Resource Analysis
of Inventoried Street Trees

Spokane, WA

June 2013

DAVEY
RESOURCE GROUP
A Division of The Davey Tree Expert Company

City of Spokane
Street Tree
Resource Analysis

June 2013

Prepared for:

City of Spokane
Parks and Recreation Department
Urban Forestry Division
808 W Spokane Blvd
Spokane, WA, 99201
Phone: 509-363-5495

Prepared by:

Davey Resource Group
A Division of the Davey Tree Expert Company
7627 Morro Road
Atascadero, California 93422
Phone: 805-461-7500
Toll Free: 800-966-2021
Fax: 805-461-8501
www.davey.com/drg

Acknowledgements:

While the specific reports and recommendations can be attributed 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.

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A healthy urban forest plays an important role in the quality of life in Spokane

Executive Summary

Trees play a vital role in the community of Spokane, Washington. They provide numerous benefits both tangible and intangible, to residents, visitors, and neighboring communities. Dedicated to managing over 76,000 trees in the city, Spokane has demonstrated that street trees are a valued community resource, an important component of the urban infrastructure, and a part of the city's identity.

With an interest in enhancing the management of their urban forest, Spokane contracted with Davey Resource Group (DRG) in 2012 to collect an inventory of street trees. Upon completion of the inventory, DRG developed a detailed and quantified analysis of the current structure, function, and value of this tree resource using the inventory data in conjunction with i-Tree benefit-cost modeling software.

The analysis estimates that Spokane's street tree population is providing annual benefits of $4,044,229 ($19.25 per capita). These benefits include energy savings, air quality improvements, stormwater interception, atmospheric CO2 reduction, and aesthetic contributions to the social and economic health of the community.

Spokane's street tree resource is reducing annual electric energy consumption by 6,549 megawatt hours (MWh) and annual natural gas consumption by 224,007 therms, for a combined value of $714,302 annually. In addition, these trees are removing 61,149 pounds of pollutants from the air, including ozone (O3), nitrogen dioxide (NO2), and particulates (PM10) for an overall annual air quality net benefit of $113,296. Canopy from this population covers 1,127 acres. It is reducing annual stormwater runoff volume by 58 million gallons, protecting local water resources by reducing sediment and pollution loading.

Spokane invests approximately $466,000 ($2.22 per capita) each year to provide care for these trees. As a result, the community realizes an overall net benefit of $3,578,229. In other words, for every $1 spent on public trees, the residents of Spokane receive $7.68 in benefits.

Trees are one community asset that, with proper maintenance, has the potential to increase in value over time. The City's ongoing commitment to maximizing and maintaining the benefits from its urban forest will ensure that the community continues to enjoy a high quality of life as the "City of Choice" in the Pacific Northwest.

Introduction

Background

Spokane is located in Eastern Washington. With an estimated population of 210,103 it is the largest city in the area. Spokane's economy has traditionally been based on natural resources such as mining, timber and agriculture. With a commitment to conserving its natural resources, the City has invested in managing over 76,533 street trees.

Individual trees and a healthy urban forest play important roles in the quality of life and the sustainability of Spokane's environment. Research has demonstrated that healthy urban trees can improve the local environment and lessen the impact resulting from urbanization and industry (CUFR). Trees improve air quality by manufacturing oxygen and absorbing carbon dioxide (CO_2), as well as filtering and reducing airborne particulate matter such as smoke and dust. Urban trees reduce energy consumption by shading structures from solar energy and reducing the overall rise in temperature created through urban heat island effects (EPA). Trees slow and reduce stormwater runoff, helping to protect critical waterways from excess pollutants and particulates. In addition, urban trees provide critical habitat for wildlife and promote a connection to the natural world for residents.

In addition to these direct improvements, healthy urban trees increase the overall attractiveness of a community and have been proven to increase the value of local real estate by 7% to 10%, as well as promoting shopping, retail sales, and tourism (Wolf, 2007). Trees support a more livable community, fostering psychological health and providing residents with a greater sense of place (Ulrich, 1986; Kaplan, 1989). Community trees, both public and private, soften the urban hardscape by providing a green sanctuary and making Spokane a more enjoyable place to live, work, and play. The City has 76,553 street trees playing a prominent role in the urban forest benefits afforded to the community. Spokane residents rely on the City's Parks and Recreation Department staff to enhance and protect this vital resource.

Reflecting appreciation, concern, and a proactive stance on the management of public trees, the City sponsored a project in 2012 for Davey Resource Group (DRG) to conduct an inventory of public trees along the City's rights-of-way. A team of ISA Certified

Spokane residents rely on the City to enhance and protect the urban forest.

An urban forest is a living and dynamic resource, changing over time and in constant response to its environment.

Arborists mapped the location and collected data of publicly owned trees using global positioning system (GPS) technology. The resulting inventory data is being maintained by the City's urban forestry staff using an existing urban forest management software system.

Report Purpose and Use

The purpose of the urban forest resource analysis and report is to provide information on the structure, function, and value of a specific tree resource. From this information, managers and citizens alike can make informed decisions about tree management strategies. This report provides the following information:

- A description of the current structure of Spokane's inventoried tree resource and an established benchmark for future management decisions.
- A quantified value of the environmental benefits provided by Spokane's inventoried trees, illustrating the relevance and relationship of the resource to local quality of life issues such as air quality, environmental health, economic development, and psychological health.
- Data that may be used by resource managers in the pursuit of alternative funding sources and collaborative relationships with utility purveyors, non-governmental organizations, air quality districts, federal and state agencies, legislative initiatives, or local assessment fees.
- Benchmark data that can be used in the development of a long-term urban forest management plan.

Urban Forest Resource Summary

Summary of Structure

Spokane's inventoried urban forest resource includes 76,553 street trees. A structural analysis is the first step towards understanding the benefits provided by these trees as well as their management needs. Upon examination of species composition, diversity, age distribution, condition, canopy coverage, and replacement value, DRG determined that the following information characterizes the inventoried tree resource:

- A total of 97 distinct tree species were identified in the inventory. The predominant tree species are Norway maple (*Acer platanoides*, 18.5%) and ponderosa pine (*Pinus ponderosa, 9.01%*).
- The age structure of the inventoried tree population is pretty close to ideal, with 40% of trees measuring between 0 to 6 inches DBH (diameter at breast height, measured 4'6" above the ground) and 59% under 12 inches DBH.
- The majority of the inventoried trees (91%) were determined to be in good condition, with an additional 7% graded as fair.
- The inventoried tree population has stored 59,622 tons of carbon (CO2), valued at approximately $393,508.
- Replacement of Spokane's 76,553 inventoried trees with trees of similar size, species, and condition would cost approximately $279.7million.

Replacement of Spokane's 76,553 inventoried trees with trees of similar size, species, and condition would cost nearly $280 million.

Summary of Benefits

Annually, Spokane's inventoried street trees provide cumulative benefits to the community at an average value of $52.83 per tree, for a total gross value of $4,044,229 per year. These trees are providing the following substantial annual benefits to the City:

- Trees reduce electricity and natural gas use through shading and climate effects; a benefit totaling $714,302, an average of $9.33 per tree.
- They sequester 4,300 tons of atmospheric CO2 per year. An additional 7,500 tons are avoided through decreased energy use, resulting in a net value of $75,778 and an average of $0.99 per tree.
- Although a few species are emitting low levels of biogenic volatile organic compounds (BVOCs), the positive benefits to deposition of atmospheric pollutants results in an air quality benefit of $113,296 annually or $1.48/tree.
- The inventoried trees intercept 58 million gallons of stormwater annually for a total value of $290,602 per year, an average of $3.80 per tree.
- Property value increases, aesthetics, and socioeconomic value added amount to $2,850,251, an average of $37.23 per tree.

A structural pruning program for young and establishing trees promotes healthy structure, extends life expectancy, and reduces future costs and liability.

Urban Forest Resource Management

Spokane's public tree population is a dynamic resource that requires continued investment to maintain and extend its full benefit potential. **These community trees are one of the few assets that have the potential to increase in value with time and proper management.** Appropriate and timely tree care can substantially increase lifespan, preserving the higher benefit stream that results from a mature community forest. As individual trees continue to mature, aging trees are replaced and stocking levels increase, increasing the overall value of the community forest and the amount of benefits provided. This vital, living resource is, however, vulnerable to a host of stressors and requires ecologically sound and sustainable best management practices to ensure a continued flow of benefits for future generations. With the benefit of a relatively young urban forest in good condition, Spokane can focus resources on maximizing the flow of benefits from the current tree population and maintaining a forward thinking approach. Based on the resource analysis, Davey Resource Group recommends the following:

- Spokane has an excellent age class distribution that can be maintained by continuing to plant new trees to promote long-term resource sustainability and greater canopy coverage. Focus on medium to large-stature trees where conditions are sustainable to maximize benefits.
- Maximize the benefits of the existing tree resource through comprehensive tree maintenance and a cyclical pruning schedule.
- Continue to provide a structural pruning program for young and establishing trees to promote healthy structure, extend life expectancy, and reduce future costs and liability.

The value of Spokane's inventoried tree resource could grow as existing trees mature and new trees are planted. As the resource grows, investment in management is critical to ensuring that residents will continue receiving a high return on investment in the future. It is not as simple as planting more trees to increase canopy cover and benefits. Planning and funding for tree care and tree management must complement planting efforts in order to ensure the long-term success and health of Spokane's urban forest. Existing mature trees should be maintained and protected whenever possible since the greatest benefits accrue from the continued growth and longevity of the existing canopy. Spokane

can take pride in knowing that trees improve the quality of life in the city.

This urban forest resource analysis and report, based on the current inventory of street trees, defines the population and structure of Spokane's public urban forest and quantifies the benefits of that resource. The analysis focuses solely on a subset of publicly owned, City-managed street trees, using i-Tree *Streets* to establish baseline information on the value to the community. This report and the included analysis, which is unique to Spokane, effectively estimates and quantifies the value of these public tree assets in regards to actual benefits derived from this resource. In addition, the report provides a baseline analysis that can be utilized when creating, implementing, and updating an urban forest management plan, determining where best to focus available resources and setting benchmarks for measuring progress. An urban forest resource analysis provides information on the structure, function, and value of the urban forest and its assets so that forest managers and citizens alike can make informed decisions about budgetary support and management priorities. This report provides the following information:

- A description of the current structure of Spokane's street trees, establishing a benchmark for future management decisions.
- A quantified value of the environmental benefits provided by the tree inventory, illustrating 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.
- Quantified data that may be used by forest resource managers in the pursuit of alternative funding sources and collaborative relationships with utility managers, non-profit organizations, air quality districts, federal and state agencies, legislative initiatives, and/or in establishing or updating local assessment fees.
- Benchmark data that can be used in the development of a long-term urban and community forest management plan.

Maintaining an appropriate age distribution by planting new trees and focusing on large-stature trees will help maximize future urban forest benefits to the community.

Resource Analysis

An urban forest is a living and dynamic resource, changing over time and in constant response to its environment. The health and stability of the urban forest can be influenced by many factors, including pruning, irrigation, climate fluctuations, emerging pests and disease, as well as development, and new tree planting. In addition, the availability of funds for routine and emergency maintenance often fluctuates over time. Given these variables, an understanding of the current structure, species distribution, and maintenance needs is essential to making the best possible management decisions. Analysis of current inventory data provides a comprehensive view of the status of Spokane's street trees.

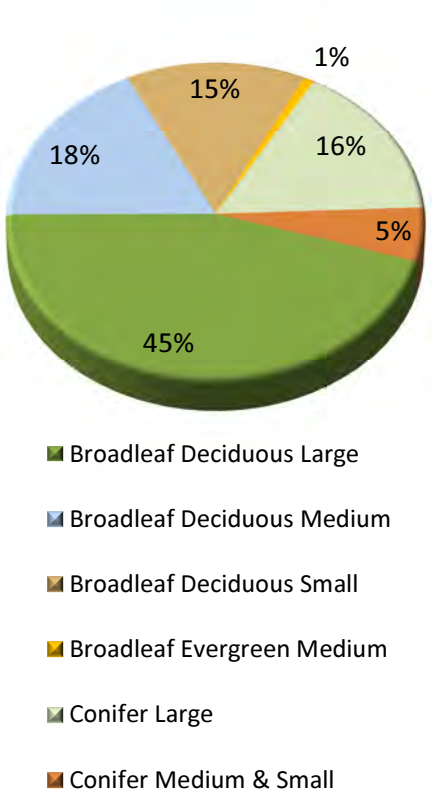


Figure 1 Composition of the street trees in Spokane

Composition

Broadleaf hardwood species dominate Spokane's tree population, comprising 78.4% of the total inventory. Broadleaf trees typically have larger canopies than coniferous trees of the same size DBH. Since many of the measurable benefits derived from trees are directly related to leaf surface area in the canopy, broadleaf trees generally provide the highest level of benefits to a community. Larger-statured broadleaf tree species provide greater benefits than smaller-statured trees, independent of diameter (DBH). Deciduous broadleaf species make up 77.6% of Spokane's street tree population, including 45.2% large-stature, 17.8% medium-stature, and 14.6% small-stature trees.

Species Richness and Diversity

Spokane's street tree population includes a mix of more than 97 unique species, far greater 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.

The top ten species represent 56% of the total population (Figure 2 and Table 1). There is a widely accepted rule that no single species should represent greater than 10% of the total population, while no single genus more than 20% (Clark Et al, 1997). Norway maple (*Acer platanoides*, 18.5%) is the only overrepresented species, and the maple genus (*Acer spp.*) comprises 30% of the urban forest. A complete population summary can be found in Appendix C: Inventory Data.

Maintaining a diverse population within an urban forest is important. Dominance of any single species or genus can have detrimental consequences in the event of storms, drought, disease, pests, or other stressors that can severely affect an urban forest and the flow of benefits and costs over time. Catastrophic pathogens, such as Dutch Elm Disease (*Ophiostoma ulmi)*, Emerald Ash Borer (*Agrilus planipennis*), Asian Longhorned Beetle (*Anoplophora glabripennis*), and Sudden Oak Death (SOD) (*Phytophthora ramorum*) are some examples of unexpected, devastating, and costly pests and pathogens that highlight the importance of diversity and the balanced distribution of species and genera.

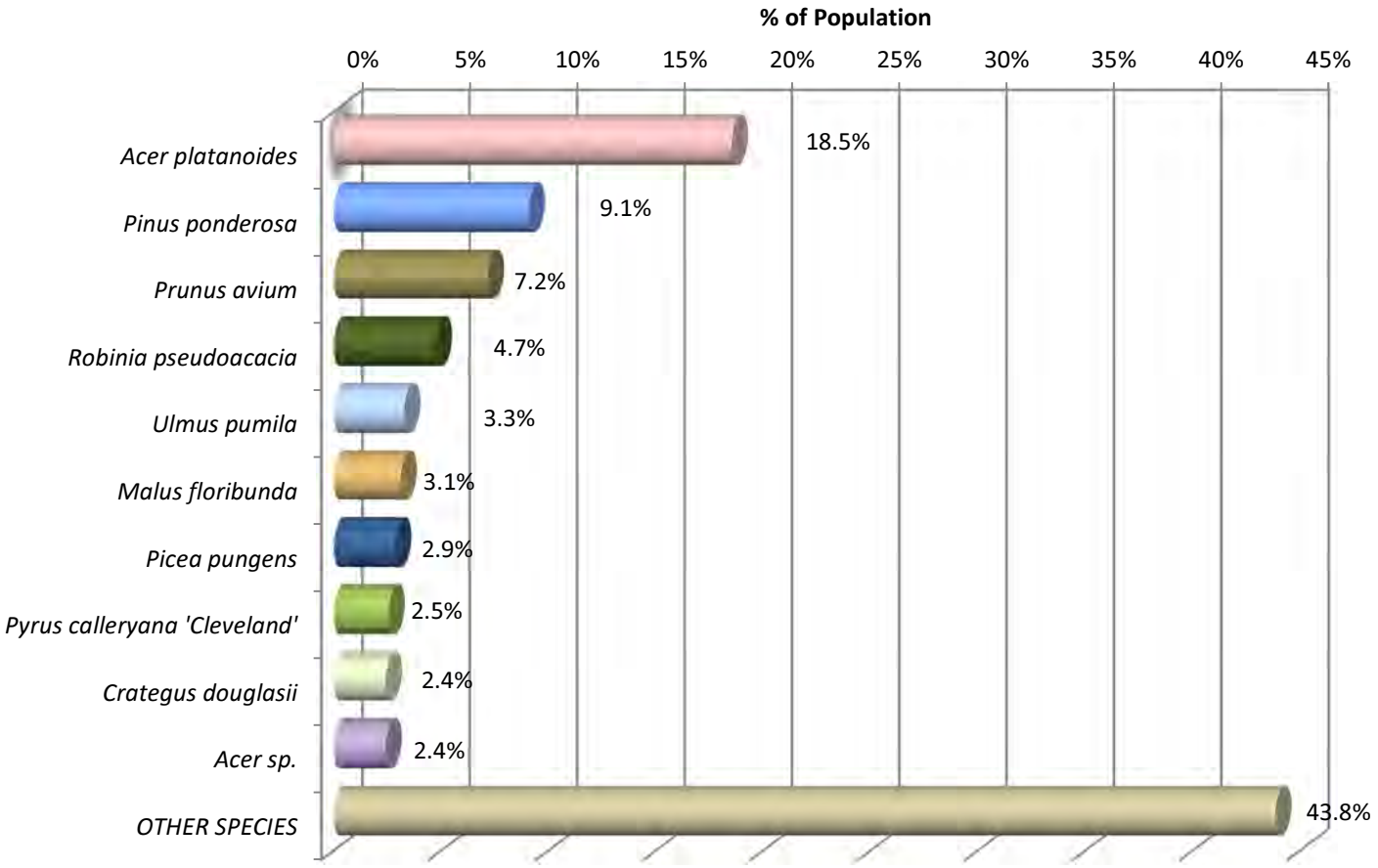


Figure 2 Species Diversity of Spokane's Street trees.

Table 1. Population Summary of Spokane's Street Tree Resource

	DBH Class (in)										
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42		
	Broadleaf Deciduous Large (BDL)									Total	% of Pop
Acer platanoides	1,362	1,510	2,089	3,569	3,647	1,637	320	54	1	14,189	18.5
Robinia pseudoacacia	728	474	465	513	692	452	217	72	22	3,635	4.7
Ulmus pumila	725	382	455	293	258	229	106	45	16	2,509	3.3
Acer rubrum	415	571	598	194	36	2	1	1	-	1,818	2.4
Gleditsia triacanthos	277	352	760	189	60	8	3	-	-	1,649	2.2
Platanus hybrida	51	60	99	189	292	321	240	142	53	1,447	1.9
Fraxinus americana	668	306	225	82	29	6	4	1	-	1,321	1.7
Populus tremuloides	617	410	236	49	3	1	-	-	-	1,316	1.7
Ulmus americana	287	239	204	164	93	94	37	19	8	1,145	1.5
Acer pseudoplatanus	28	29	99	333	322	130	26	5	1	973	1.3
BDL OTHER	984	535	784	735	668	465	258	116	81	4,626	6.0
Total	**6,142**	**4,868**	**6,014**	**6,310**	**6,100**	**3,345**	**1,212**	**455**	**182**	**34,628**	**45.2%**
Broadleaf Deciduous Medium (BDM)											
Prunus avium	1,769	1,452	1,470	604	144	40	5	2	3	5,489	7.2
Acer sp.	467	528	510	223	77	29	10	3	1	1,848	2.4
Unknown	845	302	189	87	25	12	1	1	-	1,462	1.9
Tilia cordata	252	156	245	301	254	77	20	8	3	1,316	1.7

	DBH Class (in)										
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42		% of Pop
Aesculus hippocastanum	72	35	91	321	287	123	31	7	2	969	1.3
BDM OTHER	837	520	500	343	191	74	30	19	9	2,523	3.3
Total	**4,242**	**2,993**	**3,005**	**1,879**	**978**	**355**	**97**	**40**	**18**	**13,607**	**17.8%**
Broadleaf Deciduous Small (BDS)											
Malus floribunda	902	630	594	206	47	6	-	-	1	2,386	3.1
Pyrus calleryana 'Cleveland'	685	688	511	62	4	-	-	-	-	1,950	2.5
Crategus douglasii	209	282	746	523	79	11	1	1	-	1,852	2.4
Prunus cerasifera	195	328	325	119	21	4	-	-	-	992	1.3
Sorbus acuparia	143	169	291	201	101	32	7	1	-	945	1.2
Acer palmatum	609	187	68	17	9	6	-	-	-	896	1.2
Cornus florida	390	274	99	8	1	1	-	-	-	773	1.0
BDS OTHER	532	342	336	118	24	7	1	-	-	1,360	1.8
Total	**3,665**	**2,900**	**2,970**	**1,254**	**286**	**67**	**9**	**2**	**1**	**11,154**	**14.6%**
Broadleaf Evergreen Medium (BEM)											
BEM OTHER	274	115	133	57	31	21	9	1	-	641	0.8
Total	**274**	**115**	**133**	**57**	**31**	**21**	**9**	**1**	**0**	**641**	**0.8%**

	DBH Class (in)										
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42		% of Pop
Conifer Evergreen Large (CEL)											
Pinus ponderosa	963	810	886	1,336	1,324	1,122	409	74	22	6,946	9.1
Pseudotsuga menziesii	205	168	214	277	341	300	158	47	11	1,721	2.2
Abies lasiocarpa	487	267	229	67	8	2	1	-	1	1,062	1.4
Picea abies	153	112	110	192	184	75	23	2	-	851	1.1
CEL OTHER	447	325	397	341	183	91	28	8	2	1,822	2.4
Total	**2,255**	**1,682**	**1,836**	**2,213**	**2,040**	**1,590**	**619**	**131**	**36**	**12,402**	**16.2%**
Conifer Evergreen Medium (CEM)											
Picea pungens	339	281	433	579	372	163	16	3	1	2,187	2.9
CEM OTHER	26	26	19	12	-	1	-	-	-	84	0.1
Total	**365**	**307**	**452**	**591**	**372**	**164**	**16**	**3**	**1**	**2,271**	**3.0%**
Conifer Evergreen Small (CES)											
Pinus aristata	386	267	433	313	137	52	14	3	-	1,605	2.1
CES OTHER	113	75	34	12	5	4	2	-	-	245	0.3
Total	**499**	**342**	**467**	**325**	**142**	**56**	**16**	**3**	**0**	**1,850**	**2.4%**
Citywide Total	**17,442**	**13,207**	**14,877**	**12,629**	**9,949**	**5,598**	**1,978**	**635**	**238**	**76,553**	**100%**

Condition

Tree condition was evaluated, but because of discrepancies between the recent and previously collected data, trees were consolidated into four groups: good, fair, poor, and dead or dying. The vast majority (91%) of Spokane's public street trees were determined to be in good condition, while 7% were rated as fair, and less than 2% were poor, dead or dying.

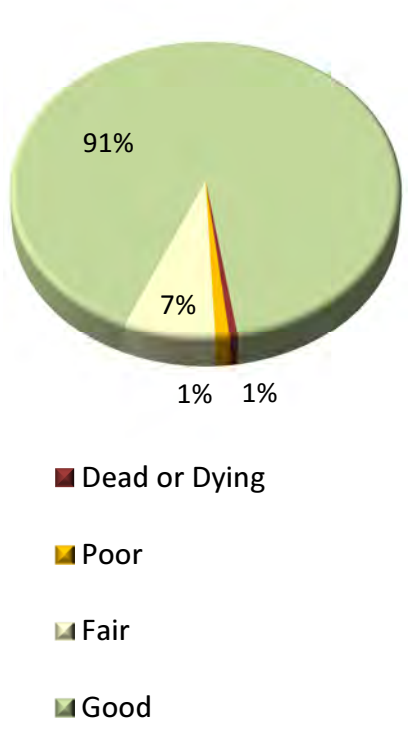


Figure 3 Condition rating of Spokane's public trees.

Species Importance

To quantify the significance of any one particular species found in Spokane's public tree population, an *importance value* (IV) is derived for each of the most common species in the inventory. Importance values are particularly meaningful to urban forest managers because they indicate a community's reliance on the functional capacity of particular species. The importance value is calculated **based on the mean of three values: percentage of total population, percentage of total leaf area, and percentage of total canopy cover.** Importance value goes beyond tree numbers alone to suggest reliance on specific species based on the benefits they provide. The importance value can range from zero (which implies no reliance) to 100 (suggesting total reliance). A tree with an IV of 50 has an average importance in the forest, and higher importance values suggest greater reliance. Since IV is related to leaf surface area, small stature trees tend to have lower importance values.

No single species should dominate the composition in the City's urban forest population. Because importance value goes beyond population numbers alone, it can help managers to better comprehend the resulting loss of benefits from a catastrophic loss of any one species. When importance values are comparatively equal among the most abundant species, the risk of major reductions to benefits is significantly reduced. Of course, suitability of the dominant species is another important consideration. Planting short-lived or poorly adapted species can result in short rotations and increased long-term management costs.

Importance value goes beyond tree numbers alone to suggest reliance on specific species based on the benefits they provide.

The twenty eight most abundant species, those that comprise greater than 1 of the population, represent 85 of the total population, 87 of the total leaf area, and 86 of the total canopy cover for a combined importance value of 86 (Table 2). Of these species, Spokane relies most on the two most prevalent species, Norway maple (*Acer platanoides*, IV=29.4), and Ponderosa pine (*Pinus ponderosa,* IV=9.6), primarily due to their large stature and

abundance in the population. These two species comprise 28 of Spokane's street trees, and 39 of the importance value. If species diversity is developed by planting less prevalent, high-performing, large-stature species, Spokane may be able to rely on more species to supply these benefits. In addition, over time, the importance value of Norway maple will diminish if it is planted with less frequency than in the past.

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 publicly managed street and park trees throughout the United States, including those in Spokane, likely represent less than 10 of the entire urban forest (Moll and Kollin, 1993). Considering just the public trees, these 76,553 individuals provide an estimated 1,127 acres of canopy.

Considering just street trees, these 76,553 individuals provide 1,127 acres of canopy.

Table 2. Importance Value of Spokane's Most Abundant Street Tree Species

Species	Number of Trees	of Total Trees	Leaf Area (ft2)	of Total Leaf Area	Canopy Cover (ft2)	of Total Canopy Cover	Importance Value
Acer platanoides	14,189	18.53	41,195,085	33.35	17,875,318	36.40	**29.43**
Pinus ponderosa	6,946	9.07	14,448,780	11.70	3,937,292	8.02	**9.60**
Prunus avium	5,489	7.17	1,694,297	1.37	1,107,284	2.25	**3.60**
Robinia pseudoacacia	3,635	4.75	10,821,023	8.76	4,462,003	9.09	**7.53**
Ulmus pumila	2,509	3.28	5,792,697	4.69	1,658,431	3.38	**3.78**
Malus floribunda	2,386	3.12	302,029	0.24	446,198	0.91	**1.42**
Picea pungens	2,187	2.86	1,472,140	1.19	860,493	1.75	**1.93**
Pyrus calleryana 'Cleveland'	1,950	2.55	137,755	0.11	232,349	0.47	**1.04**
Crategus douglasii	1,852	2.42	561,409	0.45	675,011	1.37	**1.42**
Acer sp.	1,848	2.41	678,097	0.55	428,035	0.87	**1.28**
Acer rubrum	1,818	2.37	853,933	0.69	569,953	1.16	**1.41**
Pseudotsuga menziesii	1,721	2.25	4,573,554	3.70	1,111,418	2.26	**2.74**
Gleditsia triacanthos	1,649	2.15	866,916	0.70	720,283	1.47	**1.44**
Pinus aristata	1,605	2.10	201,602	0.16	271,286	0.55	**0.94**
Unknown	1,462	1.91	259,591	0.21	177,738	0.36	**0.83**
Platanus hybrida	1,447	1.89	12,935,695	10.47	2,637,579	5.37	**5.91**
Fraxinus americana	1,321	1.73	494,641	0.40	299,308	0.61	**0.91**
Populus tremuloides	1,316	1.72	420,624	0.34	260,267	0.53	**0.86**
Tilia cordata	1,316	1.72	1,008,407	0.82	529,122	1.08	**1.20**
Ulmus americana	1,145	1.50	2,355,673	1.91	698,219	1.42	**1.61**
Abies lasiocarpa	1,062	1.39	115,913	0.09	112,694	0.23	**0.57**
Prunus cerasifera	992	1.30	54,972	0.04	151,930	0.31	**0.55**
Acer pseudoplatanus	973	1.27	3,492,712	2.83	1,503,347	3.06	**2.39**
Aesculus hippocastanum	969	1.27	1,095,466	0.89	543,490	1.11	**1.09**
Sorbus acuparia	945	1.23	290,554	0.24	336,308	0.68	**0.72**
Acer palmatum	896	1.17	41,548	0.03	72,245	0.15	**0.45**
Picea abies	851	1.11	1,158,866	0.94	392,122	0.80	**0.95**
Cornus florida	773	1.01	32,278	0.03	75,452	0.15	**0.40**
OTHER TREES	11,301	14.76	16,150,933	13.08	6,958,700	14.17	**14.00**
Total	**76,553**	**100**	**123,507,190**	**100**	**49,103,876**	**100**	**100**

The age distribution of trees in Spokane helps ensure a steady flow of benefits for many generations to come.

Relative Age Distribution

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

Generally, the age distribution of Spokane's street tree population is nearly ideal, with 59 of the population comprised of trees with a DBH (diameter at breast height) of twelve inches or smaller. The set of trees over 25 inches DBH represent 11 of the population, indicating that Spokane is preserving a relatively high portion of mature trees. Consideration should be given to the fact that these older trees may require substantial maintenance and some may be near the end of their useful lives. Since these trees are likely providing substantial benefits to the City it makes sense to preserve them as long as they remain in good or fair condition.

With an ideal age distribution and continued proactive management, Spokane can expect continued, stable benefits from these public trees. New installations should carefully consider species selection, increasing the use of well-performing species. In addition to planting, it is critical that long-term resources be dedicated to ensuring proper maintenance as trees mature. A proactive management plan, including regular inspection will ensure Spokane's street trees remain healthy and well-structured, thereby maximizing environmental services to the community, reducing risk, and promoting a consistent flow of benefits for many generations to come.

Of Spokane's top ten street tree species (Figure 4), flowering pear (*Pyrus calleryana*) and crabapple (*Malus floribunda*) have the smallest DBH, with 97 and 89 less than 12". The flowering pear is likely a younger population that will increase in size over time, while crab-apple is a small stature tree that is unlikely to grow to the larger DBH classes.

The populations of black hawthorne and Norway maple appear to have been more popular in past planting palettes, but are less prevalent in the youngest age classes. It is prudent to faze Norway maple out of the planting palette because of its overabundance in the population, but black hawthorne may still be a reasonable choice for new plantings, representing just 2.4

It is important to keep in mind that, as populations mature and eventually begin to senesce, their maintenance needs are likely to become more substantial. Future plantings should adequately represent long-standing and high-performing species, making sure to provide sufficient replacements to ensure the functional capacity and benefit streams from these populations, even as individuals begin to decline.

Spokane's street tree population demonstrates a nearly ideal age distribution.

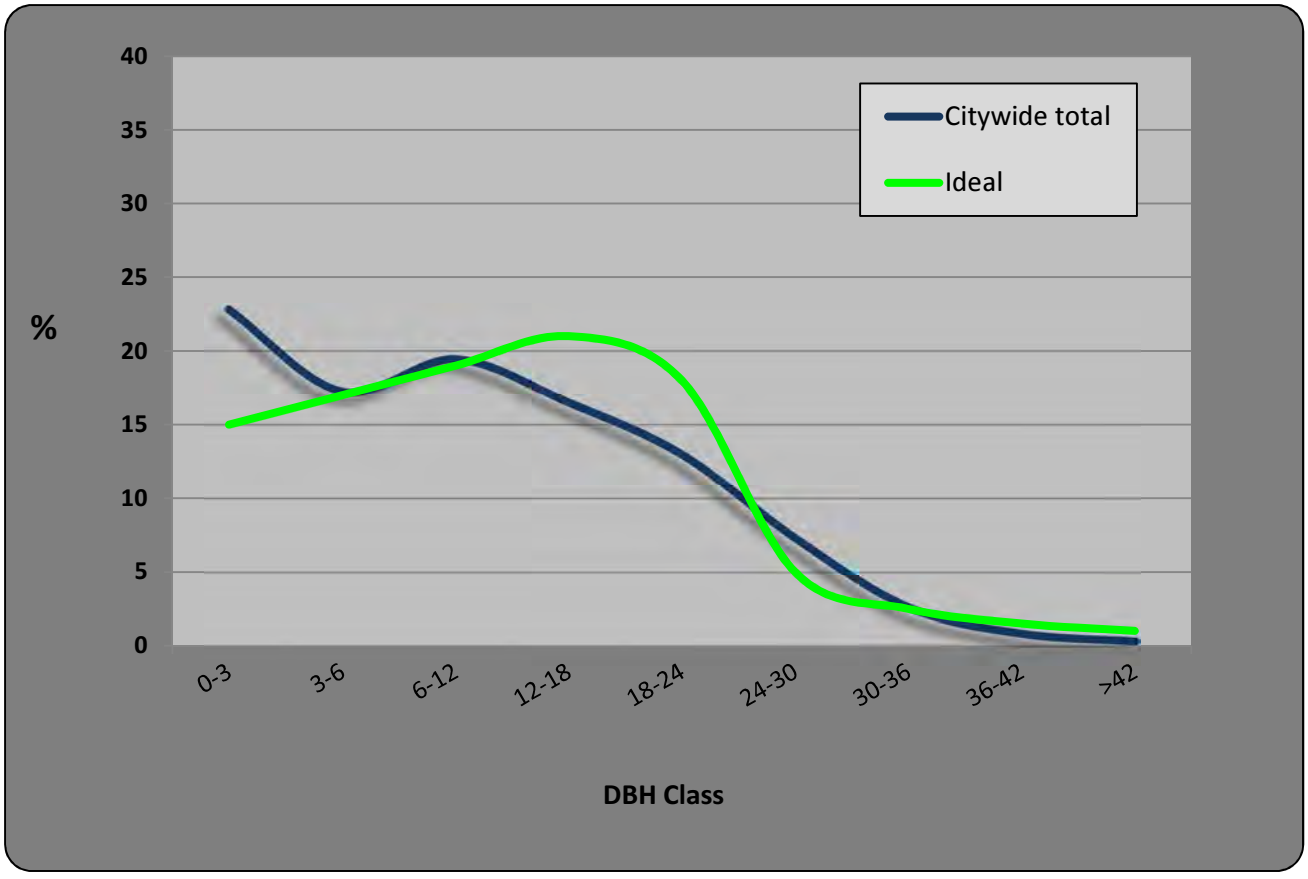
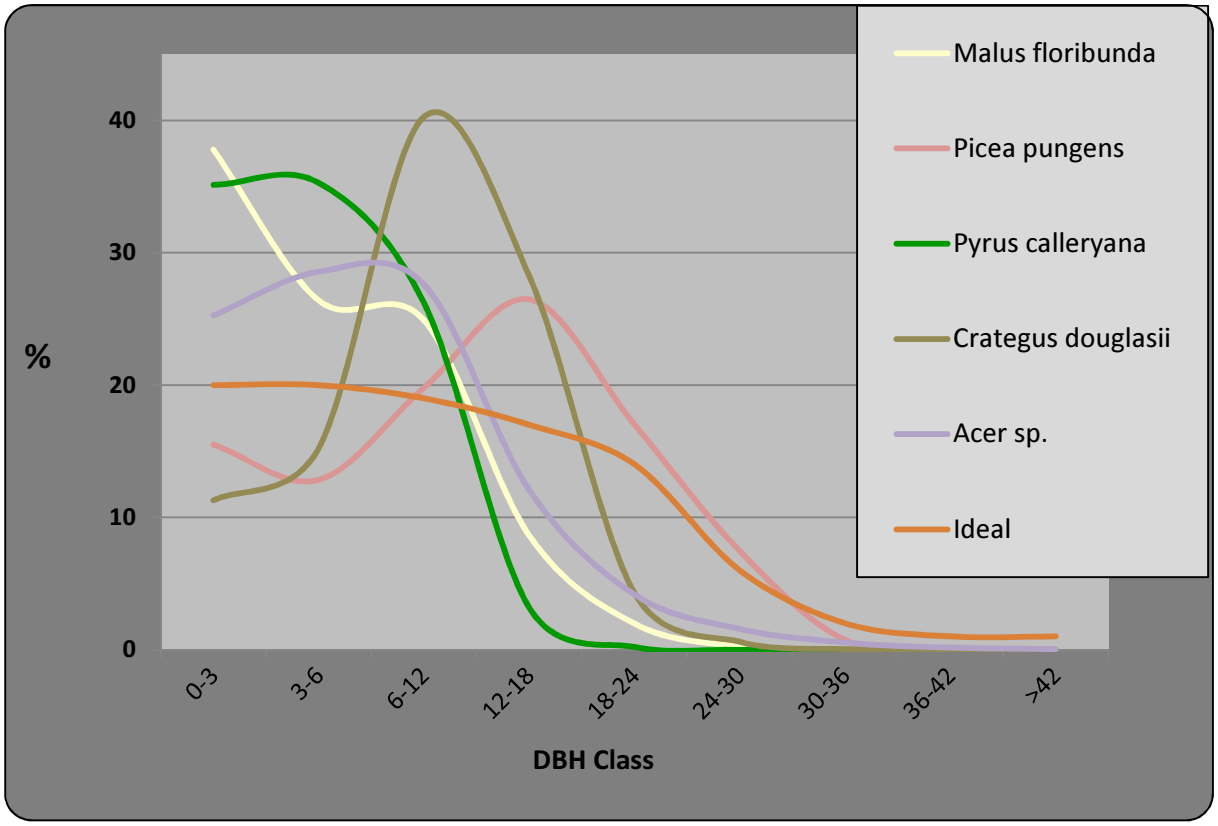


Figure 4 Overall Relative Age Distribution of Spokane's Street Tree Resource



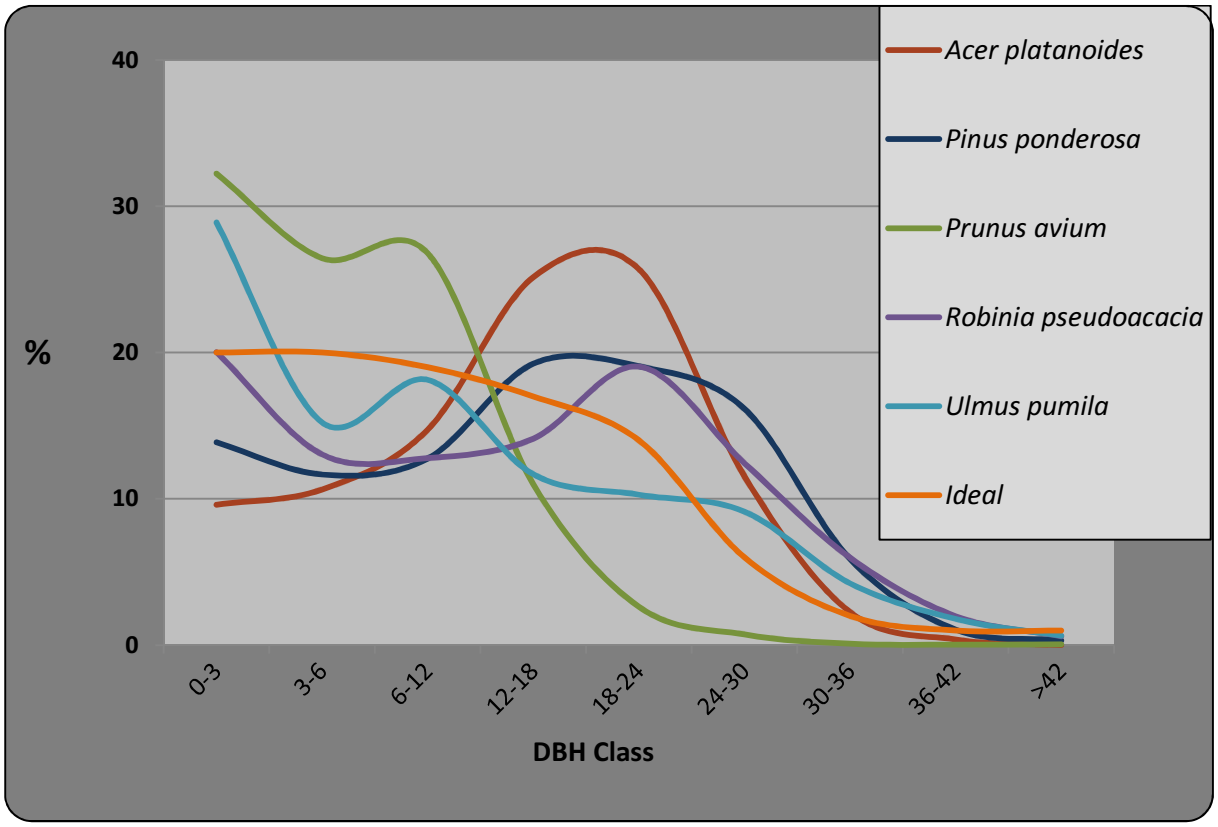


Figure 5 Relative Age Distribution of Spokane's Top Ten Tree Species

Replacement Value

The community forest is a public asset which, when properly cared for, has the potential to appreciate in value as the trees mature over time. To replace Spokane's 76,553 street trees with trees of similar size and species would cost almost $280 million, an average of $3,653 per tree.

The monetary worth, or value, of a tree is based on people's perception of it (Cullen 2000). There are several approaches that arborists use to develop a fair and reasonable perception of value (CTLA 1992, Watson 2002). The cost approach, trunk formula method used in this analysis assumes the value of a tree is equal to the cost of replacing the tree in its current state (Cullen, 2002). The trunk formula method uses tree size, species, condition, and location factors to determine tree replacement value (CTLA, 1992). It assumes that the benefits inherent in a tree are reproduced by replacing the tree, and therefore, replacement cost is an indication of value. Replacement cost is depreciated to reflect differences in the benefits that would flow from an "idealized" replacement compared to the imperfect appraised tree.

Replacement cost is separate from the value of annual benefits produced by the urban forest. Annual Benefit values are a "snapshot" of benefits during one year, while the replacement cost accounts for the long-term investment in trees now reflected in their number, stature, placement, and condition. Hence, the replacement value of a street tree population is many times greater than the value of the annual benefits it produces.

The population of Norway maple (*Acer platanoides*) accounts for 18.5 of the tree numbers and 31.3 of the replacement value. London plane (*Platanus hybrida*) represents just 1.9 of the population but 5.4 of the tree value. The high value of each of these species reinforces their importance to the City. Many of the highest valued species are large and medium-stature trees with large canopies and are therefore likely to have high Importance Values (IV) as well. Species with lower replacement values are generally smaller-stature trees with a lower IV, as evidenced by crabapple (*Malus floribunda*) representing 3.1 of the population, but just 1.1 of the replacement value.

Overall, Spokane's street trees are a vital component of the City's infrastructure and a public asset valued at almost $280 million—an asset that, with proper care and maintenance, will increase in value over time.

Spokane's street trees are a vital component of the City's infrastructure and a public asset valued at almost $280 million.

Table 3. Replacement Value of Spokane's Most Common 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 Value	% of Total Tree Numbers
Acer platanoides	427,770	1,019,755	3,902,631	16,674,898	32,752,927	24,056,838	6,988,403	1,644,913	36,443	87,504,578	31.29	18.53
Pinus ponderosa	140,890	329,042	1,141,455	4,574,424	8,782,077	12,298,780	6,675,096	1,630,279	585,327	36,157,370	12.93	9.07
Prunus avium	514,441	767,692	1,961,989	1,974,575	871,999	399,173	76,126	42,315	73,830	6,682,141	2.39	7.17
Robinia pseudoacacia	206,892	241,737	591,608	1,516,516	3,872,077	4,178,621	2,959,075	1,349,101	483,511	15,399,138	5.51	4.75
Ulmus pumila	189,890	198,916	636,186	1,041,564	1,710,660	2,470,157	1,655,091	1,035,062	399,301	9,336,826	3.34	3.28
Malus floribunda	226,853	389,208	1,088,715	965,394	414,979	77,926	0	0	36,719	3,199,793	1.14	3.12
Picea pungens	58,669	133,792	653,279	2,296,273	2,849,636	2,053,295	296,107	78,836	30,600	8,450,488	3.02	2.86
Pyrus calleryana	143,123	395,823	928,608	294,791	36,998	0	0	0	0	1,799,343	0.64	2.55
Crategus douglasii	52,487	172,493	1,331,818	2,424,458	682,338	149,582	22,642	31,541	0	4,867,358	1.74	2.42
Acer sp.	136,685	283,023	689,260	727,714	468,565	273,978	143,297	57,250	17,372	2,797,142	1.00	2.41
Acer rubrum	112,743	317,133	922,591	748,005	261,237	24,487	18,171	25,283	0	2,429,649	0.87	2.37
Pseudotsuga menziesii	29,563	68,631	280,881	948,965	2,251,238	3,257,826	2,584,997	1,073,860	292,663	10,788,625	3.86	2.25
Gleditsia triacanthos	74,626	199,351	1,199,422	746,744	443,724	96,330	55,662	0	0	2,815,859	1.01	2.15
Pinus aristata	90,694	162,122	805,872	1,521,708	1,280,200	802,463	316,419	96,499	0	5,075,977	1.82	2.10
Unknown	246,402	154,062	238,271	278,552	139,564	111,285	15,225	21,157	0	1,204,518	0.43	1.91
Platanus hybrida	14,301	33,386	144,973	687,779	2,016,896	3,636,036	4,006,504	3,278,125	1,408,304	15,226,305	5.44	1.89
Fraxinus americana	206,254	185,236	359,729	321,864	214,185	73,682	72,830	25,320	0	1,459,102	0.52	1.73
Populus tremuloides	142,585	168,648	247,908	127,009	15,099	8,181	0	0	0	709,430	0.25	1.72
Tilia cordata	74,329	84,219	329,982	996,777	1,592,152	788,670	295,549	169,260	73,830	4,404,767	1.57	1.72
Ulmus americana	76,484	126,449	287,007	585,594	634,526	1,049,211	608,299	427,918	211,775	4,007,262	1.43	1.50
Abies lasiocarpa	71,675	110,802	301,930	232,997	51,676	22,021	16,391	0	26,606	834,096	0.30	1.39
Prunus cerasifera	45,908	199,208	599,570	576,110	187,659	52,950	0	0	0	1,661,406	0.59	1.30
Acer pseudoplatanus	7,456	15,473	145,229	1,227,953	2,294,204	1,501,626	445,715	126,416	29,423	5,793,496	2.07	1.27
Aesculus hippocastanum	21,389	18,737	119,379	1,061,028	1,793,497	1,252,558	458,549	148,102	49,220	4,922,459	1.76	1.27
Sorbus acuparia	36,263	101,523	522,579	901,262	834,880	437,997	138,517	31,541	0	3,004,560	1.07	1.23
Acer palmatum	153,889	115,599	127,245	80,948	83,652	91,361	0	0	0	652,694	0.23	1.17
Picea abies	22,508	45,140	142,662	660,532	1,218,122	822,553	376,999	45,696	0	3,334,212	1.19	1.11
Cornus florida	98,753	169,685	184,400	35,914	9,295	15,227	0	0	0	513,274	0.18	1.01
OTHER TREES	778,982	995,764	3,165,399	5,680,468	7,228,200	6,925,546	4,889,137	2,829,857	2,142,750	34,636,103	12.38	14.76
Citywide total	**$4,402,503**	**$ 7,202,650**	**$23,050,577**	**$49,910,815**	**$ 74,992,263**	**$ 66,928,358**	**$33,114,801**	**$ 14,168,332**	**$ 5,897,672**	**$279,667,971**	**100 %**	**100%**

Urban Forest Resource Benefits

The annual benefits of Spokane's street trees are valued at $4,044,299

Trees are important to Spokane. Environmentally, they help conserve and reduce energy use, reduce local and global carbon dioxide (CO_2) levels, improve air quality, and mitigate stormwater runoff. Additionally, trees provide a wealth of well-documented psychological, social, and economic benefits related primarily to their aesthetic effects. Environmentally, trees make good sense, working ceaselessly to provide benefits back to the community. However, the question remains: are the collective benefits worth the costs of management? **In other words, are trees a good investment for the City of Spokane?**

To answer this question, the benefits must be quantified in financial terms. This analysis provides a snapshot of the annual benefits (along with the value of those benefits) produced by the current composition of Spokane's street tree resource. These benefits are valued at $4,044,229 annually. While the annual benefits produced by the urban forest can be substantial, it's important to recognize that the greatest benefits from the urban forest are derived from the benefit stream that results over a greater period of time from a mature forest where trees are well managed, healthy, and long-lived.

This analysis utilized Spokane's current public tree inventory and i-Tree's Streets model to assess and quantify the beneficial functions of this public tree resource and to place a dollar value on the annual environmental benefits these trees provide. These estimates provide first-order approximations of tree value. While i-Tree Streets only generally accounts for the benefits produced by Spokane's street tree population, it is an accounting based on the best available and current scientific research with an accepted degree of uncertainty. The data returned from i-Tree Streets provides a platform from which management decisions can be made (Maco and McPherson, 2003).

Property & Aesthetic Value

The total annual benefits contributed by Spokane's street trees to property value increases, aesthetics, and socioeconomics, exceed $2.85 million, an average of $37.23 per tree. Species that produced the highest average per-tree property & aesthetic benefits include sycamore maple (*Acer pseudoplatanus,* $105.62), Norway maple (*Acer platanoides,* $86.19), and black locust (*Robinia pseudoacacia*, $70.67)

Figure 6 Annual Aesthetic Benefits - Top 5 Species

Studies show that a single front yard tree can add 1% to the sale price of a home, and large specimen trees can add 10% or more to property values (CUFR, Trees in Our City). In addition, a 2002 study showed that office buildings and apartments with trees and landscaping had fewer vacancies and lower turnover than those without trees (Laverne, 2002). While no study established the cause of the disparities, there is a consistent correlation between trees and increases in property value.

Health and Social Value

Some benefits of trees are intangible or difficult to quantify, such as impacts on psychological health, crime, and violence. However, empirical evidence of these benefits does exist (Kaplan, 1989; Ulrich, 1986). Exposure to nature, including trees, has a healthy impact on humans, including increased worker productivity, higher test scores, reduced symptoms of Attention Deficit Disorder (ADD), and faster recovery times following surgery. While perhaps the most difficult to quantify, the aesthetic and socioeconomic benefits from trees may be among their greatest gifts, including:

- Beautification and comfort
- Shade and privacy
- Wildlife habitat
- Opportunities for recreation
- A reduction in violent crime
- Creating a sense of place and history
- Faster recovery from injury or illness
- Creating a pleasing environment for physical activity

Value in Business Districts

Customers are willing to pay 11% more for goods and services in well-treed shopping areas.

In addition, trees and forests have positive economic benefits for retailers. There is documented evidence that trees promote better business by stimulating more frequent and extended shopping and a willingness to pay 11% more for goods and parking (Wolf, 2007). It is thought that a well-maintained landscaped area and shady parking lot may be more inviting to shoppers and business owners alike.

Habitat and Wildlife Values

Trees and forestlands provide critical habitat (foraging, nesting, spawning, etc.) for mammals, salmon, and bird species, as well as limitless opportunities for recreation, offering a healthful respite from the pressures of work and everyday stress

In addition to the substantial economic, aesthetic, and social benefits of trees, trees have a substantial impact on urban environments in saving energy, protecting air quality, reducing storm water run-off, and sequestering carbon.

Table 4. Annual Aesthetic, Property Value, and Socioeconomic Benefits from Spokane's Street Trees

Species	Total ($)	of Total Tree Numbers	of Total $	Avg. $/tree
Acer platanoides	1,222,929	18.53	42.91	86.19
Pinus ponderosa	315,266	9.07	11.06	45.39
Robinia pseudoacacia	256,900	4.75	9.01	70.67
Acer pseudoplatanus	102,764	1.27	3.61	105.62
Pseudotsuga menziesii	89,061	2.25	3.12	51.75
Ulmus pumila	83,444	3.28	2.93	33.26
Platanus hybrida	75,443	1.89	2.65	52.14
Prunus avium	45,262	7.17	1.59	8.25
Acer rubrum	39,778	2.37	1.40	21.88
Picea pungens	38,973	2.86	1.37	17.82
Ulmus americana	35,796	1.50	1.26	31.26
Populus tremuloides	35,549	1.72	1.25	27.01
Picea abies	29,486	1.11	1.03	34.65
Gleditsia triacanthos	24,355	2.15	0.85	14.77
Fraxinus americana	19,922	1.73	0.70	15.08
Acer sp.	15,771	2.41	0.55	8.53
Tilia cordata	10,951	1.72	0.38	8.32
Aesculus hippocastanum	8,012	1.27	0.28	8.27
Unknown	7,923	1.91	0.28	5.42
Crategus douglasii	6,683	2.42	0.23	3.61
Malus floribunda	5,640	3.12	0.20	2.36
Pyrus calleryana	5,346	2.55	0.19	2.74
Abies lasiocarpa	4,788	1.39	0.17	4.51
Sorbus acuparia	2,751	1.23	0.10	2.91
Prunus cerasifera	1,586	1.30	0.06	1.60
Pinus aristata	1,417	2.10	0.05	0.88
Cornus florida	1,318	1.01	0.05	1.70
Acer palmatum	1,251	1.17	0.04	1.40
OTHER STREET TREES	361,887	14.76	12.70	32.02
CITYWIDE TOTAL	**$ 2,850,251**	**100**	**100**	**$37.23**

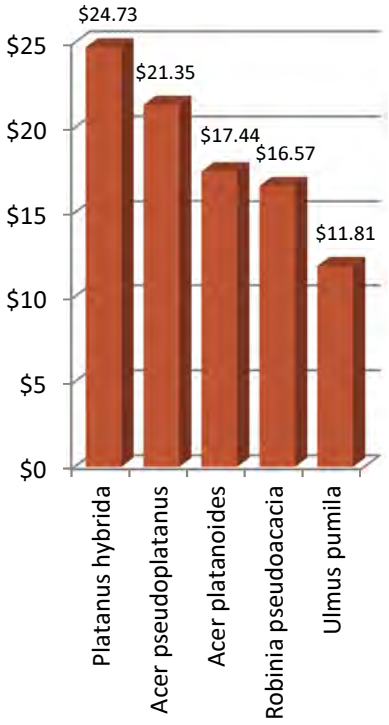


Figure 7 Annual Energy Savings Benefits - Top 5 Species

Energy Savings

Trees modify climate and conserve energy in three principal ways:

- Shading reduces the amount of radiant energy absorbed and stored by hardscape surfaces, thereby reducing the heat island effect.
- Transpiration converts moisture to water vapor, thereby cooling the air by using solar energy that would otherwise result in heating of the air.
- Reduction of wind speed and the movement of outside air into interior spaces and conductive heat loss where thermal conductivity is relatively high (e.g., glass windows) (Simpson, 1998).

The *heat island effect* describes the increase in urban temperatures in relation to surrounding locations and is associated with an increase in hardscape and impervious surfaces. Trees and other vegetation within an urbanized environment help reduce the heat island effect by lowering air temperatures 5°F (3°C) compared with outside the green space (Chandler, 1965). On a larger citywide scale, temperature differences of more than 9°F (5°C) have been observed between city centers without adequate canopy coverage and the more vegetated suburban areas (Akbari et al., 1997). The relative importance of these effects depends upon the size and configuration of trees and other landscape elements (McPherson, 1993). Tree spacing, crown spread, and vertical distribution of leaf area each influence the transport of warm air and pollutants along streets and out of urban canyons.

By reducing air movement into buildings and against conductive surfaces (e.g., glass, metal siding), trees reduce conductive heat loss from buildings. Trees can reduce wind speed and the resulting air infiltration by up to 50%, translating into potential annual heating savings of 25% (Heisler, 1986).

Electricity and Natural Gas Reduction

The shading and climate effects of trees provide benefits of 6,549 MWh ($523,896) and 224,007 therms ($190,406), for a total retail savings of approximately $714,302 and an average of $9.33 per tree (Table 5). London plane tree (*Platanus hybrida*) provides the highest average per-tree benefit, while the population of Norway maple (*Acer platanoides*) provides the greatest contribution to energy savings, due to its stature and because it comprises 18.5% of the street tree population.

Table 5. Annual Electric and Natural Gas Benefits from Spokane's Street Trees

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	of Total Tree Numbers	of Total $	Avg. $/tree
Acer platanoides	2,316	185,273	73,146	62,174	247,447	18.53	34.64	17.44
Robinia pseudoacacia	572	45,772	17,028	14,474	60,246	4.75	8.43	16.57
Pinus ponderosa	530	42,408	20,597	17,507	59,915	9.07	8.39	8.63
Platanus hybrida	338	27,035	10,300	8,755	35,790	1.89	5.01	24.73
Ulmus pumila	285	22,770	8,073	6,862	29,633	3.28	4.15	11.81
Acer pseudoplatanus	195	15,580	6,115	5,197	20,777	1.27	2.91	21.35
Prunus avium	153	12,209	6,871	5,840	18,049	7.17	2.53	3.29
Pseudotsuga menziesii	149	11,882	5,689	4,836	16,718	2.25	2.34	9.71
Picea pungens	119	9,500	4,893	4,159	13,659	2.86	1.91	6.25
Ulmus americana	119	9,544	3,454	2,936	12,480	1.50	1.75	10.9
Gleditsia triacanthos	98	7,827	4,140	3,519	11,347	2.15	1.59	6.88
Crategus douglasii	92	7,383	4,059	3,450	10,833	2.42	1.52	5.85
Acer rubrum	78	6,261	3,223	2,739	9,000	2.37	1.26	4.95
Aesculus hippocastanum	74	5,906	3,149	2,676	8,582	1.27	1.20	8.86
Tilia cordata	72	5,769	3,116	2,648	8,417	1.72	1.18	6.4
Malus floribunda	61	4,916	2,768	2,352	7,268	3.12	1.02	3.05
Acer sp.	59	4,714	2,635	2,240	6,953	2.41	0.97	3.76
Picea abies	53	4,275	2,126	1,808	6,083	1.11	0.85	7.15
Sorbus acuparia	46	3,671	2,010	1,709	5,380	1.23	0.75	5.69
Fraxinus americana	40	3,236	1,587	1,349	4,584	1.73	0.64	3.47
Pinus aristata	38	3,054	1,726	1,467	4,521	2.10	0.63	2.82
Populus tremuloides	36	2,881	1,616	1,373	4,254	1.72	0.60	3.23
Pyrus calleryana	33	2,606	1,528	1,299	3,905	2.55	0.55	2
Unknown	24	1,955	1,113	946	2,901	1.91	0.41	1.98
Prunus cerasifera	21	1,713	1,006	855	2,568	1.30	0.36	2.59
Abies lasiocarpa	16	1,268	704	598	1,867	1.39	0.26	1.76
Cornus florida	10	840	491	417	1,257	1.01	0.18	1.63
Acer palmatum	10	799	461	391	1,190	1.17	0.17	1.33
OTHER STREET TREES	911	72,851	30,384	25,827	98,678	14.76	13.81	8.73
CITYWIDE TOTAL	**6,549**	**$523,896**	**224,007**	**$190,406**	**$714,302**	**100**	**100**	**$ 9.33**

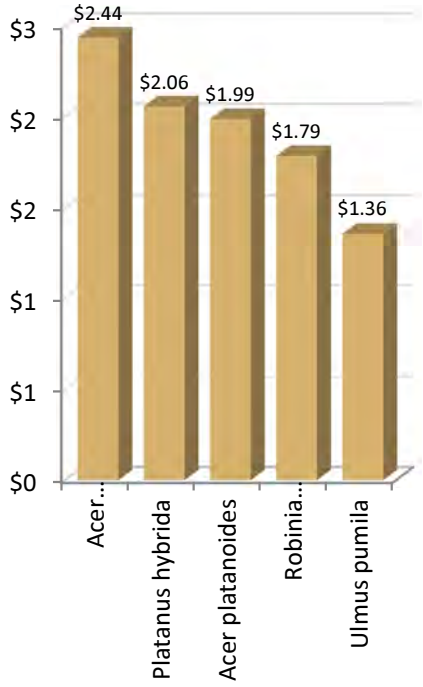


Figure 8. Annual CO_2 Benefits - Top 5 Species

Atmospheric Carbon Dioxide Reduction

As environmental awareness continues to increase, more attention is paid to the effects of greenhouse gas emissions. Two national policy options are currently under debate, the establishment of a carbon tax and a greenhouse gas cap-and-trade system, aimed at the reduction of atmospheric carbon dioxide (CO_2) and other greenhouse gases. A carbon tax would place a tax burden on each unit of greenhouse gas emission and would require regulated entities to pay for their level of emissions. Alternatively, in a cap-and-trade system, an upper limit (or cap) is placed on global (federal, regional, or other jurisdiction) levels of greenhouse gas emissions and the regulated entities would be required to either reduce emissions to required limits or purchase emissions allowances in order to meet the cap (Williams and others, 2007).

The concept of purchasing emission allowances (offsets) has led to the acceptance of carbon credits as a commodity that can be exchanged for financial gain. The Center for Urban Forest Research (CUFR, Pacific Southwest Research Station, and USDA Forest Service) recently led the development of Urban Forest Project Reporting Protocol. The protocol, which incorporates methods of the Kyoto Protocol and Voluntary Carbon Standard (VCS), establishes methods for calculating reductions, provides guidance for accounting and reporting, and guides urban forest managers in developing tree planting and stewardship projects that could be registered for greenhouse gas (GHG) reduction credits (offsets). The protocol can be applied to urban tree planting projects within municipalities, campuses, and utility service areas anywhere in the United States.

While Spokane's street tree resource may or may not qualify for carbon offset credits or be traded in the open market, the City's street trees are providing a significant reduction in atmospheric carbon dioxide (CO_2) for a positive environmental and financial benefit to the community.

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

- Directly, through growth and the sequestration of CO_2 as wood and foliar biomass.
- Indirectly, by lowering the demand for heating and air conditioning, thereby reducing the emissions associated with electric power generation and natural gas consumption.

Conversely, CO_2 is released by vehicles and other combustible engines used to plant and care for trees. Additionally, when a tree dies, most of the CO_2 that accumulated as woody biomass is released back into the atmosphere during decomposition, except in cases where the wood is recycled. Each of these factors must be considered when calculating the CO_2 reduction benefits of trees.

In Washington, on average, 100 trees remove 23 tons of CO_2 annually. (CUFR)

Sequestered Carbon Dioxide

To date, Spokane's street trees have stored a total of 59,622 tons of carbon dioxide (CO_2) valued at $393,508[1]. This calculation is based on the current living tree population, calculating the woody biomass and leaf volume of the tree resource. Annually, the street trees directly sequester 8.6 million pounds of CO_2, valued at $28,395, into woody and foliar biomass. Accounting for estimated CO_2 emissions from tree decomposition (409 tons), tree related maintenance activity (34 tons), and avoided CO_2 (11,481tons), Spokane's trees provide an annual net reduction in atmospheric CO_2 of 11,481 tons, valued at $75,778 with an average of $0.99 per tree (Table 6).

The most effective tree for carbon sequestration is Sycamore maple (*Acer pseudoplatanus*). Although it represents just 1.27 of the tree population, it is providing 3.13 of the annual carbon related benefit. The high per-tree average carbon benefit ($2.44) may be partially attributed to the relatively mature age of this population, as 83 of trees are over 12" DBH.

[1] Based on i-Tree Streets default value of $15 per ton. Market value may vary.

Table 6. Annual CO_2 Benefits from Spokane's Street Tree Resource

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release(lb)	Maintenance Release (lb)	Total Release ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total ($)	of Total Tree Numbers	of Total $	Avg. $/tree
Acer platanoides	3,402,168	11,227	-241,992	-2,767	-808	5,391,449	17,792	8,548,858	28,211	18.53	37.23	1.99
Pinus ponderosa	895,957	2,957	-92,742	- 14,023	- 352	1,234,082	4,072	2,023,274	6,677	9.07	8.81	0.96
Robinia pseudoacacia	707,167	2,334	-63,241	- 709	- 211	1,331,977	4,396	1,975,194	6,518	4.75	8.60	1.79
Ulmus pumila	446,541	1,474	-68,023	- 3,747	- 237	662,616	2,187	1,037,387	3,423	3.28	4.52	1.36
Platanus hybrida	180,524	596	-60,266	- 4,493	- 214	786,712	2,596	902,476	2,978	1.89	3.93	2.06
Acer pseudoplatanus	286,626	946	-20,496	- 190	- 68	453,372	1,496	719,313	2,374	1.27	3.13	2.44
Pseudotsuga menziesii	248,961	822	-28,673	- 3,839	- 107	345,774	1,141	562,223	1,855	2.25	2.45	1.08
Picea pungens	247,971	818	-17,208	- 3,543	- 68	276,448	912	503,669	1,662	2.86	2.19	0.76
Prunus avium	140,053	462	-13,403	- 4,622	- 59	355,282	1,172	477,310	1,575	7.17	2.08	0.29
Ulmus americana	194,723	643	-28,205	- 1,637	- 98	277,722	916	442,603	1,461	1.50	1.93	1.28
Gleditsia triacanthos	163,417	539	-12,932	- 1,722	- 48	227,773	752	376,535	1,243	2.15	1.64	0.75
Acer rubrum	113,483	374	-5,266	- 355	- 19	182,191	601	290,053	957	2.37	1.26	0.53
Crategus douglasii	42,584	141	-7,428	- 2,360	- 32	214,845	709	247,641	817	2.42	1.08	0.44
Picea abies	86,845	287	-7,818	- 1,471	- 31	124,409	411	201,965	666	1.11	0.88	0.78
Tilia cordata	33,283	110	-6,741	- 2,002	- 29	167,876	554	192,416	635	1.72	0.84	0.48
Aesculus hippocastanum	24,180	80	-7,071	- 1,995	- 30	171,851	567	186,965	617	1.27	0.81	0.64
Acer sp.	49,121	162	-5,258	- 1,759	- 23	137,171	453	179,275	592	2.41	0.78	0.32
Malus floribunda	36,289	120	-4,086	- 1,794	- 19	143,043	472	173,452	572	3.12	0.76	0.24
Pyrus calleryana	80,518	266	-4,458	- 380	- 16	75,845	250	151,524	500	2.55	0.66	0.26
Fraxinus americana	57,395	189	-3,020	- 258	- 11	94,157	311	148,274	489	1.73	0.65	0.37
Sorbus acuparia	17,670	58	-3,835	- 1,275	- 17	106,827	353	119,386	394	1.23	0.52	0.42
Prunus cerasifera	52,383	173	-3,821	- 193	- 13	49,851	165	98,219	324	1.30	0.43	0.33
Pinus aristata	15,715	52	-4,795	- 1,911	- 22	88,862	293	97,872	323	2.10	0.43	0.20
Populus tremuloides	543	2	-2,962	- 744	- 12	83,826	277	80,663	266	1.72	0.35	0.20
Unknown	23,962	79	-2,173	- 839	- 10	56,888	188	77,838	257	1.91	0.34	0.18
Abies lasiocarpa	20,016	66	-1,063	- 687	- 6	36,900	122	55,166	182	1.39	0.24	0.17
Cornus florida	8,753	29	-470	- 374	- 3	24,440	81	32,349	107	1.01	0.14	0.14
Acer palmatum	7,632	25	-571	- 386	- 3	23,263	77	29,937	99	1.17	0.13	0.11
OTHER STREET TREES	1,020,079	3,366	-100,827	- 8,034	- 359	2,119,967	6,996	3,031,186	10,003	14.76	13.20	0.89
CITYWIDE TOTAL	**8,604,560**	**$28,395**	**-818,845**	**- 68,109**	**$- 2,927**	**15,245,419**	**$50,310**	**22,963,025**	**$75,778**	**100**	**100**	**$0.99**

Air Quality Improvement

Urban trees improve air quality in five fundamental ways:

- Absorption of gaseous pollutants such as ozone (O_3) and nitrogen dioxide (NO_2) through leaf surfaces,
- Interception of particulate matter (PM_{10}), such as dust, ash, dirt, pollen, and smoke,
- Reduction of emissions from power generation by reducing energy consumption,
- Increase of oxygen levels through photosynthesis, and
- Transpiration of water and shade provision, resulting in lower local air temperatures, thereby reducing ozone (O_3) levels.

In the absence of cooling effects provided by 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 US cities (Bell, 2004). However, it should be noted that while trees do a great deal to absorb air pollutants (especially ozone and particulate matter); they also negatively contribute 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 by i-Tree Streets in the air quality net benefit and summarized below and in Table 8.

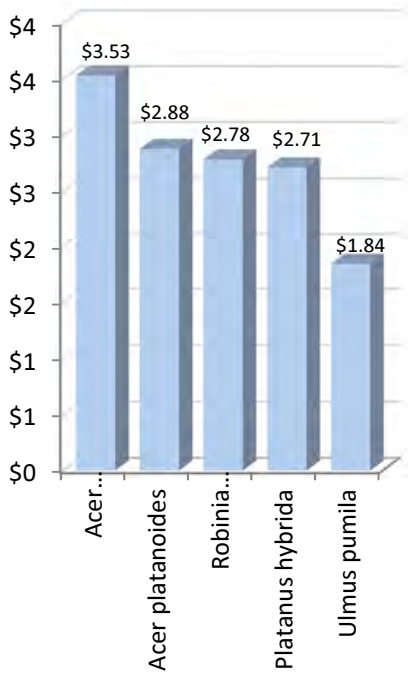


Figure 9. Annual Air Quality Benefits - Top 5 Species

Deposition and Interception

Each year, approximately 30 tons of nitrogen dioxide (NO_2), small particulate matter (PM10), ozone (O_3) and sulfur dioxide (SO_2) are intercepted or absorbed by the street trees in Spokane, for a value of $44,602 (Table 7). As a population, Norway maple (*Acer platanoides*, 48,301 lbs.) is the greatest contributor to air quality improvements, accounting for approximately 14 of total air quality benefits.

Avoided Pollutants

By reducing energy needs, the energy savings provided by trees have the additional indirect benefit of reducing air pollutant emissions (NO_2, PM_{10}, SO_2, and VOCs) that result from energy production. Altogether, 36 tons of pollutants, valued at $73,211, are avoided annually through the shading effects of Spokane's street trees.

BVOC Emissions

Biogenic volatile organic compound (BVOC) emissions from trees, which negatively affect air quality, are also considered. Approximately 12 tons of BVOCs are emitted annually from Spokane's street trees, offsetting the total air quality benefit by -$4,534. Despite BVOC emissions, the net air quality impact is positive for all species. The highest per tree BVOC emissions from populations of ponderosa pine (*Pinus ponderosa*) and London planetree (*Platanus hybrida*) provide 9 and 1.8 of the net air quality improvements despite the fact that they release some BVOCs (valued at $9,933 and $3,924, respectively).

Net Air Quality Improvement

Net air pollutants removed, avoided, and released by Spokane's street tree population are valued at $113,296 annually. The average net benefit per tree is $1.48. 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 of BVOCs produce the greatest benefits. On a per tree basis, sycamore maple (*Acer pseudoplatanus*) provides the highest benefit ($3.53), followed by four species between $2.88 and $1.88 per tree. Norway maple (*Acer platanoides*, $2.88), black locust (*Robinia pseudoacacia*, $2.78), London planetree (*Platanus hybrida,* $2.71), and Siberian elm (*Ulmus pumila*, $1.84) are all good choices for maximizing air quality benefits. (Figure 9). These trees represent 37.5 of the City's total street tree population.

Table 7. Annual Air Quality Improvements from Spokane's Street Tree Resource

Species	Deposition O3 (lb)	Deposition NO2 (lb)	Deposition PM10 (lb)	Deposition SO2 (lb)	Total Deposition ($)	Avoided NO2 (lb)	Avoided PM10 (lb)	Avoided VOC (lb)	Avoided SO2 (lb)	Total Avoided ($)	BVOC Emissions (lb)	BVOC Emissions ($)	Total (lb)	Total ($)	of Total Tree Numbers	Avg. $/tree
Acer platanoides	13,755	2,142	4,562	59	14,981	12,473	2,342	2,315	10,654	25,846	0	0	48,301	40,827	18.53	2.88
Robinia pseudoacacia	3,433	535	1,139	15	3,739	3,071	578	571	2,632	6,378	0	0	11,973	10,117	4.75	2.78
Pinus ponderosa	4,203	826	1,668	30	5,012	2,894	539	532	2,439	5,944	- 5,383	- 1,023	7,748	9,933	9.07	1.43
Ulmus pumila	1,332	197	442	5	1,444	1,524	287	284	1,309	3,170	0	0	5,381	4,614	3.28	1.84
Platanus hybrida	2,030	316	673	9	2,210	1,816	341	338	1,555	3,769	- 10,818	- 2,056	- 3,741	3,924	1.89	2.71
Acer pseudoplatanus	1,157	180	384	5	1,260	1,049	197	195	896	2,173	0	0	4,061	3,433	1.27	3.53
Pseudotsuga menziesii	1,186	233	471	8	1,415	810	151	149	683	1,665	- 1,704	- 324	1,988	2,756	2.25	1.60
Prunus avium	875	134	297	4	959	843	156	154	702	1,718	0	0	3,164	2,677	7.17	0.49
Picea pungens	919	180	365	7	1,095	651	121	119	546	1,334	- 565	- 107	2,343	2,322	2.86	1.06
Ulmus americana	561	83	186	2	608	639	120	119	549	1,329	0	0	2,260	1,937	1.50	1.69
Gleditsia triacanthos	542	81	172	2	580	538	100	98	450	1,100	- 132	- 25	1,851	1,654	2.15	1.00
Crategus douglasii	519	81	172	2	566	509	94	93	425	1,038	- 1,152	- 219	744	1,385	2.42	0.75
Acer rubrum	439	68	145	2	478	429	80	79	360	879	0	0	1,602	1,357	2.37	0.75
Aesculus hippocastanum	429	66	146	2	471	406	75	74	340	830	0	0	1,538	1,301	1.27	1.34
Tilia cordata	418	64	142	2	458	397	74	73	332	811	0	0	1,501	1,269	1.72	0.96
Acer sp.	338	52	115	1	371	325	60	59	271	663	0	0	1,222	1,034	2.41	0.56
Picea abies	419	82	166	3	499	292	54	54	246	600	- 432	- 82	884	1,017	1.11	1.19
Malus floribunda	343	53	114	1	374	339	63	62	283	692	- 620	- 118	639	948	3.12	0.40
Pinus aristata	290	57	115	2	345	211	39	38	176	430	- 133	- 25	795	750	2.10	0.47
Fraxinus americana	230	36	76	1	251	221	41	41	186	454	0	0	832	704	1.73	0.53
Sorbus acuparia	259	40	86	1	282	253	47	46	211	516	- 596	- 113	347	685	1.23	0.72
Pyrus calleryana	192	29	65	1	210	181	33	33	150	367	0	0	683	577	2.55	0.30
Populus tremuloides	215	32	73	1	235	199	37	36	166	405	- 478	- 91	281	550	1.72	0.42
Unknown	140	22	48	1	154	135	25	25	112	275	0	0	507	429	1.91	0.29
Prunus cerasifera	122	18	40	0	132	119	22	22	99	241	0	0	442	374	1.30	0.38
Abies lasiocarpa	120	24	48	1	143	87	16	16	73	178	- 43	- 8	342	314	1.39	0.30
Cornus florida	58	9	19	0	63	58	11	11	48	118	- 66	- 13	148	169	1.01	0.22
Acer palmatum	56	9	18	0	61	55	10	10	46	113	- 85	- 16	119	157	1.17	0.18
OTHER STREET TREES	5,625	911	1,929	26	6,223	4,921	922	911	4,189	10,175	- 1,657	- 315	17,778	16,083	14.76	1.42
CITYWIDE TOTAL	**40,205**	**6,561**	**13,876**	**193**	**$44,620**	**35,445**	**6,635**	**6,555**	**30,127**	**$73,211**	**- 23,864**	**$- 4,534**	**115,733**	**$113,296**	**100**	**$1.48**

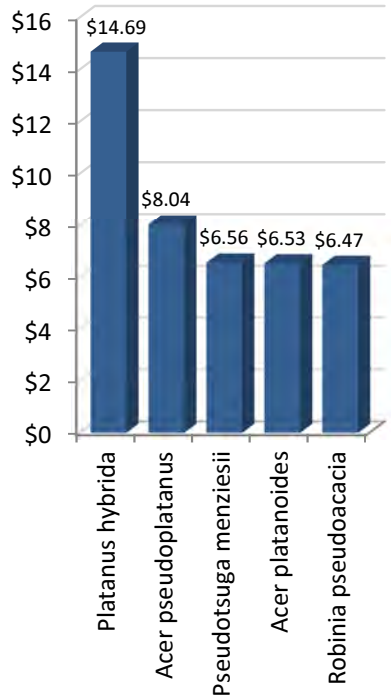


Figure 10. Annual Stormwater Benefits - Top 5 Species

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.

Rainfall interception by trees can reduce the amount of stormwater that enters collection and treatment facilities during large storm events. Trees intercept rainfall in their canopy, acting as mini-reservoirs, controlling runoff at the source. This is especially important in an urban setting with a significant quantity of impervious surfaces near a major waterway. 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 flows by diminishing the impact of raindrops on barren surfaces.

Spokane's street trees intercept over 58 million gallons of stormwater annually for an average of 757.8 gallons per tree (Table 8). That amount of water is equivalent to half of the water stored in Spokane's water department facilities each year. The value of this benefit to the City is $290,602, an average of $3.80 per tree. London plane tree (*Platanus hybrida*, $14.69) provides the greatest per-tree benefit (Figure 10), while the population of Norway maples (*Acer platanoides*) and ponderosa pine (*Pinus ponderosa*) provide the greatest portions of the total benefits (31.89 & 13.14, respectively.

Flowering dogwood (*Cornus florida)* and Japanese maple (*Acer palmatum*) provide the smallest stormwater benefits among the most prevalent 12 species, primarily due to their young age distribution and smaller mature canopy.

Table 8. Annual Stormwater Runoff Reduction Benefits from Spokane's Street Tree Resource

Species	Total Rainfall Interception (Gal)	Total ($)	of Total Tree Numbers	of Total $	Avg. $/tree
Platanus hybrida	4,251,804	21,261	1.89	7.32	14.69
Acer pseudoplatanus	1,563,694	7,819	1.27	2.69	8.04
Pseudotsuga menziesii	2,257,506	11,288	2.25	3.88	6.56
Acer platanoides	18,533,734	92,675	18.53	31.89	6.53
Robinia pseudoacacia	4,704,108	23,522	4.75	8.09	6.47
Pinus ponderosa	7,638,891	38,197	9.07	13.14	5.50
Ulmus pumila	2,125,174	10,627	3.28	3.66	4.24
Picea abies	697,524	3,488	1.11	1.20	4.10
Ulmus americana	882,211	4,411	1.50	1.52	3.85
Picea pungens	1,269,448	6,348	2.86	2.18	2.90
Aesculus hippocastanum	541,024	2,705	1.27	0.93	2.79
Tilia cordata	517,241	2,586	1.72	0.89	1.97
Gleditsia triacanthos	608,289	3,042	2.15	1.05	1.84
Crategus douglasii	584,013	2,920	2.42	1.00	1.58
Sorbus acuparia	293,004	1,465	1.23	0.50	1.55
Acer rubrum	518,967	2,595	2.37	0.89	1.43
Acer sp.	395,593	1,978	2.41	0.68	1.07
Fraxinus americana	279,165	1,396	1.73	0.48	1.06
Populus tremuloides	265,260	1,326	1.72	0.46	1.01
Pinus aristata	298,264	1,491	2.10	0.51	0.93
Prunus avium	1,013,602	5,068	7.17	1.74	0.92
Malus floribunda	372,463	1,862	3.12	0.64	0.78
Abies lasiocarpa	129,966	650	1.39	0.22	0.61
Prunus cerasifera	115,070	575	1.30	0.20	0.58
Unknown	160,319	802	1.91	0.28	0.55
Pyrus calleryana	192,193	961	2.55	0.33	0.49
Cornus florida	59,241	296	1.01	0.10	0.38
Acer palmatum	58,815	294	1.17	0.10	0.33
OTHER STREET TREES	7,789,680	38,951	14.76	13.40	3.45
CITYWIDE TOTAL	**58,116,267**	**$290,602**	**100**	**100**	**$3.80**

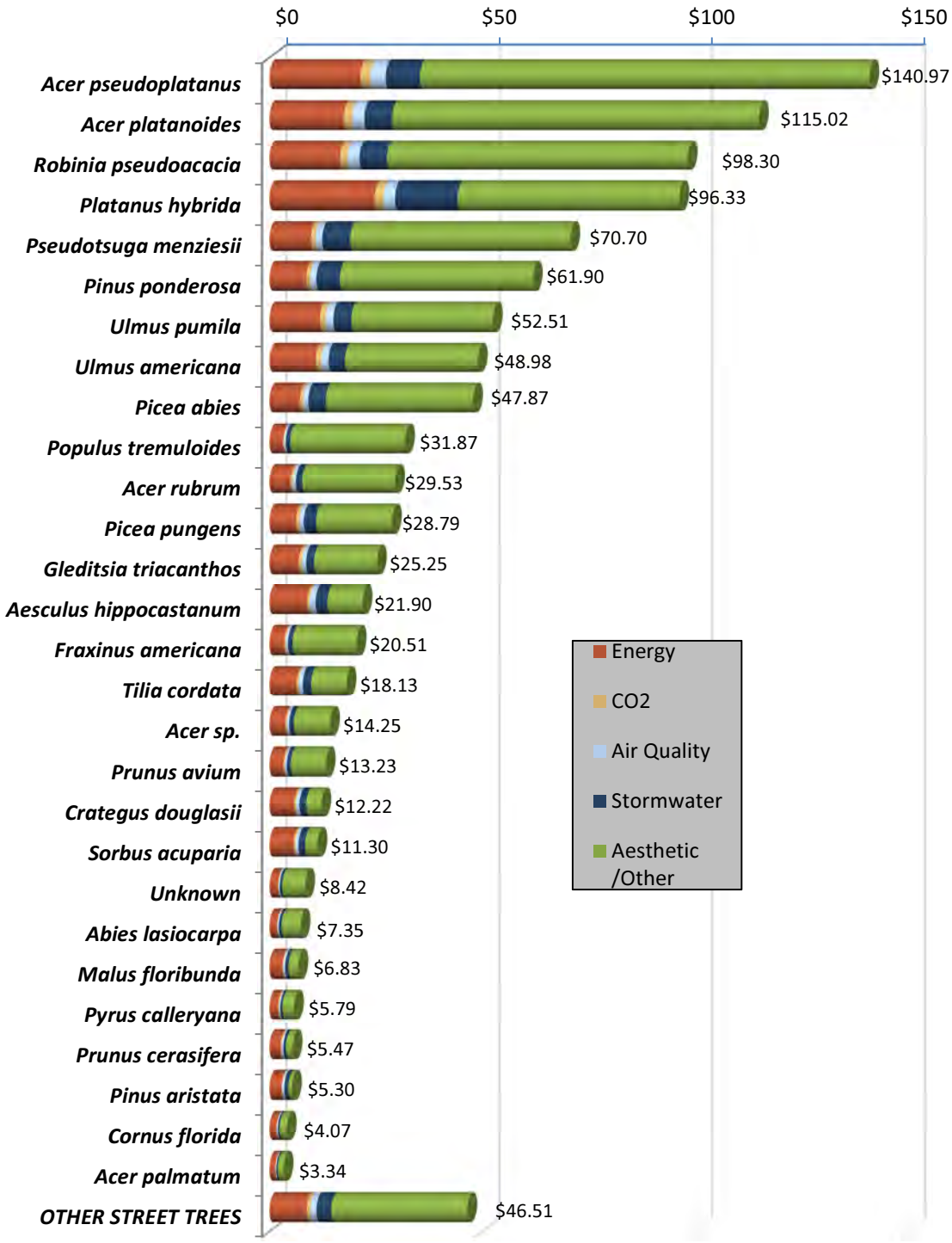


Figure 11. Summary of Annual Per Tree Benefits from Spokane's Most Prevalent Street Trees

Net Benefits & Benefit-Investment Ratio

In order to recognize the full value of the benefits from Spokane's street trees, it is important to take into account the investments (cost) of caring for this resource. Applying a Benefit-Investment Ratio (BIR) is a useful way to evaluate the public investment in the community tree population. A BIR is an indicator used to summarize the overall value compared to the costs of a given project.

Specifically, in this analysis, BIR is the ratio of the total benefits provided by the City's street trees expressed in monetary terms compared to the costs (investment) associated with their management, also expressed in monetary terms. In 2011, the City spent a total of $466,000 for maintenance, including administration and infrastructure repairs resulting from tree roots damaging sidewalks. Considering this resource provided $4,044,229 in total benefits, for every $1 invested in caring for street trees, the community currently receives $7.68 in benefits (Table 9).

Annual increases in property value, socioeconomic, and other aesthetic values are substantial benefits ($2,850,251), accounting for 70% of the total benefits. Approximately 42% ($1.19 Million) of the total annual benefits quantified in this study are environmental services (Figure 12). Energy savings ($714,302) account for 60% of the annual environmental benefits and 18% of all annual benefits. Stormwater benefits ($290,602) account for 24% of the annual environmental benefits and 7% of all benefits. Air quality benefits ($113,296) account for 9% of annual environmental benefits and 3% of all annual benefits. Carbon reduction benefits, valued at $75,778, account for 6% of environmental benefits and 2% of all benefits.

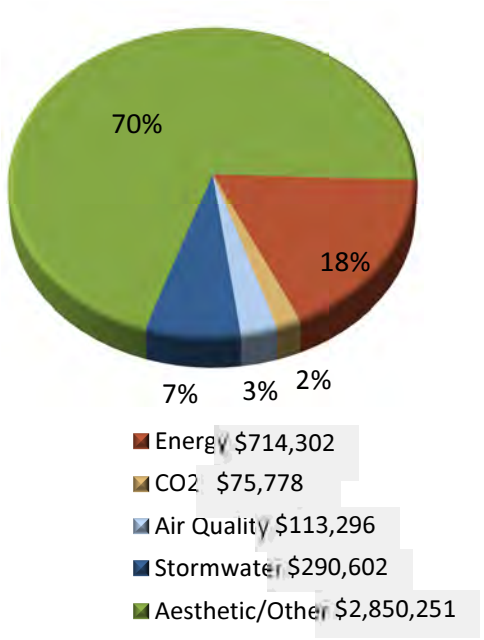


Figure 12 Annual Benefits from Spokane's Street Tree Resource

Total Annual Benefits from Spokane's Street Tree Resource:
$4,044,229

Average Annual per Tree Benefits:
$52.83

Annual Value of Benefits Per Capita:
$19.25

Table 9. Benefits versus Investment Ratio

Benefits	Total ($)	$/tree	$/capita
Energy	714,302	9.33	3.40
CO2	75,778	0.99	0.36
Air Quality	113,296	1.48	0.54
Stormwater	290,602	3.80	1.38
Aesthetic/Other	2,850,251	37.23	13.57
Total Benefits	**$4,044,229**	**$52.83**	**$19.25**
Cost			
Planting	36,160	0.47	0.17
Contract Pruning	66,160	0.86	0.31
Irrigation	15,350	0.20	0.07
Removal	66,160	0.86	0.31
Administration	210,325	2.75	1.00
Inspection/Service	32,845	0.43	0.16
Other Costs	39,000	0.51	0.19
Total Costs	**$466,000**	**$6.09**	**$2.22**
Net Benefits	**$3,578,229**	**$46.74**	**$17.03**
Benefit-cost ratio	**$7.68**		

Total Annual Investment in Spokane's Public Tree Resource:
$466,000

Average Annual per Tree Investment:
$6.09

Annual Investment Per Capita:
$2.22

The estimated sum of benefits provided by Spokane's street tree resource is $4,044,229, a value of $52.83 per tree and $19.25 per capita. These benefits are realized on an annual basis. It is important to acknowledge that this is not a full accounting of the benefits provided by this public tree resource as some benefits are intangible and/or difficult to quantify, such as impacts on psychological health, crime, and violence. Empirical evidence of these benefits does exist (Wolf, 2007; Kaplan, 1989; Ulrich, 1986), but there is limited knowledge about the physical processes at work and their interactions make quantification 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.

Considering the related expenditures (or investment) of $466,000, the net annual benefit (benefits minus investment) to the City is $3,578,229. The average net benefit for an individual street tree in Spokane is $46.74 and the per capita net benefit is $17.03.

Annual net benefits from Spokane's street tree resource:

$3,578,229

For EVERY $1 invested in street trees, Spokane receives $7.68 in benefits

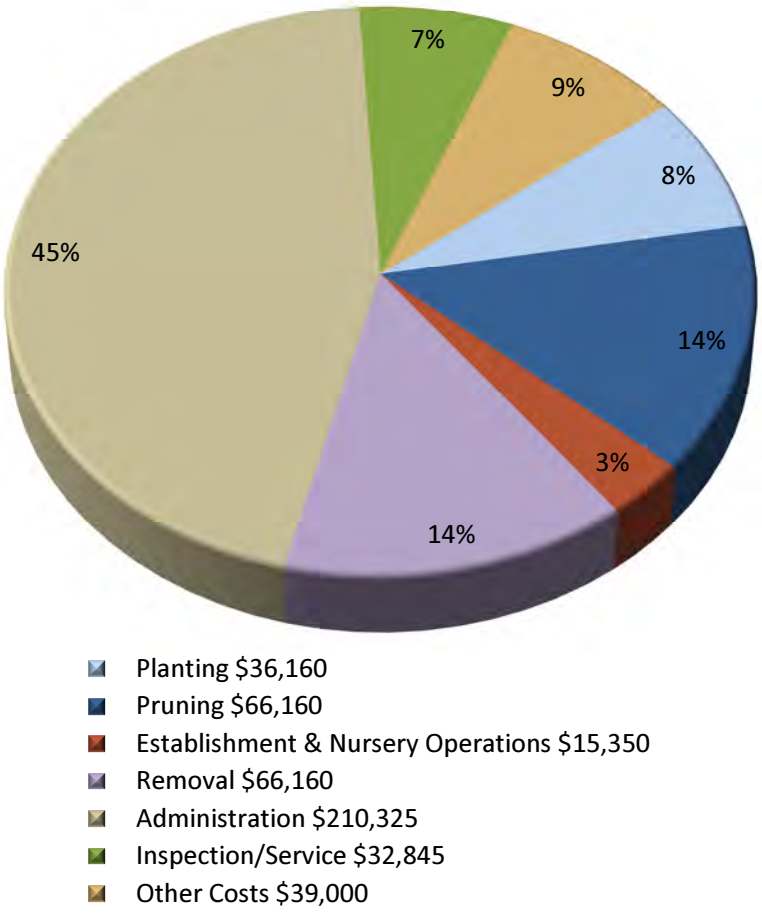


Figure 13. Annual Investment for Street Tree Care

Recommendation: Focus on large stature trees where conditions are favorable to maximize benefits.

Conclusion

This analysis describes the current structural characteristics of Spokane's municipal forest using established tree sampling, numerical modeling, and statistical methods and GIS technologies to provide a general accounting of the benefits produced by this tree resource. The analysis provides a "snapshot" of this resource at its current population and condition level. Rather than examining each individual tree as an inventory does, the resource analysis examines trends and performance measures over the entire urban forest and each of the major species populations within.

When evaluating the bottom line, Spokane's public trees are worth the investment. This public resource gives back more in quantifiable benefits, including energy savings, reduction in stormwater runoff, reduction in atmospheric CO_2, and aesthetic benefits, than the community invests in its care. The City's 76,533 trees from this inventory are providing $4.04 million in annual gross benefits. Taking into consideration the modest investment applied to manage this resource ($466,000); Spokane's trees currently provide $3.58 million in annual net benefits. That is an average of $46.74 per tree and $17.03 per capita. **For every $1 invested in Spokane's public trees, the community receives $7.68 in net benefits.**

The street trees inventoried in this project are favorably weighted in the younger age classes and are in good condition with more than 97 different species. It is critical to maintain an adequate level of invest in resource protection and enhancement if Spokane's public street trees can be expected to provide even greater benefits in the future and for many generations to come. The City can focus resources on maximizing the flow of benefits from the current tree population and maintaining a forward-thinking approach. Based on the resource analysis, Davey Resource Group recommends the following:

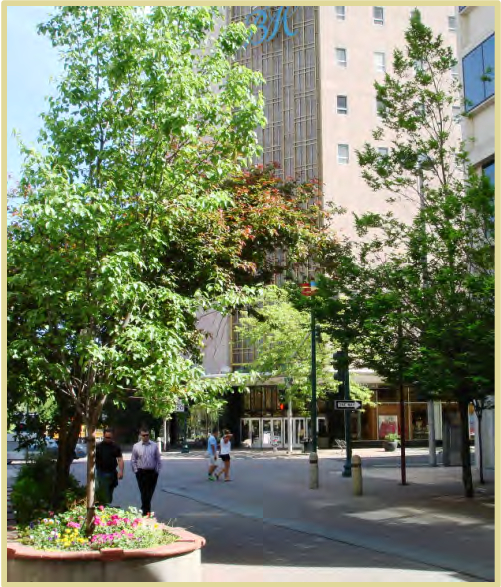
- Advocate for planting space design standards during infrastructure improvement projects in order to enhance the quality of planting spaces (i.e. connected tree pits or structured soils).
- Maintain an appropriate age distribution by planting new trees to improve long-term resource sustainability and greater canopy coverage. Focus on large-stature trees where conditions are sustainable to maximize benefits.

- Maximize the benefits of the existing tree resource through on-going tree maintenance according to the City's cyclical pruning schedule.
- Implement a structural pruning program for young and establishing trees to promote healthy structure, extend life expectancy, and reduce future costs and liability.

Understanding the current status of the City's tree population allows forest managers to consider what future trends are likely and what management challenges will need to be overcome to sustain or, more importantly, increase the current level of benefits. Performance data from the analysis can be used to make determinations regarding species selection, distribution, and maintenance policies. Another important consideration is that while larger statured trees like ponderosa pine tend to have the greatest benefits, they may not always be the most suitable as a street tree. Larger stature trees should only be planted where space will allow for their maturity without conflicting existing utilities and other infrastructure.

Documenting current structure is necessary for establishing goals and performance objectives and can serve as a benchmark for measuring future success. Information from the urban forest resource analysis can be referenced in development of an urban forest management or master plan.

With this street tree inventory, Spokane can take a forward-looking approach to urban forest management, and recognize the vital importance of trees to the environmental, social, and economic well-being of the city. Spokane has demonstrated that public trees are a valued community resource, a vital component of the urban infrastructure, and an important part of the city's history and identity. The City takes a proactive approach to caring for the community's trees, as evidenced by the condition and structure of this public resource. Current and complete inventory data will help staff to more efficiently track maintenance activities and tree health and will provide a strong basis for making informed management decisions. With additional tree planting and continued proactive management, Spokane's urban forest can be expected to produce an even greater flow of benefits as this resource continues to mature. With a demonstrated commitment to maintaining and maximizing the benefits from its public trees, the community will continue to be a safe and environmentally-focused city with vibrant neighborhoods, businesses and public places.



Spokane's urban forest can be expected to produce an even greater flow of benefits as this resource continues to mature.

Appendix A: Methods and Procedures

With an estimated 76,533 public trees in Spokane, the City contracted with Davey Resource Group (DRG) during 2012-2013 to collect an inventory of public trees and append to the City's existing database of trees.

Certified Arborists collected the tree inventory using ArcPad software. This approach helped the arborist to locate trees on the ground and simplified data collection of tree attributes (details about each tree's species, size, and condition).

The data was formatted for use in i-Tree's public tree population assessment tool, **i-Tree *Streets, a STRATUM Analysis Tool*** (*Streets* v 5.0.1; i-Tree v 5.0.6). i-Tree *Streets* 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 Spokane's trees, i-Tree *Streets* calculates the dollar value of annual resource functionality and compares that to annual program expenditures. This analysis combines the results of the City's tree inventory with benefit-cost modeling data to produce information regarding resource structure, function, and value for use in determining management recommendations. i-Tree *Streets* regionalizes the calculations of its output by incorporating detailed reference city project information for 17 climate zones across the United States (Spokane is located in the Interior west climate zone, the reference city is Albuquerque, New Mexico).

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 saved per tree; MBtu of natural gas conserved per tree, pounds of atmospheric CO_2 reduced per tree; pounds 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.

Price values assigned to each resource unit (tree) were generated based on economic indicators of society's willingness to pay for the environmental benefits trees provide. The City's tree care costs were estimated from the annual city budget of $ $618.6 million.

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 based on current research. It is intended to be a general accounting of the benefits produced by urban trees.

Table 10 Spokane Benefit Prices Used In This Analysis

Benefits	Price	Unit	Source
Electricity	$0.08	$/Kwh	*Avista Utilities*
Natural Gas	$0.85	$/Therm	Avista utilities
CO_2	$0.0033	$/lb	*Streets* default – Interior west
PM_{10}	$1.14	$/lb	*Streets* default – Interior west
NO_2	$0.61	$/lb	*Streets* default – Interior west
SO_2	$1.42	$/lb	*Streets* default – Interior west
VOC	$0.19	$/lb	*Streets* default – Interior west
Stormwater Interception	$0.005	$/gallon	*Streets* default – Interior west
Median Home Value	$165,500	$	2011 Census data

i-Tree *Streets* default values (

Table ***10***) from the Interior west were used for all benefit prices except for median home values, stormwater, electric and natural gas rates. Electric and natural gas rates are 2013 rates obtained from Avista Utilities Company Web site (http://www.avistautilities.com/services/energypricing).

The median home value (2013) for Spokane was verified generated from US census bureau data at (http://quickfacts.census.gov/qfd/states/53/5367000.html) Using these rates, the magnitude of the benefits provided by the public tree resource was calculated using i-Tree *Streets***.** This software models tree benefits based on first order approximations from reference cities. For this project, the reference city was Albuquerque, New Mexico.

Program budget values used in the benefit versus investment ratio calculations were estimates, supplied by City of Spokane, Parks and Recreation Department.

Appendix B: References

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Appendix C: Inventory Data

Spokane's Inventory Population of Trees

Broadleaf Deciduous Large (BDL)	DBH Class (in)									Total
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	
Acer platanoides	1,362	1,510	2,089	3,569	3,647	1,637	320	54	1	14,189
Robinia pseudoacacia	728	474	465	513	692	452	217	72	22	3,635
Ulmus pumila	725	382	455	293	258	229	106	45	16	2,509
Acer rubrum	415	571	598	194	36	2	1	1	-	1,818
Gleditsia triacanthos	277	352	760	189	60	8	3	-	-	1,649
Platanus hybrida	51	60	99	189	292	321	240	142	53	1,447
Fraxinus americana	668	306	225	82	29	6	4	1	-	1,321
Populus tremuloides	617	410	236	49	3	1	-	-	-	1,316
Ulmus americana	287	239	204	164	93	94	37	19	8	1,145
Acer pseudoplatanus	28	29	99	333	322	130	26	5	1	973
Acer saccharinum	36	21	42	111	125	142	121	57	26	681
Acer saccharum	82	40	118	85	138	48	10	2	-	523
Quercus rubra	158	34	95	63	69	61	24	10	4	518
Juglans regia	106	46	101	114	84	28	8	1	-	488
Acer negundo	55	67	96	95	71	57	24	17	5	487
Populus alba	74	61	65	69	47	32	25	18	36	427
Ailanthus altissima	119	51	53	25	16	16	5	1	1	287
Catalpa speciosa	5	10	25	65	71	45	23	5	4	253
Fagus sylvatica	71	50	37	17	3	3	2	1	-	184
Liquidambar styraciflua	86	30	25	14	1	1	-	-	-	157
Populus nigra	26	28	39	25	11	13	6	2	5	155
Fraxinus pennsylvanica 'Marshall'	46	38	14	6	4	3	2	1	-	114
Liriodendron tulipifera	43	24	13	5	4	3	1	-	-	93
Salix matsudana	24	18	11	14	8	4	3	1	-	83
Quercus palustris	16	4	30	16	7	7	2	-	-	82
Quercus	19	1	13	5	5	1	-	-	-	44

coccinia										
Quercus macrocarpa	14	6	1	2	1	-	-	-	-	24
Quercus alba	2	4	6	3	3	-	1	-	-	19
Ulmus procera	2	1	-	1	-	1	-	-	-	5
Populus balsamifera ssp. trichocarpa	-	-	-	-	-	-	1	-	-	1
Taxodium distichum	-	1	-	-	-	-	-	-	-	1
Total	**6,142**	**4,868**	**6,014**	**6,310**	**6,100**	**3,345**	**1,212**	**455**	**182**	**34,628**
Broadleaf Deciduous Medium (BDM)										
Prunus avium	1,769	1,452	1,470	604	144	40	5	2	3	5,489
Acer sp.	467	528	510	223	77	29	10	3	1	1,848
Unknown	845	302	189	87	25	12	1	1	-	1,462
Tilia cordata	252	156	245	301	254	77	20	8	3	1,316
Aesculus hippocastanum	72	35	91	321	287	123	31	7	2	969
Carpinus betulus 'Fastigiata'	290	159	64	23	2	-	2	-	-	540
Betula pendula	75	105	137	121	72	13	8	3	1	535
Betula nigra	128	86	123	76	15	6	3	1	1	439
Tilia americana	102	27	32	41	49	21	6	2	-	280
Salix amygdaloides	64	42	66	32	23	22	7	11	6	273
Larix dedidua	29	16	16	18	18	3	1	-	-	101
Morus alba	22	17	18	15	11	7	3	2	1	96
Parrotia persica	52	30	5	-	-	-	-	-	-	87
Cercidiphyllum japonicum	44	15	22	4	-	-	-	-	-	85
Alnus rubra	6	10	6	9	1	1	-	-	-	33
Celtis occidentalis	7	10	9	-	-	1	-	-	-	27
Koelreuteria paniculata	18	3	2	4	-	-	-	-	-	27
Total	**4,242**	**2,993**	**3,005**	**1,879**	**978**	**355**	**97**	**40**	**18**	**13,607**
Broadleaf Deciduous Small (BDS)										
Malus floribunda	902	630	594	206	47	6	-	-	1	2,386
Pyrus calleryana 'Cleveland'	685	688	511	62	4	-	-	-	-	1,950

Crategus douglasii	209	282	746	523	79	11	1	1	-	1,852
Prunus cerasifera	195	328	325	119	21	4	-	-	-	992
Sorbus acuparia	143	169	291	201	101	32	7	1	-	945
Acer palmatum	609	187	68	17	9	6	-	-	-	896
Cornus florida	390	274	99	8	1	1	-	-	-	773
Rhus glabra	163	122	82	14	8	1	-	-	-	390
Syringa reticulata	141	107	66	12	3	-	-	-	-	329
Crategus laevigata	8	15	76	54	8	2	-	-	-	163
Corylus maxima var. purpurea	65	24	37	6	2	-	-	-	-	134
Prunus persica	60	20	5	1	-	-	-	-	-	86
Acer circinatum	28	24	26	5	-	1	-	-	-	84
Laburnum anagyroidies	29	10	14	8	2	-	-	-	-	63
Crategus x lavallei	1	5	19	12	-	-	-	-	-	37
Prunus yedoensis	13	5	-	-	-	-	-	-	-	18
Sambucus caerulea var neomexicana	5	2	5	3	1	2	-	-	-	18
Pyrus communis	9	3	1	-	-	-	-	-	-	13
Prunus serrulata	9	-	1	1	-	-	-	-	-	11
Magnolia x soulangiana	-	3	2	1	-	1	1	-	-	8
Crategus phaenopyrum	1	2	1	-	-	-	-	-	-	4
Prunus subhirtella	-	-	1	1	-	-	-	-	-	2
Total	**3,665**	**2,900**	**2,970**	**1,254**	**286**	**67**	**9**	**2**	**1**	**11,154**
Broadleaf Evergreen Medium (BEM)										
Quercus agrifolia	145	49	75	27	24	15	8	1	-	344
Magnolia grandiflora	125	64	58	30	7	6	1	-	-	291
Ilex aqualifolium	4	2	-	-	-	-	-	-	-	6
Total	**274**	**115**	**133**	**57**	**31**	**21**	**9**	**1**	**0**	**641**
Conifer Evergreen Large (CEL)										
Pinus ponderosa	963	810	886	1,336	1,324	1,122	409	74	22	6,946
Pseudotsuga	205	168	214	277	341	300	158	47	11	1,721

menziesii										
Abies lasiocarpa	487	267	229	67	8	2	1	-	1	1,062
Picea abies	153	112	110	192	184	75	23	2	-	851
Abies grandis	114	67	102	88	70	45	9	5	-	500
Thuja plicata	82	54	76	91	44	23	14	3	2	389
Pinus sylvestris	12	35	77	80	26	5	-	-	-	235
Thuja occidentalis	29	56	46	15	4	3	-	-	-	153
Picea glauca	24	19	32	38	27	9	3	-	-	152
Chamaecyparis nootkatensis	23	24	29	11	7	5	-	-	-	99
Cedrus atlantica	50	14	10	2	1	-	-	-	-	77
Abies procera	41	10	4	3	1	-	-	-	-	59
Tsuga martensiana	32	10	10	2	2	1	-	-	-	57
Chamaecyparis lawsoniana	8	16	6	2	-	-	1	-	-	33
Tsuga heterophylla	15	10	4	2	-	-	-	-	-	31
Cedrus deodara	10	4	1	1	-	-	-	-	-	16
Picea sitchensis	5	1	-	6	-	-	1	-	-	13
Sequoia giganteum	2	3	-	-	1	-	-	-	-	6
Calocedrus decurrens	-	2	-	-	-	-	-	-	-	2
Total	**2,255**	**1,682**	**1,836**	**2,213**	**2,040**	**1,590**	**619**	**131**	**36**	**12,402**
Conifer Evergreen Medium (CEM)										
Picea pungens	339	281	433	579	372	163	16	3	1	2,187
Pinus mugo	26	26	19	12	-	1	-	-	-	84
Total	**365**	**307**	**452**	**591**	**372**	**164**	**16**	**3**	**1**	**2,271**
Conifer Evergreen Small (CES)										
Pinus aristata	386	267	433	313	137	52	14	3	-	1,605
Juniperus chinensis	104	64	19	4	1	1	-	-	-	193
Pinus contorta	2	4	10	6	3	2	1	-	-	28
Taxus baccata	7	7	5	2	1	1	1	-	-	24
Total	**499**	**342**	**467**	**325**	**142**	**56**	**16**	**3**	**0**	**1,850**
Citywide Total	**17,442**	**13,207**	**14,877**	**12,629**	**9,949**	**5,598**	**1,978**	**635**	**238**	**76,553**

Relative Performance Index (RPI) for Spokane's Tree Species

Species	Dead or Dying	Poor	Fair	Good	RPI	# of Trees	% of Public Trees
Abies grandis	0.80	0.40	3.20	95.60	1.02	500	0.65
Abies lasiocarpa	0.28	0.00	1.22	98.49	1.03	1062	1.39
Abies procera	0.00	1.69	5.08	93.22	1.01	59	0.08
Acer circinatum	0.00	0.00	4.76	95.24	1.02	84	0.11
Acer negundo	0.21	8.21	26.90	64.68	0.90	487	0.64
Acer palmatum	0.22	1.12	2.57	96.09	1.02	896	1.17
Acer platanoides	0.25	1.09	9.14	89.51	1.00	14189	18.53
Acer pseudoplatanus	0.41	2.26	14.08	83.25	0.97	973	1.27
Acer rubrum	0.17	1.21	5.67	92.96	1.01	1818	2.37
Acer saccharinum	0.44	2.79	14.10	82.67	0.97	681	0.89
Acer saccharum	0.00	1.91	10.90	87.19	0.99	523	0.68
Acer sp.	0.60	1.03	5.68	92.69	1.01	1848	2.41
Aesculus hippocastanum	0.21	0.31	4.95	94.53	1.02	969	1.27
Ailanthus altissima	0.35	1.39	12.20	86.06	0.99	287	0.37
Alnus rubra	0.00	0.00	9.09	90.91	1.01	33	0.04
Betula nigra	0.23	1.59	3.19	94.99	1.01	439	0.57
Betula pendula	3.74	0.75	8.97	86.54	0.97	535	0.70
Calocedrus decurrens	0.00	0.00	0.00	100.00	1.03	2	0.00
Carpinus betulus 'Fastigiata'	0.93	1.48	3.33	94.26	1.01	540	0.71
Catalpa speciosa	0.00	5.53	14.23	80.24	0.96	253	0.33
Cedrus atlantica	0.00	1.30	3.90	94.81	1.01	77	0.10
Cedrus deodara	0.00	0.00	0.00	100.00	1.03	16	0.02
Celtis occidentalis	0.00	0.00	0.00	100.00	1.03	27	0.04
Cercidiphyllum japonicum	0.00	0.00	2.35	97.65	1.03	85	0.11
Chamaecyparis lawsoniana	0.00	0.00	9.09	90.91	1.01	33	0.04
Chamaecyparis nootkatensis	0.00	0.00	6.06	93.94	1.02	99	0.13
Citywide	0.63	1.12	7.21	91.04	1.00	76553	100.00
Cornus florida	0.52	0.39	2.72	96.38	1.02	773	1.01
Corylus maxima var. purpurea	0.75	0.00	5.22	94.03	1.01	134	0.18
Crategus douglasii	0.43	1.03	11.18	87.37	0.99	1852	2.42
Crategus laevigata	0.00	8.59	16.56	74.85	0.93	163	0.21
Crategus phaenopyrum	0.00	0.00	50.00	50.00	0.88	4	0.01
Crategus x lavallei	0.00	8.11	21.62	70.27	0.92	37	0.05
Fagus sylvatica	0.00	2.17	4.35	93.48	1.01	184	0.24
Fraxinus americana	0.15	0.76	3.03	96.06	1.02	1321	1.73

Species	Dead or Dying	Poor	Fair	Good	RPI	# of Trees	of Public Trees
Fraxinus pennsylvanica 'Marshall2'	0.88	1.75	8.77	88.60	0.99	114	0.15
Gleditsia triacanthos	0.42	0.61	5.76	93.21	1.01	1649	2.15
Ilex aqualifolium	0.00	0.00	0.00	100.00	1.03	6	0.01
Juglans regia	0.00	1.23	6.15	92.62	1.01	488	0.64
Juniperus chinensis	0.00	0.00	1.55	98.45	1.03	193	0.25
Koelreuteria paniculata	0.00	0.00	3.70	96.30	1.02	27	0.04
Laburnum anagyroidies	0.00	0.00	6.35	93.65	1.02	63	0.08
Larix dedidua	0.00	0.00	2.97	97.03	1.03	101	0.13
Liquidambar styraciflua	0.00	0.64	0.00	99.36	1.03	157	0.21
Liriodendron tulipifera	0.00	1.08	7.53	91.40	1.01	93	0.12
Magnolia grandiflora	1.03	1.03	2.75	95.19	1.01	291	0.38
Magnolia x soulangiana	0.00	0.00	0.00	100.00	1.03	8	0.01
Malus floribunda	0.38	0.29	6.16	93.17	1.01	2386	3.12
Morus alba	0.00	0.00	9.38	90.63	1.01	96	0.13
Parrotia persica	1.15	3.45	3.45	91.95	0.99	87	0.11
Picea abies	0.71	0.12	2.47	96.71	1.02	851	1.11
Picea glauca	0.00	0.66	1.97	97.37	1.02	152	0.20
Picea pungens	0.27	0.00	2.29	97.44	1.03	2187	2.86
Picea sitchensis	0.00	0.00	0.00	100.00	1.03	13	0.02
Pinus contorta	0.00	3.57	3.57	92.86	1.00	28	0.04
Pinus mugo	0.00	0.00	7.14	92.86	1.01	84	0.11
Pinus ponderosa	0.35	0.26	3.50	95.90	1.02	6946	9.07
Pinus sylvestris	0.43	0.00	8.51	91.06	1.00	235	0.31
Pittosporum arborescens	0.93	0.25	4.61	94.21	1.01	1605	2.10
Platanus hybrida	0.00	0.41	4.98	94.61	1.02	1447	1.89
Populus alba	1.17	3.04	13.35	82.44	0.96	427	0.56
Populus balsamifera ssp. trichocarpa	0.00	0.00	100.00	0.00	0.73	1	0.00
Populus nigra	4.52	1.94	2.58	90.97	0.97	155	0.20
Populus tremuloides	2.43	0.91	3.95	92.71	0.99	1316	1.72
Prunus avium	0.84	1.15	7.29	90.73	1.00	5489	7.17
Prunus cerasifera	0.60	0.40	7.26	91.73	1.00	992	1.30
Prunus persica	1.16	0.00	5.81	93.02	1.01	86	0.11
Prunus serrulata	0.00	0.00	0.00	100.00	1.03	11	0.01
Prunus subhirtella	0.00	0.00	0.00	100.00	1.03	2	0.00

Species	Dead or Dying	Poor	Fair	Good	RPI	# of Trees	of Public Trees
Prunus yedoensis	0.00	0.00	0.00	100.00	1.03	18	0.02
Pseudotsuga menziesii	0.35	0.29	3.31	96.05	1.02	1721	2.25
Pyrus calleryana 'Cleveland'	0.31	0.41	2.46	96.82	1.02	1950	2.55
Pyrus communis	0.00	0.00	0.00	100.00	1.03	13	0.02
Quercus agrifolia	0.29	0.58	5.81	93.31	1.01	344	0.45
Quercus alba	0.00	5.26	0.00	94.74	1.00	19	0.02
Quercus coccinia	0.00	0.00	0.00	100.00	1.03	44	0.06
Quercus macrocarpa	0.00	0.00	0.00	100.00	1.03	24	0.03
Quercus palustris	0.00	0.00	1.22	98.78	1.03	82	0.11
Quercus rubra	0.19	0.39	4.05	95.37	1.02	518	0.68
Rhus glabra	3.85	1.79	6.15	88.21	0.97	390	0.51
Robinia pseudoacacia	1.73	4.59	16.92	76.75	0.94	3635	4.75
Salix amygdaloides	0.37	2.56	8.42	88.64	0.99	273	0.36
Salix matsudana	1.20	6.02	9.64	83.13	0.96	83	0.11
Sambucus caerulea var neomexicana	0.00	0.00	27.78	72.22	0.95	18	0.02
Sequoia giganteum	0.00	0.00	0.00	100.00	1.03	6	0.01
Sorbus acuparia	0.42	3.07	11.53	84.97	0.98	945	1.23
Syringa reticulata	0.91	0.30	3.34	95.44	1.01	329	0.43
Taxodium distichum	0.00	0.00	0.00	100.00	1.03	1	0.00
Taxus baccata	0.00	0.00	0.00	100.00	1.03	24	0.03
Thuja occidentalis	1.96	0.00	7.84	90.20	0.99	153	0.20
Thuja plicata	0.26	0.00	3.08	96.66	1.02	389	0.51
Tilia americana	0.36	0.71	6.07	92.86	1.01	280	0.37
Tilia cordata	0.08	0.53	4.56	94.83	1.02	1316	1.72
Tsuga heterophylla	0.00	0.00	6.45	93.55	1.01	31	0.04
Tsuga martensiana	0.00	0.00	10.53	89.47	1.00	57	0.07
Ulmus americana	1.48	1.48	7.77	89.26	0.99	1145	1.50
Ulmus procera	0.00	0.00	0.00	100.00	1.03	5	0.01
Ulmus pumila	1.12	1.08	15.11	82.70	0.97	2509	3.28
Unknown	3.35	1.03	5.47	90.15	0.98	1462	1.91