, 1997). The genus maple (*Acer*) makes up 36% of the total street tree population. The next most abundant genera include: linden (*Tilia*, 11%), pear (*Pyrus*, 11%), sycamore (*Platanus*, 9%), and oak (*Quercus*, 6%). At the ward level, Norway maple is the predominant species in 11 of the City's 20 ward-groupings. Nearly all of the wards in the City exceed the goals of 10% species composition and 20% genus composition, further highlighting the need to diversify the mix of species used along the streets (*Appendix C*).

Dominance of maples (36%) in the street tree population is of concern because of the catastrophic impact that storms, drought, disease, pests, or other stressors can have on the urban forest and its effect on the flow of benefits and costs to the City over time. Urban forest managers have become well aware of the implications of a heavily skewed population. Historical examples of Dutch elm disease and the present threat of pests, such as emerald ash borer (*Agrilus planipennis* Fairmaire) and Asian longhorned beetle (*Anoplophora glabripennis*), highlight the importance of a balanced distribution of species and genera. In fact, on June 27, 2007, the presence of emerald ash borer in western

Pennsylvania was confirmed by U. S. Department of Agriculture surveyors in Butler County, as close as 20 miles from the City. While ash trees are relatively few among the street tree population (412 trees, 1.4% of all street trees), the impact of this pest will certainly pose management difficulties to the City beyond these 412 trees. Considering the prevalence of ash trees in the region, as many as 3 million trees statewide (Majors [Wolff], 2007) and roughly 15% of trees in Pittsburgh's parks (Heinrichs [Gruszka], 2007), emerald ash borer poses the potential for a much larger impact on Pittsburgh's urban forest than the street tree numbers suggest.

Table 1. Most Frequently Occurring Street Tree Species by DBH Class and Tree Type*

DBH Class (in)											
Species	**0-3**	**3-6**	**6-12**	**12-18**	**18-24**	**24-30**	**30-36**	**36-42**	**>42**	**Total**	**% of Total**
Broadleaf Deciduous Large (BDL)											
Norway maple	164	410	1,876	1,388	570	213	37	2	0	4,660	15.7
London planetree	76	214	63	64	397	885	616	203	36	2,554	8.6
honeylocust	181	535	464	181	131	76	6	0	1	1,575	5.3
sugar maple	25	149	542	240	71	11	4	0	0	1,042	3.5
pin oak	12	25	70	97	221	356	174	57	11	1,023	3.5
silver maple	42	211	290	143	94	86	38	14	9	927	3.1
sweetgum	6	10	226	440	163	15	5	0	0	865	2.9
northern red oak	11	25	88	199	185	149	67	26	3	753	2.5
ginkgo	24	69	207	150	140	67	17	2	0	676	2.3
black locust	4	11	49	104	107	51	26	15	2	369	1.2
BDL OTHER	161	249	610	341	240	181	80	30	7	1,899	6.4
Total	706	1,908	4,485	3,347	2,319	2,090	1,070	349	69	16,343	55.1
Broadleaf Deciduous Medium (BDM)											
red maple	317	881	1,393	679	82	15	4	0	0	3,371	11.4
littleleaf linden	33	201	614	1,567	641	162	17	4	1	3,240	10.9
BDM OTHER	181	199	205	105	48	22	1	0	0	761	2.6
Total	531	1,281	2,212	2,351	771	199	22	4	1	7,372	24.9
Broadleaf Deciduous Small (BDS)											
callery pear	563	1,390	1,121	240	25	0	0	0	0	3,339	11.3
apple	156	201	174	68	4	0	0	0	0	603	2.0
BDS OTHER	343	299	174	37	11	2	0	0	0	866	2.9
Total	1,062	1,890	1,469	345	40	2	0	0	0	4,808	16.2
Broadleaf Evergreen Medium (BEM)											
BEM OTHER	3	7	10	0	1	0	0	0	0	21	0.1
Total	3	7	10	0	1	0	0	0	0	21	0.1
Conifer Evergreen Large (CEL)											
CEL OTHER	30	37	108	97	26	5	0	0	0	303	1.0
Total	30	37	108	97	26	5	0	0	0	303	1.0
Conifer Evergreen Medium (CEM)											
Colorado spruce	36	56	150	137	27	0	0	0	0	406	1.4
BEM OTHER	174	117	82	12	3	0	0	0	0	388	1.3
Total	210	173	232	149	30	0	0	0	0	794	2.7
Citywide Total	**2,542**	**5,296**	**8,516**	**6,289**	**3,187**	**2,296**	**1,092**	**353**	**70**	**29,641**	**100.0**

*Species listed represent >1% of the total population. All other species are included in "Other".

Species Importance

To quantify the significance of any one particular species found in the City's street tree population, an Importance Value (IV) is assigned to each species in the street tree inventory. Importance values are particularly meaningful to urban forest managers because they indicate a community's reliance on the functional capacity of particular species. STRATUM calculates IV based on the mean of three important values: percentage of total population, percentage of total leaf area, and percentage of total canopy cover. IV goes beyond tree numbers alone to suggest reliance on different species based on the benefits they provide.

The IV can range from zero, which implies no reliance, to 100, which suggests total reliance. No single species should dominate the species composition in the City's street tree population. Because IV goes beyond population numbers alone, it can help managers better understand the loss of benefits from a catastrophic loss of one species. When IVs are evenly dispersed among the 10 to 15 most abundant species, the risk of significant reductions to benefits is reduced. High IVs alone do not equate to an endorsement of that species; the suitability of dominant species to the area and intended use are important considerations. Planting short-lived or poorly adapted species can result in short rotations and increased long-term management costs.

The 15 most abundant street tree species in Pittsburgh represent 85.7% of the total population, 89.4% of the total leaf area, and 89.8% of the total canopy cover from street trees for a combined IV of 88.3 (*Table 2*). Of these species, Pittsburgh relies most on the functional capacity of London planetree (IV=17.6), Norway maple (IV=13.3), and littleleaf linden (IV=10.2). London planetree's high IV suggests that even though it only comprises 8.6% of the total population, it is more important than the four most common street tree species (Norway maple, red maple, callery pear, and littleleaf linden) in terms of its capacity to produce benefits. This is due to its relative maturity, greater size, and greater leaf area compared to the other trees. London planetree and pin oak are among the largest street trees in Pittsburgh, having significant percentages of trees in mature size classes (> 24-inch DBH), 68% and 58%, respectively. Pittsburgh's pin oaks have an IV of 7.1, and are providing the greatest functional capacity to provide benefits, behind London planetree, compared to their representation in the population (3.5% of total trees).

Due to their relatively small leaf area and canopy coverage, immature trees and small-stature trees tend to have lower importance values than their population numbers suggest. In Pittsburgh, red maple represents 11.4% of the total population and has an IV of only 8.7. An analysis of tree size shows that 76.8% of the red maples are immature (< 12-inch DBH). Callery pear, a small-stature tree, represents 11.3% of the total population, but has an IV of only 6.5. However, red maple and other medium- and large-growing species have the potential to increase their importance as they mature.

Table 2. Importance Values for Pittsburgh's Most Abundant Street Trees

Species	Number of Trees	% of Total Trees	Leaf Area (ft^2)	% of Total Leaf Area	Canopy Cover (ft^2)	% of Total Canopy Cover	Importance Value
Norway maple	4,660	15.7	6,584,104	10.4	3,115,548	13.7	13.3
red maple	3,371	11.4	5,328,029	8.4	1,425,889	6.3	8.7
callery pear	3,339	11.3	2,479,836	3.9	958,373	4.2	6.5
littleleaf linden	3,240	10.9	5,945,893	9.4	2,324,428	10.2	10.2
London planetree	2,554	8.6	14,459,833	22.9	4,846,240	21.3	17.6
honeylocust	1,575	5.3	2,969,074	4.7	1,178,365	5.2	5.1
sugar maple	1,042	3.5	1,728,579	2.7	542,361	2.4	2.9
pin oak	1,023	3.5	5,670,358	9.0	1,985,699	8.7	7.1
silver maple	927	3.1	2,538,596	4.0	750,536	3.3	3.5
sweetgum	865	2.9	2,121,408	3.4	736,309	3.2	3.2
northern red oak	753	2.5	3,198,906	5.1	1,227,229	5.4	4.3
ginkgo	676	2.3	1,192,898	1.9	478,268	2.1	2.1
apple	603	2.0	268,090	0.4	126,362	0.6	1.0
Colorado spruce	406	1.4	194,724	0.3	137,209	0.6	0.8
black locust	369	1.2	1,891,336	3.0	557,971	2.5	2.2
OTHER TREES	4,238	14.3	6,699,931	10.6	2,309,969	10.2	11.7
Total	**29,641**	**100.0**	**63,271,628**	**100.0**	**22,700,756**	**100.0**	**100.0**

Stocking Level

Although the inventory on which this study is based does not include complete information on vacant sites to determine stocking levels, stocking can be estimated based on total street miles and the total number of existing street trees (29,641). Pittsburgh has 1,325 linear miles of street (Gable, 2006), for an average of 22 trees per street mile. Theoretically, a given street would have room for a tree every 50 feet along both sides of the street, or 211 trees per mile. This suggests that there is room for an additional 250,000 street trees in Pittsburgh to reach full stocking potential. The actual number of street tree planting sites may be significantly less due to inadequate planting spaces, proximity of private trees, and utility conflicts. Nonetheless, by this measure, Pittsburgh's street tree stocking level is 10.6%, which is significantly less than the mean stocking level for 22 U. S. cities (38.4%) (McPherson and Rowntree, 1989).

Calculating the number of street trees per capita is another important measure of tree stocking. Assuming a human population of 325,337 (U. S. Census Bureau, 2003), Pittsburgh's number of street trees per capita is 0.09, approximately one tree for every 11 people. This is of great concern, as the mean for 22 U. S. cities is approximately one tree for every 2.7 people (McPherson and Rowntree, 1989). It would take an additional 90,000 newly planted trees to approach this reported benchmark.

Relative Age Distribution

The distribution of ages within a tree population influences present and future costs as well as the flow of benefits. An uneven-aged population allows managers to allocate annual maintenance costs uniformly over many years and assures continuity in overall tree canopy cover. A desirable distribution has a high proportion of young trees to offset establishment- and age-related mortality, while the percentage of older trees declines with age (Richards, 1982/83). This "ideal", uneven distribution suggests the largest fraction of trees (40% of the total) should be young, with diameters less than 8 inches, while only 10% should be in the large diameter classes (> 24-inch DBH).

Comparing Pittsburgh's actual distribution to the ideal, the City's street trees are distributed somewhat evenly, with 26% young trees (< 6-inch DBH), 29% established trees (6- to 12-inch DBH), 32% maturing trees (12- to 24-inch DBH), and 13% mature trees (> 24-inch DBH). Given the fact that Pittsburgh has no budget for new tree plantings, the results are concerning—compare the ideal proportion of younger trees/smaller size classes (40%) to that of the current population (26%). As time goes by and the current tree population matures, the relative age distribution will skew towards the mature size classes without new plantings taking place. A street tree population with mostly mature trees faces greater maintenance costs and is susceptible to large fluctuations in functional benefits. An uneven age distribution, heavily weighted in younger trees, is an age structure that provides an even flow of benefits, even if major losses in canopy or species occur.

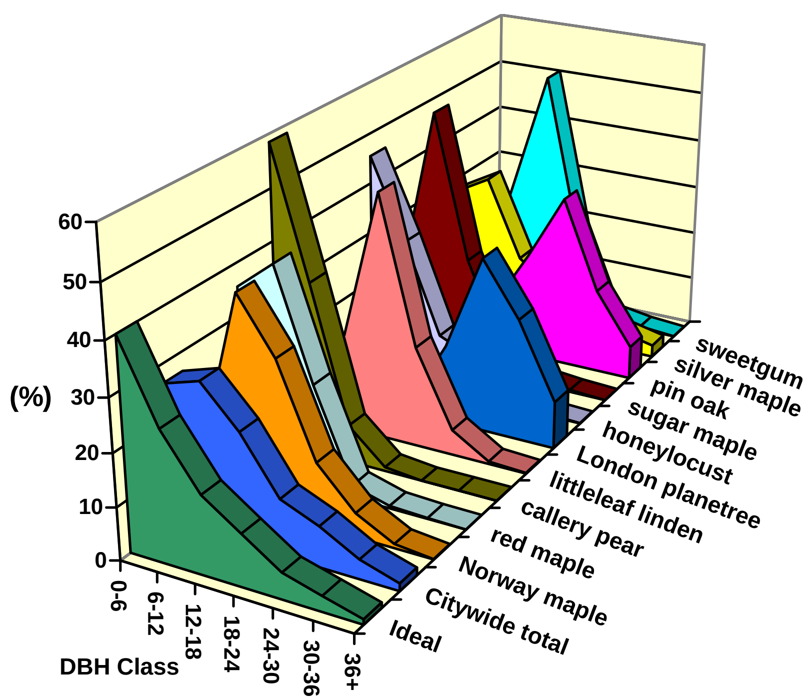


Figure 1. Relative Age Distribution of Pittsburgh's Top 10 Street Trees

Specifically, *Figure 1* shows that London planetree (68.1%) and pin oak (58.5%) dominate the larger size classes (> 24-inch DBH) and have inadequate representation in the smaller size classes (0- to 6-inch DBH). As these species begin to senesce, their maintenance needs become more frequent and there will not be sufficient replacement stock in place to help stabilize the functional capacity of these large-stature trees. The majority of littleleaf linden and sweetgum (87.2% and 95.8%, respectively) are found in the middle size classes (6- to 24-inch DBH). These medium- and large-growing species have inadequate representation in the smaller size classes and the larger size classes. Pittsburgh's most abundant street tree, Norway maple, only has 12.3% of its total in the 0- to 6-inch DBH class. These results are indicative of an insufficient new tree planting program and warn of a future population crash. Four of the most heavily relied upon species in Pittsburgh lack an appropriate age distribution, which warns of a management crisis in the near future. Relative age distributions among wards are varied, and only Wards 8–9 approach the ideal distribution. However, looking at age distributions of the individual species within Wards 8–9 reveals that London planetree represents the only mature species, 78% of which are greater than 24-inch DBH. Not surprisingly, Ward 14 has the highest concentration of mature trees (28%) due to its high concentration of London planetree (*Appendix C*). This trend indicates a one-time, single-species planting effort focused only in select wards, followed by years of little or no street tree planting. Today, the results of that trend are realized by an imbalance of maintenance needs and insufficient replacement stock required for long-term resource sustainability.

Tree Condition and Relative Performance

Tree condition indicates both how well trees are managed and how well they perform given site-specific condition. The majority of Pittsburgh's street trees are only in fair condition and may suggest inadequate maintenance, poorly chosen species, or poor planting site conditions (*Figure 2*). When trees are performing at their peak—as are the 27% of trees classified as good and very good—the benefits they provide will be maximized. Pittsburgh has 21% of its street tree resource in poor condition, and almost 2% of trees are critical or dead. The goal for critical and dead trees should be zero. Wards 21–22 have the highest percentage of trees in poor condition or worse (37.7%) and Ward 4 has the highest concentration of trees in good condition or better (56.1%). As evidenced by the overall condition distribution, nearly every ward has the majority of its trees in fair condition (*Appendix C*).

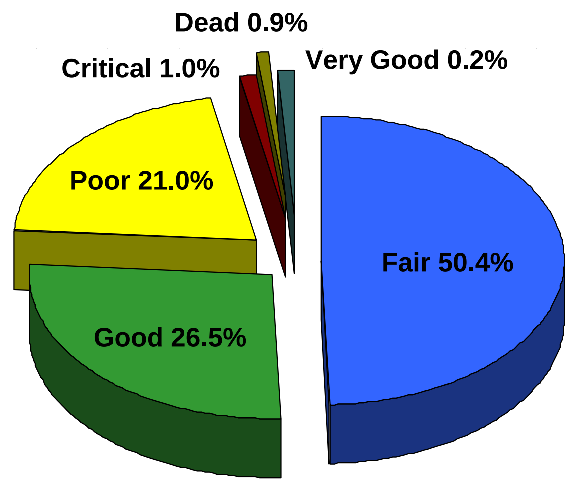


Figure 2. Condition Distribution for Pittsburgh's Street Tree Population

One way to analyze the conditions of urban tree species in more detail is the relative performance index (RPI). RPI gives the urban forest manager an interesting look at how one species' performance compares to other species. This index compares the condition rating assigned to each tree and relates that condition to the inventoried tree population as a whole. RPI is calculated by taking the percentage of each species in good condition and dividing it by the percentage of the total population that is in good condition. A value of 1.0 or better indicates that the species is performing well when compared to other species, because its percentage of good trees is at least equal to that of the entire population. RPI values below 1.0 indicate that the species is not performing well compared to the rest of the population. Poor performing species (RPI <1.00) should be scrutinized as planting choices because they may indicate species that are not well adapted to local conditions. As such, they may present increased safety and maintenance issues. However, before making decisions concerning good and poor performers, a manager must take into account the age range of the species. A species that has a RPI of less than one (1.00), but has a significant number of trees in larger dbh classes, may just be exhibiting signs of population senescence. The individuals of this species have produced a number of benefits over the years, which must be taken into account when making decisions

Among the 15 most abundant street tree species in Pittsburgh, seven have a RPI greater than 1.0 (*Table 3*). Of these, Colorado spruce (1.22), honeylocust (1.11), callery pear (1.06), and sweetgum (1.06) are performing the best. Black locust (0.77) and Norway maple (0.94) are performing below average. Honeylocust is the only species that comes close to the ideal age distribution (*Figure 1*). With such a strong RPI value, honeylocust is a proven performer in Pittsburgh and is deserving of increased consideration as a street tree. Some of Pittsburgh's most important street trees species—London planetree, littleleaf linden, and pin oak—have lower RPI values because the majority of these trees are in the larger size classes, having performed well for the City over a number of years. Achieving a more appropriate age distribution for these species through new plantings will not only ensure long-term results from these species, but would likely result in increased RPI values as well.

Table 3. Relative Performance Index for Pittsburgh's Most Abundant Street Trees

Species	Dead	Critical	Poor	Fair	Good	Very Good	RPI	# of Trees	% of Total
Norway maple	0.6	1.1	29.2	54.0	15.0	0.1	0.94	4,658	15.72
red maple	1.1	1.1	20.5	48.8	28.3	0.2	1.00	3,371	11.37
callery pear	0.8	0.9	13.9	46.2	38.1	0.1	1.06	3,339	11.27
littleleaf linden	0.5	0.7	25.2	56.2	17.4	0.0	0.96	3,240	10.93
London planetree	0.2	0.4	26.1	54.2	18.8	0.4	0.97	2,555	8.62
honeylocust	0.1	0.7	9.0	46.0	44.3	0.0	1.11	1,575	5.31
sugar maple	0.9	2.1	28.8	44.9	23.1	0.2	0.96	1,042	3.52
pin oak	0.1	0.2	23.9	55.2	20.1	0.4	0.98	1,023	3.45
silver maple	0.3	1.2	22.5	52.4	23.2	0.3	0.99	927	3.13
sweetgum	0.0	0.2	16.4	48.6	34.3	0.5	1.06	865	2.92
northern red oak	0.0	0.4	17.4	53.8	28.0	0.4	1.03	753	2.54
ginkgo	0.6	0.4	16.3	58.6	24.0	0.1	1.01	676	2.28
apple	1.2	1.8	13.9	54.4	28.7	0.0	1.02	603	2.03
Colorado spruce	0.2	0.0	2.5	26.4	70.7	0.2	1.22	406	1.37
black locust	5.4	8.4	39.0	44.4	2.7	0.0	0.77	369	1.24
Total	**0.8**	**1.3**	**20.3**	**49.6**	**27.8**	**0.2**	**1.01**	**25,402**	**85.70**

RPI can be used by managers to make important urban forestry decisions. If a city has been planting two new species in their urban forest, RPI can be utilized to compare the two. If RPI indicates that one is performing relatively poorly, a city can reduce, or even stop, planting that species and subsequently save money on planting stock and replacement costs. RPI enables managers to look at the performance of long-standing species as well. Species planted for many years that have a RPI of one (1.00) have performed well compared to the population as a whole. These good performers should be maintained as a significant portion of the urban forest.

RPI can also be used to identify underutilized species that may be good performers. Of the street trees with a RPI value greater than 1.00, but at least representative of 0.10% (30 trees) of the total population, some species stand out as suitable selections that should receive particular consideration for future plantings (*Table 4*). Of the large-stature trees, honeylocust (1.11) and sweetgum (1.06) are proven performers. Green ash (1.05) also scores well; unfortunately, ash trees should not be planted due to the current threat of emerald ash borer. There are only 412 (1.4%) ash trees (*Fraxinus*) along Pittsburgh's streets, a fortunate situation considering how many communities are facing elevated costs for treatment and/or removal in the wake of emerald ash borer, as well as the significant loss of canopy and associated benefits.

Of the medium-stature street trees, hedge maple (1.20) is a top performing species. However, the genus of maples (*Acer*) makes up 36% of the total population; American hornbeam and Japanese snowbell may serve as suitable medium-stature species selections to supplement a diverse planting program. Of the small-stature street trees, Japanese tree lilac (1.20) is a top performing species deserving of a more significant role along Pittsburgh's streets. RPI values for the entire population are included in *Appendix B*.

Table 4. Pittsburgh's Underutilized Street Trees with RPI > 1.00

Species	RPI	# of Trees Total	% of Total Population
Broadleaf Deciduous Large (BDL)			
honeylocust	**1.11**	1,575	5.31
sweetgum	**1.06**	865	2.92
northern red oak	**1.03**	753	2.54
ginkgo	**1.01**	676	2.28
green ash*	**1.05**	284	0.96
Japanese zelkova	**1.03**	242	0.82
black oak	**1.01**	28	0.09
Broadleaf Deciduous Medium (BDM)			
hedge maple	**1.20**	270	0.91
American hornbeam	**1.08**	39	0.13
Japanese snowbell	**1.01**	34	0.11
Broadleaf Deciduous Small (BDS)			
callery pear	**1.06**	3,339	11.27
apple	**1.02**	603	2.03
plum	**1.09**	217	0.73
amur maple	**1.12**	147	0.50
Tatarian maple	**1.18**	81	0.27
flowering dogwood	**1.10**	62	0.21
Japanese maple	**1.15**	61	0.21
Japanese tree lilac	**1.20**	33	0.11
kwanzan cherry	**1.17**	32	0.11

* While green ash may be a well-performing species for the City, this and other ash should not be planted under the current threat of emerald ash borer (EAB).

Canopy Cover

The amount and distribution of leaf surface area is the driving force behind the urban forest's ability to produce benefits for the community (Clark, 1997). As canopy cover increases, so do the benefits afforded by leaf area. It is important to remember that street trees throughout the United States—and those of Pittsburgh—likely represent less than 10% of the entire urban forest (Moll and Kollin, 1993). In Pittsburgh, the estimated street tree canopy covers only 521 acres of the total land area of 35,200 acres (55 square miles), or 1.5% of the City. Ward 14 contributes the vast majority (28.2%) to street tree canopy cover and no other wards contribute more than 6.4% (*Appendix C*). The street tree canopy cover is less than 10% of that of the total street and sidewalk area (5,461 acres) covered within the City.

Photograph 4. Pittsburgh's street tree canopy accounts for an estimated 521 acres, which equates to 1.5% of the City's total land area or 9.5% of the area taken up by streets and sidewalks (5,461 acres).

Having canopy cover over paved surfaces has added value from reduced maintenance as well. Trees along streets have been shown to reduce the wear on asphalt by lowering surface temperatures, thereby reducing maintenance costs (McPherson and Muchnick, 2005). A study comparing several blocks in Modesto, California demonstrated that streets shaded by large trees required fewer than half the number of slurry seals (2.5 vs. 6 on an unshaded street) over a 30-year period, with an associated saving of $0.66/ft^2.

Replacement Value

Pittsburgh's street tree resource is an asset, valued at $137 million, which can increase in value over time if cared for properly. Replacement value accounts for the historical investment in trees over their lifetime and is a way of describing the value of trees at a given time, reflecting their current number, stature, placement, and condition. There are several methods to obtain a fair and reasonable perception of a tree's value (CTLA, 1992; Watson, 2002). The cost approach, used in this study, assumes the value of a tree is equal to the cost of replacing a tree in its current state (Cullen, 2002). To replace Pittsburgh's 29,641 trees with trees of similar size, species, and condition would cost approximately $137 million (*Table 5*). The average replacement value per tree is approximately $4,600. With the largest concentration of street trees occurring in Ward 14—most of which are mature London planetrees—this area accounts for approximately 32% ($43 million) of the City's total street tree replacement value and is Pittsburgh's most significant ward in terms of street trees, with an average replacement value per tree in Ward 14 at $7,535 (*Appendix C*).

Citywide, London planetrees account for 30% of the total replacement value, followed by littleleaf linden (14%), Norway maple (11%), and northern red oak (7%). The high values of these species reinforce their importance to the City. Many of the highest value species are large-stature trees with large canopies and, therefore, also have high Importance Values (IV). For example, the City's littleleaf linden and Norway maple are behind only London planetree in terms of both replacement value and importance. Species with low replacement values are usually smaller-stature trees and have lower Importance Values, as evidenced by callery pear—despite its prevalence in the population.

Pittsburgh's street trees are a central component to the City's green infrastructure and should be considered a public asset valued at $137 million; an asset which, with proper maintenance and care, will increase in value over time. Replacement value should be distinguished from the value of annual benefits produced. Chapter 4 will present the annual benefits produced by Pittsburgh's street trees.

*Table 5. Replacement Values of Pittsburgh's Most Valuable Street Tree Species**

Species	**DBH Class (in)**										
	0-3	**3-6**	**6-12**	**12-18**	**18-24**	**24-30**	**30-36**	**36-42**	**>42**	**Total #**	**% of Total**
London planetree	9,215	107,344	114,856	303,022	3,815,582	14,275,331	14,767,038	6,341,732	1,319,645	41,053,764	30.06
littleleaf linden	4,107	98,522	1,086,425	7,962,738	6,368,426	2,683,112	414,215	129,130	27,493	18,774,168	13.75
Norway maple	27,605	180,572	2,731,664	5,344,844	4,023,281	2,418,422	637,459	37,006	0	15,400,851	11.28
northern red oak	1,066	14,178	200,704	1,236,608	2,245,208	3,046,897	2,010,522	1,010,201	145,818	9,911,202	7.26
red maple	34,248	470,966	2,836,531	3,868,502	870,033	249,940	100,920	0	0	8,431,140	6.17
pin oak	2,471	9,963	74,172	262,485	1,098,844	2,916,506	2,083,807	915,195	195,161	7,558,604	5.53
sweetgum	686	5,500	461,227	2,469,958	1,787,533	287,658	131,487	0	0	5,144,048	3.77
ginkgo	2,652	36,593	429,444	838,014	1,607,796	1,278,347	490,355	78,322	0	4,761,522	3.49
honeylocust	26,412	261,000	777,626	823,562	1,153,656	1,142,286	120,814	0	24,084	4,329,440	3.17
silver maple	8,881	83,827	311,677	386,017	461,005	675,994	413,593	215,510	165,136	2,721,640	1.99
callery pear	112,858	555,217	1,199,303	625,337	121,806	0	0	0	0	2,614,521	1.91
black locust	762	4,385	64,294	341,596	692,988	559,899	437,808	309,614	24,121	2,435,467	1.78
sugar maple	5,038	55,541	555,452	623,480	353,470	88,690	43,356	0	0	1,725,028	1.26
American sycamore	191	0	0	47,264	192,985	475,537	507,080	302,213	29,290	1,554,559	1.14
American elm	6,021	8,200	66,585	126,161	188,650	228,756	278,249	132,367	39,263	1,074,253	0.79
Other	166,686	524,310	2,102,305	2,590,080	1,779,994	1,251,010	377,883	182,149	113,565	9,087,981	6.65
Citywide Total	**$408,899**	**$2,416,116**	**$13,012,263**	**$27,849,668**	**$26,761,258**	**$31,578,384**	**$22,814,587**	**$9,653,438**	**$2,083,575**	**$136,578,187**	**100.00**

*Species listed represent >$1 million total. All other species are included in "Other". See *Appendix B* for replacement values of all street tree species.

Chapter 3: Costs of Managing Pittsburgh's Municipal Trees

The costs of managing Pittsburgh's street trees are an investment back into the community. The return on that investment is realized through the ecological, psychological, social, and economic benefits they provide. This chapter presents a breakdown of the City's investment for fiscal year 2006 and compares Pittsburgh's costs to the annual expenditures of four benchmark communities. The four benchmark communities were chosen to represent a range of annual budgets, resource extent, human population, and geographical distribution. While it is difficult to compare one municipal forestry program to another in every aspect, some insight can be gained by looking at other programs spending per tree, per capita, as well as benefit-cost ratio (an indicator of the value of an investment). The four benchmark communities used in this study are New York City, New York (Peper and others, 2007), Minneapolis, Minnesota, Charleston, South Carolina, and Charlotte, North Carolina (McPherson and others, 2005a-c). The benefit-cost ratio for Pittsburgh and how it compares to the benchmark communities is discussed in Chapter 4.

The total tree-related expenditures for Pittsburgh's street trees totaled approximately $816,400, 0.19% of the City's total municipal budget of $427.5 million (Gable/Ames, 2006). The annual operating budget allocation for the Forestry Division is approximately $650,000; however, the entire budget was not spent due to staffing vacancies in 2006. Pittsburgh's Forestry Division operating budget, as a percentage of the entire Department of Public Works budget, has been close to 3%, with a low of 2.4% in 1997 and a high of 3.6% in 2004 (Jahn, 2005). In 2006, the operating budget was 1.7% of the Department of Public Works budget ($38.7 million). Additional funding sources—beyond the Forestry Division's operating budget—in fiscal year 2006 were applied to a management need of hazard tree removals identified during the City's 2005 street tree inventory. This additional funding included monies from the City's capital budget, Community Development Block Grants, and the Shade Tree Trust Fund.

Photograph 5. The City of Pittsburgh spends an average of $27.54 per street tree and approximately $2.51 per capita annually to maintain its urban forest.

Using fiscal year 2006 numbers, the City spends an average of $27.54 per street tree and approximately $2.51 per capita. Pittsburgh's annual expenditures are well below that of New York City ($37), Minneapolis ($46), and Charleston ($35), but the City spends more per tree than Charlotte ($21). Comparing Pittsburgh's spending to each of these benchmark communities, Pittsburgh spends the least per capita (*Table 6*). The City's Forestry Division is responsible for public trees in addition to those in the street rights-of-way; however, it is difficult to determine what percentage is solely dedicated to the maintenance of street trees. Per tree and per capita spending on street trees in Pittsburgh may be overstated.

Street tree expenditures fall into three general categories: tree planting and establishment, maintenance, and administration.

Tree Planting and Establishment

Quality nursery stock, careful planting, and follow-up care are critical to perpetuation of a healthy urban forest. In 2006, little to no City funds were allocated for planting new street trees. While a few City projects may have had a small street tree planting component in 2006, no formal planting program exists. This leaves the City with only existing tree maintenance and program administration costs that comprise the total expenditures. Pittsburgh has been faced with a large backlog of urgent maintenance needs from years of neglect. While this may seem an efficient use of funding in this situation, a balance must be achieved to allow for street tree plantings in addition to existing maintenance needs. Without such a balance, Pittsburgh's urban forest is not sustainable and the benefits it provides are finite. Funding a citywide street tree planting, in addition to existing tree maintenance, must become a priority. As with many municipal urban forestry programs, partnerships with local non-profits and other City departments are instrumental in applying expertise, funding, and manpower to a successful tree planting and establishment program. For example, non-profits are an excellent resource for organizing volunteers to canvass neighborhoods for potential planting sites, assist with tree planting, and perform new tree maintenance activities such as mulching, watering, and light pruning.

Photograph 6. Many municipal forestry programs, including Pittsburgh's, utilize volunteers and non-profit partners to assist with maintenance activities for young trees, such as watering, mulching, and simple pruning. Such efforts are a cost-effective way to help assure young tree survival and minimize future maintenance costs, all while fostering interest and enthusiasm in the City's forestry program from the community.

Table 6. Pittsburgh's Annual Street Tree Expenditures (Fiscal Year 2006) Compared to Four Benchmark Communities

Expenditures	Pittsburgh				New York City				Minneapolis				Charlotte				Charleston			
	Total $)	**$/Tree**	**$/Capita**	**% of Total**	**Total ($)**	**$/Tree**	**$/Capita**	**% of Total**	**Total ($)**	**$/Tree**	**$/Capita**	**% of Total**	**Total ($)**	**$/Tree**	**$/Capita**	**% of Total**	**Total ($)**	**$/Tree**	**$/Capita**	**% of Total**
Purchasing Trees and Planting	0	0	0	0.00	8,160,000	13.97	1	0.37	223,855	1.13	0.59	0.02	180,000	2.11	0.3	0.10	109,125	7.16	1.04	0.21
Contract Pruning	18,650	0.63	0.06	0.02	1,871,000	3.2	0.23	0.09	2,505,680	12.61	6.55	0.27	380,000	4.46	0.64	0.21	243,750	15.99	2.32	0.46
Pest Management	50,000	1.69	0.15	0.06	135,000	0.23	0.02	0.01	-	-	-	-	1,500	0.02	0	0.00	-	-	-	-
Irrigation	50,000	1.69	0.15	0.06	-	-	-	-	95,100	0.48	0.25	0.01	8,000	0.09	0.01	0.00	4,700	0.31	0.04	0.01
Removal	475,850	16.05	1.46	0.58	1,784,976	3.06	0.22	0.08	4,078,585	20.53	10.66	0.44	420,000	4.93	0.7	0.23	23,625	1.55	0.23	0.04
Administration	55,000	1.86	0.17	0.07	6,255,000	10.71	0.77	0.29	1,097,338	5.52	2.87	0.12	117,900	1.39	0.2	0.06	60,000	3.94	0.57	0.11
Inspection/ Service Calls	104,000	3.51	0.32	0.13	-	-	-	-	317,779	1.6	0.83	0.03	-	-	-	-	-	-	-	-
Infrastructure Repairs	0	0	0	0.00	3,000,000	5.14	0.37	0.14	828,000	4.17	2.16	0.09	637,500	7.49	1.07	0.35	45,000	2.95	0.43	0.08
Litter Clean-up	12,900	0.44	0.04	0.02	-	-	-	-	37,065	0.19	0.1	0.00	4,500	0.05	0.01	0.00	45,000	2.95	0.43	0.08
Liability/Claim	50,000	1.69	0.15	0.06	-	-	-	-	25,639	0.13	0.07	0.00	70,000	0.82	0.12	0.04	-	-	-	-
Other Cost	-	-	-	-	568,600	0.97	0.07	0.03	-	-	-	-	-	-	-	-	-	-	-	-
Total Expenditures	**$816,400**	**$27.54**	**$2.51**	**1.00**	**$21,774,576**	**$37.28**	**$2.67**	**1.00**	**$9,209,041**	**$46.36**	**$24.07**	**1.00**	**$1,819,460**	**$21.37**	**$3.05**	**1.00**	**$531,200**	**$34.85**	**$5.06**	**1.00**

Maintenance

Removals, pruning, and litter clean-up dominate the City's annual tree-related expenditures, totaling approximately $607,400 in fiscal year 2006, or 74% of the total expenditures (Gable/Ames, 2006). Monies allocated for pest management and irrigation are only disbursed towards certain trees in downtown Pittsburgh.

Based on the complete street tree inventory performed in 2005, a budget for a seven-year period was estimated to be approximately $8 million—an average of $1.1 million per year—to mitigate all identified risk trees and begin a cyclical pruning program (Davey Resource Group, 2005). Since risk reduction should be a primary objective of any municipal forestry program, the estimated budget for 2006 was projected to be $1.7 million and focused primarily on risk reduction and new tree planting. As it stands, the City is not allocating enough funding to perform all the tasks identified in the City's seven-year program. The City is currently prioritizing its available funding towards risk reduction, in the form of tree removals. Removals account for the majority of the City's expenditures (58% of the total expenditures, and 78% of all maintenance activity). Without new plantings, Pittsburgh is not replenishing its resource.

Comparing removal expenditures to the four benchmark communities, Pittsburgh allocates the most money (58%) towards removals. Minneapolis allocates 44% of its expenditures towards removals, with Charlotte allocating 23%, New York City allocating 8%, and Charleston allocating only 4%. With American elm making up a large portion of Minneapolis' street tree resource, many removals of mature elm trees affected by Dutch elm disease has dictated their increased removal expenditures (McPherson and others, 2005a). The bulk of Charleston's maintenance activity is allocated towards cyclical pruning, an important task for hurricane-prone areas (McPherson and others, 2005b). New York City and Charlotte are achieving a relative balance of pruning expenditures and removal expenditures (*Table 6*). In Pittsburgh, the disproportionate expenditures of pruning and removal—2% pruning compared to 58% removal—is an indication of the City's backlog of hazardous trees due to past years of deferred maintenance. The City's seven-year maintenance program has already fallen behind in terms of cyclical pruning goals, which portends additional removals as a result from neglected pruning and maintenance needs for existing trees.

Administration

Administration costs include salaries of forestry personnel and clerical staff, equipment, supplies, training, site inspection, and service calls. Combined, costs from administration and inspection services totaled $159,000 in fiscal year 2006 (Gable/Ames, 2006); however, the entire allocation for budgeted positions was not utilized due to staffing vacancies. Pittsburgh is allocating 20% of its expenditures on administration and inspections, compared to 29% in New York City, 15% in Minneapolis, 11% in Charleston, and 6% in Charlotte (*Table 6*). Currently, there are no costs associated with enforcing the City's Tree Ordinance or any tree-related activity that may occur in conjunction with Capital Improvement Projects. In Pittsburgh, the Planning Department is positioned as the City entity that will assist in future tree ordinance enforcement and street tree planning related to Capital Improvement Projects. Again, partnerships and interdepartmental cooperation of this level are fundamental in achieving a sustainable street tree resource and should be encouraged throughout the City government.

Additional Tree-Related Expenditures

Additional tree-related expenditures, such as infrastructure repair related to tree-hardscape conflicts, are not fully captured in this study. Infrastructure repair costs in Pittsburgh are incurred by the City's property owners in most cases. This type of expenditure represents a significant source of spending for the four benchmark communities, accounting for 35% of Charlotte's tree-related expenditures, 14% of New York City's expenditures, 9% of Minneapolis' expenditures, and 8% in Charleston's expenditures (*Table 6*). Trip-and-fall claims, property damage payments, and legal staff time required to process tree-related claims can be substantial in cities like Pittsburgh. Annual expenditures related to tree-related liability, claims, and payments totaled approximately $50,000 in fiscal year 2006, or 6% of the City's total tree-related expenditures (Gable/Ames, 2006).

Shallow roots that heave sidewalks, crack curbs, and damage driveways are an important aspect of municipal tree care. Pittsburgh currently has a reimbursement program for homeowners required to repair damaged sidewalks caused by public trees. The City provides root pruning services to facilitate sidewalk repair; however, these costs have not been distinguished in this analysis from other maintenance activities and are lumped in with maintenance and administrative expenditures. The City should consider solutions that minimize damage to the tree, such as ramping sidewalks over shallow roots or grinding down lifted concrete. Additionally, these costs can be managed through use of structural soils, alternative sidewalk materials, and proper planning and species selection for future street tree plantings.

Chapter 4: Benefits of Pittsburgh's Municipal Trees

Street trees are important to Pittsburgh. They help conserve and reduce energy use, reduce local carbon dioxide levels, improve air quality, and mitigate stormwater runoff. Additionally, trees provide a wealth of psychological, social, and economic benefits related primarily to their beauty and calming effect. Environmentally, trees make good sense, working ceaselessly to provide benefits back to the community; but are the collective benefits worth the costs of management? In other words, are street trees a good investment for Pittsburgh? To answer that question, we must first quantify these benefits in financial terms.

This study utilizes the City's street tree inventory and i-Tree's STRATUM model to assess and quantify the beneficial functions of Pittsburgh's street tree resource and to place a dollar value on the annual environmental benefits they provide. These estimates provide first-order approximations of tree value. STRATUM only generally accounts for the benefits produced by Pittsburgh's street trees—an accounting that is based on the best available science, with accepted degree of uncertainty that can nonetheless provide a platform from which real management decisions can be made (Maco and McPherson, 2003). A discussion on the methods used to quantify and price these benefits can be found in *Appendix A*.

Energy Savings

Trees modify climate and conserve energy in three principal ways:

- Shading reduces the amount of radiant energy absorbed and stored by built surfaces.
- Transpiration converts moisture to water vapor and, thus, cools the air by using solar energy that would otherwise result in heating of the air.
- Wind-speed reduction reduces the movement of outside air into interior spaces and conductive heat loss where thermal conductivity is relatively high, *e.g.,* glass windows (Simpson, 1998).

Trees and other vegetation within the built environment may lower air temperatures 5° F (3° C) compared to outside the green space (Chandler, 1965). At the larger scale of city-wide climate (6 miles or 10 km square), temperature differences of more than 9° F (5° C) have been observed between city centers and more vegetated suburban areas (Akbari and others, 1992). The relative importance of these effects depends on the size and configuration of trees and other landscape elements (McPherson, 1993). Tree spacing, crown spread, and vertical distribution of leaf area influence the transport of warm air and pollutants along streets and out of urban canyons.

Trees reduce air movement into buildings and conductive heat loss from buildings. Trees can reduce wind speed and resulting air infiltration by up to 50%, translating into potential annual heating savings of 25% (Heisler, 1986).

Photograph 7. Through shading, transpiration, and wind-speed reduction, street trees cool urban heat islands. Urban trees' ability to modify the local climate helps reduce energy usage—a quantifiable benefit provided back to the community.

Electricity and Natural Gas Results

Electricity and natural gas saved annually in Pittsburgh from both shading and climate effects equal 2,227 MWh ($222,713) and 811,917 therms ($982,419), for a total retail savings of approximately $1.2 million or a citywide average of $40.66 per street tree (*Table 7*). London planetree accounts for nearly 17.7% of the energy savings, while only representing 8.6% of the total tree numbers. Norway maple (15.1%) and littleleaf linden (11.6%) provide the next greatest contribution towards energy savings, due in large part to their prevalence in the population, 15.7% and 10.9% of all street trees, respectively. Callery pear, the third-most abundant street tree in Pittsburgh, only accounts for 4.4% of the energy savings because of its small stature.

Looking at average energy savings on a per tree basis, London planetree ($83.66), pin oak ($78.13), northern red oak ($77.57), and sweetgum ($50.35) are the greatest contributors due to their large stature and relatively mature age distribution compared to the rest of the population. Small-stature trees, such as callery pear ($15.93) and apple ($14.90), are providing energy-saving benefits well below that of the average population ($40.66). Some of Pittsburgh's better performing street trees (RPI >1), such as honeylocust and ginkgo, are providing energy savings nearly equal to the population's average, despite their under-representation in the population.

Table 7. Annual Energy Savings Produced by Pittsburgh's Street Trees

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	% of Total Tree Numbers	% of Total $	Avg. $/Tree
Norway maple	323.81	32,380.84	123,762.96	149,753.19	182,134.00	15.72	15.11	39.08
red maple	155.17	15,517.36	63,013.83	76,246.73	91,764.09	11.37	7.61	27.22
callery pear	97.51	9,751.15	35,893.89	43,431.61	53,182.77	11.26	4.41	15.93
littleleaf linden	259.36	25,935.59	93,630.78	113,293.25	139,228.80	10.93	11.55	42.97
London planetree	418.41	41,841.29	142,005.02	171,826.06	213,667.41	8.62	17.73	83.66
honeylocust	112.29	11,228.91	41,794.46	50,571.30	61,800.21	5.31	5.13	39.24
sugar maple	58.85	5,885.20	23,892.74	28,910.21	34,795.41	3.52	2.89	33.39
pin oak	164.84	16,483.56	52,436.73	63,448.45	79,932.01	3.45	6.63	78.13
silver maple	73.60	7,360.22	28,002.13	33,882.58	41,242.80	3.13	3.42	44.49
sweetgum	81.03	8,103.44	29,294.45	35,446.29	43,549.73	2.92	3.61	50.35
northern red oak	112.07	11,206.98	39,009.04	47,200.93	58,407.91	2.54	4.85	77.57
ginkgo	48.41	4,840.88	18,295.58	22,137.66	26,978.54	2.28	2.24	39.91
apple	13.53	1,352.98	6,308.74	7,633.57	8,986.55	2.03	0.75	14.90
Colorado spruce	16.24	1,623.54	5,230.70	6,329.15	7,952.69	1.37	0.66	19.59
black locust	52.74	5,273.86	18,543.46	22,437.59	27,711.45	1.24	2.30	75.10
Other street trees	239.27	23,927.45	90,802.46	109,870.98	133,798.41	14.30	11.10	31.57
Citywide Total	**2,227.13**	**$222,713.27**	**811,916.81**	**$982,419.44**	**$1,205,133.00**	**100.00**	**100.00**	**$40.66**

Atmospheric Carbon Dioxide Reduction

As environmental awareness continues to increase in government, particular attention is being paid to global warming and the effects of greenhouse gas emissions. Currently, there are two national policy options aimed at the reduction of atmospheric carbon dioxide and other greenhouse gases being debated—establishment of a carbon tax or a greenhouse gas cap-and-trade system. A carbon tax places a tax burden on each unit of greenhouse gas emissions and requires regulated entities to pay for their level of emissions. Alternatively, in a cap-and-trade system, an upper limit—the cap—is placed on global (or federal, regional, or other jurisdiction) levels of greenhouse gas emissions, and regulated entities must either reduce emissions to the required limit or buy emissions allowances in order to meet the cap (Williams and others, 2007). The idea of purchasing emission allowances (offsets) has led to carbon credits as a commodity that can be exchanged for financial gain. Trading systems, such as the Chicago Climate Exchange, are still exploring the functions of urban forests or, more precisely, aggregations of regional urban forest benefits, for relevancy in this new market. While Pittsburgh's urban forest resource may not reduce large enough quantities of greenhouse gases to be traded in the open market, the City's street trees are nonetheless reducing atmospheric carbon dioxide for a positive environmental and financial benefit to the community.

Urban trees can reduce atmospheric carbon dioxide (CO_2) in two ways:

- Directly, through sequestration of CO_2 as woody and foliar biomass as they grow.
- Indirectly, through lowering the demand for heating and air conditioning, thereby reducing emissions associated with electric power production and consumption of natural gas.

Conversely, CO_2 is released by vehicles, chain saws, chippers, and other equipment during the process of planting and maintaining trees. Also, when trees die, most of the CO_2 that has accumulated in their woody biomass is released back into the atmosphere as they decompose, unless the wood is recycled. These factors must be taken into consideration when calculating the CO_2 reduction benefits of trees.

<u>Avoided and Sequestered Carbon Dioxide</u>

Pittsburgh's street tree resource directly reduces 2,621 tons of CO_2 into woody and foliar biomass and indirectly reduces 3,354 tons of CO_2 through avoided power plant emissions, valued at $39,910 of benefits. Accounting for CO_2 emissions from tree decomposition (-533 tons) and tree-related maintenance activity (-139 tons), the street trees in Pittsburgh reduce atmospheric CO_2 by a net of 5,303 tons, valued at $35,424 per year (*Table 8*). On a per tree basis, Pittsburgh's street trees net benefit per tree is $1.20. Pin oak ($3.32), London planetree ($2.56), and northern red oak ($2.43) are providing the greatest benefits on a per tree basis. Norway maple and London planetree, because of their prevalence in the population, provide the greatest total benefit, accounting for 35.8% of citywide CO_2 reduction.

Table 8. Net Atmospheric CO_2 Reduction by Pittsburgh's Street Trees

Species	Sequestered (lb)	Decomposition Release (lb)	Maintenance Release (lb)	Avoided (lb)	Net Total (lb)	Total ($)	% of Total Tree Numbers	% of Total $	Avg. $/Tree
Norway maple	1,107,552	-199,674	-44,788	975,306	1,838,396	6,140.24	15.72	17.33	1.32
red maple	271,617	-74,420	-22,404	467,380	642,172	2,144.86	11.37	6.05	0.64
callery pear	361,142	-9,896	-3,814	293,703	641,135	2,141.39	11.26	6.04	0.64
littleleaf linden	447,974	-193,141	-36,868	781,176	999,142	3,337.13	10.93	9.42	1.03
London planetree	863,562	-117,772	-49,270	1,260,253	1,956,772	6,535.62	8.62	18.45	2.56
honeylocust	154,316	-48,357	-11,130	338,213	433,042	1,446.36	5.31	4.08	0.92
sugar maple	131,784	-37,289	-8,457	177,261	263,299	879.42	3.52	2.48	0.84
pin oak	647,839	-108,740	-18,983	496,482	1,016,599	3,395.44	3.45	9.59	3.32
silver maple	150,434	-36,844	-9,343	221,689	325,936	1,088.63	3.13	3.07	1.17
sweetgum	76,290	-20,450	-9,657	244,074	290,258	969.46	2.92	2.74	1.12
northern red oak	269,162	-48,253	-11,555	337,552	546,907	1,826.67	2.54	5.16	2.43
ginkgo	88,939	-14,890	-7,499	145,807	212,356	709.27	2.28	2.00	1.05
apple	25,611	-5,452	-2,900	40,751	58,011	193.76	2.03	0.55	0.32
Colorado spruce	49,295	-10,134	-3,258	48,901	84,804	283.25	1.37	0.80	0.70
black locust	85,516	-32,886	-5,406	158,848	206,071	688.28	1.24	1.94	1.87
Other street trees	509,967	-107,772	-31,678	720,691	1,091,208	3,644.63	14.30	10.29	0.86
Citywide Total	**5,241,001**	**-1,065,970**	**-277,011**	**6,708,087**	**10,606,107**	**$35,424.41**	**100.00**	**100.00**	**$1.20**

Air Quality Improvement

Urban trees improve air quality in five fundamental ways:

- Absorbing gaseous pollutants, such as ozone (O_3) and nitrogen dioxide (NO_2), through leaf surfaces.
- Intercepting particulate matter (PM_{10}), such as dust, ash, dirt, pollen, and smoke.
- Reducing emissions from power generation by reducing energy consumption.
- Releasing oxygen through photosynthesis.
- Transpiring water and providing shade, resulting in lower local air temperatures, thereby reducing O_3 levels.

The American Lung Association ranked Pittsburgh second behind Los Angeles on the list of dirtiest metropolitan areas on short-term and annual airborne particle measurement scales in their 2005 *State of the Air* report (American Lung Association, 2005). The Surface Transportation Policy Partnership, a non-profit organization, ranked the Pittsburgh metro area as the sixth worst in air pollution among major metropolitan areas (Ernst and others, 2003). Given the concern over air quality in Pittsburgh, the air quality benefits trees provide present a strong argument to the protection and maintenance of Pittsburgh's street tree population.

In the absence of the cooling effects of trees, higher temperatures contribute to ozone (O_3) formation. Additionally, short-term increases in ozone concentrations have been statistically associated with increased tree mortality for 95 large U. S. cities (Bell and others, 2004). However, it should be noted that while trees do a great deal to absorb air pollutants (especially ozone and particulate matter), they also contribute negatively to air pollution. Trees emit various biogenic volatile organic compounds (BVOCs), such as isoprenes and monoterpenes, which can also contribute to ozone formation. These BVOC emissions are accounted for in the air quality net benefit.

Deposition and Interception

Each year, 12.8 tons of NO_2, small particulate matter PM_{10}, O_3, and sulfur dioxide (SO_2) are intercepted or absorbed by street trees in Pittsburgh, for a value of $138,154 (*Table 9*). London planetree (2.7 tons), littleleaf linden (1.3 tons), Norway maple (1.8 tons), and pin oak (1.1 tons) are the greatest contributors to air quality improvements largely due to their prevalence in the population and relative maturity, accounting for 54% of the total benefits.

Avoided Pollutants

The energy savings trees provide also have the indirect benefit of reduced air pollutant emissions of NO_2, PM_{10}, volatile organic compounds (VOCs), and SO_2 that result from energy production. Together, 15.4 tons of pollutants are avoided annually with an implied value of $133,274. London planetree, Norway maple, and littleleaf linden have the greatest impact on reducing energy needs and, therefore, avoid the production of pollutants (2.8 tons, 2.3 tons, and 1.8 tons, respectively), accounting for 45% of the total benefits.

BVOC Emissions

Biogenic Volatile Organic Compound (BVOC) emissions from trees—which negatively affect air quality—must be considered. Four tons annually are emitted from Pittsburgh's street trees, offsetting the total air quality benefit by $18,492. London planetrees are the heaviest emitters of BVOCs, accounting for 39% (1.6 tons of BVOC) of the street tree population's emissions. In contrast, Pittsburgh's London planetrees reduce air pollutants by 5.5 tons, for a net reduction of approximately 4 tons, valued at $46, 099, or $18 per tree.

Net Air Quality Improvement

Net air pollutants removed, avoided, and released by the street tree population, are valued at $252,935 per year. The average net benefit per tree is $8.53 (1.63 lb.). Trees vary dramatically in their ability to produce net air-quality benefits. Typically, large-canopied trees with large leaf surface areas that are not high emitters produce the greatest benefits. Although London planetrees are higher emitters, they are among the top producers of net air quality benefits. On a per tree basis, Pittsburgh's pin oaks produce the greatest net air quality improvement, valued at nearly $19 per tree. Norway maples are producing net benefits valued at $8 per tree, and due to their prevalence in the population, account for a net annual benefit of $38,600, second only to the benefit provided by London planetrees ($46,099).

Photograph 8. In addition to the aesthetic benefits of urban trees, they help improve local air quality—an issue of great concern in Pittsburgh.

Table 9. Annual Air Quality Benefits by Pittsburgh's Street Trees

Species	Deposition O_3 (lb)	Deposition NO_2 (lb)	Deposition PM_{10} (lb)	Deposition SO_2 (lb)	Total Deposition ($)	Avoided NO_2 (lb)	Avoided PM_{10} (lb)	Avoided VOC (lb)	Avoided SO_2 (lb)	Total Avoided ($)	BVOC Emissions (lb)	BVOC Emissions ($)	Net Total (lb)	Net Total ($)	% of Total Trees	Avg. $/Tree
Norway maple	1734	750	852	285	19,469.26	2825	183	109	1421	19,688.22	-241	-557.42	7918	38,600.06	15.72	8.28
red maple	763	329	381	127	8,618.77	1391	91	54	681	9,636.58	-224	-517.59	3594	17,737.76	11.37	5.26
callery pear	576	251	281	98	6,473.34	837	54	32	428	5,853.99	0	0.00	2557	12,327.33	11.26	3.69
littleleaf linden	1249	525	602	192	13,814.58	2206	143	85	1138	15,470.06	-642	-1,482.88	5498	27,801.77	10.93	8.58
London planetree	2605	1095	1255	400	28,802.26	3467	224	131	1836	24,464.94	-3103	-7,168.20	7909	46,099.00	8.62	18.05
honeylocust	601	244	285	92	6,568.61	968	63	37	493	6,766.24	-271	-625.81	2512	12,709.04	5.31	8.07
sugar maple	302	131	148	50	3,389.25	528	34	21	258	3,654.48	-138	-319.76	1333	6,723.97	3.52	6.45
pin oak	1062	459	530	177	12,002.54	1330	85	50	723	9,447.15	-939	-2,169.58	3478	19,280.11	3.45	18.85
silver maple	418	181	205	69	4,690.15	641	42	25	323	4,468.12	-135	-311.14	1768	8,847.13	3.13	9.54
sweetgum	376	152	178	58	4,104.44	690	45	26	356	4,835.72	-1116	-2,578.10	764	6,362.05	2.92	7.35
northern red oak	657	284	328	110	7,417.97	939	61	36	492	6,605.82	-582	-1,343.59	2322	12,680.21	2.54	16.84
ginkgo	257	108	124	39	2,842.45	420	27	16	212	2,932.10	-96	-220.89	1109	5,553.65	2.28	8.22
apple	76	33	37	13	853.51	130	9	5	59	884.57	-1	-1.50	361	1,736.59	2.03	2.88
Colorado spruce	104	50	66	28	1,353.89	132	8	5	71	934.09	-16	-37.89	448	2,250.09	1.37	5.54
black locust	300	126	145	46	3,316.14	444	29	17	231	3,118.76	0	0.00	1337	6,434.90	1.24	17.44
Other street trees	1276	546	640	217	14,436.95	2081	135	80	1050	14,512.95	-501	-1,158.14	5524	27,791.76	14.30	6.56
Citywide Total	12,355	5,262	6,056	2,001	$138,154.09	19,028	1,232	730	9,774	$133,273.80	-8,005	$-18,492.48	48,433	$252,935.41	100.00	$8.53

Stormwater Runoff Reductions

According to federal Clean Water Act regulations, municipalities must obtain a permit for managing their stormwater discharges into water bodies. Each city's program must identify the Best Management Practices (BMPs) it will implement to reduce its pollutant discharge. Many older cities, such as Pittsburgh, have combined sewer outflow systems and, during rainfall events, excess runoff can mix with raw sewage. Rainfall interception by trees can reduce the magnitude of this problem. Trees are mini-reservoirs, controlling runoff at the source. This is especially important in an urban setting with a significant quantity of impervious surfaces in such close proximity to the Allegheny, Monongahela, and Ohio Rivers. Healthy urban trees can reduce the amount of runoff and pollutant loading in receiving waters in three primary ways:

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

Pittsburgh's street trees intercept 41.8 million gallons of stormwater annually, or 1,411 gallons per tree on average (*Table 10*). The total value of this benefit to the City is $334,601 at an average value of $11 per tree. Again, while only accounting for 8.6% of the street tree population, London planetree provides more stormwater benefits than any other species, accounting for 21.9% of the annual benefit at $29/tree. Due to their shear numbers, Norway maples provide the next greatest benefit, accounting for 12.3% of the annual benefit, but only $9/tree due primarily to their smaller size and relative immaturity compared to Pittsburgh's planetrees. On a benefits per trees basis, additional top performing species include pin oak ($29), northern red oak ($24), and black locust ($24). As Pittsburgh's large- and medium-stature trees, such as red maple and littleleaf linden, continue to mature, their stormwater reduction performance will improve. For trees such as callery pear and crabapple, their performance will not likely improve due to their small stature.

Photograph 9. In addition to the stormwater interception benefits afforded by tree canopy, increasing the amount of permeable growing space around trees can also help to increase stormwater infiltration as well as reduce infrastructure damage.

Table 10. Annual Stormwater Reduction Benefits for Pittsburgh's Street Trees

Species	Total Rainfall Interception (Gal)	Total ($)	% of Total Tree Numbers	% of Total $	Avg. $/Tree
Norway maple	5,130,433	41,046.31	15.72	12.27	8.81
red maple	3,143,653	25,150.97	11.37	7.52	7.46
callery pear	1,834,978	14,680.85	11.26	4.39	4.40
littleleaf linden	4,049,905	32,401.49	10.93	9.68	10.00
London planetree	9,170,854	73,371.93	8.62	21.93	28.73
honeylocust	1,863,936	14,912.53	5.31	4.46	9.47
sugar maple	1,088,801	8,711.02	3.52	2.60	8.36
pin oak	3,727,974	29,825.87	3.45	8.91	29.16
silver maple	1,579,348	12,635.66	3.13	3.78	13.63
sweetgum	1,269,397	10,155.88	2.92	3.04	11.74
northern red oak	2,231,106	17,850.09	2.54	5.33	23.71
ginkgo	813,433	6,507.92	2.28	1.94	9.63
apple	207,133	1,657.18	2.03	0.50	2.75
Colorado spruce	241,532	1,932.39	1.37	0.58	4.76
black locust	1,111,590	8,893.34	1.24	2.66	24.10
Other street trees	4,358,180	34,867.87	14.30	10.42	8.23
Citywide Total	**41,822,256**	**$334,601.31**	**100.00**	**100.00**	**$11.29**

Aesthetic, Property Value, Social, Economic, and Other Benefits

It is difficult to place a dollar value on the benefit Pittsburgh's street trees provide to the overall well-being of City residents. Trees provide beauty in the urban landscape, privacy to homeowners, improved human health, a sense of comfort and place, and refuge for urban wildlife. Trees promote better business by stimulating frequent shopping, longer shopping trips, and a willingness to pay more for goods and parking by the residents in the urban environment (Wolf, 1999). The value of some of these benefits may be captured in the property values of the land on which trees stand.

To estimate the value of these intangible benefits, research that compares differences in sale prices of houses was used to estimate the contribution associated with trees. Differences in housing prices in relation to the presence of a street tree help define the aesthetic value of street trees in the urban environment. Consideration is given to the location of the street tree in relation to land use. Street trees located in front of multi-family homes will not increase the property value at the same rate as single-family homes. Furthermore, street trees located adjacent to commercial and nonresidential properties do not have the same resale potential as residential areas. These factors are taken into consideration and the value of those trees is adjusted accordingly.

The calculation of annual aesthetic and other benefits corresponds with a tree's annual increase in leaf area. When a tree is actively growing, leaf area increases rapidly. At maturity, there may be no net increase in leaf area from year to year; thus, there is little or no incremental annual aesthetic benefit for that year, although the cumulative benefit over the course of the entire life of the tree may be large. Since this report represents a one-year snapshot of the street tree population, benefits reflect the increase in leaf area for each tree over the course of one year. As a result, a very young population of 100 callery pears will have a greater *annual* aesthetic benefit than an equal number of mature planetrees. However, the cumulative aesthetic value of the planetrees would be much greater than that of the pears.

The estimated total annual benefit associated with property value increases and other less tangible benefits is $573,000, for an average of $19 per tree (*Table 11*). Tree species that produced the highest average annual benefits include black locust ($37), pin oak ($34), and London planetree ($28). Some species rank high due to their size and growth rates, but may not be desirable to plant for other reasons. For example, 52.8% of Pittsburgh's black locust are in poor condition or worse and have a very low Relative Performance Index value (0.77).

Table 11. Annual Aesthetic/Other Benefits for Pittsburgh's Street Trees

Species	Total ($)	% of Total Tree Numbers	% of Total $	Avg. $/Tree
Norway maple	80,343.02	15.72	14.02	17.24
red maple	62,400.45	11.37	10.89	18.51
callery pear	81,638.91	11.26	14.25	24.45
littleleaf linden	40,565.41	10.93	7.08	12.52
London planetree	71,684.22	8.62	12.51	28.07
honeylocust	35,202.32	5.31	6.14	22.35
sugar maple	16,337.87	3.52	2.85	15.68
pin oak	34,974.70	3.45	6.11	34.19
silver maple	15,616.01	3.13	2.73	16.85
sweetgum	17,465.91	2.92	3.05	20.19
northern red oak	16,555.21	2.54	2.89	21.99
ginkgo	11,101.48	2.28	1.94	16.42
apple	3,263.22	2.03	0.57	5.41
Colorado spruce	3,422.05	1.37	0.60	8.43
black locust	13,527.54	1.24	2.36	36.66
Other street trees	68,784.20	14.30	12.01	16.23
Citywide Total	**$572,882.38**	**100.00**	**100.00**	**$19.33**

Photograph 10. The estimated total value for Pittsburgh's street trees associated with aesthetic, social, and economic benefits is $573,000 per year.

Net Benefits and Benefit-Cost Ratio (BCR)

Pittsburgh receives substantial benefits from its street trees. However, the City must also consider the costs of maintaining this resource. Applying a benefit-cost ratio (BCR) is a useful way to evaluate the public investment in the street tree population. A BCR is an indicator used to summarize the overall value compared to the costs of a given project. Specifically in this analysis, BCR is the ratio of the cumulative benefits provided by the City's street trees, expressed in monetary terms, compared to the costs associated with their management, also expressed in monetary terms.

Pittsburgh's municipal trees have beneficial effects on the environment. The vast majority (76%) of the annual benefits quantified in this study and provided to the community are environmental services (*Table 12*). Energy savings account for 66% of the annual environmental benefits and 50% of all annual benefits. The reduction of stormwater runoff accounts for 18% of the environmental benefits and 14% of the total benefits. Net air quality improvements (14%) and CO_2 reduction (2%) provide the balance of annual environmental benefits, and 12% of the total benefits. Annual increases in property value are very valuable, accounting for 24% of the total benefits. However, the street tree resource is not equally dispersed throughout the City. Street trees in Ward 14 alone account for nearly 26% of net benefits throughout the City (*Appendix C*). Due to the extent, species makeup, and relative maturity of trees present in Ward 14, the benefits provided in every category far outweigh the contributions for other wards.

The sum of estimated benefits for Pittsburgh's street tree resource is $2.4 million; that is a value of $81 per street tree and $7.38 per capita. These benefits are realized on an annual basis. It should be noted that this is not a full accounting of benefits because some benefits are intangible and/or difficult to quantify, such as impacts on psychological health, crime, and violence. Also, there is limited knowledge about the physical processes at work and their interactions make these estimates imprecise. Tree growth and mortality rates are highly variable. A true and full accounting of benefits and costs must consider variability among sites (*e.g.*, tree species, growing conditions, maintenance practices) throughout the City, as well as variability in tree growth.

The total annual benefit that trees provide to the City of Pittsburgh is approximately $2.4 million. When the City's annual tree-related expenditures are considered ($816,400), the net annual benefit (benefits minus costs) to the City is $1.6 million. The average net benefit for an individual street tree in Pittsburgh is $53, nearly $5 of benefits per capita. Based on the inventory count of 29,641 street trees, Pittsburgh receives $2.94 in benefits for every $1 that is spent on its municipal forestry program (*Table 12*). Compared to the four benchmark communities, Pittsburgh receives a good return on its street tree population investment. Pittsburgh's benefit-cost ratio of 2.94 is greater than Minneapolis (1.57) and Charleston (1.35), while it is lower than Charlotte (3.25) and New York (5.60) (McPherson and others, 2005a-c; Peper and others, 2007). While Pittsburgh's BCR fairs well against the benchmark communities, conclusions must take into account several factors on a city-by-city basis. For example, Pittsburgh has an aging tree population skewed towards mature trees (*Figure* 1) and is spending over half of its annual expenditures on removals and nothing on new tree planting (*Table 6*). Proper maintenance and regular pruning is crucial to maintaining these levels of benefits in the existing tree population and can result in the difference between a functional street tree and a risk-tree; however, the City is only allocating 2% of its tree-related funding to pruning. To achieve a sustainable resource, these trends must be reversed.

Table 12. Benefit–Cost Summary for Pittsburgh's Street Trees

Benefits	Total ($)	$/Tree	$/Capita
Energy	1,205,133	40.66	3.70
CO_2	35,424	1.20	0.11
Air Quality	252,935	8.53	0.78
Stormwater	334,601	11.29	1.03
Aesthetic/Other	572,882	19.33	1.76
Total Benefits	**$2,400,975**	**$81.00**	**$7.38**
Cost			
Planting	0	0.00	0.00
Contract Pruning	18,650	0.63	0.06
Pest Management	50,000	1.69	0.15
Irrigation	50,000	1.69	0.15
Removal	475,850	16.05	1.46
Administration	55,000	1.86	0.17
Inspection/Service	104,000	3.51	0.32
Infrastructure Repairs	0	0.00	0.00
Litter Clean-up	12,900	0.44	0.04
Liability/Claims	50,000	1.69	0.15
Total Costs	$816,400	$27.54	$2.51
Net Benefits	**$1,584,575**	**$53.46**	**$4.87**
Benefit-Cost Ratio	**2.94**		

Chapter 5: Management Implications

Pittsburgh's urban forest has endured decades of neglect and the City is falling behind its peers when it comes to urban forest management. The street tree resource in Pittsburgh is aging and the benefits produced are heavily concentrated in only a few neighborhoods. However, past trends can be reversed through change brought on by improved management and increased investment. Although this study provides a "snapshot" in time of the resource, it also serves as an opportunity to speculate about the future. Given the status of the City's street tree population, what future trends are likely and what management challenges will need to be met to sustain, or more importantly, increase this level of benefits?

Pittsburgh has joined over 800 cities nationwide in striving to reduce global warming pollution by committing to the U. S. Mayors Climate Protection Agreement. Under this Agreement, participating communities are encouraged to meet Kyoto Protocol targets—specifically, the reduction of greenhouse gas emission by the United States by 7% from 1990 levels by 2012—through actions in their own operations and communities ranging from anti-sprawl land-use polices to urban forest restoration projects to public information campaigns. Maintaining a healthy and sustainable urban forest is a direct and tangible way that the City and its partners can help meet the commitments set forth in the U. S. Mayors Climate Protection Agreement. Achieving resource sustainability and increasing overall benefits to the City within a framework of a manageable, realistic annual budget is the fundamental goal. Resource sustainability—and the management recommendations necessary to achieve it—is discussed here in terms of resource extent, resource complexity, and maintenance.

Resource Extent–Trends and Challenges

Canopy cover, or more precisely, the amount and distribution of leaf surface area, is the driving force behind the urban forest's ability to produce benefits for the community. As canopy cover increases, so do the benefits afforded by leaf area. Maximizing the return on this investment is contingent upon maximizing and maintaining the quality and extent of Pittsburgh's canopy cover.

Stocking Level

This analysis shows that the City is behind national benchmarks for trees per street mile and trees per capita. Additionally, the resource is too heavily concentrated in the neighborhoods that make up Ward 14. With an aging resource and no formal planting program in place, the City is currently experiencing a net loss of trees due to removals. To maintain benefits, an adequate planting program is needed. **Pittsburgh should implement a planting program to increase its street tree resource in terms of trees per capita and more evenly distribute trees across wards, thus, increasing the benefits afforded by trees to Pittsburgh residents.**

Canopy Cover

Without adequate forest canopy cover, Pittsburgh will not realize the many tangible and intangible benefits trees provide. Over 28% of street tree canopy cover originates from Ward 14 (*Appendix C*). The City has an opportunity to define its character and economic livelihood by increasing canopy cover across all wards and achieving a more equitable distribution throughout Pittsburgh's neighborhoods. **The City should set a goal to increase total canopy cover, thus, increasing the environmental benefits afforded by leaf area.** Pittsburgh's stakeholders need to decide what this important goal should be and set out to achieve it through a combination of the following:

- creating and implementing a municipal tree planting program,
- requiring new and existing residential and commercial areas to plant more trees,
- revising current legislation and enacting new legislation to set and monitor canopy cover goals,
- creating incentives for private property owners to have public trees planted on private property, and
- ensuring there is adequate funding for levels of tree planting and maintenance required to meet the goal.

Without a new tree planting program, Pittsburgh's street tree resource is not sustainable. However, planting trees without funds for maintenance is equally unsustainable. The flow of benefits is not currently being "recharged" through adequate new tree plantings. If no new plantings were to continue, the existing population will become more expensive to maintain, and overall tree numbers will decline as trees continue to be removed for safety and other reasons. Any loss in tree numbers will reduce the flow of benefits the City currently enjoys.

Considering the air quality issues facing Pittsburgh, along with the urban heat island effect generated by the large areas of hardscape and buildings, it is vital that the City increase its tree canopy through new tree plantings. It would take an additional 90,000 trees for Pittsburgh to reach national stocking level benchmarks (*Chapter 2*). An additional 90,000 trees would improve local air quality by avoiding and removing an additional 73 tons of pollutants, valued at over $760,000 above the current resource benefit ($252,935). Planting so many new trees will undoubtedly pose challenges; however, the need to distribute these benefits more equally throughout the City warrants a dramatic change from past practices.

Photograph 11. "Bump outs", like the ones pictured, can provide planting space for shade-providing trees in areas where other options for improving growing space are nominal.

Large-stature trees have the largest canopies, cast the most shade and, therefore, the City should direct the focus of any new tree planting program towards planting the largest growing tree suitable for the available planting space. Planetree, oak, sweetgum, honeylocust, and zelkova are important large-stature trees to Pittsburgh and the City's effort to improve local air quality. These species selections should be a focus for future planting projects.

In an older community like Pittsburgh, available space for large trees is limited and the City must employ creative means to increase available planting space if it is to successfully plant more large-stature trees. One solution the City is currently exploring is an initiative to obtain tree-planting-easements in residential front yards where tree lawn space is inadequate or sometimes non-existent. These tree-planting easements will allow the City to plant more trees and larger-growing species in areas where the existing public planting space is restrictive. Another solution to increasing available planting space within a restrictive infrastructure is by implementing "bump outs" during the redevelopment of streets, curbs, and on-street parking. "Bump outs" can provide planting space for shade-providing trees in areas where other options for improving growing space are nominal.

Resource Complexity–Trends and Challenges

Pittsburgh's current mix of species (130) is good; however, the distribution is skewed towards the top five most abundant species, which make up 58% of the total numbers. With such a reliance on these top species—Norway maple, red maple, callery pear, littleleaf linden, and London planetree—a catastrophic loss of any one of these species will drastically affect the flow of benefits and its ability to recover from such a loss.

Photograph 12. City planting efforts should focus on filling available planting spaces with a diverse mix of species. Of Pittsburgh's street tree population, there are several underutilized species that are worthy of increased consideration, such as goldenraintree (*Koelreuteria paniculata*). There are only 9 goldenraintrees in the inventory, but they are performing relatively well (RPI = 1.07).

<u>Species Distribution</u>

Pittsburgh's street tree population has a skewed species distribution, too heavily reliant on too few species (*Table 2*). **The City should set a goal to diversify its mix of species through new tree plantings, focusing on underutilized but good performing species, to reduce dependence on maple and London planetree, and to guard against catastrophic losses due to storms, pests, or disease.** Underutilized species, such as northern red oak, zelkova, hedge maple, American hornbeam, and Japanese lilac (*Table 4*), are performing well as street trees throughout the City and should be a focus of future planting efforts. Proven performers, such as honeylocust and sweetgum, are good choices for large-growing species and warrant increased consideration as alternatives to London planetree and maple (*Table 3*). That is not to say, however, that London planetree and maple do not have their place as street trees. London planetree is the most important species to Pittsburgh, and the City should continue to plant it—beyond Ward 14—helping to ensure the wealth of benefits it provides back to the community. However, the utilization of London planetree and maple in future planting efforts should occur within the framework of a balanced planting plan that takes into account citywide species distribution, geographical distribution by ward, and diversity goals.

Large-Stature Trees vs. Small-Stature Trees

Numerous considerations drive species choice, including planting site conditions, potential conflicts with infrastructure, maintenance concerns, and design considerations. In some cases, small- or medium-stature trees are the best, or only, option. Nonetheless, the results of this analysis emphasize **that large-growing trees should be planted and replaced wherever possible to increase the benefits realized and the return on the investment from the City.** Large trees provide the most benefits, and average annual benefits increase with mature tree size. From the *Northeast Community Tree Guide* (McPherson and others, 2007), the average annual net benefits of an individual public tree 40 years after planting were reported as follows:

- $26–$30 for a small tree,
- $69–$79 for a medium tree,
- $125–$147 for a large tree, and
- $54–$56 for a conifer.

The City relies on its large-stature trees (broadleaf-deciduous, large-growing trees) to provide the most benefits. Emphasis should be placed on identifying existing planting space suitable for new large-stature trees. While large trees may be associated with higher maintenance costs over time compared to smaller trees, implementing a new tree establishment program and a proactive young tree training pruning program can help distribute those costs more evenly and protect the initial investment of planting while ensuring maximum benefits provided to the community.

Relative Age Distribution

In addition to species distribution, the City's current mix of tree ages also gives cause for concern. Specifically, the threat of severe weather in Pittsburgh, such as high winds or snow and ice loading, has the potential to have a major impact on the mature populations of callery pear due to their weak wooded nature, but also on species such as London planetree (68%) and pin oak (59%), which are represented primarily in the mature size classes (> 24-inch DBH). The dominant representation of mature size classes from these species can result in a major loss, in terms of mature trees' ability to recover from canopy loss caused by severe storm events, leaving them more susceptible to secondary pests and stresses. Facing the likelihood of severe weather and the certainty of natural mortality, **the City should set a goal to achieve an uneven distribution of relative ages in the street tree population through new tree plantings and appropriate species selection to ensure a stable population and flow of benefits over time.** The City should continue to plant London planetree, pin oak, and even callery pear, but these species should be complemented with a diverse selection of other species. Perhaps most importantly, the City's planting program should be structured to continue in perpetuity to ensure long-term stability by continuing to "recharge" the population with new trees and replacement trees alike.

An ideal, uneven distribution of tree ages has a high proportion of young trees to offset establishment- and age-related mortality, while the percentage of older trees declines with age (Richards, 1982/83).

By extension, for every large-sized (mature) street tree, there should be four small-sized (young) street trees. Pittsburgh's actual distribution for young trees to mature is currently 2:1, which yields a deceptive benefit-cost ratio (2.94). If Pittsburgh were to continue this trend, it would see a temporary increase in benefits (as trees mature and leaf area increases), but also an increase in necessary maintenance costs associated with a one-sided population of mature trees. With no formal planting program in place to replenish the street tree resource, this trend is headed for a management crisis as trees eventually require removal, an eventual decline in canopy cover, as well as a reduction in BCR. An uneven-aged population, heavily weighted towards young trees, allows managers to allocate annual maintenance costs uniformly over many years and assures continuity in overall tree canopy cover.

Maintenance—Trends and Challenges

Pittsburgh's annual expenditures on tree maintenance in 2006 totaled $607,400, representing 74% of all the City's tree-related expenditures (*Table 6*). With a BCR of 2.94, the City realizes an annual benefit far greater than what it is spending. To maintain, and more importantly increase, the overall benefits from the existing street tree resource, the City must implement a comprehensive tree care program that faces the challenges of an aging resource in poor health and low canopy cover for the size of the City. A comprehensive tree care program should include—at a minimum—an aggressive risk tree removal program, cyclical pruning for all mature street trees, a young tree training program, and a new tree establishment program. Such a program not only allows the City to maintain a resource that gives back to the community in terms of the benefits detailed in this study, but also meets the City's charge of due diligence to ensure safety and establishes a framework for the efficient use of public funds.

Photograph 13. A new tree establishment program that includes young tree maintenance tasks, such as watering, mulching, and pruning, is a critical component to a successful planting program.

Removal

Pittsburgh's citizens expect that their City's trees are safe. The 2005 street tree inventory revealed over 500 trees in critical condition and over 500 trees that were standing dead (Davey Resource Group, 2005). While the majority of those trees have been addressed, the City should not lose site of its primary charge, ensuring a safe public resource. The urban environment is stressful on trees, and the City's public trees will continue to decline and die as these stresses compromise their ability to thrive. **The City should set a goal to implement a tree removal program that establishes a prompt response to dead and declining trees to minimize the overall potential for damage or harm caused by high-risk trees.**

Cyclical Pruning

Looking at IV for some of Pittsburgh's prominent street tree species, such as red maple (8.7), honeylocust (5.1), sweetgum (3.2), and ginkgo (2.1), their values are relatively low. These values reflect a distribution in the smaller size classes (> 18-inch DBH). However, as these trees mature, their importance will undoubtedly increase, along with their ability to provide benefits back to the community. One fundamental way to ensure that these species reach their full potential is through the implementation of a cyclical pruning program, thereby establishing good structure, promoting appropriate form, and minimizing the nuisance into which unmaintained trees can often develop.

Pittsburgh's street trees are a public asset valued at $137 million; an asset which, with proper maintenance and care, will increase in value over time. As trees continue to grow, pruning costs will also increase. Increased costs are primarily influenced on how long it takes to prune. Trees that are pruned more frequently—such as on a cyclical basis—will take less time to prune, thereby improving overall cost-effectiveness of the City's pruning expenditures. Although pruning frequency differs by species and location, a return frequency of about 5 to 8 years is usually sufficient for older trees (Miller, 1997). **The City should set a goal to achieve a citywide cyclical pruning program aimed at increasing overall benefits and effectively mitigating developing safety risks.** A cyclical pruning program allows the City to evenly distribute pruning costs over time and is critical to include in annual budget planning.

New Tree Establishment

New trees need to be maintained annually for three to five years after planting. A new tree establishment program should be based on the needs of new trees and the site's ability to provide for those needs. For example, many urban sites do not provide for sufficient irrigation and/or nutrient needs, required especially during the critical establishment period. Additional tasks could include mulching, pruning, staking, and trunk protection. **The City should expand new tree establishment efforts to further sustain its new transplant's ability to thrive.** Such a program effectively manages new trees to minimize transplant mortality and minimizes future maintenance costs associated with neglected mature trees.

Photograph 14. Expanding growing spaces wherever possible allows for more large-stature trees and improves new transplants' ability to thrive in urban sites.

Additional Tree-Related Maintenance Considerations

Some additional tree-related maintenance considerations include conflicts between trees and infrastructure. For example, tree root-sidewalk conflicts can account for a significant portion of any forestry department's workload and usually contributes significantly to annual program costs after taking into account manpower, repairs, root pruning, and liability claims. Of the most abundant street trees in Pittsburgh associated with sidewalk heaving, littleleaf linden (74%), London planetree (52%), and Norway maple (43%) are among the most frequent offenders (*Appendix B*). However, not all curb and sidewalk damage is due to tree roots, especially in areas where infrastructure is old. In Pittsburgh's case, limited growing space for medium- and large-growing trees is a concern, as these trees provide the most benefits. As density and redevelopment increase in Pittsburgh, **the City should explore use of structural soils, rerouting sidewalks around root flares, and expanding growing space sizes wherever possible to improve cost-effectiveness associated with these infrastructure conflicts.** In many cases where root pruning damages the trees and/or renders the tree a safety risk, tree removal and replacement should be considered as the optimal solution.

Tree canopy-overhead utility conflicts are another major concern of any municipal forestry program. While these costs usually come at the utility company's expense, those costs are transferred ultimately onto the company's customers—the citizens of Pittsburgh. Overhead utilities, such as electric wires, require sufficient clearance from tree canopy, and often result in a significant reduction in leaf area, which reduces overall benefits from the tree. In Pittsburgh, nearly 60% of the street tree canopy is within ten feet of an overhead utility (*Appendix B*). **The City should carefully select species and match them to existing site conditions to avoid conflicts with overhead power lines, sidewalks, and underground utilities.** Time spent planning future plantings will result in long-term savings.

Inventory

The City currently utilizes Davey Resource Group's TreeKeeper® inventory management software to maintain accurate records on the street tree resource and assist with maintenance planning. While the inventory management system comes at a cost, the annual investment helps improve overall program organizational efforts and customer service by facilitating more efficient work planning, call/request logging, and inventory updates. **The City should continue to utilize its inventory to help implement comprehensive maintenance programs, manage removals, track customer requests, update new tree planting information, and assist in budget planning.** Maintaining an up-to-date inventory also allows managers to track the successes and failures of newly planted species, planting techniques, sidewalk restoration activities, and other maintenance activities.

Partnerships

The *Tree Inventory and Management Plan* (Davey Resource Group, 2005) for Pittsburgh provides a clear path to improved stewardship of the City's resources, but one that is beyond the City of Pittsburgh's current fiscal means. The Friends of the Pittsburgh Urban Forest was organized in 2006 to carry out fund-raising, education, and stewardship activities that Pittsburgh Shade Tree Commission had coordinated in the past. The City has an extended network of additional partners responsible for the care and maintenance of the street tree resource, which includes, at a minimum:

- City of Pittsburgh Department of Public Works, Forestry Division.
- City of Pittsburgh's Department of City Planning.
- Other local non-profits.
- Local utility purveyors.

Expanding and improving management, planning, and funding partnerships will be key to meeting the goals laid out in the City's inventory management plan and this analysis. By distributing management tasks across the network of partners, the work can be accomplished more efficiently. For example, local utility partners often have funds for education and tree planting. The Friends of the Pittsburgh Urban Forest and other non-profits can organize volunteers to help identify planting sites, plant trees, and maintain young trees. The Department of City Planning has the means to enforce the City's tree ordinance and assist with tree-related planning during new construction projects.

The challenge ahead is to better integrate the City's green infrastructure with its gray infrastructure. This can be achieved by including green space and trees in the planning phase of development, re-development, and street improvement projects, providing maximum space for trees, filling available planting spaces, and properly maintaining trees to maximize net benefits over the long term. These recommendations will require manpower, funding, and support beyond the City's current commitment. **To benefit from a more functional and sustainable street tree resource, the City should act now to strengthen its network of partners and urban forest managers to work together towards the common goals outlined in this analysis.**

Photograph 15. Pittsburgh's street tree resource is a good investment that helps mitigate the City's environmental impact and provides annual benefits back to the community that outweighs the costs associated with maintaining them. However, current management practices are not sustainable, with a maturing population and a current net loss of trees. Increased investment will be necessary to achieve resource sustainability and maintain the flow of benefits over time.

Chapter 6: Conclusion

This analysis describes the structural characteristics of Pittsburgh's street trees. It uses STRATUM to determine the monetary value of environmental, economic, and social benefits provided to the City and its residents. From this, we derived a benefit-cost ratio and identified management needs. The approach is based on the established tree sampling, numerical modeling, and statistical methods (developed by the U. S. Forest Service) and provides a general accounting of the benefits produced by Pittsburgh's street trees. This information can be used to make informed management decisions regarding the current status of the City's forestry program and the resource it maintains. Future changes and improvements to the program should be directed towards increasing both cost-effectiveness and overall benefits.

When evaluating the bottom line, Pittsburgh's trees are worth the management investment. The street tree resource gives back three-fold to the community in stormwater runoff reductions, energy savings, atmospheric CO_2 reductions, and other benefits. The City's 29,641 street trees are a valuable asset, providing approximately $2.4 million ($81 per tree) in annual gross benefits. Taking into account the costs to manage this resource, Pittsburgh's street trees provide $1.6 million ($53 per tree) in net annual benefits. **The citizens of Pittsburgh see a great return on their investment—receiving $2.94 in benefits for every $1 spent on management.** However, the current state of the resource is not sustainable. It must be expanded and managed for safety and to realize the full benefits that trees provide—both in the short term and for the long term. Several improvements to the City's forestry program must be considered if the City is to maintain such a positive return on its investment and a sustainable resource for generations to come.

Management Recommendations Derived From This Analysis

- Achieve a citywide cyclical pruning program aimed at prolonging the lives of existing trees, increasing overall benefits, and effectively mitigating developing safety risks.

- Continue to utilize the street tree inventory to help implement comprehensive maintenance programs, manage removals, track customer requests, update new tree planting information, assist in budget planning, and evaluate program effectiveness.

- Implement a planting program designed to increase the street tree resource in terms of trees per capita and more evenly distribute trees across wards, thus, increasing the benefits afforded by trees to Pittsburgh residents.

- Plant large-growing species wherever possible to increase the benefits realized and the return on the investment from the City.

- Increase total canopy cover and achieve a more equitable distribution of canopy across all wards, thus, increasing the environmental benefits afforded by leaf area citywide.

- Diversify its mix of species through new tree plantings, focusing on underutilized but good performing species, to reduce dependence on Norway maple and London planetree to provide benefits, and to guard against catastrophic losses due to storms, pests, or disease.

- Achieve an uneven distribution of relative ages in the street tree population through new tree plantings and appropriate species selection to ensure a stable population and flow of benefits over time.

- Implement a tree removal program that establishes a prompt response to dead and declining trees to minimize the overall potential for damage or harm caused by high-risk trees.

- Expand new tree establishment efforts to further sustain its new transplant's ability to thrive.

- Explore use of structural soils, reroute sidewalks around root flares, and expand growing space sizes wherever possible to improve cost-effectiveness associated with these infrastructure conflicts.

- Carefully select species and match them to existing site conditions to avoid conflicts with overhead power lines, sidewalks, and underground utilities.

- Strengthen the City's network of partners and urban forest managers to work together towards the common goal of an improved, more functional, and sustainable street tree resource.

Managers of the urban forest and the community can take pride in knowing that street trees substantially improve the quality of life for the residents of Pittsburgh. Furthermore, the City's investment in the management of the existing resource generates a positive return economically, environmentally, and socially. However, the City is faced with challenges ahead to expand the extent and distribution of the resource, to create long-term stability and sustain the flow of benefits, and to provide a high level of service to its citizens.

The City's 2005 *Tree Inventory and Management Plan* outlines specific priorities and benchmarks to be implemented over a seven-year period to maintain Pittsburgh's existing street trees. Trees are long-term assets and require maintenance to sustain their ability to provide benefits back to the community and, therefore, be economically viable in the scheme of municipal management. Fully implementing the Management Plan is the basic first step in achieving resource stability.

This analysis demonstrates the value of the City's street tree resource and calls attention to the need for adequate funding to maintain it. The magnitude of benefits related to environmental services provides a compelling argument for continual tree care and resource management. Additionally, a well-structured planting program is necessary to create long-term sustainability of this resource. Without new plantings, the tree population will dwindle and lose its capacity to enhance the City. Increased levels of maintenance and the establishment of a planting program will undoubtedly require the technical and financial assistance from all of the City's partners and stakeholders.

Entities such as the Pittsburgh Shade Tree Commission and the non-profit Friends of the Pittsburgh Urban Forest, among others, have already positioned themselves as key partners in the City's efforts to improve the urban forest and the benefits it provides. Moreover, these benefits extend beyond the site where trees are planted, furthering collaborative efforts to build better communities.

Appendix A: Methods and Procedures

In 2005, Pittsburgh initiated a comprehensive inventory of 31,524 street trees. The inventory also included public space trees along streets, stumps, and high-risk private trees that could impact the right-of-way. Tree data were collected and analyzed, providing information concerning the species composition, relative age, health, and maintenance recommendations for the Pittsburgh's street tree population. These data and recommendations are presented in the *Tree Inventory and Management Plan: Pittsburgh, Pennsylvania* (Davey Resource Group, 2005). Tree data are currently maintained in the City's TreeKeeper® 7.6 tree inventory management software. In November, 2006, Davey Resource Group obtained the latest inventory database from the City—29,461 public street trees were included in this analysis. Stumps, vacant planting sites, and private trees are excluded. The inventory data used in this analysis is included in *Appendix E*.

Pittsburgh's tree inventory data was formatted for use in i-Tree's street tree population assessment tool, STRATUM (Version 3.2 Build 3). STRATUM assesses tree population structure and the function of those trees, such as their role in building energy use, air pollution removal, stormwater interception, carbon dioxide removal, and property value increases. In order to analyze the economic benefits of Pittsburgh's street trees, STRATUM assigns a dollar value to the annual resource functionality and compares that to annual program expenditures. This analysis combines the results of the City's street tree inventory with benefit-cost modeling data to produce information regarding resource structure, resource function, and resource value to make resource management recommendations. For a detailed accounting of how STRATUM handles tree sampling, tree growth modeling, replacement value, and the calculations of annual benefits, refer to the *New York City, New York Municipal Forest Resource Analysis* (Peper and others, 2007) and the *Northeast Community Tree Guide* (McPherson and others, 2007). The City of Pittsburgh Public Works Department provided city-specific information and program costs (*Table 6*).

STRATUM regionalizes the calculations of its output by incorporating detailed reference city project information for 17 climate zones across the United States. Pittsburgh falls within the Northeast Climate Zone (*Appendix E*). Sample inventory data from New York City, concentrating mostly in the borough of Queens, represents the basis for the Northeast Reference City Project for the Northeast Community Tree Guidelines. The basis for the benefit modeling in this study compares the inventory data from Pittsburgh, to the results of Northeast Reference City Project to obtain an estimation of the annual benefits provided by Pittsburgh's resource.

Annual benefits for Pittsburgh's street trees were estimated for the fiscal year 2006. Growth rate modeling information was used to perform computer-simulated growth of the existing tree population for one year and account for the associated annual benefits. This "snapshot" analysis assumed that no trees were added to, or removed from, the existing population during the year. Calculations of CO_2 released due to decompositions of wood from removed trees did consider average annual mortality. This approach directly connects benefits with tree-size variables such as DBH and leaf-surface area. Many benefits of trees are related to processes that involve interactions between leaves and the atmosphere (*e.g.;* interception, transpiration, photosynthesis); therefore, benefits increase as tree canopy cover and leaf surface area increase.

For each of the modeled benefits, an annual resource unit was determined on a per-tree basis. Resource units are measured as MWh of electricity save per tree; MBtu of natural gas conserved per tree, lbs. of atmospheric CO_2 reduced per tree; lbs. of NO_2, PM_{10}, and VOCs reduced per tree; cubic feet of stormwater runoff reduced per tree; and square feet of leaf area added per tree to increase property values.

Prices were assigned to each resource unit using economic indicators of society's willingness to pay for the environmental benefits trees provide. Estimates of benefits are initial approximations as some benefits are difficult to quantify (*e.g.*, impacts on psychological health, crime, and violence). In addition, limited knowledge about the physical processes at work and their interactions makes estimates imprecise (*e.g.*, fate of air pollutants trapped by trees and then washed to the ground by rainfall). Therefore, this method of quantification provides first-order approximations. It is meant to be a general accounting of the benefits produced by urban trees—an accounting with an accepted degree of uncertainty that can, nonetheless, provide science-based platform for decision-making.

A detailed description of how the default benefit prices are derived, refer to the *New York City, New York Municipal Forest Resource Analysis* (Peper and others, 2007) and the *Northeast Community Tree Guide* (McPherson and others, 2007). In order to further refine the estimation of benefits to Pittsburgh, certain benefit prices have been obtained specific for Pittsburgh.

Pittsburgh's Benefit Prices Used in this Analysis

Benefits	Price	Unit	Source
Electricity	$.010	$/Kwh	Duquesne Light Company
Natural Gas	$1.21	$/Therm	Dominion Peoples
CO_2	$0.00334	$/lb	STRATUM default- Northeast
PM_{10}	$8.31	$/lb	STRATUM default- Northeast
NO_2	$4.59	$/lb	STRATUM default- Northeast
SO_2	$3.48	$/lb	STRATUM default- Northeast
VOC	$2.31	$/lb	STRATUM default- Northeast
Stormwater Interception	$0.008	$/gallon	STRATUM default- Northeast
Average Home Resale Value	$116,100	$	National Association of Realtors

The local benefit price for electricity ($0.10/Kwh) was obtained from the Duquesne Light Company in November, 2007. The local benefit price for natural gas ($12.3451/Mcf; $1.21/Therm) was obtained from the Dominion Peoples in October, 2007. STRATUM's default values from the Northeast Climate Zone were used for all additional benefit prices (air quality, stormwater, aesthetic/other). Using these prices, the magnitude of the benefits provided by the street tree resource was calculated using STRATUM. For a detailed description of how the magnitudes of benefit prices are calculated, refer to the *New York City, New York Municipal Forest Resource Analysis* (Peper and others, 2007) and the *Northeast Community Tree Guide (*McPherson and others, 2007).

Appendix B: Additional STRATUM Output Reports

City of Pittsburgh, Pennsylvania

Complete Population of Public Trees

12/10/2007

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
	DBH Class (in)									
Broadleaf Deciduous Large (BDL)										
Norway maple	164	410	1,876	1,388	570	213	37	2	0	4,660
London planetree	76	214	63	64	397	885	616	203	36	2,554
Honeylocust	181	535	464	181	131	76	6	0	1	1,575
Sugar maple	25	149	542	240	71	11	4	0	0	1,042
Pin oak	12	25	70	97	221	356	174	57	11	1,023
Silver maple	42	211	290	143	94	86	38	14	9	927
Sweetgum	6	10	226	440	163	15	5	0	0	865
Northern red oak	11	25	88	199	185	149	67	26	3	753
Ginkgo	24	69	207	150	140	67	17	2	0	676
Black locust	4	11	49	104	107	51	26	15	2	369
Green ash	15	28	177	43	12	5	2	2	0	284
American elm	27	20	65	53	38	27	22	8	2	262
Japanese zelkova	34	101	105	1	0	0	1	0	0	242
Tree of heaven	28	19	56	31	23	9	4	0	0	170
Horsechestnut	4	2	10	26	55	40	6	2	1	146
White ash	7	11	51	29	17	9	2	1	0	127
American sycamore	1	0	0	12	26	39	27	12	1	118
Siberian elm	4	4	15	27	25	23	8	1	0	107
Maple: Freeman	4	28	49	22	1	0	0	0	0	104
Black cherry	5	3	29	37	6	13	1	1	0	95
Black oak	0	0	6	18	4	0	0	0	0	28
Northern hackberry	3	5	9	4	3	0	0	0	0	24
River birch	8	8	5	1	0	0	0	0	0	22
American basswood	1	0	2	9	5	0	1	2	2	22
Scarlet oak	0	0	0	8	5	5	3	0	0	21
Tulip tree	1	0	3	2	4	5	1	0	0	16
Paper birch	2	2	10	1	0	0	0	0	0	15
Sycamore maple	0	0	5	6	1	2	0	0	0	14
Black walnut	1	1	3	1	2	0	1	0	0	9
Magnolia: Cucumbertree	6	0	0	1	0	1	0	0	0	8
Bitternut hickory	0	1	0	1	3	1	1	0	0	7
Chinese elm	0	6	1	0	0	0	0	0	0	7
Swamp white oak	0	1	0	1	2	1	0	1	0	6
Baldcypress	5	0	0	0	0	0	0	0	1	6
American beech	2	1	1	0	0	0	0	0	0	4
Dawn redwood	2	0	0	2	0	0	0	0	0	4
Black poplar	0	1	1	2	0	0	0	0	0	4
White oak	0	0	0	1	3	0	0	0	0	4
European beech	1	0	2	0	0	0	0	0	0	3
Kentucky coffeetree	0	2	0	0	1	0	0	0	0	3
Eastern cottonwood	0	0	1	1	0	0	0	0	0	2
Quaking aspen	0	0	1	0	1	0	0	0	0	2
Sawtooth oak	0	2	0	0	0	0	0	0	0	2
Overcup oak	0	2	0	0	0	0	0	0	0	2
Pignut hickory	0	0	0	1	0	0	0	0	0	1
Turkish hazelnut	0	0	1	0	0	0	0	0	0	1
Black ash	0	0	0	0	1	0	0	0	0	1
European larch	0	0	1	0	0	0	0	0	0	1
Bigtooth aspen	0	0	0	0	1	0	0	0	0	1
Willow oak	0	1	0	0	0	0	0	0	0	1
Chestnut oak	0	0	0	0	1	0	0	0	0	1
English oak	0	0	0	0	0	1	0	0	0	1
Elm: spp.	0	0	1	0	0	0	0	0	0	1

City of Pittsburgh, Pennsylvania

Complete Population of Public Trees

12/10/2007

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Total	**706**	**1,908**	**4,485**	**3,347**	**2,319**	**2,090**	**1,070**	**349**	**69**	**16,343**
Broadleaf Deciduous Medium (BDM)										
Red maple	317	881	1,393	679	82	15	4	0	0	3,371
Littleleaf linden	33	201	614	1,567	641	162	17	4	1	3,240
Hedge maple	103	105	58	3	1	0	0	0	0	270
White mulberry	29	37	73	43	15	7	0	0	0	204
Northern catalpa	2	3	11	15	9	4	1	0	0	45
American hornbeam	21	14	3	1	0	0	0	0	0	39
Unknown	11	13	9	3	0	0	0	0	0	36
Japanese snowbell	1	5	11	7	7	3	0	0	0	34
Amur corktree	0	1	7	13	4	2	0	0	0	27
Boxelder	7	0	7	9	2	1	0	0	0	26
Osage-orange	0	3	2	8	4	2	0	0	0	19
European white birch	2	6	7	1	0	0	0	0	0	16
Buckeye: Ohio	0	0	0	1	5	3	0	0	0	9
Maple	3	2	3	0	0	0	0	0	0	8
Eastern hophornbeam	0	2	4	1	0	0	0	0	0	7
European hornbeam	0	3	2	0	0	0	0	0	0	5
Katsura tree	0	1	3	0	0	0	0	0	0	4
Willow	1	2	1	0	0	0	0	0	0	4
Gray birch	0	2	0	0	0	0	0	0	0	2
Chinese chestnut	1	0	0	0	0	0	0	0	0	1
Black tupelo	0	0	0	0	1	0	0	0	0	1
Royal paulownia	0	0	1	0	0	0	0	0	0	1
Weeping willow	0	0	1	0	0	0	0	0	0	1
Black willow	0	0	1	0	0	0	0	0	0	1
Slippery elm	0	0	1	0	0	0	0	0	0	1
Total	**531**	**1,281**	**2,212**	**2,351**	**771**	**199**	**22**	**4**	**1**	**7,372**
Broadleaf Deciduous Small (BDS)										
Callery pear	563	1,390	1,121	240	25	0	0	0	0	3,339
Apple	156	201	174	68	4	0	0	0	0	603
Plum	69	83	49	9	7	0	0	0	0	217
Amur maple	75	46	25	1	0	0	0	0	0	147
Maple: Tatarian	28	46	6	1	0	0	0	0	0	81
Hawthorn	17	20	31	9	0	1	0	0	0	78
Flowering dogwood	31	24	7	0	0	0	0	0	0	62
Japanese maple	22	27	10	1	1	0	0	0	0	61
Japanese tree lilac	26	6	1	0	0	0	0	0	0	33
Kwanzan cherry	12	12	8	0	0	0	0	0	0	32
Yoshino flowering cherry	5	7	11	5	0	0	0	0	0	28
Eastern redbud	18	3	2	2	0	0	0	0	0	25
Serviceberry	12	3	0	0	0	0	0	0	0	15
Trident maple	4	3	4	1	1	0	0	0	0	13
Kousa dogwood	8	2	1	0	0	0	0	0	0	11
Chinese magnolia; Saucer	2	2	5	1	0	0	0	0	0	10
Mimosa	2	3	4	0	0	0	0	0	0	9
Goldenrain tree	1	0	1	4	2	1	0	0	0	9
Cherry plum	0	4	1	0	0	0	0	0	0	5
Peach	2	1	2	0	0	0	0	0	0	5
Willow: Pussy	0	2	2	1	0	0	0	0	0	5
Smoketree: Common	2	1	1	0	0	0	0	0	0	4
European mountain ash	2	1	1	0	0	0	0	0	0	4
Pawpaw	1	1	0	0	0	0	0	0	0	2

Complete Population of Public Trees

12/10/2007

DBH Class (in)

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Dogwood	2	0	0	0	0	0	0	0	0	2
Star magnolia	0	1	1	0	0	0	0	0	0	2
Common pear	0	1	1	0	0	0	0	0	0	2
Maple: Paperback	1	0	0	0	0	0	0	0	0	1
Cornelian cherry	1	0	0	0	0	0	0	0	0	1
Mulberry: spp.	0	0	0	1	0	0	0	0	0	1
Pin cherry	0	0	0	1	0	0	0	0	0	1
Total	**1,062**	**1,890**	**1,469**	**345**	**40**	**2**	**0**	**0**	**0**	**4,808**
Broadleaf Evergreen Large (BEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Broadleaf Evergreen Medium (BEM)										
Magnolia	2	6	10	0	1	0	0	0	0	19
Southern magnolia	1	1	0	0	0	0	0	0	0	2
Total	**3**	**7**	**10**	**0**	**1**	**0**	**0**	**0**	**0**	**21**
Broadleaf Evergreen Small (BES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Conifer Evergreen Large (CEL)										
Norway spruce	1	6	47	64	16	3	0	0	0	137
Eastern white pine	12	10	31	15	3	2	0	0	0	73
White spruce	5	11	8	0	0	0	0	0	0	24
Austrian pine	0	4	7	9	4	0	0	0	0	24
Scotch pine	0	1	8	6	0	0	0	0	0	15
Falsecypress: Lawson	6	0	0	0	0	0	0	0	0	6
Pine: Red	0	2	1	1	2	0	0	0	0	6
Douglas fir	3	1	0	1	0	0	0	0	0	5
Arborvitae: Western	0	1	3	0	0	0	0	0	0	4
Balsam fir	1	1	1	0	0	0	0	0	0	3
Spruce	2	0	0	0	0	0	0	0	0	2
Pine	0	0	2	0	0	0	0	0	0	2
Rock elm	0	0	0	1	1	0	0	0	0	2
Total	**30**	**37**	**108**	**97**	**26**	**5**	**0**	**0**	**0**	**303**
Conifer Evergreen Medium (CEM)										
Spruce: Colorado	36	56	150	137	27	0	0	0	0	406
Northern white cedar	97	41	25	2	0	0	0	0	0	165
Eastern hemlock	52	42	38	6	3	0	0	0	0	141
Eastern red cedar	25	32	12	3	0	0	0	0	0	72
Atlantic white cedar	0	1	7	1	0	0	0	0	0	9
Atlas cedar	0	1	0	0	0	0	0	0	0	1
Total	**210**	**173**	**232**	**149**	**30**	**0**	**0**	**0**	**0**	**794**
Conifer Evergreen Small (CES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Palm Evergreen Large (PEL)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Palm Evergreen Medium (PEM)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Palm Evergreen Small (PES)										
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Grand Total:	**2,542**	**5,296**	**8,516**	**6,289**	**3,187**	**2,296**	**1,092**	**353**	**70**	**29,641**

City of Pittsburgh, Pennsylvania

Replacement Value for Public Trees by Species

12/7/2007

	DBH Class (in)											
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error	% of Total
Norway maple	27,605	180,572	2,731,664	5,344,844	4,023,281	2,418,422	637,459	37,006	0	15,400,851	(±0)	11.28
Red maple	34,248	470,966	2,836,531	3,868,502	870,033	249,940	100,920	0	0	8,431,140	(±0)	6.17
Callery pear	112,858	555,217	1,199,303	625,337	121,806	0	0	0	0	2,614,521	(±0)	1.91
Littleleaf linden	4,107	98,522	1,086,425	7,962,738	6,368,426	2,683,112	414,215	129,130	27,493	18,774,168	(±0)	13.75
London planetree	9,215	107,344	114,856	303,022	3,815,582	14,275,331	14,767,038	6,341,732	1,319,645	41,053,764	(±0)	30.06
Honeylocust	26,412	261,000	777,626	823,562	1,153,656	1,142,286	120,814	0	24,084	4,329,440	(±0)	3.17
Sugar maple	5,038	55,541	555,452	623,480	353,470	88,690	43,356	0	0	1,725,028	(±0)	1.26
Pin oak	2,471	9,963	74,172	262,485	1,098,844	2,916,506	2,083,807	915,195	195,161	7,558,604	(±0)	5.53
Silver maple	8,881	83,827	311,677	386,017	461,005	675,994	413,593	215,510	165,136	2,721,640	(±0)	1.99
Sweetgum	686	5,500	461,227	2,469,958	1,787,533	287,658	131,487	0	0	5,144,048	(±0)	3.77
Northern red oak	1,066	14,178	200,704	1,236,608	2,245,208	3,046,897	2,010,522	1,010,201	145,818	9,911,202	(±0)	7.26
Ginkgo	2,652	36,593	429,444	838,014	1,607,796	1,278,347	490,355	78,322	0	4,761,522	(±0)	3.49
Apple	24,124	97,768	286,599	303,501	35,715	0	0	0	0	747,708	(±0)	0.55
Spruce: Colorado	5,726	24,232	216,154	518,277	195,428	0	0	0	0	959,818	(±0)	0.70
Black locust	762	4,385	64,294	341,596	692,988	559,899	437,808	309,614	24,121	2,435,467	(±0)	1.78
Green ash	2,432	12,716	256,692	164,307	89,408	57,738	40,116	37,006	0	660,415	(±0)	0.48
Hedge maple	12,662	51,970	105,656	16,927	7,743	0	0	0	0	194,958	(±0)	0.14
American elm	6,021	8,200	66,585	126,161	188,650	228,756	278,249	132,367	39,263	1,074,253	(±0)	0.79
Japanese zelkova	3,677	52,088	211,457	6,308	0	0	29,580	0	0	303,109	(±0)	0.22
Plum	13,452	33,307	52,217	23,305	32,858	0	0	0	0	155,139	(±0)	0.11
White mulberry	7,858	12,605	44,359	54,954	37,673	29,645	0	0	0	187,094	(±0)	0.14
Tree of heaven	7,487	6,970	38,025	44,994	57,684	38,707	25,534	0	0	219,401	(±0)	0.16
Northern white cedar	12,296	20,748	47,847	10,289	0	0	0	0	0	91,179	(±0)	0.07
Amur maple	9,748	23,217	46,051	3,983	0	0	0	0	0	82,998	(±0)	0.06
Horsechestnut	806	908	10,545	66,410	255,162	301,763	64,569	24,819	19,632	744,614	(±0)	0.55
Eastern hemlock	8,909	20,383	59,004	21,908	21,009	0	0	0	0	131,212	(±0)	0.10
Norway spruce	123	3,034	86,591	318,621	150,987	51,026	0	0	0	610,382	(±0)	0.45
White ash	1,447	4,434	55,091	78,395	83,306	67,599	23,036	12,409	0	325,718	(±0)	0.24
American sycamore	191	0	0	47,264	192,985	475,537	507,080	302,213	29,290	1,554,559	(±0)	1.14
Siberian elm	1,095	1,426	10,719	40,499	67,461	92,572	40,776	7,369	0	261,915	(±0)	0.19
Maple: Freeman	452	14,358	96,055	112,062	12,301	0	0	0	0	235,228	(±0)	0.17
Black cherry	751	1,095	28,480	96,268	30,535	114,108	9,404	12,409	0	293,049	(±0)	0.21
Maple: Tatarian	5,721	18,056	6,582	2,979	0	0	0	0	0	33,338	(±0)	0.02
Hawthorn	2,869	7,895	44,800	33,724	0	13,633	0	0	0	102,920	(±0)	0.08
Eastern white pine	1,677	5,286	52,992	68,498	25,511	28,907	0	0	0	182,871	(±0)	0.13
Eastern red cedar	4,023	14,163	17,827	12,932	0	0	0	0	0	48,945	(±0)	0.04
Flowering dogwood	6,472	9,642	8,068	0	0	0	0	0	0	24,183	(±0)	0.02
Japanese maple	2,873	14,332	17,515	3,983	7,743	0	0	0	0	46,445	(±0)	0.03

Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error	% of Total
	DBH Class (in)											
Northern catalpa	464	1,282	11,635	35,991	40,823	31,366	9,404	0	0	130,966	(±0)	0.10
American hornbeam	2,785	7,427	5,166	3,983	0	0	0	0	0	19,361	(±0)	0.01
Unknown	166	960	2,449	2,226	0	0	0	0	0	5,801	(±0)	0.00
Japanese snowbell	105	2,916	21,905	40,075	86,106	45,357	0	0	0	196,464	(±0)	0.14
Japanese tree lilac	4,236	2,863	1,356	0	0	0	0	0	0	8,456	(±0)	0.01
Kwanzan cherry	1,950	5,727	12,886	0	0	0	0	0	0	20,563	(±0)	0.02
Yoshino flowering	1,161	2,938	12,173	12,791	0	0	0	0	0	29,063	(±0)	0.02
Black oak	0	0	9,882	69,577	27,849	0	0	0	0	107,308	(±0)	0.08
Amur corktree	0	627	15,102	73,100	42,691	28,646	0	0	0	160,167	(±0)	0.12
Boxelder	1,584	0	8,068	25,057	11,284	9,194	0	0	0	55,187	(±0)	0.04
Eastern redbud	3,214	972	2,406	5,432	0	0	0	0	0	12,025	(±0)	0.01
Northern hackberry	634	2,271	11,317	13,507	16,820	0	0	0	0	44,549	(±0)	0.03
White spruce	692	4,812	15,990	0	0	0	0	0	0	21,494	(±0)	0.02
Austrian pine	0	1,335	4,377	14,824	11,915	0	0	0	0	32,451	(±0)	0.02
River birch	1,266	3,541	7,073	3,550	0	0	0	0	0	15,430	(±0)	0.01
American basswood	149	0	3,567	50,780	50,974	0	26,328	59,441	54,985	246,225	(±0)	0.18
Scarlet oak	0	0	0	42,483	49,039	78,665	52,239	0	0	222,426	(±0)	0.16
Magnolia	309	3,152	17,261	0	9,637	0	0	0	0	30,360	(±0)	0.02
Osage-orange	0	1,882	3,946	37,478	34,732	40,582	0	0	0	118,620	(±0)	0.09
European white birch	451	2,105	4,824	1,356	0	0	0	0	0	8,735	(±0)	0.01
Tulip tree	170	0	4,728	9,953	34,014	68,071	23,077	0	0	140,012	(±0)	0.10
Serviceberry	1,471	1,569	0	0	0	0	0	0	0	3,040	(±0)	0.00
Paper birch	382	828	11,182	2,453	0	0	0	0	0	14,846	(±0)	0.01
Scotch pine	0	374	8,847	13,843	0	0	0	0	0	23,063	(±0)	0.02
Sycamore maple	0	0	7,460	19,524	8,306	24,859	0	0	0	60,150	(±0)	0.04
Trident maple	661	1,416	6,104	4,311	3,615	0	0	0	0	16,107	(±0)	0.01
Kousa dogwood	866	1,033	2,313	0	0	0	0	0	0	4,213	(±0)	0.00
Chinese magnolia;	309	919	8,356	4,976	0	0	0	0	0	14,561	(±0)	0.01
Buckeye: Ohio	0	0	0	6,308	57,886	54,906	0	0	0	119,100	(±0)	0.09
Mimosa	499	973	2,814	0	0	0	0	0	0	4,286	(±0)	0.00
Atlantic white cedar	0	488	14,637	5,642	0	0	0	0	0	20,767	(±0)	0.02
Black walnut	22	523	4,941	4,311	15,146	0	19,825	0	0	44,768	(±0)	0.03
Goldenrain tree	123	0	2,091	20,578	21,938	12,756	0	0	0	57,486	(±0)	0.04
Maple	67	123	581	0	0	0	0	0	0	772	(±0)	0.00
Magnolia:	686	0	0	4,453	0	14,323	0	0	0	19,462	(±0)	0.01
Bitternut hickory	0	523	0	3,043	23,451	13,633	13,994	0	0	54,644	(±0)	0.04
Eastern hophornbeam	0	907	7,749	4,647	0	0	0	0	0	13,302	(±0)	0.01
Chinese elm	0	2,586	1,356	0	0	0	0	0	0	3,943	(±0)	0.00
Falsecypress: Lawson	838	0	0	0	0	0	0	0	0	838	(±0)	0.00
Pine: Red	0	525	1,869	4,098	15,873	0	0	0	0	22,366	(±0)	0.02
Swamp white oak	0	488	0	5,642	21,938	18,072	0	28,696	0	74,836	(±0)	0.05
Baldcypress	613	0	0	0	0	0	0	0	38,948	39,561	(±0)	0.03
European hornbeam	0	1,465	3,444	0	0	0	0	0	0	4,909	(±0)	0.00
Cherry plum	0	1,426	759	0	0	0	0	0	0	2,185	(±0)	0.00

			DBH Class (in)									
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error	% of Total
Peach	464	321	1,840	0	0	0	0	0	0	2,625	(±0)	0.00
Douglas fir	538	523	0	3,550	0	0	0	0	0	4,611	(±0)	0.00
Willow: Pussy	0	908	2,052	2,979	0	0	0	0	0	5,939	(±0)	0.00
Katsura tree	0	545	7,157	0	0	0	0	0	0	7,703	(±0)	0.01
Smoketree: Common	355	454	1,203	0	0	0	0	0	0	2,012	(±0)	0.00
American beech	309	460	1,869	0	0	0	0	0	0	2,638	(±0)	0.00
Dawn redwood	234	0	0	10,390	0	0	0	0	0	10,623	(±0)	0.01
Black poplar	0	272	536	3,294	0	0	0	0	0	4,102	(±0)	0.00
White oak	0	0	0	6,974	36,086	0	0	0	0	43,060	(±0)	0.03
Willow	191	828	1,203	0	0	0	0	0	0	2,222	(±0)	0.00
European mountain	382	374	849	0	0	0	0	0	0	1,606	(±0)	0.00
Arborvitae: Western	0	460	4,947	0	0	0	0	0	0	5,407	(±0)	0.00
Balsam fir	225	385	759	0	0	0	0	0	0	1,369	(±0)	0.00
European beech	105	0	4,218	0	0	0	0	0	0	4,323	(±0)	0.00
Kentucky coffeetree	0	1,255	0	0	8,683	0	0	0	0	9,938	(±0)	0.01
Pawpaw	191	374	0	0	0	0	0	0	0	565	(±0)	0.00
Gray birch	0	908	0	0	0	0	0	0	0	908	(±0)	0.00
Dogwood	234	0	0	0	0	0	0	0	0	234	(±0)	0.00
Southern magnolia	149	488	0	0	0	0	0	0	0	637	(±0)	0.00
Star magnolia	0	593	2,091	0	0	0	0	0	0	2,684	(±0)	0.00
Spruce	271	0	0	0	0	0	0	0	0	271	(±0)	0.00
Pine	0	0	283	0	0	0	0	0	0	283	(±0)	0.00
Eastern cottonwood	0	0	759	1,647	0	0	0	0	0	2,406	(±0)	0.00
Quaking aspen	0	0	759	0	2,103	0	0	0	0	2,862	(±0)	0.00
Common pear	0	454	1,203	0	0	0	0	0	0	1,657	(±0)	0.00
Sawtooth oak	0	907	0	0	0	0	0	0	0	907	(±0)	0.00
Overcup oak	0	1,186	0	0	0	0	0	0	0	1,186	(±0)	0.00
Rock elm	0	0	0	4,311	8,306	0	0	0	0	12,616	(±0)	0.01
Maple: Paperback	191	0	0	0	0	0	0	0	0	191	(±0)	0.00
Pignut hickory	0	0	0	3,550	0	0	0	0	0	3,550	(±0)	0.00
Chinese chestnut	164	0	0	0	0	0	0	0	0	164	(±0)	0.00
Atlas cedar	0	517	0	0	0	0	0	0	0	517	(±0)	0.00
Turkish hazelnut	0	0	2,091	0	0	0	0	0	0	2,091	(±0)	0.00
Cornelian cherry	128	0	0	0	0	0	0	0	0	128	(±0)	0.00
Black ash	0	0	0	0	5,863	0	0	0	0	5,863	(±0)	0.00
European larch	0	0	1,163	0	0	0	0	0	0	1,163	(±0)	0.00
Mulberry: spp.	0	0	0	1,297	0	0	0	0	0	1,297	(±0)	0.00
Black tupelo	0	0	0	0	10,969	0	0	0	0	10,969	(±0)	0.01
Royal paulownia	0	0	1,203	0	0	0	0	0	0	1,203	(±0)	0.00
Bigtooth aspen	0	0	0	0	2,453	0	0	0	0	2,453	(±0)	0.00
Pin cherry	0	0	0	2,979	0	0	0	0	0	2,979	(±0)	0.00
Willow oak	0	488	0	0	0	0	0	0	0	488	(±0)	0.00
Chestnut oak	0	0	0	0	10,969	0	0	0	0	10,969	(±0)	0.01
English oak	0	0	0	0	0	14,883	0	0	0	14,883	(±0)	0.01

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error	% of Total
Weeping willow	0	0	1,633	0	0	0	0	0	0	1,633	(±0)	0.00
Black willow	0	0	991	0	0	0	0	0	0	991	(±0)	0.00
Slippery elm	0	0	1,647	0	0	0	0	0	0	1,647	(±0)	0.00
Elm: spp.	0	0	1,905	0	0	0	0	0	0	1,905	(±0)	0.00
Citywide total	408,899	2,416,116	13,012,263	27,849,668	26,761,258	31,578,384	22,814,587	9,653,438	2,083,575	136,578,187	(±0)	100.00

City of Pittsburgh, Pennsylvania

Relative Performance Index for Public Trees

12/10/2007

Species	Dead	Critical	Poor	Fair	Good	Very Good	RPI	# of Trees	% of Total Population
Norway maple	0.6	1.1	29.2	54.0	15.0	0.1	0.94	4,658	15.72
Red maple	1.1	1.1	20.5	48.8	28.3	0.2	1.00	3,371	11.37
Callery pear	0.8	0.9	13.9	46.2	38.1	0.1	1.06	3,339	11.27
Littleleaf linden	0.5	0.7	25.2	56.2	17.4	0.0	0.96	3,240	10.93
London planetree	0.2	0.4	26.1	54.2	18.8	0.4	0.97	2,555	8.62
Honeylocust	0.1	0.7	9.0	46.0	44.3	0.0	1.11	1,575	5.31
Sugar maple	0.9	2.1	28.8	44.9	23.1	0.2	0.96	1,042	3.52
Pin oak	0.1	0.2	23.9	55.2	20.1	0.4	0.98	1,023	3.45
Silver maple	0.3	1.2	22.5	52.4	23.2	0.3	0.99	927	3.13
Sweetgum	0.0	0.2	16.4	48.6	34.3	0.5	1.06	865	2.92
Northern red oak	0.0	0.4	17.4	53.8	28.0	0.4	1.03	753	2.54
Ginkgo	0.6	0.4	16.3	58.6	24.0	0.1	1.01	676	2.28
Apple	1.2	1.8	13.9	54.4	28.7	0.0	1.02	603	2.03
Spruce: Colorado	0.2	0.0	2.5	26.4	70.7	0.2	1.22	406	1.37
Black locust	5.4	8.4	39.0	44.4	2.7	0.0	0.77	369	1.24
Green ash	0.0	0.4	19.4	44.7	35.2	0.4	1.05	284	0.96
Hedge maple	1.1	1.1	5.2	20.0	72.2	0.4	1.20	270	0.91
American elm	5.7	1.1	19.8	70.2	3.1	0.0	0.88	262	0.88
Japanese zelkova	4.5	2.5	10.3	44.2	38.4	0.0	1.03	242	0.82
Plum	0.9	2.3	10.6	41.0	45.2	0.0	1.09	217	0.73
White mulberry	1.0	5.4	37.7	52.5	3.4	0.0	0.84	204	0.69
Tree of heaven	1.8	3.5	17.6	73.5	3.5	0.0	0.91	170	0.57
Northern white cedar	0.6	0.0	0.6	24.8	73.9	0.0	1.23	165	0.56
Amur maple	0.0	2.0	10.9	36.1	51.0	0.0	1.12	147	0.50
Horsechestnut	0.0	1.4	47.9	41.1	9.6	0.0	0.86	146	0.49
Eastern hemlock	0.7	0.7	4.3	59.6	34.8	0.0	1.09	141	0.48
Norway spruce	0.0	0.0	6.6	35.8	56.9	0.7	1.17	137	0.46
White ash	0.0	1.6	28.3	58.3	11.8	0.0	0.93	127	0.43
American sycamore	0.0	0.8	22.9	68.6	7.6	0.0	0.94	118	0.40
Siberian elm	0.9	0.0	32.7	63.6	2.8	0.0	0.89	107	0.36
Maple: Freeman	0.0	0.0	43.3	34.6	22.1	0.0	0.93	104	0.35
Black cherry	2.1	2.1	38.9	54.7	2.1	0.0	0.84	95	0.32
Maple: Tatarian	1.2	0.0	2.5	35.8	60.5	0.0	1.18	81	0.27
Hawthorn	2.6	2.6	28.2	48.7	17.9	0.0	0.92	78	0.26
Eastern white pine	0.0	0.0	4.1	47.9	45.2	2.7	1.15	73	0.25
Eastern red cedar	0.0	0.0	1.4	22.2	76.4	0.0	1.24	72	0.24
Flowering dogwood	0.0	0.0	9.7	50.0	40.3	0.0	1.10	62	0.21
Japanese maple	0.0	1.6	6.6	36.1	55.7	0.0	1.15	61	0.21
Northern catalpa	0.0	4.4	42.2	48.9	4.4	0.0	0.84	45	0.15
American hornbeam	0.0	0.0	15.4	43.6	41.0	0.0	1.08	39	0.13
Unknown	100.0	0.0	0.0	0.0	0.0	0.0	0.00	36	0.12
Japanese snowbell	0.0	0.0	20.6	55.9	23.5	0.0	1.01	34	0.11
Japanese tree lilac	0.0	0.0	6.1	27.3	66.7	0.0	1.20	33	0.11
Kwanzan cherry	0.0	0.0	0.0	46.9	53.1	0.0	1.17	32	0.11
Yoshino flowering	0.0	0.0	0.0	57.1	42.9	0.0	1.14	28	0.09
Black oak	0.0	3.6	10.7	64.3	21.4	0.0	1.01	28	0.09
Amur corktree	0.0	0.0	11.1	44.4	44.4	0.0	1.11	27	0.09
Boxelder	0.0	0.0	11.5	84.6	3.8	0.0	0.97	26	0.09
Eastern redbud	8.0	8.0	12.0	40.0	32.0	0.0	0.93	25	0.08
Northern hackberry	0.0	0.0	25.0	62.5	12.5	0.0	0.95	24	0.08
White spruce	0.0	0.0	33.3	37.5	29.2	0.0	0.98	24	0.08
Austrian pine	0.0	0.0	0.0	58.3	37.5	4.2	1.15	24	0.08
River birch	0.0	0.0	4.5	13.6	81.8	0.0	1.25	22	0.07
American basswood	0.0	0.0	18.2	72.7	9.1	0.0	0.97	22	0.07
Scarlet oak	0.0	4.8	14.3	47.6	33.3	0.0	1.03	21	0.07

Relative Performance Index for Public Trees

12/10/2007

Species	Dead	Critical	Poor	Fair	Good	Very Good	RPI	# of Trees	% of Total Population
Magnolia	0.0	0.0	10.5	68.4	21.1	0.0	1.03	19	0.06
Osage-orange	0.0	0.0	63.2	36.8	0.0	0.0	0.79	19	0.06
European white birch	0.0	0.0	6.3	43.8	50.0	0.0	1.14	16	0.05
Tulip tree	0.0	0.0	12.5	50.0	37.5	0.0	1.08	16	0.05
Serviceberry	0.0	0.0	0.0	6.7	93.3	0.0	1.31	15	0.05
Paper birch	0.0	0.0	0.0	46.7	53.3	0.0	1.17	15	0.05
Scotch pine	6.7	0.0	13.3	53.3	26.7	0.0	0.97	15	0.05
Sycamore maple	0.0	0.0	42.9	42.9	14.3	0.0	0.90	14	0.05
Trident maple	0.0	7.7	15.4	53.8	23.1	0.0	0.97	13	0.04
Kousa dogwood	0.0	0.0	0.0	18.2	81.8	0.0	1.27	11	0.04
Chinese magnolia;	0.0	0.0	0.0	40.0	60.0	0.0	1.19	10	0.03
Buckeye: Ohio	0.0	0.0	22.2	77.8	0.0	0.0	0.92	9	0.03
Mimosa	0.0	0.0	22.2	55.6	22.2	0.0	1.00	9	0.03
Atlantic white cedar	0.0	0.0	0.0	88.9	11.1	0.0	1.03	9	0.03
Black walnut	11.1	0.0	0.0	77.8	11.1	0.0	0.92	9	0.03
Goldenrain tree	0.0	0.0	11.1	55.6	33.3	0.0	1.07	9	0.03
Maple	100.0	0.0	0.0	0.0	0.0	0.0	0.00	8	0.03
Magnolia:	0.0	0.0	37.5	37.5	25.0	0.0	0.95	8	0.03
Bitternut hickory	0.0	0.0	28.6	57.1	14.3	0.0	0.95	7	0.02
Eastern hophornbeam	0.0	0.0	28.6	42.9	28.6	0.0	1.00	7	0.02
Chinese elm	0.0	0.0	0.0	0.0	85.7	14.3	1.38	7	0.02
Falsecypress: Lawson	0.0	0.0	0.0	0.0	100.0	0.0	1.33	6	0.02
Pine: Red	16.7	0.0	0.0	16.7	66.7	0.0	1.05	6	0.02
Swamp white oak	0.0	0.0	0.0	66.7	16.7	16.7	1.16	6	0.02
Baldcypress	0.0	0.0	0.0	16.7	83.3	0.0	1.27	6	0.02
European hornbeam	0.0	0.0	0.0	0.0	100.0	0.0	1.33	5	0.02
Cherry plum	0.0	0.0	20.0	80.0	0.0	0.0	0.93	5	0.02
Peach	0.0	0.0	40.0	40.0	20.0	0.0	0.93	5	0.02
Douglas fir	0.0	0.0	0.0	60.0	40.0	0.0	1.13	5	0.02
Willow: Pussy	0.0	0.0	20.0	80.0	0.0	0.0	0.93	5	0.02
Katsura tree	0.0	0.0	0.0	50.0	50.0	0.0	1.16	4	0.01
Smoketree: Common	0.0	0.0	25.0	50.0	25.0	0.0	1.00	4	0.01
American beech	0.0	0.0	0.0	50.0	50.0	0.0	1.16	4	0.01
Dawn redwood	0.0	0.0	0.0	25.0	50.0	25.0	1.33	4	0.01
Black poplar	0.0	0.0	50.0	50.0	0.0	0.0	0.83	4	0.01
White oak	0.0	0.0	0.0	50.0	50.0	0.0	1.16	4	0.01
Willow	0.0	0.0	0.0	50.0	50.0	0.0	1.16	4	0.01
European mountain	0.0	0.0	25.0	0.0	75.0	0.0	1.16	4	0.01
Arborvitae: Western	0.0	0.0	0.0	25.0	75.0	0.0	1.24	4	0.01
Balsam fir	0.0	0.0	0.0	66.7	33.3	0.0	1.11	3	0.01
European beech	0.0	0.0	0.0	33.3	66.7	0.0	1.22	3	0.01
Kentucky coffeetree	0.0	0.0	33.3	66.7	0.0	0.0	0.89	3	0.01
Pawpaw	0.0	0.0	0.0	0.0	100.0	0.0	1.33	2	0.01
Gray birch	0.0	0.0	0.0	100.0	0.0	0.0	1.00	2	0.01
Dogwood	0.0	0.0	0.0	50.0	50.0	0.0	1.16	2	0.01
Southern magnolia	0.0	0.0	0.0	50.0	50.0	0.0	1.16	2	0.01
Star magnolia	0.0	0.0	0.0	100.0	0.0	0.0	1.00	2	0.01
Spruce	0.0	0.0	0.0	50.0	50.0	0.0	1.16	2	0.01
Pine	100.0	0.0	0.0	0.0	0.0	0.0	0.00	2	0.01
Eastern cottonwood	0.0	0.0	0.0	100.0	0.0	0.0	1.00	2	0.01
Quaking aspen	0.0	0.0	50.0	50.0	0.0	0.0	0.83	2	0.01
Common pear	0.0	0.0	0.0	100.0	0.0	0.0	1.00	2	0.01
Sawtooth oak	0.0	0.0	50.0	0.0	50.0	0.0	1.00	2	0.01
Overcup oak	0.0	0.0	0.0	100.0	0.0	0.0	1.00	2	0.01
Rock elm	0.0	0.0	0.0	100.0	0.0	0.0	1.00	2	0.01
Maple: Paperback	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Pignut hickory	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Chinese chestnut	0.0	0.0	100.0	0.0	0.0	0.0	0.66	1	0.00

Relative Performance Index for Public Trees

12/10/2007

Species	Dead	Critical	Poor	Fair	Good	Very Good	RPI	# of Trees	% of Total Population
Atlas cedar	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Turkish hazelnut	0.0	0.0	0.0	100.0	0.0	0.0	1.00	1	0.00
Cornelian cherry	0.0	0.0	0.0	100.0	0.0	0.0	1.00	1	0.00
Black ash	0.0	0.0	100.0	0.0	0.0	0.0	0.66	1	0.00
European larch	0.0	0.0	100.0	0.0	0.0	0.0	0.66	1	0.00
Mulberry: spp.	0.0	100.0	0.0	0.0	0.0	0.0	0.33	1	0.00
Black tupelo	0.0	0.0	0.0	100.0	0.0	0.0	1.00	1	0.00
Royal paulownia	0.0	0.0	0.0	100.0	0.0	0.0	1.00	1	0.00
Bigtooth aspen	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Pin cherry	0.0	0.0	0.0	100.0	0.0	0.0	1.00	1	0.00
Willow oak	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Chestnut oak	0.0	0.0	0.0	100.0	0.0	0.0	1.00	1	0.00
English oak	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Weeping willow	0.0	0.0	100.0	0.0	0.0	0.0	0.66	1	0.00
Black willow	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Slippery elm	0.0	0.0	0.0	100.0	0.0	0.0	1.00	1	0.00
Elm: spp.	0.0	0.0	0.0	0.0	100.0	0.0	1.33	1	0.00
Citywide total	0.9	1.0	21.0	50.4	26.5	0.2	1.00	29,640	100.00

City of Pittsburgh, Pennsylvania

Total Number of Sidewalk Conflicts for Public Trees

12/10/2007

Zone	No	Yes	Total
01, 02, 03	1,219	79	1,298
04	989	116	1,105
05, 06	942	213	1,155
07	1,120	395	1,515
08, 09	1,346	405	1,751
10	1,169	248	1,417
11	1,176	362	1,538
12, 13	1,091	353	1,444
14	3,979	1,748	5,727
15	645	315	960
16	865	117	982
17, 18	811	372	1,183
19	1,097	376	1,473
20	966	296	1,262
21, 22	1,149	471	1,620
23, 24, 25	695	190	885
26	525	217	742
27, 28	1,156	508	1,664
29, 30	788	162	950
31, 32	896	75	971
Citywide total	22,624	7,018	29,642

City of Pittsburgh, Pennsylvania

Total Number of Sidewalk Conflicts for Public Trees

12/10/2007

Zone	No	Yes	Total

Total Percentage of Sidewalk Heave Conflicts for Public Trees

Zone	No	Yes	Total
01, 02, 03	93.9	6.1	100.0
04	89.5	10.5	100.0
05, 06	81.6	18.4	100.0
07	73.9	26.1	100.0
08, 09	76.9	23.1	100.0
10	82.5	17.5	100.0
11	76.5	23.5	100.0
12, 13	75.6	24.4	100.0
14	69.5	30.5	100.0
15	67.2	32.8	100.0
16	88.1	11.9	100.0
17, 18	68.6	31.4	100.0
19	74.5	25.5	100.0
20	76.5	23.5	100.0
21, 22	70.9	29.1	100.0
23, 24, 25	78.5	21.5	100.0
26	70.8	29.2	100.0
27, 28	69.5	30.5	100.0
29, 30	82.9	17.1	100.0
31, 32	92.3	7.7	100.0
Citywide total	76.3	23.7	100.0

City of Pittsburgh, Pennsylvania

Total Number of Overhead Utility Lines Conflicts for Public Trees

12/10/2007

Zone	No	Yes	Total
01, 02, 03	1,098	200	1,298
04	764	341	1,105
05, 06	474	681	1,155
07	524	991	1,515
08, 09	508	1,243	1,751
10	543	874	1,417
11	686	852	1,538
12, 13	663	781	1,444
14	2,127	3,600	5,727
15	265	695	960
16	473	509	982
17, 18	347	836	1,183
19	374	1,099	1,473
20	462	800	1,262
21, 22	911	709	1,620
23, 24, 25	210	675	885
26	238	504	742
27, 28	559	1,105	1,664
29, 30	364	586	950
31, 32	380	591	971
Citywide total	11,970	17,672	29,642

City of Pittsburgh, Pennsylvania

Total Number of Overhead Utility Lines Conflicts for Public Trees

12/10/2007

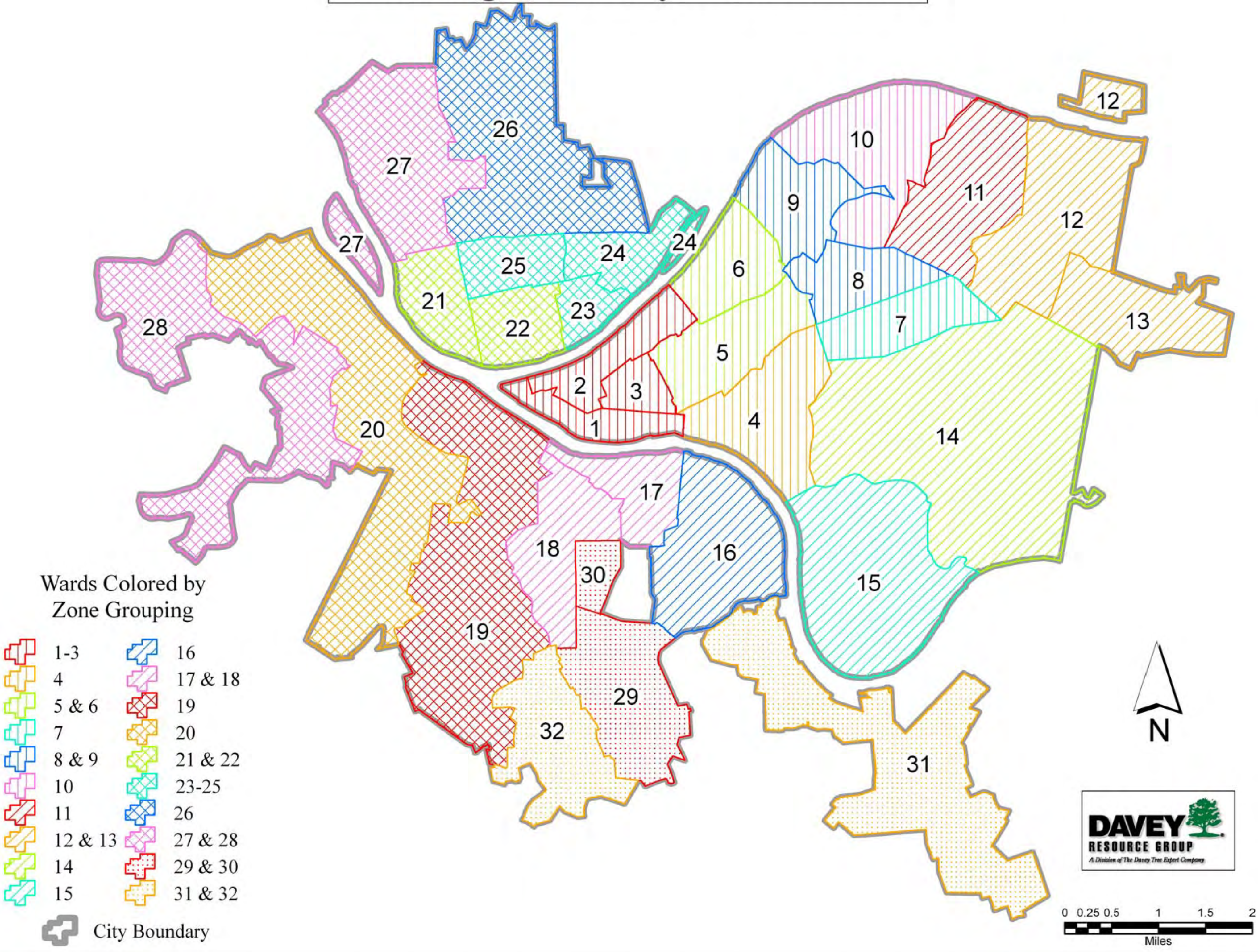
Zone	No	Yes	Total

Total Percentage of Overhead Utility Lines Conflicts for Public Trees

Zone	No	Yes	Total
01, 02, 03	84.6	15.4	100.0
04	69.1	30.9	100.0
05, 06	41.0	59.0	100.0
07	34.6	65.4	100.0
08, 09	29.0	71.0	100.0
10	38.3	61.7	100.0
11	44.6	55.4	100.0
12, 13	45.9	54.1	100.0
14	37.1	62.9	100.0
15	27.6	72.4	100.0
16	48.2	51.8	100.0
17, 18	29.3	70.7	100.0
19	25.4	74.6	100.0
20	36.6	63.4	100.0
21, 22	56.2	43.8	100.0
23, 24, 25	23.7	76.3	100.0
26	32.1	67.9	100.0
27, 28	33.6	66.4	100.0
29, 30	38.3	61.7	100.0
31, 32	39.1	60.9	100.0
Citywide total	40.4	59.6	100.0

Appendix C: STRATUM Output Reports by Ward (Zone)

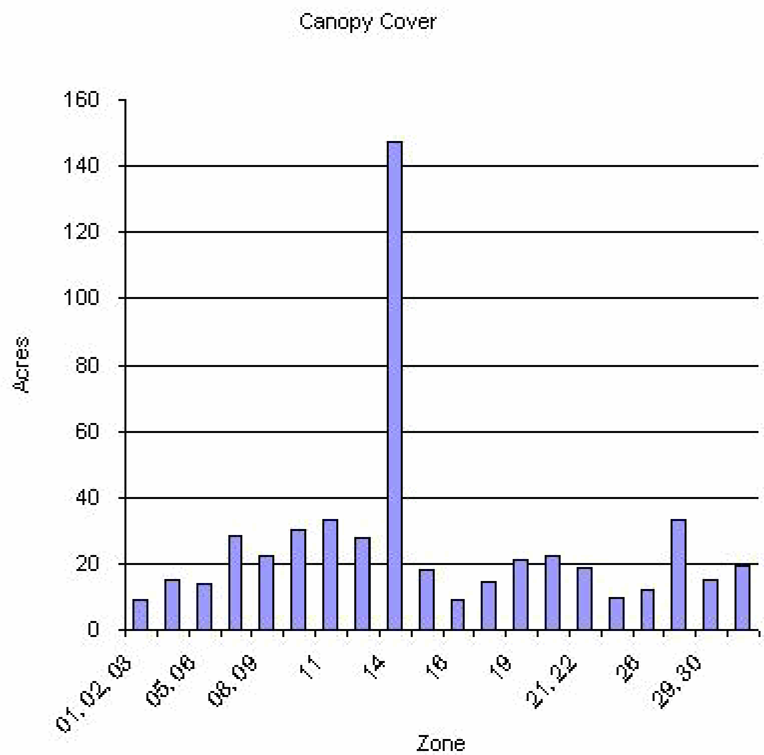
Pittsburgh, Pennsylvania Wards



City of Pittsburgh, Pennsylvania

Canopy Cover of Public Trees (Acres)

3/11/2008



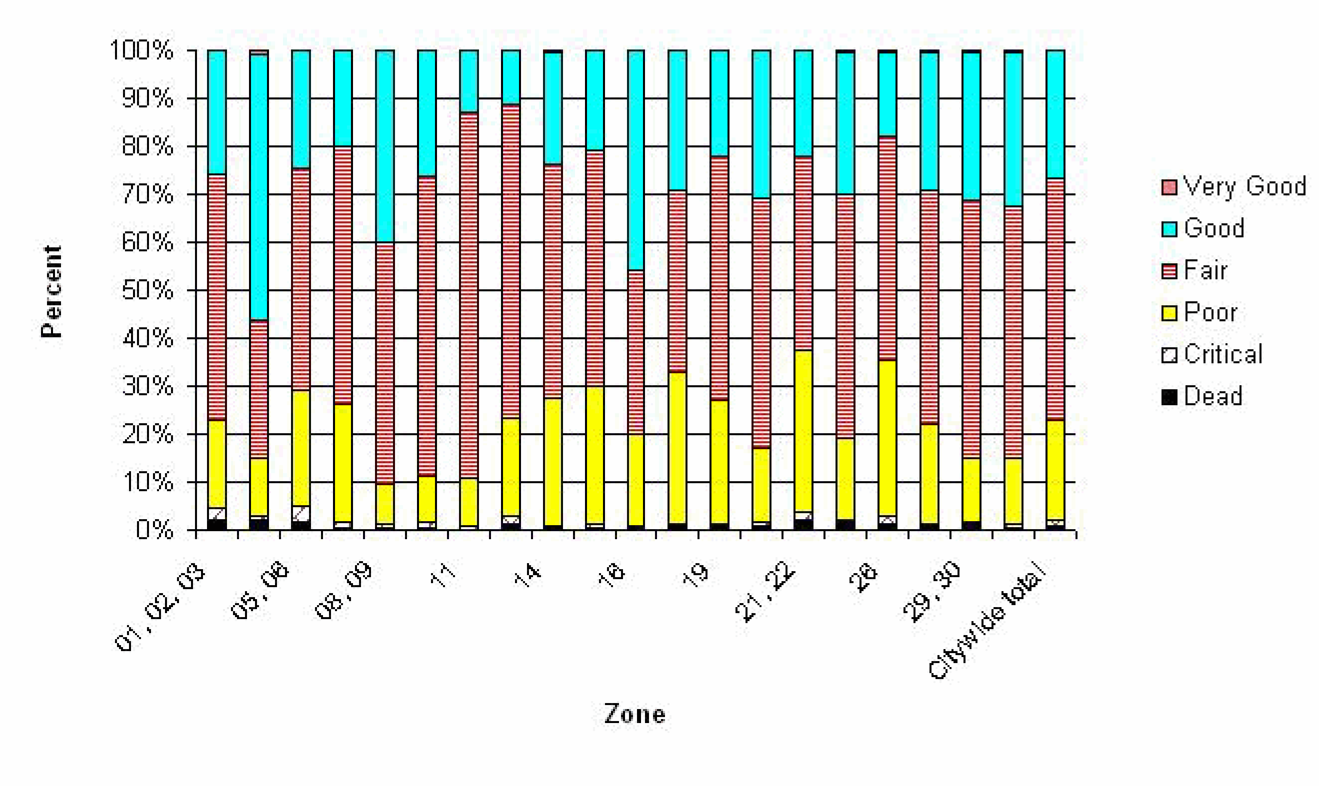
Zone	Acres	% of Total Canopy Cover
01, 02, 03	9	1.8
04	15	2.9
05, 06	14	2.7
07	28	5.4
08, 09	22	4.3
10	30	5.8
11	33	6.3
12, 13	28	5.4
14	147	28.2
15	18	3.5
16	9	1.8
17, 18	14	2.8
19	21	4.1
20	22	4.3
21, 22	19	3.6
23, 24, 25	10	1.9
26	12	2.3
27, 28	33	6.4
29, 30	15	2.9
31, 32	20	3.7
Citywide total	521	100.0

	Total Land Area	Total Street and Sidewalk Area	Total Canopy Cover	Canopy Cover as % of Total Land Area	Canopy Cover as % of Total Streets and Sidewalks
Citywide	35,200	5,461	521	1.48	9.54

City of Pittsburgh, Pennsylvania

Structural (Woody) Condition of Public Trees by Zone (%)

3/11/2008

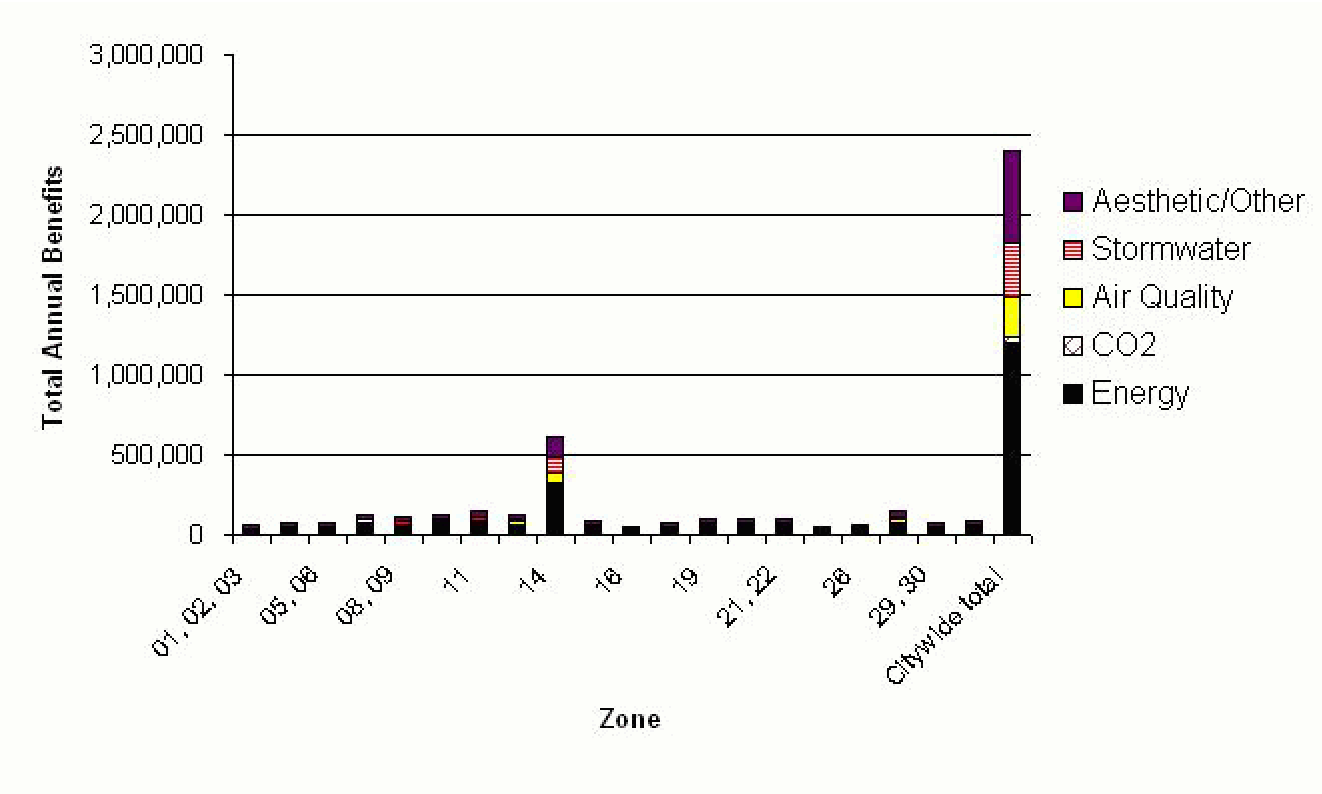


Zone	Dead	Critical	Poor	Fair	Good	Very Good
01, 02, 03	2.2	2.2	18.3	51.5	25.7	0.0
04	2.0	0.7	12.2	29.0	55.3	0.8
05, 06	1.8	3.4	24.2	46.1	24.5	0.0
07	0.3	1.4	24.4	53.8	20.1	0.1
08, 09	0.2	1.0	8.6	50.2	40.0	0.0
10	0.4	1.1	9.9	62.3	26.3	0.0
11	0.0	1.0	9.9	76.0	12.9	0.2
12, 13	1.3	1.5	20.4	65.4	11.4	0.0
14	0.3	0.6	26.6	48.6	23.6	0.3
15	0.4	0.9	28.5	49.3	20.7	0.1
16	0.7	0.2	18.9	34.1	46.0	0.0
17, 18	0.8	0.7	31.4	38.1	28.9	0.1
19	0.7	0.7	25.6	50.9	22.0	0.1
20	1.0	0.9	15.2	52.0	31.0	0.0
21, 22	1.9	1.9	33.9	40.1	22.2	0.0
23, 24, 25	1.5	0.7	17.1	50.6	29.6	0.6
26	1.3	1.6	32.5	46.6	17.4	0.5
27, 28	0.8	0.5	20.9	48.6	28.8	0.4
29, 30	1.4	0.3	13.5	53.7	30.7	0.4
31, 32	0.5	0.6	13.9	52.4	32.1	0.4
Citywide total	0.9	1.0	21.0	50.4	26.5	0.2

City of Pittsburgh, Pennsylvania

Total Annual Benefits of Public Trees by Zone ($)

3/12/2008

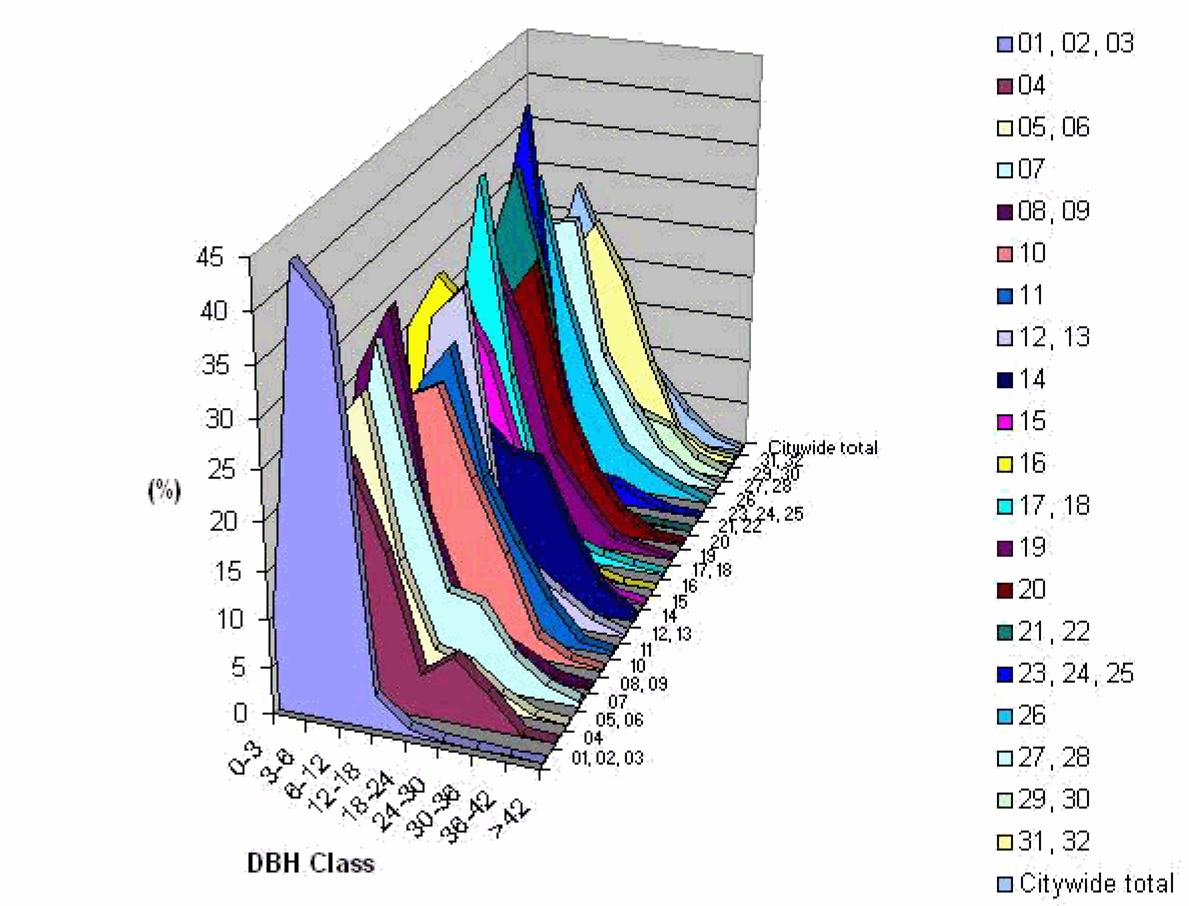


Zone	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
01, 02, 03	26,376	735	5,062	5,725	26,103	64,001	(N/A)	2.7
04	35,902	1,033	7,314	9,771	21,084	75,103	(N/A)	3.1
05, 06	33,450	946	6,842	8,760	20,809	70,807	(N/A)	2.9
07	64,663	1,957	13,616	18,291	30,839	129,366	(N/A)	5.4
08, 09	54,984	1,559	11,161	14,032	30,232	111,967	(N/A)	4.7
10	68,121	1,979	14,587	18,604	27,565	130,857	(N/A)	5.5
11	75,447	2,239	15,802	21,181	32,138	146,807	(N/A)	6.1
12, 13	66,356	1,856	13,906	18,257	28,188	128,563	(N/A)	5.4
14	313,374	9,740	67,289	95,627	125,600	611,629	(N/A)	25.5
15	42,341	1,236	9,016	11,657	18,165	82,414	(N/A)	3.4
16	23,067	630	4,731	5,854	16,137	50,419	(N/A)	2.1
17, 18	37,239	1,062	7,544	9,103	21,484	76,434	(N/A)	3.2
19	52,457	1,439	10,946	13,734	24,478	103,054	(N/A)	4.3
20	52,289	1,457	10,773	14,200	21,627	100,346	(N/A)	4.2
21, 22	49,184	1,370	9,934	12,004	32,026	104,518	(N/A)	4.4
23, 24, 25	24,673	720	5,062	6,069	15,529	52,054	(N/A)	2.2
26	29,058	884	6,098	7,780	14,478	58,299	(N/A)	2.4
27, 28	76,556	2,262	16,168	21,366	32,320	148,671	(N/A)	6.2
29, 30	35,120	1,033	7,480	10,021	16,757	70,410	(N/A)	2.9
31, 32	44,475	1,287	9,605	12,566	17,324	85,257	(N/A)	3.6
Citywide total	1,205,133	35,424	252,935	334,601	572,883	2,400,977	(N/A)	100.0

City of Pittsburgh, Pennsylvania

Relative Age Distribution of Public Tree Species for All Zones (%)

3/11/2008



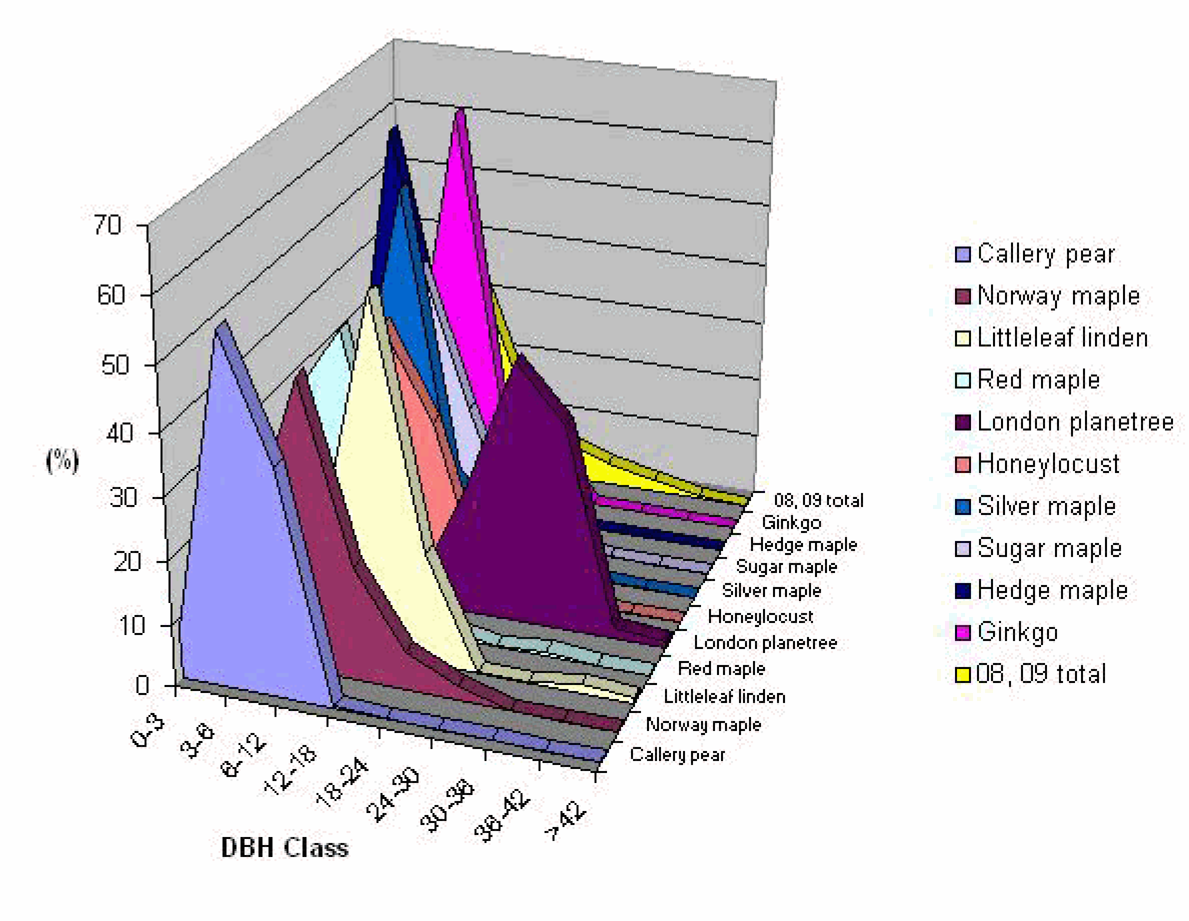
DBH class (in)

Zone	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42
01, 02, 03	10.3	44.7	40.8	3.5	0.6	0.2	0.0	0.0	0.0
04	20.4	22.5	24.9	16.4	4.4	7.1	4.0	0.3	0.1
05, 06	18.4	26.0	30.0	13.8	5.3	4.4	1.9	0.3	0.0
07	4.6	16.4	33.9	20.3	9.6	9.0	4.1	1.5	0.7
08, 09	7.6	28.8	35.7	15.2	6.2	3.8	2.1	0.4	0.1
10	3.2	12.8	25.3	27.0	17.9	10.6	2.5	0.6	0.1
11	3.4	9.8	25.3	29.6	16.6	9.9	4.4	0.8	0.3
12, 13	3.8	8.1	30.7	34.3	12.0	5.8	3.7	1.4	0.3
14	4.3	12.5	19.5	19.5	16.2	15.9	8.5	3.2	0.4
15	7.2	10.6	30.3	24.7	13.4	9.1	3.6	0.8	0.2
16	24.5	30.7	27.3	10.4	3.4	2.7	0.9	0.1	0.0
17, 18	12.8	18.3	40.1	19.2	5.8	2.0	1.1	0.5	0.2
19	13.7	16.5	30.1	22.3	9.7	5.2	1.5	0.7	0.2
20	13.1	9.5	24.1	28.9	14.2	6.9	2.6	0.6	0.2
21, 22	6.3	27.0	37.5	25.4	2.9	0.7	0.2	0.1	0.0
23, 24, 25	7.0	27.6	42.8	16.3	2.6	2.5	1.0	0.1	0.1
26	6.5	17.5	34.1	21.2	11.6	5.1	2.8	1.2	0.0
27, 28	5.7	10.2	28.1	28.8	13.7	8.3	3.7	1.4	0.2
29, 30	17.3	18.9	24.3	18.4	8.2	5.9	4.8	1.6	0.5
31, 32	7.0	11.1	21.0	26.2	19.7	10.5	3.1	0.9	0.5
Citywide total	8.6	17.9	28.7	21.2	10.8	7.7	3.7	1.2	0.2

City of Pittsburgh, Pennsylvania

Relative Age Distribution of Top 10 Public Tree Species for Zone 08, 09 (%)

3/12/2008



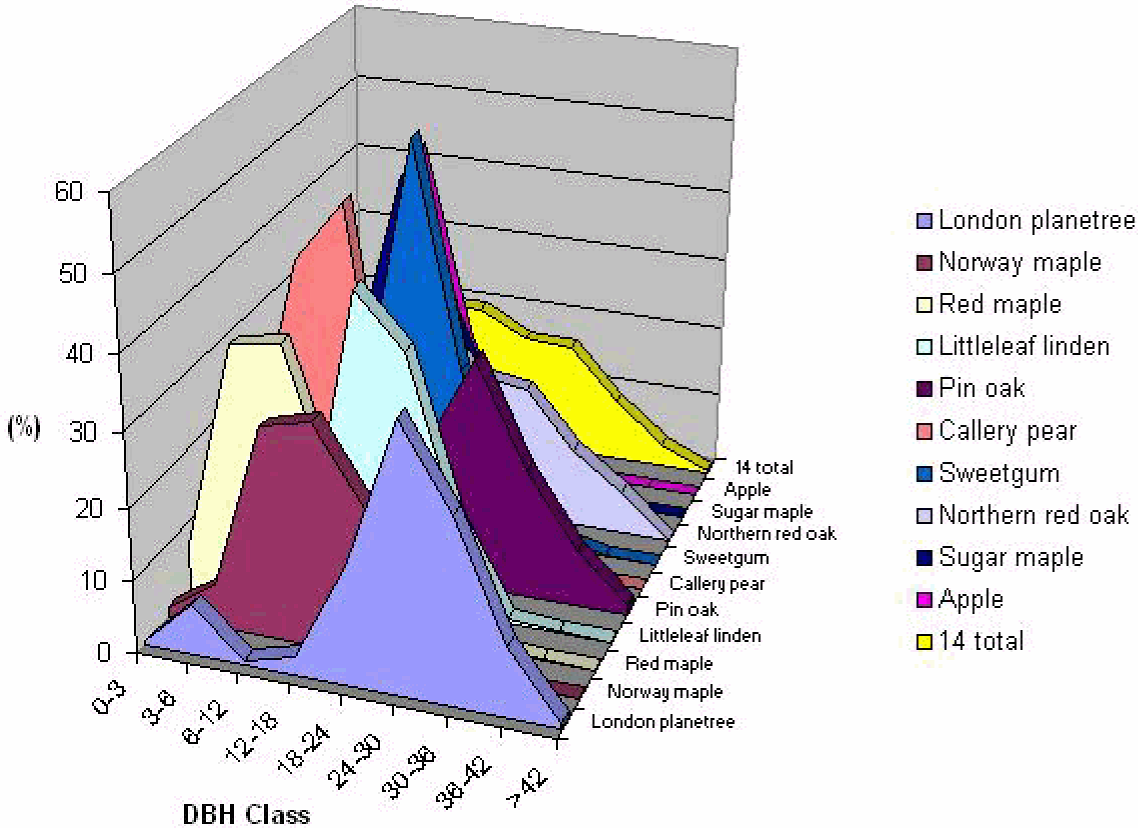
DBH class (in)

Zone	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	
Callery pear	8.0	55.4	36.3	0.3	0.0	0.0	0.0	0.0	0.0	
Norway maple	6.0	20.9	46.4	18.2	6.3	2.3	0.0	0.0	0.0	
Littleleaf linden	0.0	3.5	19.4	56.9	18.1	0.0	0.0	1.4	0.7	
Red maple	1.5	34.6	46.9	14.6	1.5	0.0	0.8	0.0	0.0	
London planetree	0.0	0.0	0.0	2.0	19.6	42.2	33.3	2.0	1.0	
Honeylocust	12.6	18.9	41.1	26.3	1.1	0.0	0.0	0.0	0.0	
Silver maple	0.0	20.2	59.6	13.8	4.3	2.1	0.0	0.0	0.0	
Sugar maple	8.0	23.9	44.3	21.6	1.1	1.1	0.0	0.0	0.0	
Hedge maple	8.2	62.3	27.9	0.0	1.6	0.0	0.0	0.0	0.0	
Ginkgo	0.0	15.5	63.8	12.1	8.6	0.0	0.0	0.0	0.0	
08, 09 total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00

City of Pittsburgh, Pennsylvania

Relative Age Distribution of Top 10 Public Tree Species for Zone 14 (%)

3/12/2008



				DBH class (in)						
Zone	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	
London planetree	0.5	6.9	0.6	2.7	16.4	36.6	25.6	9.7	1.0	
Norway maple	1.6	6.1	28.9	30.7	20.6	10.3	1.7	0.1	0.0	
Red maple	6.9	35.6	36.7	17.0	2.6	1.0	0.2	0.0	0.0	
Littleleaf linden	0.7	2.4	6.4	42.1	35.0	12.8	0.5	0.2	0.0	
Pin oak	1.0	2.9	4.7	13.1	18.8	31.9	18.1	7.9	1.6	
Callery pear	9.5	38.5	47.3	4.2	0.4	0.0	0.0	0.0	0.0	
Sweetgum	0.0	0.5	18.0	54.4	23.3	2.4	1.5	0.0	0.0	
Northern red oak	1.5	1.0	16.5	26.0	19.5	18.5	11.0	6.0	0.0	
Sugar maple	1.2	17.4	43.5	25.5	9.9	1.9	0.6	0.0	0.0	
Apple	12.2	23.7	45.0	18.3	0.8	0.0	0.0	0.0	0.0	
14 total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00

City of Pittsburgh, Pennsylvania

Replacement Value for Public Trees by Zone

12/7/2007

	DBH Class (in)											
Zone	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error	% of Total
01, 02, 03	20,727	263,849	769,417	189,397	69,742	22,379	0	0	0	1,335,512	(±0)	0.98
04	30,894	112,465	418,697	797,365	462,221	1,238,814	1,014,282	86,087	38,948	4,199,774	(±0)	3.07
05, 06	31,298	137,478	496,235	672,586	446,805	694,792	402,546	88,192	0	2,969,933	(±0)	2.17
07	12,047	115,747	769,050	1,354,758	1,204,758	1,740,380	1,236,566	537,195	297,294	7,267,795	(±0)	5.32
08, 09	22,712	220,093	930,859	1,276,905	1,050,965	1,057,949	916,320	246,774	66,440	5,789,016	(±0)	4.24
10	7,073	79,343	532,610	1,786,648	2,287,125	2,230,223	777,249	309,286	97,212	8,106,769	(±0)	5.94
11	9,025	71,417	637,814	2,263,844	2,367,089	2,379,253	1,639,780	399,255	155,791	9,923,268	(±0)	7.27
12, 13	9,297	52,524	738,158	2,257,781	1,327,922	1,041,586	1,094,320	535,629	155,791	7,213,007	(±0)	5.28
14	40,071	338,006	1,746,759	4,971,415	7,634,057	12,498,513	10,209,504	5,091,303	615,337	43,144,964	(±0)	31.59
15	12,393	47,672	430,305	986,816	980,223	923,836	554,909	172,614	43,715	4,152,484	(±0)	3.04
16	33,723	139,695	408,426	383,779	280,235	377,297	179,495	17,580	0	1,820,231	(±0)	1.33
17, 18	26,042	97,600	715,285	950,887	491,566	220,337	219,589	155,888	58,579	2,935,774	(±0)	2.15
19	32,723	106,986	702,527	1,385,498	1,157,941	990,840	392,132	274,334	97,527	5,140,509	(±0)	3.76
20	28,312	52,742	474,270	1,654,829	1,509,911	1,164,003	747,040	206,281	39,263	5,876,652	(±0)	4.30
21, 22	17,258	204,955	916,898	1,723,386	409,406	177,248	46,469	24,596	0	3,520,216	(±0)	2.58
23, 24, 25	10,541	108,424	593,833	618,917	137,109	221,361	142,772	26,212	3,446	1,862,616	(±0)	1.36
26	8,545	58,800	357,054	653,775	558,193	463,143	410,289	217,390	0	2,727,187	(±0)	2.00
27, 28	16,295	75,634	716,713	2,071,340	1,949,365	1,823,673	1,134,456	526,148	99,930	8,413,554	(±0)	6.16
29, 30	28,460	82,733	361,872	792,081	704,752	806,219	1,067,025	489,875	131,016	4,464,034	(±0)	3.27
31, 32	11,462	49,954	295,481	1,057,663	1,731,872	1,506,537	629,842	248,798	183,284	5,714,894	(±0)	4.18
Citywide total	408,899	2,416,116	13,012,263	27,849,668	26,761,257	31,578,384	22,814,588	9,653,439	2,083,575	136,578,189	(±0)	100.00

City of Pittsburgh, Pennsylvania

Species Distribution for the Five Most Abundant Species of Public Trees

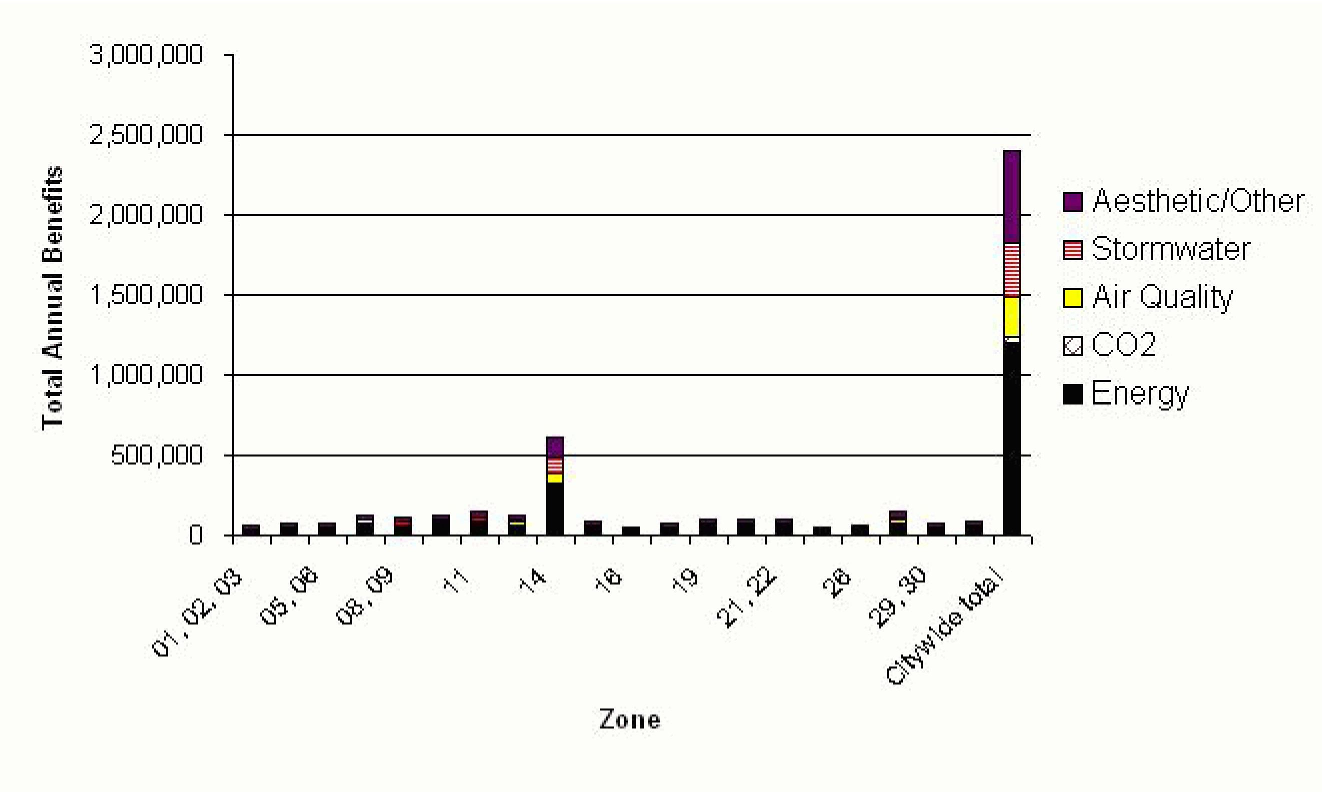
2/8/2008

Zone	1st (%)	2nd (%)	3rd (%)	4th (%)	5th (%)	# of Trees
01, 02, 03	Callery pear (35.2)	Honeylocust (20.1)	Japanese zelkova (8.2)	London planetree (6.7)	Red maple (6.1)	1,298
04	Littleleaf linden (16.4)	London planetree (14.9)	Callery pear (14.3)	Red maple (11)	Honeylocust (10)	1,105
05, 06	Callery pear (18.7)	Red maple (12.6)	Norway maple (11.9)	Honeylocust (10.6)	Littleleaf linden (10)	1,155
07	Norway maple (14.1)	Littleleaf linden (12.3)	Red maple (11)	Callery pear (9.9)	Sugar maple (7.4)	1,515
08, 09	Callery pear (22)	Norway maple (17.2)	Littleleaf linden (8.2)	Red maple (7.4)	London planetree (5.8)	1,751
10	Norway maple (18.3)	Littleleaf linden (13.9)	Honeylocust (11.4)	Callery pear (8.5)	Red maple (8.2)	1,417
11	Littleleaf linden (17.9)	Norway maple (15.7)	Red maple (13.9)	London planetree (11.6)	Callery pear (9.9)	1,538
12, 13	Littleleaf linden (17.9)	Norway maple (16.1)	Red maple (12.8)	Black locust (6.2)	Sweetgum (5.5)	1,444
14	London planetree (21.6)	Norway maple (15.4)	Red maple (10.6)	Littleleaf linden (9.6)	Pin oak (6.7)	5,726
15	Norway maple (22.1)	Littleleaf linden (15.7)	Red maple (12.3)	Pin oak (9.1)	Callery pear (6)	960
16	Red maple (14.9)	Callery pear (14.1)	Honeylocust (11.7)	London planetree (10.7)	Norway maple (10.2)	982
17, 18	Norway maple (19.9)	Callery pear (18.2)	Red maple (10.7)	Littleleaf linden (10.6)	Maple: Freeman (6.3)	1,183
19	Norway maple (20)	Red maple (12.5)	Littleleaf linden (10.4)	Callery pear (9.2)	Sugar maple (5.5)	1,473
20	Norway maple (14.4)	Littleleaf linden (12.4)	Red maple (9.4)	Sweetgum (9.3)	Callery pear (7.4)	1,262
21, 22	Red maple (25.3)	Callery pear (15.4)	Littleleaf linden (14.4)	Honeylocust (14.2)	Norway maple (10.9)	1,620
23, 24, 25	Norway maple (21.6)	Callery pear (20.9)	Littleleaf linden (13.8)	Red maple (8.7)	Silver maple (7.3)	885
26	Norway maple (29.1)	Red maple (10.8)	Callery pear (8.9)	London planetree (5.4)	Littleleaf linden (5)	742
27, 28	Norway maple (23.8)	Red maple (11.5)	Littleleaf linden (7.8)	Callery pear (7.5)	London planetree (7.2)	1,664
29, 30	Norway maple (13.9)	Red maple (10.1)	London planetree (10.1)	Callery pear (7.2)	Honeylocust (6.2)	950
31, 32	Norway maple (13.4)	Ginkgo (9.6)	Spruce: Colorado (7.4)	Littleleaf linden (6.2)	Red maple (5.9)	971
Citywide total	Norway maple (15.7)	Red maple (11.4)	Callery pear (11.3)	Littleleaf linden (10.9)	London planetree (8.6)	29,641

City of Pittsburgh, Pennsylvania

Total Annual Benefits of Public Trees by Zone ($)

12/7/2007



Zone	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
01, 02, 03	26,376	735	5,062	5,725	26,103	64,001	(N/A)	2.7
04	35,902	1,033	7,314	9,771	21,084	75,103	(N/A)	3.1
05, 06	33,450	946	6,842	8,760	20,809	70,807	(N/A)	2.9
07	64,663	1,957	13,616	18,291	30,839	129,366	(N/A)	5.4
08, 09	54,984	1,559	11,161	14,032	30,232	111,967	(N/A)	4.7
10	68,121	1,979	14,587	18,604	27,565	130,857	(N/A)	5.5
11	75,447	2,239	15,802	21,181	32,138	146,807	(N/A)	6.1
12, 13	66,356	1,856	13,906	18,257	28,188	128,563	(N/A)	5.4
14	313,374	9,740	67,289	95,627	125,600	611,629	(N/A)	25.5
15	42,341	1,236	9,016	11,657	18,165	82,414	(N/A)	3.4
16	23,067	630	4,731	5,854	16,137	50,419	(N/A)	2.1
17, 18	37,239	1,062	7,544	9,103	21,484	76,434	(N/A)	3.2
19	52,457	1,439	10,946	13,734	24,478	103,054	(N/A)	4.3
20	52,289	1,457	10,773	14,200	21,627	100,346	(N/A)	4.2
21, 22	49,184	1,370	9,934	12,004	32,026	104,518	(N/A)	4.4
23, 24, 25	24,673	720	5,062	6,069	15,529	52,054	(N/A)	2.2
26	29,058	884	6,098	7,780	14,478	58,299	(N/A)	2.4
27, 28	76,556	2,262	16,168	21,366	32,320	148,671	(N/A)	6.2
29, 30	35,120	1,033	7,480	10,021	16,757	70,410	(N/A)	2.9
31, 32	44,475	1,287	9,605	12,566	17,324	85,257	(N/A)	3.6
Citywide total	1,205,133	35,424	252,935	334,601	572,883	2,400,977	(N/A)	100.0

Appendix D: References

Akbari H, Davis S, Dorsano S, Huang J, Winnett S, editors. 1992. Cooling our communities: a guidebook on tree planting and light-colored surfacing. Washington, DC: U.S. Environmental Protection Agency. 26 p.

American Lung Association. 2005. State of the Air 2005. New York City, NY: American Lung Association National Headquarters. 223 p.

Ames D. 2006. Personal Communication. President, Friends of the Pittsburgh Urban Forest, Pittsburgh, PA 15206.

Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. 2004. Ozone and short-term mortality in 95 US urban communities, 1987-2000. J Amer Med Assoc 292:2372-2378.

Chandler TJ. 1965. The Climate of London. London: Hutchinson.

Clark JR, Matheny NP, Cross G, Wake V. 1997. A model of urban forest sustainability. J Arbor 23(1):17-30.

CTLA. 1992. Guide for Plant Appraisal. 8th ed. Savoy, IL: ISA. 103 p.

Cullen S. 2002. Tree appraisal: can depreciation factors be rated greater than 100%? J Arbor 28(3):153-158.

Davey Resource Group. 2005. Tree Inventory and Management Plan: Pittsburgh, Pennsylvania. Davey Resource Group, Kent, OH.

Ernst M, Corless J, Greene-Roesel R. 2003. Clearing the Air. Washington, D.C.: Surface Transportation Policy Project. 67 p.

Forbes. 2007. Which are the World's Cleanest Cities? http://www.forbes.com/2007/04/16/worlds-cleanest-cities-biz-logistics-cx_rm_0416cleanest.html. (November 2007)

Gable M. 2006. Personal Communication. Deputy Director, Department of Public Works, City of Pittsburgh, Pittsburgh, PA 15219.

Heinrichs AM [Gruszka P]. 2007. Destructive Asian insect found in Cranberry. Pittsburgh Tribune-Review [Internet] [cited 2008 Feb 12]; para 15. Available from: http://www.pittsburghlive.com/x/pittsburghtrib/news/mostread/s_514585.html

Heisler GM. 1986. Energy savings with trees. J Arbor 12(5):113–125.

Jahn D. 2005. Personal Communication. City Forester, City of Pittsburgh Forestry Division, Pittsburgh, PA 15206.

Maco SE, McPherson EG. 2002. Assessing canopy cover over streets and sidewalks in street tree populations. J Arbor 28(6):270-276.

Maco SE, McPherson EG. 2003. A practical approach to assessing structure, function, and value of street tree populations in small communities. J Arbor 29(2):84-97.

Majors D [Wolff D]. 2007. Ash trees in danger of disappearing in Pa. post-gazette NOW. Pittsburgh Post-Gazette [Internet] [cited 2008 Feb 12]; para.5. Available from: http://www.post-gazette.com/pg/07180/798152-100.stm

McPherson EG, Muchnick J. 2005. Effects of street tree shade on asphalt concrete pavement performance. Journal of Arboriculture 31(6): 303–310.

McPherson EG, Rowntree RA. 1989. Using structural measures to compare twenty two U.S. street tree populations. Land J 8:13-23.

McPherson EG. 1993. Evaluating the cost effectiveness of shade trees for demand-side management. Elec J 6(9):57-65.

McPherson EG, Simpson JR, Peper PJ, Maco S, Xiao Q. 2005a. City of Minneapolis, Minnesota, municipal forest resource analysis. Internal Tech Rep. Davis, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research. 46 p.

McPherson EG, Simpson JR, Peper PJ, Gardner SL, Vargas KE, Ho J, Maco S, Xiao Q. 2005b. City of Charleston, South Carolina, municipal forest resource analysis. Internal Tech Rep. Davis, CA: U.S. Department of Agriculture, Center for Urban Forest Research. 57 p.

McPherson EG, Simpson JR, Peper PJ, Gardner SL, Vargas KE, Ho J, Maco S, Xiao Q. 2005c. City of Charlotte, North Carolina, municipal forest resource analysis. Internal Tech Rep. Davis, CA: U.S. Department of Agriculture, Center for Urban Forest Research. 57 p.

McPherson EG, Simpson JR, Peper PJ, Gardner SL, Vargas KE, Ho J, Maco S, Xiao Q. 2006. City of Charleston, South Carolina, Municipal Tree Resource Analysis. Internal Tech Rep. Davis, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research. 57 p.

McPherson EG, Simpson JR, Peper PJ, Gardner SL, Vargas KE, Xiao Q. 2007. Northeast Community Tree Guide: Benefits, Costs and Strategic Planting. General Tech Rep. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research. 121 p.

Miller RW. 1997. Urban forestry: planning and managing urban greenspaces. 2nd ed.

Upper Saddle River: Prentice-Hall. 502 p.

Moll G, Kollin C. 1993. A new way to see our city forests. American Forests 99(9-10): 29-31.

Peper PJ, McPherson EG, Simpson JR, Gardner SL, Vargas KE, Xiao Q. 2007. New York City, New York, Municipal Tree Resource Analysis. Tech Rep. New York City, NY: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research. 72 p.

Richards NA. 1982/83. Diversity and stability in a street tree population. Urban Ecology. 7: 159–171.

Savageau D. 2007. Places Rated Almanac: Your Guide to Finding the Best Places to Live in America. 7th ed. Washington, DC: Places Rated Books LLC; 601 pp.

Simpson JR. 1998. Urban forest impacts on regional space conditioning energy use: Sacramento County case study. Journal of Arboriculture. 24(4): 201–214.

U.S. Census Bureau. 2003. http://quickfacts.census.gov/qfd/states/42/4261000.html (November, 2007)

Watson G. 2002. Comparing formula methods of tree appraisal. Journal of Arboriculture. 28(1): 11-18.

Williams E, Lotstein R, Galik C, Knuffman H. 2007. A Convenient Guide to Climate Change Policy and Technology. Vol 2: 134 p.

Wolf KL. 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, DC: American Forests: 56–59.

Appendix E: Additional Resources

Information provided in this report is the result of a STRATUM (Street Tree Resource Analysis Tool for Urban Forest Managers) analysis of Pittsburgh's street tree resource. Data used for this analysis were obtained from the City of Pittsburgh's street tree inventory. STRATUM generates a variety of reports detailing annual benefits, management costs, replacement value, and structural analyses. Inventory data and all STRATUM reports are included on the attached CD. STRATUM is a computer-based tool found within the i-Tree software suite (i-Tree Cooperative, 2006). Additional information concerning i-Tree can be found at www.itreetools.org.

This report is based on the entire series of *Municipal Forest Resource Analysis* reports prepared and published by the USDA Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research. These reports are companions to the regional *Tree Guides* and i–Tree's STRATUM application developed by the USDA Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research and can be found at www.fs.fed.us/psw/programs/cufr/.