URBAN FOREST RESOURCE ANALYSIS
OF INVENTORIED STREET TREES

City of Victoria, British Columbia

September 2014

Appendix 2

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RESOURCE GROUP
A Division of The Davey Tree Expert Company

City of Victoria, British Columbia
Resource Analysis
Of Inventoried Street trees

September 2014

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Executive Summary

Trees play a vital role in the community of Victoria, British Columbia. They provide numerous benefits both tangible and intangible, to residents, visitors, and neighboring communities. Dedicated to maintaining 18,869 street trees, Victoria 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.

In 2012, Victoria contracted with Davey Resource Group (DRG) to collect an inventory of all public street trees. During the inventory, a certified arborist briefly inspected each tree and recorded information including species, size, condition, geographic location, and current maintenance needs. Upon completion of the inventory, DRG performed 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.

Victoria's inventoried street trees are providing annual benefits of $2,805,508 ($35.05 per capita). These benefits include energy savings, air quality improvements, stormwater interception, atmospheric CO_2 reduction, and aesthetic contributions to the social and economic health of the community.

Victoria's inventoried street tree resource is reducing annual electric energy consumption by 5,430 GJ and annual natural gas consumption by 15,107 GJ, for a combined value of $153,484 annually. In addition, these trees are removing 7,604 kg of pollutants from the air, including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulates (PM_{10}) for an overall net annual air quality benefit of $31,914. Canopy from this population covers 127 hectares. This canopy reduces annual stormwater runoff by 93,683 cubic meters, enough to fill more than 37 Olympic swimming pools, protecting local water resources by reducing sediment and pollution loading.

Victoria's tree population is established, and much of the population is providing peak benefits due to the trees' mature size. The species diversity is adequate, but *Prunus* species are overrepresented and underperforming in terms of benefits. With a shift in new planting palettes toward other, underrepresented large to medium stature trees, and adequate maintenance, the benefits of Victoria's urban forest can be expected to increase.

Trees are a part of the community infrastructure. The estimated investment in maintenance for the street trees is $741,171. For every $1 invested in this resource, Victoria is receiving $3.79 in benefits. However, unlike many other public assets, with proper maintenance, trees have the potential to increase in value over time. Victoria's inventoried street tree resource is primarily in excellent, very good, good, and fair condition (93% of trees). With 238 different species, Victoria is well positioned to realize a significant increase in environmental benefits as tree populations continue to mature. An ongoing commitment to maximizing and maintaining the health of the urban forest will ensure that the community continues to be a healthy, safe, and enjoyable place to live.

Introduction

Victoria is located on the southern tip of Vancouver Island on the west coast of British Columbia. With a population of 84,511, it is part of the Greater Victoria metropolitan area. The climate is temperate, and receives an average annual rainfall of 608 mm. With over 2,000 hours of sunshine each year, Victoria is known as BC's garden city. The established urban forest provides structure and form to the city's landscape, giving residents a beautiful place to live.

This analysis takes a closer look at 18,869 inventoried trees, the City's street trees. The inventoried park trees, stumps, vacant sites, and unknown species are not included in the analysis, but stocking levels are calculated to provide a sense of the availability of planting sites. The park trees are excluded because i-Tree Streets is a model based on street trees. Stumps, vacant sites, and unknown species have no calculable benefits

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

Individual trees and a healthy urban forest play important roles in the quality of life and the sustainability of every community. Research demonstrates that healthy urban trees can improve the local environment and diminish the impact resulting from urbanization and industry (Center for Urban Forest Research). 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 City residents.

In addition to these direct improvements, healthy urban trees increase the overall attractiveness of a community and the value of local real estate by 7% to 10%. Trees promote 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. Victoria's urban forest is well established and diverse, reflecting a broad cross section of species that have arrived and thrived in the port city over hundreds of years. Victoria's trees reflect the City's proud history, and bright future. The City's street trees play a prominent role in the overall urban forest benefits afforded to the community. Residents rely on the City of Victoria to protect and maintain this vital resource.

The urban forest is a dynamic resource, constantly changing and growing in response to environment and care. A team of International Society of Arboriculture certified arborists from Davey Resource Group (DRG) mapped the location and collected data for street trees using global positioning system technology. In addition to location, the arborists collected information about the species, size, condition, and current maintenance needs of each tree.

The inventory data was analyzed with i-Tree's *Streets*, a STRATUM Analysis Tool (*Streets* v5.1.2; i-Tree v6.0.0), to develop a resource analysis and report of the current condition of the inventoried urban forest. This report, unique to Victoria, effectively quantifies the value of the community's public trees with regard to actual benefits derived from the tree resource. In addition, the report provides baseline values that can be used to develop and update an urban forest management plan. Management plans help communities determine where to focus available resources and set benchmarks for measuring progress.

This analysis describes the structure, function, and value of Victoria's 18,869 street trees. With this information, managers and citizens can make informed decisions about tree management strategies. This report provides the following information:

- A description of the current structure of Victoria's inventoried tree resource and an established benchmark for future management decisions.
- The economic value of the benefits from the urban forest, illustrating the relevance and relationship of trees 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 for developing a long-term urban forest management plan.

Chapter 1: Urban Forest Resource Summary

Summary of Urban Forest Resource Structure

Victoria's urban forest resource analysis considered 18,869 public street trees.

A structural analysis is the first step towards understanding the benefits provided by these trees as well as their management needs. Considering species composition, diversity, age distribution, condition, canopy coverage, and replacement value, DRG determined that the following information characterizes this urban forest resource:

- There were 238 unique tree species identified in the inventory. The predominant tree species are flowering plum (*Prunus cerasifera*, 10.3%), flowering cherry (*Prunus serrulata*, 8.3%), and hawthorn (*Crategus oxyacantha*, 6.3%)
- The age structure of the inventoried tree population is weighted in established, mature trees, with 66%% of trees measuring between 15.2 and 61 cm DBH (diameter at breast height, measured at 1.4 meters above the ground).
- A majority of the inventoried trees (56%) are in good or better condition and 37% are in fair condition.
- To date, the inventoried tree population has sequestered 33 million kg. of carbon (CO_2), valued at approximately $547,113.
- Replacement of Victoria's 18,869 inventoried trees with trees of similar size, species, and condition would cost over $84 million.

Replacement of Victoria's 18,869 inventoried trees with trees of similar size, species, and condition would cost over $84 million.

Summary of Urban Forest Benefits

Annually, Victoria's inventoried street trees provide cumulative benefits to the community at an average value of $148.68 per tree, for a total gross value of $2,805,508 per year. These annual benefits include:

- Trees reduce electricity and natural gas use in their neighborhoods through shading and climate effects for an overall benefit of $153,484, an average of $8.13 per tree.
- Trees sequester 1.1 million kg. of atmospheric CO_2 per year. An additional 1.5 million kg are avoided[1] by reducing energy generation, resulting in a net value of $39,493 and an average of $2.09 per tree.
- Net air quality improvements, including removal and avoidance of pollutants, provided by the city tree population are valued at $31,914, an average per tree benefit of $1.69.
- Victoria's inventoried street trees intercept an estimated 93,683 cubic meters of stormwater

For every $1 invested in public trees, Victoria receives $3.79 in benefits.

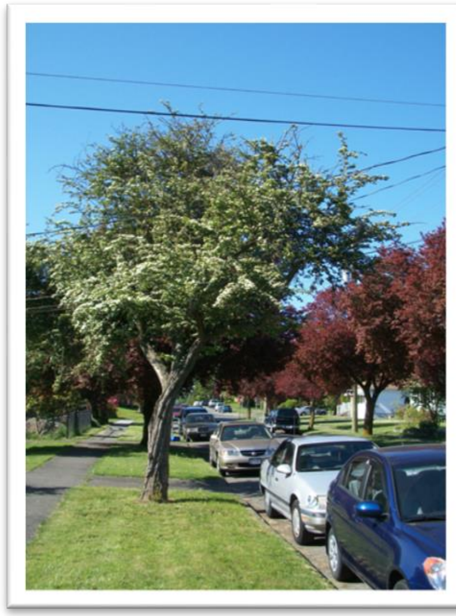
[1] Avoided pollution is a result of reducing energy consumption. The avoided value represents pollution that would have resulted from the generation of additional energy.

annually for a total value of $267,282, an average of $14.17 per tree.

- The benefit contributed by Victoria's inventoried street trees to property value increases, aesthetics, and socioeconomics equals $2.3 million, an average of $122.60 per tree.
- When the City's annual investment of $741,171 for maintenance of this resource is considered, the annual net benefit (benefits minus investment) to the City is $2,064,337, an average of $109.40 per tree. In other words**,** for every $1 invested in street trees, Victoria receives $3.79 in benefits.

Urban Forest Resource Management

Victoria's street tree population is a dynamic resource that requires continued investment to maintain and realize its full benefit potential. **These community trees are one of the few elements of city infrastructure that have the potential to increase in value with time and proper management.** Appropriate and timely tree care can substantially increase lifespan. When trees live longer, they provide greater benefits. As individual trees continue to mature and aging trees are replaced, the overall value of the community forest and the amount of benefits provided grow as well. 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.



Victoria has the benefit of an established tree population in good condition. The City should focus resources on maximizing the flow of benefits from the current tree population and maintaining a forward- thinking approach. Based on the resource analysis, DRG recommends the following:

- Maintain an appropriate age distribution by continuing to plant new trees to improve long-term resource sustainability and greater canopy coverage. To maximize benefits, focus on medium to large-stature trees where planting sites allow.
- Maximize the condition of the existing tree resource through continuing comprehensive tree maintenance and a 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.
- Maintain and update the tree inventory database.
- Discontinue or greatly reduce the planting of overrepresented species and genera in favor of less common trees.

The value of Victoria's inventoried tree resource will continue to increase 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 the 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 Victoria's urban forest. Existing mature trees should be evaluated and removed as they reach the end of their useful life. Trees in good condition should be maintained and protected whenever possible since the greatest benefits accrue from the continued growth and longevity of the existing canopy.

Chapter 2: Victoria's Urban Forest Resource

A city's urban forest resource is more thoroughly understood through examination of composition and species richness (diversity). Inferences based on this data can help managers understand the importance of individual tree species to the overall forest as it exists today. Consideration of stocking level (trees per available space), canopy cover, age distribution, condition, and performance helps to project the potential of the forest resource.

Population Composition

Broadleaf deciduous species are the most common among Victoria's inventoried street tree population, comprising 94% of the total inventory. Broadleaf trees typically have larger canopies than conifers with the same size DBH. Since many of the measurable benefits derived from trees are directly related to leaf surface area, 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 DBH. Victoria's deciduous broadleaf tree population includes 21% large-stature, 28% medium-stature, and 45% small-stature trees. Conifers comprise 5% of the population, including 1% large, 3% medium, and 1% small stature trees. Broadleaf Evergreens comprise less than 1% of the population of street trees.

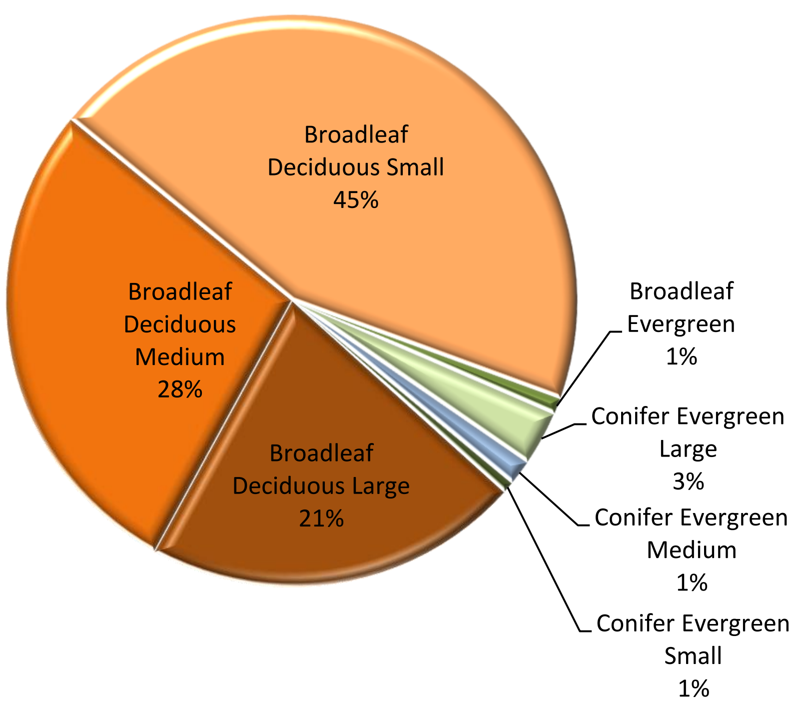


Figure 1. Overall Composition of Victoria's Inventoried Street Tree Population

Species Richness and Composition

Victoria's inventoried street tree population (Table 1) includes a mix of 238 unique species, substantially above the mean of 53 species reported by McPherson and Rowntree (1989) in their nationwide survey of street tree populations in 22 U.S. cities. Victoria's temperate climate allows a wide range of species, earning the nickname "City of Gardens". Despite the large number of species found in the inventory, the top 10 species represent 52% of the total population (Figure 2). The predominant tree species are flowering plum (*Prunus cerasifera*, 10.3%), flowering cherry (*Prunus serrulata*, 8.3%), and hawthorn (*Crategus oxyacantha*, 6.3%)

There is a widely accepted rule that no single species should represent greater than 10% of the total population, and no single genus more than 20% (Clark Et al, 1997). Purple plum (*Prunus cerasifera*, 10.3%) is slightly overrepresented, while the plum and cherry genus (*Prunus*) is substantially overrepresented, comprising 27% of the population. New plantings in the immediate future should limit these species to reduce overreliance.

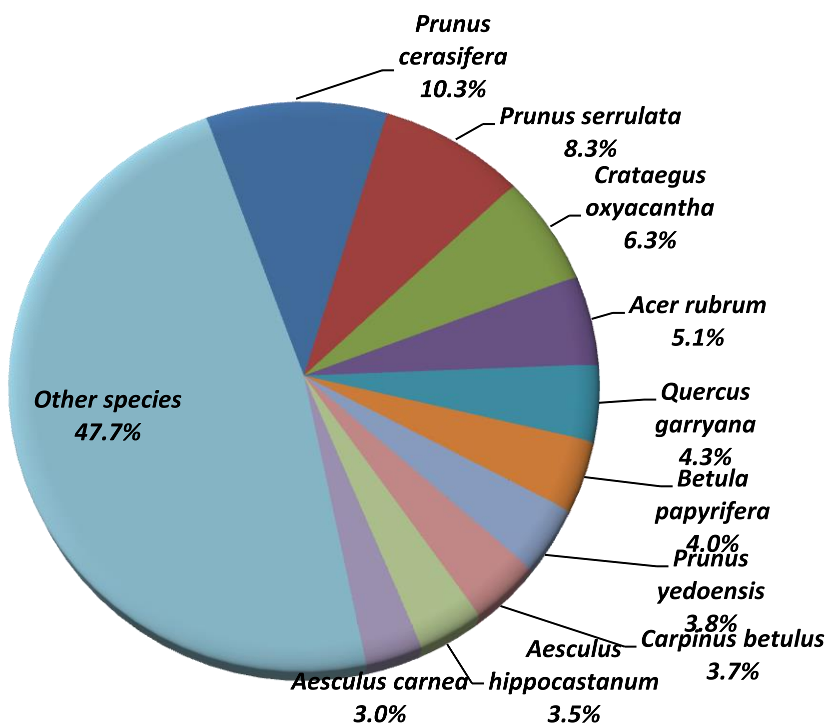


Figure 2. Prevalence of Top 10 Species in Victoria's Inventoried Street Tree Population

It is important to maintain a diverse population within an urban forest. 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.

Table 1. Population Distribution of Victoria's Most Prevalent Species

Species	DBH Class (cm) 0-8	8-15	15-30	30-46	46-61	61-76	76-91	91-107	>107	Total	% of Pop.
Broadleaf Deciduous Large (BDL)											
Acer rubrum	156	141	205	296	122	39	6	0	0	965	5.1
Quercus robur	4	9	79	115	31	15	14	8	9	284	1.5
Fagus sylvatica	21	63	106	31	8	4	3	0	2	238	1.3
Platanus acerifolia	1	4	18	13	34	42	35	34	51	232	1.2
Acer pseudoplatanus	10	4	31	63	60	43	14	2	1	228	1.2
Liquidambar styraciflua	2	23	41	84	58	9	0	0	0	217	1.2
Liriodendron tulipifera	0	12	55	25	35	39	22	10	5	203	1.1
BDL OTHER	168	324	355	226	249	178	82	38	33	1,653	8.8
Total	**362**	**580**	**890**	**853**	**597**	**369**	**176**	**92**	**101**	**4,020**	**21.3**
Broadleaf Deciduous Medium (BDM)											
Quercus garryana	98	24	65	135	162	144	80	71	38	817	4.3
Betula papyrifera	29	89	294	232	80	26	8	4	0	762	4.0
Carpinus betulus	23	74	158	331	92	18	0	0	0	696	3.7
Aesculus hippocastanum	9	13	33	105	165	186	96	33	17	657	3.5
Acer campestre	5	15	89	214	193	50	3	0	0	569	3.0
Betula pendula	4	13	208	205	70	7	1	0	0	508	2.7
Ulmus carpinifolia	12	13	28	70	91	119	100	28	16	477	2.5
Magnolia kobus	113	48	6	10	10	7	0	0	0	194	1.0
BDM OTHER	110	144	178	77	60	20	6	2	0	597	3.2
Total	**403**	**433**	**1,059**	**1,379**	**923**	**577**	**294**	**138**	**71**	**5,277**	**28.0**
Broadleaf Deciduous Small (BDS)											
Prunus cerasifera	124	203	479	647	390	91	6	0	0	1,940	10.3
Prunus serrulata	111	180	450	435	259	109	11	2	0	1,557	8.3
Crataegus oxyacantha	44	108	535	454	37	5	0	0	0	1,183	6.3
Prunus yedoensis	62	62	152	219	139	67	12	0	1	714	3.8
Aesculus carnea	14	40	73	239	160	30	14	1	0	571	3.0
Fraxinus ornus	23	50	135	85	83	48	7	1	0	432	2.3
Prunus accolade	20	58	169	87	8	1	0	0	0	343	1.8
Crataegus x lavallei	56	16	35	74	29	7	0	0	0	217	1.2
BDS OTHER	363	229	378	333	100	51	8	1	0	1,463	7.8
Total	**817**	**946**	**2,406**	**2,573**	**1,205**	**409**	**58**	**5**	**1**	**8,420**	**44.6**
Broadleaf Evergreen Medium (BEM)											
BEM OTHER	11	20	38	43	17	4	0	0	0	133	0.7

Species	DBH Class (cm) 0-8	8-15	15-30	30-46	46-61	61-76	76-91	91-107	>107	Total	% of Pop.
Broadleaf Evergreen Small (BES)											
BES OTHER	7	11	14	5	4	0	2	0	0	43	0.2
Conifer Evergreen Large (CEL)											
CEL OTHER	83	78	106	106	70	84	20	18	17	582	3.1
Conifer Evergreen Medium (CEM)											
CEM OTHER	7	36	76	57	62	26	2	2	2	270	1.4
Total											
Conifer Evergreen Small (CES)											
CES OTHER	28	40	55	0	1	0	0	0	0	124	0.7
Citywide Total	**1,718**	**2,144**	**4,644**	**5,016**	**2,879**	**1,469**	**552**	**255**	**192**	**18,869**	**100%**

Species Importance

To quantify the significance of any one particular species to Victoria's urban forest, an *importance value* (IV) is derived for each of the most common species. Importance values are particularly meaningful to urban forest managers because they indicate a community's reliance on the functional capacity of a particular species. **i-Tree *Streets* calculates importance value 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).

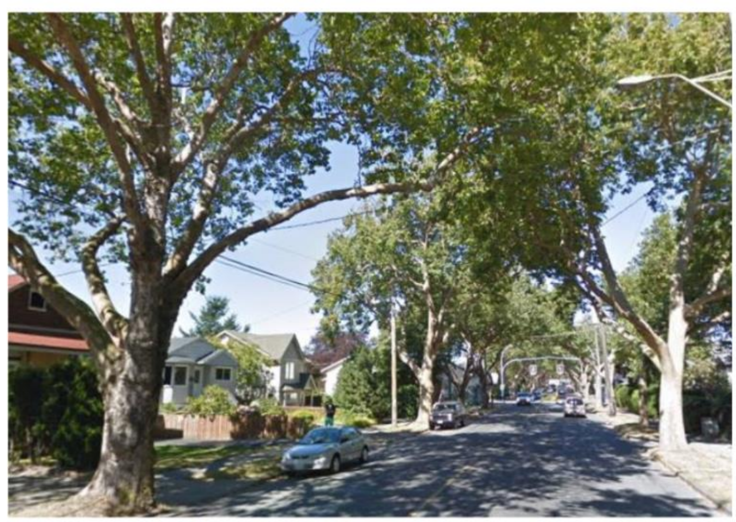
No single species should dominate the composition in the City's urban forest population. Since importance value goes beyond population numbers alone, it can help managers to better comprehend the resulting loss of benefits from a catastrophic loss of any one species. When importance values are almost equal among the 10 to 15 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 shorter lifespans and increased long-term management investments.

The 23 most abundant species each represent greater than 1% of the total population. Together, these 23 species represent 74% of the total population, 77% of the total leaf area, and 79% of the total canopy cover for a combined importance value of 76.7 (Table 2). Of these species, Victoria relies most on Garry oak (*Quercus garryana*, IV=7.6), and horse chestnut (*Aesculus hippocastanum*, IV=6.7)

The low importance value of some species is a function of tree type. Immature and small-stature populations tend to have lower importance values than their percentage in the overall population might suggest. This is due to their relatively small leaf area and canopy coverage. For instance, purple plum (*Prunus cerasifera)* represents 10% of the population but has an IV of just 5.8.

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. Overall, the inventoried trees provide 127 hectares of tree canopy cover. The greatest percent of canopy cover is provided by Garry oak (*Quercus garryana*, 8.3%) followed by horse chestnut (*Aesculus hippocastanum*, 7.7%) It is noteworthy that the most common species are not providing the largest amounts of canopy, mostly due to their comparatively small statures at maturity.



The street trees provide 127 hectares of canopy cover.

Table 2. Importance Value (IV) of Victoria's Most Prevalent Species

Species	Number of Trees	% of Pop.	Leaf Area (m²)	% of Total Leaf Area	Canopy Cover (m²)	% of Total Canopy Cover	Importance Value
Prunus cerasifera	1,940	10.3	133,926	2.6	56,577	4.5	**5.8**
Prunus serrulata	1,557	8.3	105,937	2.0	44,799	3.5	**4.6**
Crataegus oxyacantha	1,183	6.3	157,977	3.0	69,134	5.5	**4.9**
Acer rubrum	965	5.1	310,090	5.9	68,585	5.4	**5.5**
Quercus garryana	817	4.3	527,103	10.1	105,653	8.3	**7.6**
Betula papyrifera	762	4.0	216,967	4.2	52,390	4.1	**4.1**
Prunus yedoensis	714	3.8	48,595	0.9	20,561	1.6	**2.1**
Carpinus betulus	696	3.7	208,164	4.0	52,191	4.1	**3.9**
Aesculus hippocastanum	657	3.5	468,732	9.0	97,444	7.7	**6.7**
Aesculus carnea	571	3.0	150,269	2.9	49,707	3.9	**3.3**
Acer campestre	569	3.0	234,143	4.5	57,270	4.5	**4.0**
Betula pendula	508	2.7	150,782	2.9	37,913	3.0	**2.9**
Ulmus carpinifolia	477	2.5	358,482	6.9	72,326	5.7	**5.0**
Fraxinus ornus	432	2.3	93,341	1.8	31,346	2.5	**2.2**
Prunus accolade	343	1.8	22,918	0.4	9,696	0.8	**1.0**
Quercus robur	284	1.5	119,474	2.3	25,406	2.0	**1.9**
Fagus sylvatica	238	1.3	51,893	1.0	12,632	1.0	**1.1**
Platanus acerifolia	232	1.2	235,729	4.5	43,348	3.4	**3.1**
Acer pseudoplatanus	228	1.2	144,514	2.8	28,689	2.3	**2.1**
Liquidambar styraciflua	217	1.2	96,693	1.8	20,799	1.6	**1.5**
Crataegus x lavallei	217	1.2	35,203	0.7	12,664	1.0	**0.9**
Liriodendron tulipifera	203	1.1	136,367	2.6	26,622	2.1	**1.9**
Magnolia kobus	194	1.0	19,682	0.4	4,577	0.4	**0.6**
Other Species	4,865	25.8	1,201,093	23.0	266,282	21.0	**23.3**
Total	**18,869**	**100%**	**5,228,074**	**100%**	**1,266,610**	**100%**	**100**

Relative Age Distribution

Age distribution can be approximated by considering the DBH range of the overall population and of individual species. Trees with smaller diameters tend to be younger. It is important to consider that for multi-trunk trees DBH was collected as the diameter of the largest trunk added to half the sum of all other trunks.

The distribution of individual tree ages within a tree population influences present and future costs as well as the flow of benefits. An ideally 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%) should be young with DBH less than 20 cm, while only 10% should be in the large diameter classes (>61 cm).

Overall, the age distribution of Victoria's urban forest is weighted towards established trees (Figure 3); with 66% of the population consisting of trees with a DBH of 15.2 - 61 cm. Young trees (under 15.2 cm DBH) comprise just 20% of the population. This type of established tree population provides very high benefits on a per-tree basis. It is important for managers to understand that this established population may have higher pruning and removal costs associated with it than a comparable younger urban forest in another city. With a stocking rate of 94%, there are 1,111 planting opportunities in the City. It is recommended those sites be planted in the near future, and that trees are replaced within a year of removal.

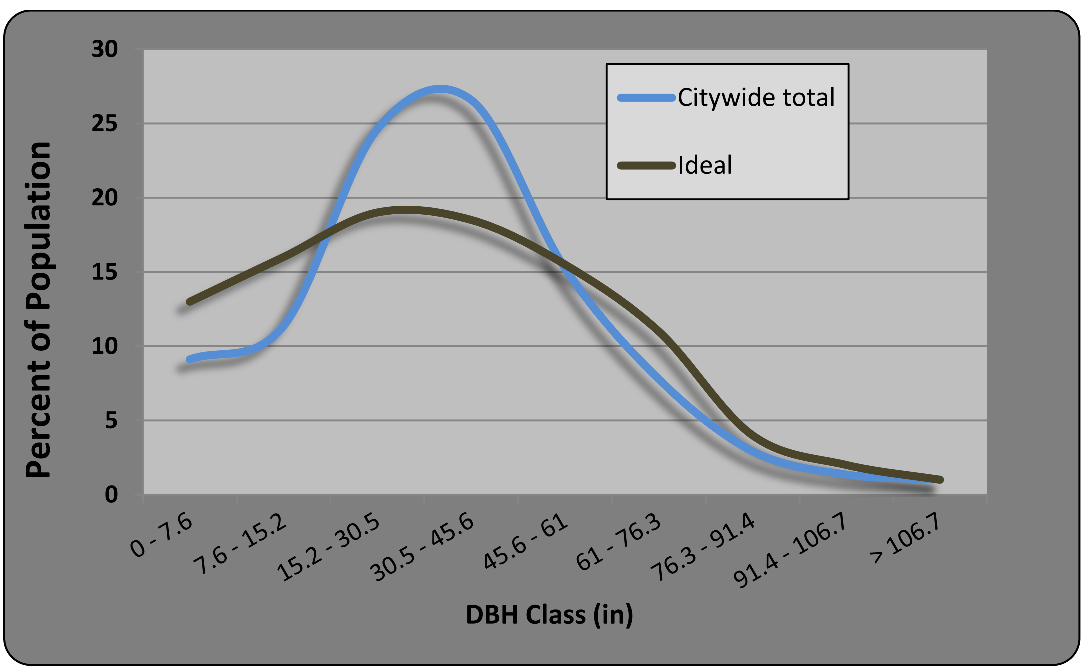
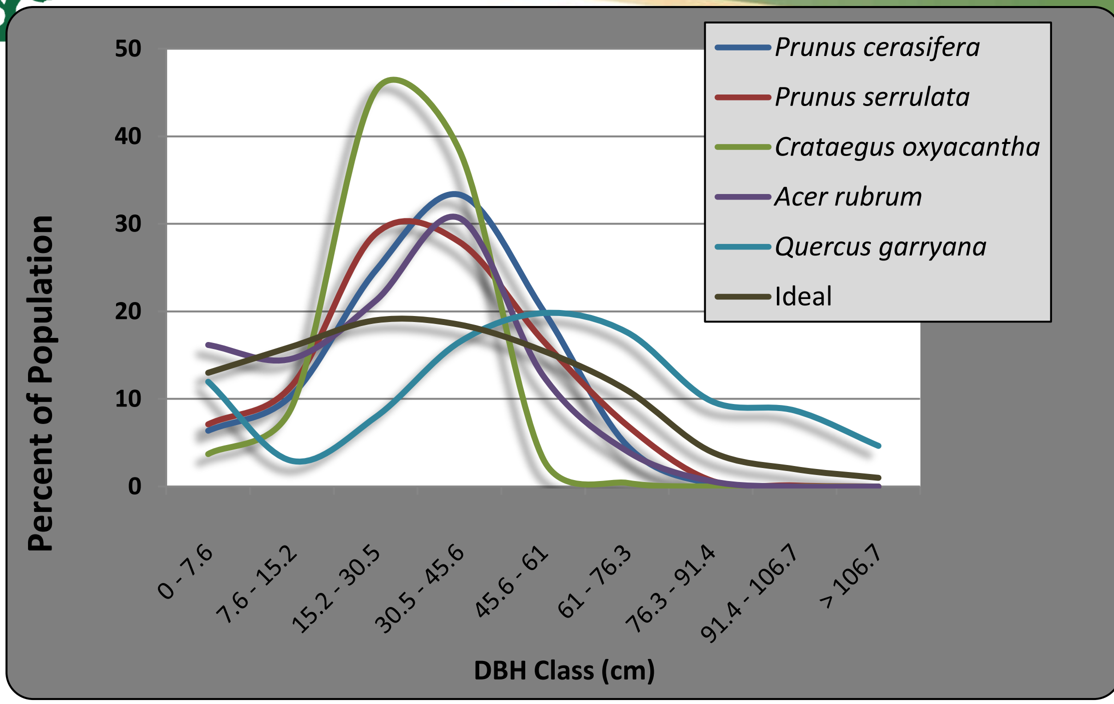


Figure 3. Overall Relative Age Distribution of Victoria's Tree Inventory

Two populations, Garry oak (*Quercus garryana*) and horse chestnut (*Aesculus hippocastanum*) are well represented in the large, mature DBH classes (61 cm and above), however, while there are very few young horse chestnuts (just 3% under 15.2 cm), Garry oak is well represented in the 0-7.6 cm class (12% of the population). This indicates that Garry oak is still in the planting palette, while horse chestnut may have fallen out of favor. If it is desirable to maintain a population of horse chestnut, the species should be reintroduced into the planting palette.

As young populations mature and eventually grow old, their maintenance needs are likely to increase. Future plantings should adequately represent long-standing and high-performing species. Sufficient replacements should be planted to ensure the functional capacity and benefit streams from these populations, even as individuals begin to decline.

New installations should carefully consider species selection, increasing the use of underused and well-performing species, and focusing on medium and large-statured species. In addition to planting, it is critical to dedicate resources to ensuring proper maintenance as trees mature. A long-term, sustainable management plan, including regular inspection and pruning cycles, can ensure Victoria's urban forest remains 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.



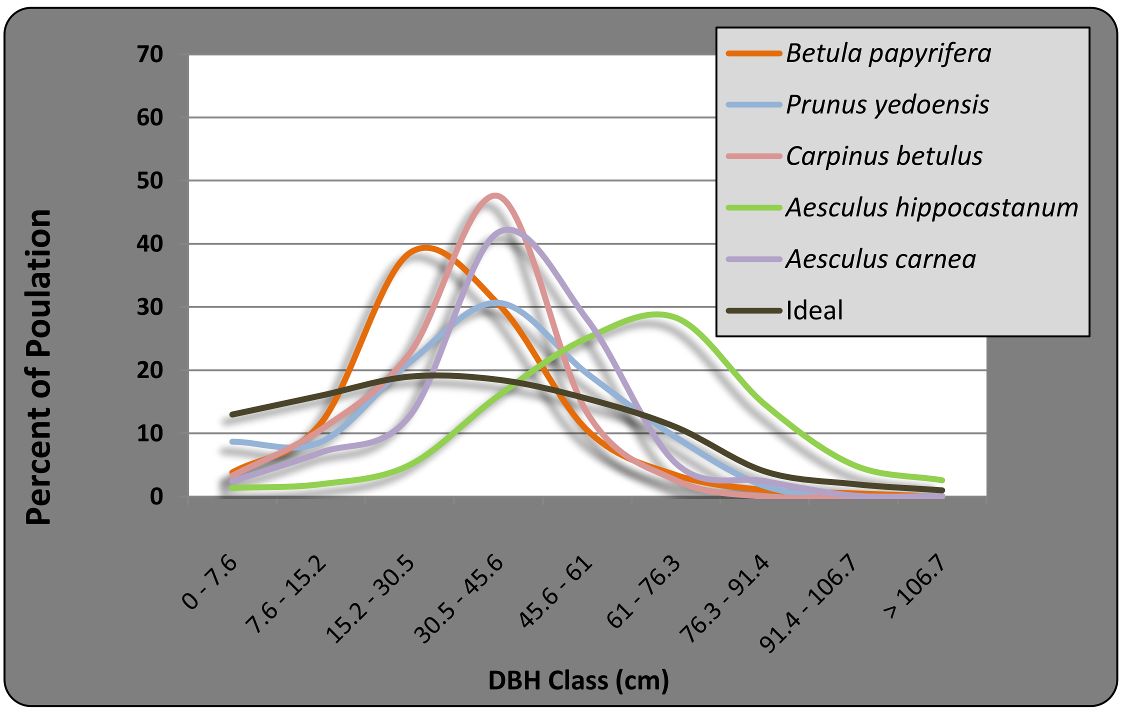


Figure 4. Relative Age Distribution of Victoria's Top 10 Inventoried Tree Species

Urban Forest Condition

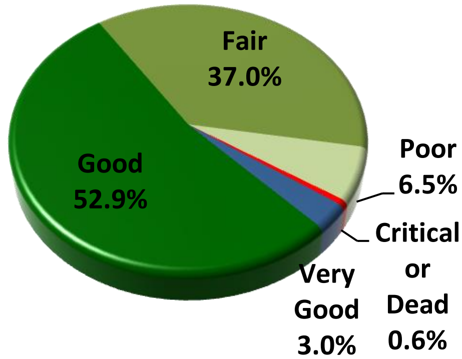


Figure 5. Wood Condition of Victoria's Street Trees

Tree condition is an indication of how well trees are managed and how well they are performing. Each inventoried tree was rated for the condition of the wood, and the foliage. Wood condition is considered in Figure 5. When trees are performing at their peak, the benefits they provide are maximized.

The inventory found 56% of Victoria's trees in good or better condition and 37% in fair condition. Over 7% of the population was determined to be in poor, critical or dead condition. Removal or mitigation of failing trees is recommended as soon as possible to reduce liability exposure.

Relative Performance

The *relative performance index* (RPI) is another way to analyze the condition and suitability of specific tree species. The RPI provides an urban forest manager with a detailed perspective on how one species' performance compares to that of another. The index compares the condition ratings of each tree species with the condition ratings of every other tree species within a given urban forest population. An RPI value of 1.0 or better indicates that the species is performing as well or better than average when compared to other species. An RPI value below 1.0 indicates that the species is not performing as well in comparison to the rest of the population.

Among the 23 most common species collected by the inventory, 13 have an RPI of 1.0 or greater (Table 3). Of these, beech (*Fagus sylvatica*, RPI=1.1), Lavalle hawthorn (*Crategus x lavallei*, RPI=1.07), hornbeam (*Carpinus betulus*, RPI = 1.07), and Kobus magnolia (*Magnolia kobus*, RPI=1.07 have the highest performance ratings.

The RPI can be a useful tool for urban forest managers. For example, if a community has been planting two or more new species, the RPI can be used to compare their relative performance. If the RPI indicates that one is performing relatively poorly, managers may decide to reduce or even stop planting that species and subsequently save money on both planting stock and replacement costs. The RPI enables managers to look at the performance of long-standing species as well. Established species with an RPI of 1.00 or greater have performed well when compared to the population as a whole. These top performers should be retained, and planted, as a healthy proportion of the overall population. It is important to keep in mind that, because RPI is based on condition at the time of the inventory, it may not reflect cosmetic or nuisance issues, especially seasonal issues that are not threatening the health or structure of the trees.

An RPI value less than 1.00 may be indicative of a species that is not well adapted to local conditions. Poorly adapted species are more likely to present increased safety and maintenance issues. Species with an RPI less than 1.00 should receive careful consideration before being selected for future planting choices. Prior to selecting or deselecting trees based on RPI alone, managers are encouraged to take into account the age distribution of the species, among other factors. A species that has a RPI of less than 1.00, but has a significant number of trees in larger DBH classes, may simply be exhibiting signs of population senescence. The individuals of this species may have produced substantial benefits over the years and the species should continue to be considered when making determinations for future planting.

Table 3. Relative Performance Index (RPI) for Victoria's Most Common Street Trees

Species	Excellent	Very Good	Good	Fair	Poor	Critical	Dead or Dying	RPI	# of Trees	% of Pop.
Prunus cerasifera	0.0	1.4	48.8	39.4	10.1	0.2	0.1	**0.96**	1,940	10.3
Prunus serrulata	0.0	1.2	43.0	48.0	6.6	0.7	0.4	**0.95**	1,557	8.3
Crataegus oxyacantha	0.0	0.5	34.1	57.4	7.4	0.3	0.3	**0.92**	1,183	6.3
Acer rubrum	0.1	5.3	59.0	33.6	1.6	0.2	0.4	**1.04**	965	5.1
Quercus garryana	0.0	1.2	59.2	36.1	2.8	0.1	0.7	**1.02**	817	4.3
Betula papyrifera	0.0	1.6	57.8	36.2	3.7	0.3	0.3	**1.02**	762	4.0
Prunus yedoensis	0.0	1.7	39.8	48.8	8.7	0.6	0.4	**0.93**	714	3.8
Carpinus betulus	0.1	3.1	70.1	24.1	2.2	0.1	0.3	**1.07**	696	3.7
Aesculus hippocastanum	0.0	0.5	48.1	46.0	5.3	0.1	0.0	**0.98**	657	3.5
Aesculus carnea	0.0	0.7	51.7	44.7	2.6	0.1	0.2	**1.00**	571	3.0
Acer campestre	0.0	0.6	64.8	33.7	0.8	0.0	0.1	**1.05**	569	3.0
Betula pendula	0.0	0.3	49.1	44.7	4.8	0.3	0.8	**0.97**	508	2.7
Ulmus carpinifolia	0.0	0.0	44.3	53.1	2.5	0.0	0.0	**0.97**	477	2.5
Fraxinus ornus	0.0	2.7	48.7	43.5	4.6	0.2	0.2	**0.99**	432	2.3
Prunus accolade	0.0	0.4	39.4	53.2	6.0	1.0	0.0	**0.94**	343	1.8
Quercus robur	0.0	0.4	68.7	29.6	1.2	0.2	0.0	**1.06**	284	1.5
Fagus sylvatica	0.0	6.1	74.2	18.3	1.5	0.0	0.0	**1.10**	238	1.3
Platanus acerifolia	0.0	0.4	55.2	42.2	1.9	0.2	0.0	**1.01**	232	1.2
Acer pseudoplatanus	0.0	0.4	44.3	45.6	9.6	0.0	0.0	**0.95**	228	1.2
Liquidambar styraciflua	0.0	1.8	63.6	33.4	0.9	0.2	0.0	**1.05**	217	1.2
Crataegus x lavallei	0.0	3.5	71.0	22.4	3.2	0.0	0.0	**1.07**	217	1.2
Liriodendron tulipifera	0.0	0.7	58.9	35.5	4.4	0.5	0.0	**1.02**	203	1.1
Magnolia kobus	0.0	12.4	59.3	25.0	2.8	0.5	0.0	**1.07**	194	1.0
Other Species	0.0	5.2	58.2	30.9	4.9	0.2	0.4	**1.03**	4,865	25.8
Citywide	**0.0**	**2.6**	**53.2**	**38.6**	**5.1**	**0.4**	**0.3**	**1.00**	**18,869**	**100%**

Table 3 shows the percent of each species that is performing in each condition category. These values are based on the average of both the foliar and woody condition ratings.

The RPI value can also help to identify underused species that are demonstrating good performance. Trees with an RPI value greater than 1.00 and an established age distribution may be indicating their suitability in the local environment and should receive consideration for additional planting (Table 4). When considering new species, it helps to base the decision on established populations. The greater number of trees of a particular species, the more relevant the RPI becomes. The following species appear to be performing well and should be considered for future tree plantings.

Table 4. Tree Species Which May be Underused, Based on RPI

Species	RPI	# of Trees	% of Pop.
Fagus sylvatica	**1.1**	238	1.3
Crataegus x lavallei	**1.07**	217	1.2
Quercus robur	**1.06**	284	1.5
Liquidambar styraciflua	**1.05**	217	1.2
Liriodendron tulipifera	**1.02**	203	1.1
Platanus acerifolia	**1.01**	232	1.2

Replacement Value

The current value of Victoria's inventoried tree resource is approximately $84 million. The community forest is a public asset that, when properly cared for, has the potential to appreciate in value as the trees mature over time. Replacement value accounts for the historical investment in trees over their lifetime. Replacement value is also a way of describing the value of a tree population (and/or average value per tree) at a given time. The replacement value reflects current population numbers, stature, placement, and condition. There are several methods available for obtaining a fair and reasonable perception of a tree's 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).

To replace Victoria's current inventoried tree population of 18,869 trees with trees of similar size, species, and condition would cost over $84 million (Table 5). The average replacement value per tree is $4,465. Among the most common species, Garry oak (*Quercus garryana*) represents the largest percent of the value at $8,300,052, or 9.9% of the value while comprising just 4.3% of the population. The high value of this species reinforces its 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 as well.

Victoria's street trees represent a vital component of the City's infrastructure and a public asset valued at approximately $84 million—an asset that, with proper care and maintenance, will increase in value over time. Distinguishing replacement value from the value of annual benefits produced by Victoria's inventoried street trees is very important. Annual benefits are examined in Chapter 3.

Table 5. Replacement Value of Victoria's Street Trees

	DBH Class (cm)										
Species	0-7.6	7.6-15.2	15.2-30.5	30.5-45.6	45.6-61	61-76.3	76.3-91.4	91.4-106.7	> 106.7	Total	% of Total $
Quercus garryana	29,559	14,658	104,142	559,318	1,321,967	1,924,252	1,536,831	1,779,203	1,030,121	**8,300,052**	9.9
Prunus cerasifera	28,838	116,979	791,138	2,557,439	2,703,108	1,004,003	82,320	0	0	**7,283,826**	8.6
Aesculus hippocastanum	2,668	8,921	60,209	439,158	1,238,253	2,318,844	1,763,959	791,421	374,157	**6,997,590**	8.3
Prunus serrulata	25,653	101,492	706,064	1,667,122	1,853,067	1,232,352	163,313	35,071	0	**5,784,133**	6.9
Ulmus carpinifolia	3,654	7,594	46,210	289,672	682,798	1,493,016	1,792,430	718,853	379,869	**5,414,096**	6.4
Acer campestre	1,421	10,106	158,546	927,238	1,597,922	661,825	49,826	0	0	**3,406,883**	4.0
Prunus yedoensis	14,151	33,094	228,633	852,576	1,028,895	733,096	184,557	0	23,473	**3,098,474**	3.7
Aesculus carnea	3,149	23,066	123,145	983,135	1,259,645	388,897	259,540	29,807	0	**3,070,384**	3.6
Crataegus oxyacantha	9,388	55,328	800,942	1,701,664	247,480	48,040	0	0	0	**2,862,842**	3.4
Carpinus betulus	7,191	48,507	280,273	1,482,837	747,151	226,567	0	0	0	**2,792,526**	3.3
Platanus acerifolia	124	1,950	24,528	41,632	187,954	367,727	440,101	569,507	920,387	**2,553,911**	3.0
Acer rubrum	49,127	80,204	281,244	932,323	726,222	366,138	88,794	0	0	**2,524,052**	3.0
Betula papyrifera	6,609	44,631	389,212	763,910	482,660	231,420	105,441	74,606	0	**2,098,488**	2.5
Fraxinus ornus	5,123	28,991	216,674	352,617	617,031	595,698	124,792	25,424	0	**1,966,350**	2.3
Quercus robur	1,065	5,706	139,455	511,065	266,852	215,907	283,659	221,509	270,590	**1,915,807**	2.3
Betula pendula	805	5,435	282,411	711,681	427,854	72,601	13,076	0	0	**1,513,863**	1.8
Liriodendron tulipifera	0	6,738	86,639	100,705	247,799	425,109	308,623	192,392	119,632	**1,487,636**	1.8
Acer pseudoplatanus	2,539	2,030	37,381	165,050	304,891	359,845	158,086	33,466	15,436	**1,078,726**	1.3
Sorbus intermedia	4,755	27,357	42,738	144,908	401,662	207,351	53,061	0	0	**881,832**	1.0
Fagus sylvatica	6,169	48,579	264,078	203,507	93,147	76,684	70,822	0	78,615	**841,601**	1.0
Other Species	763,779	2,643,497	6,013,090	7,916,986	7,788,444	5,377,265	2,754,907	2,205,994	19,435,776	**18,378,020**	21.8
Citywide Total	**$436,244**	**$1,200,887**	**$7,177,637**	**$19,286,672**	**$20,454,229**	**$16,719,945**	**$9,085,922**	**$5,619,477**	**$4,270,058**	**$84,251,071**	**100%**

Chapter 3: Urban Forest Resource Benefits

Trees are important to Victoria. Environmentally, they help conserve and reduce energy use, reduce 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 cost of management? In other words, are trees a good investment for Victoria? To answer this question, the benefits must be quantified in financial terms.

The i-Tree *Streets* analysis model allows benefits to be quantified based on regional reference cities and local community attributes, such as median home values and local energy prices. This analysis provides a snapshot of the annual benefits (along with the value of those benefits) produced by Victoria's inventoried urban forest. While the annual benefits produced by the urban forest can be substantial, it is important to recognize that the greatest benefits from the urban forest are derived from the benefit stream that results over time, from a mature forest where trees are well managed, healthy, and long-lived.

This analysis used Victoria's current inventory data and i-Tree's *Streets* software to assess and quantify the beneficial functions of this resource and to place a dollar value on the annual environmental benefits these trees provide. The benefits calculated by i-Tree *Streets* are estimations based on the best available and current scientific research with an accepted degree of uncertainty. The data returned from i-Tree *Streets* can provide a platform from which informed management decisions can be made (Maco and McPherson, 2003). A discussion on the methods used to calculate and assign a monetary value to these benefits is included in Appendix A.

Energy Savings

Trees modify climate and conserve energy in three principal ways:

- Shading reduces the amount of radiant energy absorbed and stored by 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 suburban and rural areas. Heat islands are 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 more vegetated suburban areas (Akbari and others, 1992). 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.

Trees reduce conductive heat loss from buildings by reducing air movement into buildings and against conductive surfaces (e.g., glass, metal siding). 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

Electricity and natural gas saved annually in Victoria from both the shading and climate effects of trees is equal to 5,430 GJ (valued at $104,084) from electricity savings and 15,107 GJ (valued at $49,400) from natural gas savings, for a total retail savings of approximately $153,484 and an average of $8.13 per tree (Table 6). On a per-tree basis, London plane (*Platanus acerifolia*) is providing the greatest benefit at $23.30. The population of Garry oak (*Quercus garryana*) provides 8.5% of the energy savings while representing just 4.3% of the population.

Small stature trees are less able to provide electricity and natural gas reductions. On a per-tree basis, *Prunus* species provide the lowest benefits. Among the 23 most common species, the population of Yoshino cherry (*Prunus yedoensis*) provides the lowest benefits with an average of $2.39 per tree annually. Purple plum (*Prunus ceracifera.*, $2.46 per tree) and flowering cherry (*Prunus serrulata*, $2.44 per tree) provide 5.6% of energy benefits while representing 18.5% of the population.

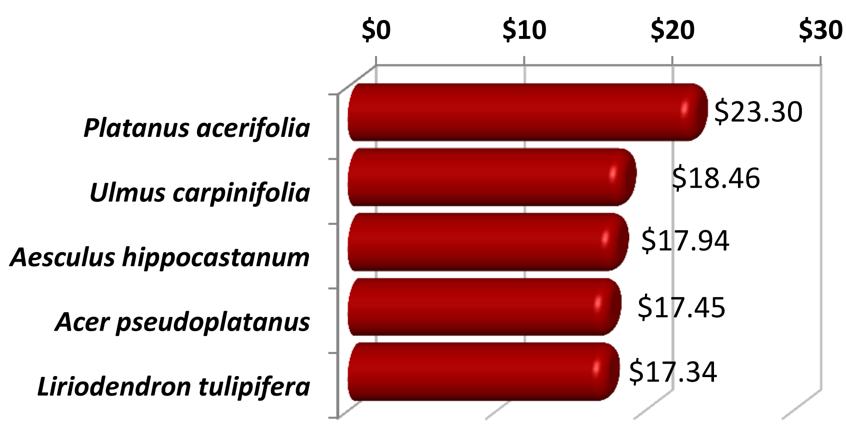


Figure 6. Annual Electricity and Natural Gas Benefits - Top Five Species

Table 6. Annual Electric and Natural Gas Benefits from Victoria's Street Trees

Species	Total Electricity (GJ)	Electricity ($)	Total Natural Gas (GJ)	Natural Gas ($)	Total ($)	% of Pop.	% of Total $	Avg. $/tree
Prunus cerasifera	150.2	2,879	578.8	1,893	4,771	10.3	3.1	**2.46**
Prunus serrulata	119.5	2,290	459.9	1,504	3,794	8.3	2.5	**2.44**
Crataegus oxyacantha	202.6	3,883	596.9	1,952	5,835	6.3	3.8	**4.93**
Acer rubrum	350.7	6,722	971.1	3,175	9,897	5.1	6.4	**10.26**
Quercus garryana	484.4	9,285	1,160.0	3,793	13,079	4.3	8.5	**16.01**
Betula papyrifera	246.0	4,716	740.6	2,422	7,138	4.0	4.7	**9.37**
Prunus yedoensis	53.7	1,029	206.3	675	1,704	3.8	1.1	**2.39**
Carpinus betulus	241.3	4,624	712.0	2,328	6,953	3.7	4.5	**9.99**
Aesculus hippocastanum	436.0	8,357	1,049.0	3,430	11,787	3.5	7.7	**17.94**
Aesculus carnea	169.5	3,249	465.8	1,523	4,772	3.0	3.1	**8.36**
Acer campestre	253.6	4,861	698.4	2,284	7,144	3.0	4.7	**12.56**
Betula pendula	175.8	3,370	530.5	1,735	5,105	2.7	3.3	**10.05**
Ulmus carpinifolia	327.2	6,271	775.0	2,534	8,805	2.5	5.7	**18.46**
Fraxinus ornus	102.1	1,957	290.8	951	2,908	2.3	1.9	**6.73**
Prunus accolade	27.4	525	106.2	347	873	1.8	0.6	**2.54**
Quercus robur	128.5	2,463	375.0	1,226	3,690	1.5	2.4	**12.99**
Fagus sylvatica	60.2	1,153	177.1	579	1,732	1.3	1.1	**7.28**
Platanus acerifolia	203.8	3,906	458.3	1,499	5,405	1.2	3.5	**23.30**
Acer pseudoplatanus	144.8	2,775	368.0	1,203	3,978	1.2	2.6	**17.45**
Liquidambar styraciflua	106.8	2,048	291.8	954	3,002	1.2	2.0	**13.83**
Crataegus x lavallei	42.3	810	118.0	386	1,196	1.2	0.8	**5.51**
Liriodendron tulipifera	129.3	2,479	318.5	1,042	3,520	1.1	2.3	**17.34**
Magnolia kobus	22.4	429	67.7	222	651	1.0	0.4	**3.36**
Other Species	1,252.2	24,002	3,591.5	11,744	35,746	25.8	23.3	**7.35**
Total	**5,430**	**$104,084**	**15,107**	**$49,400**	**$153,484**	**100%**	**100%**	**$8.13**

Atmospheric Carbon Dioxide Reduction

As environmental awareness continues to increase, governments are paying particular attention to global warming and 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, 2007).

The idea that carbon credits are a commodity that can be exchanged for financial gain is based on the growth of emerging carbon markets. The Center for Urban Forest Research 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 Victoria's urban forest resource may or may not qualify for carbon-offset credits or be traded in the open market, the City's inventoried trees are nonetheless providing a significant reduction in atmospheric carbon dioxide (CO_2) for a positive environmental and financial benefit to the community.

Urban trees reduce atmospheric CO_2 in two ways:

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

At the same time, vehicles and other combustion engines used to plant and care for trees release CO_2 during operation. 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 net CO_2 benefits of trees.

Sequestered Carbon Dioxide

To date, Victoria's inventoried urban forest has sequestered a total of 33 million kg of carbon dioxide (CO_2), valued at $547,113[2]. Annually, this tree resource directly sequesters 1.1 million kg of CO_2, valued at $18,331, into woody and foliar biomass. Accounting for estimated CO_2 emissions from tree decomposition (-158,895 kg), tree-related maintenance activity (-73,181 kg), and avoided CO_2 (1.5 million kg), Victoria's trees provide an annual net reduction in atmospheric CO_2 of 2.4 million kg, valued at $39,493, with an average of $2.09 per tree, as shown in Table 7.

London plane (*Platanus acerifolia*, $5.25) is providing the highest per-tree carbon benefit, while the population of Garry oak (*Quercus garryana*, $3,076) is providing the largest percent of the benefit, with 7.8% of the carbon benefit, yet representing 4.3% of the population. Small-stature plum and cherry (*Prunus*) species produce the lowest benefits with values of $0.40 to $0.53 on average per tree.

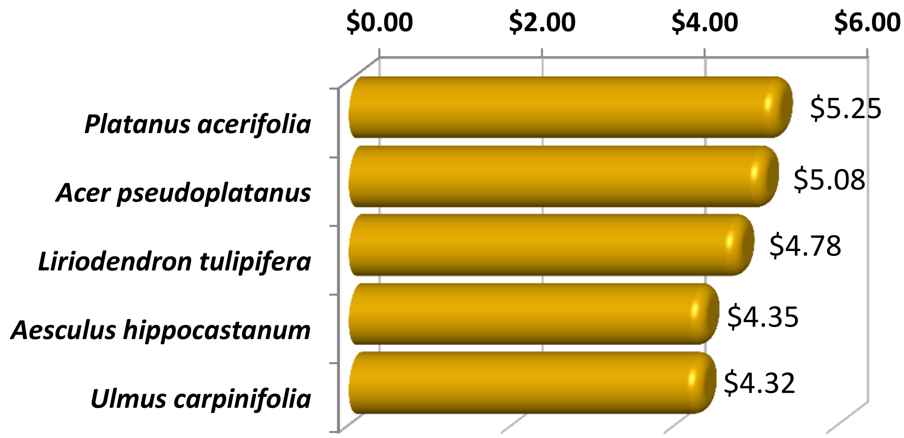


Figure 7. Annual Reduction of CO_2 - Top Five species

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

Table 7. Annual CO_2 Reduction Benefits Provided by Victoria's Inventoried Street Trees

Species	Sequestered (kg)	Sequestered ($)	Decomposition Release(kg)	Maintenance Release (kg)	Total Release ($)	Avoided (kg)	Avoided ($)	Net Total (kg)	Total ($)	% of Pop.	% of Total $	Avg. $/tree
Prunus cerasifera	12,610	208.5	-3,843	-1,035	-17.1	41,817	691.4	49,549	819.3	10.3	2.1	**0.42**
Prunus serrulata	11,622	192.2	-3,024	-830	-13.7	33,272	550.1	41,039	678.6	8.3	1.7	**0.44**
Crataegus oxyacantha	65,725	1,086.7	-4,713	-4,650	-76.9	56,411	932.7	112,773	1,864.7	6.3	4.7	**1.58**
Acer rubrum	88,975	1,471.2	-6,815	-3,896	-64.4	97,648	1,614.6	175,911	2,908.6	5.1	7.4	**3.01**
Quercus garryana	77,839	1,287.0	-20,494	-6,142	-101.6	134,883	2,230.2	186,086	3,076.9	4.3	7.8	**3.77**
Betula papyrifera	59,506	983.9	-5,459	-3,330	-55.1	68,507	1,132.7	119,223	1,971.3	4.0	5.0	**2.59**
Prunus yedoensis	4,015	66.4	-1,401	-381	-6.3	14,948	247.2	17,181	284.1	3.8	0.7	**0.40**
Carpinus betulus	60,276	996.6	-5,172	-3,259	-53.9	67,175	1,110.7	119,021	1,968.0	3.7	5.0	**2.83**
Aesculus hippocastanum	74,960	1,239.4	-17,998	-5,566	-92.0	121,395	2,007.2	172,790	2,857.0	3.5	7.2	**4.35**
Aesculus carnea	34,813	575.6	-4,744	-3,204	-53.0	47,189	780.3	74,055	1,224.5	3.0	3.1	**2.14**
Acer campestre	60,869	1,006.5	-6,947	-3,407	-56.3	70,610	1,167.5	121,125	2,002.8	3.0	5.1	**3.52**
Betula pendula	44,275	732.1	-3,596	-2,382	-39.4	48,958	809.5	87,256	1,442.7	2.7	3.7	**2.84**
Ulmus carpinifolia	51,617	853.5	-14,103	-4,131	-68.3	91,098	1,506.3	124,481	2,058.3	2.5	5.2	**4.32**
Fraxinus ornus	20,262	335.0	-2,887	-2,134	-35.3	28,423	470.0	43,664	722.0	2.3	1.8	**1.67**
Prunus accolade	4,124	68.2	-641	-183	-3.0	7,630	126.2	10,931	180.7	1.8	0.5	**0.53**
Quercus robur	21,240	351.2	-2,455	-1,677	-27.7	35,784	591.7	52,892	874.5	1.5	2.2	**3.08**
Fagus sylvatica	15,335	253.6	-1,080	-781	-12.9	16,751	277.0	30,225	499.8	1.3	1.3	**2.10**

Species	Sequestered (kg)	Sequestered ($)	Decomposition Release(kg)	Maintenance Release (kg)	Total Release ($)	Avoided (kg)	Avoided ($)	Net Total (kg)	Total ($)	% of Pop.	% of Total $	Avg. $/tree
Platanus acerifolia	28,422	469.9	-8,996	-2,490	-41.2	56,744	938.2	73,681	1,218.3	1.2	3.1	**5.25**
Acer pseudoplatanus	35,416	585.6	-4,119	-1,516	-25.1	40,309	666.5	70,091	1,158.9	1.2	2.9	**5.08**
Liquidambar styraciflua	27,014	446.7	-2,148	-1,136	-18.8	29,752	491.9	53,482	884.3	1.2	2.2	**4.08**
Crataegus x lavallei	10,138	167.6	-1,096	-845	-14.0	11,766	194.6	19,964	330.1	1.2	0.8	**1.52**
Liriodendron tulipifera	28,507	471.4	-4,405	-1,441	-23.8	36,007	595.4	58,668	970.1	1.1	2.5	**4.78**
Magnolia kobus	5,803	95.9	-518	-351	-5.8	6,237	103.1	11,171	184.7	1.0	0.5	**0.95**
Other Species	265,266	4,386.1	-32,241	-18,417	-304.5	348,661	5,765.0	563,269	9,313.5	25.8	23.6	**1.91**
Citywide Total	**1,108,629**	**$18,331**	**-158,895**	**-73,181**	**-$1,210**	**1,511,974**	**$25,000**	**2,388,527**	**$39,493**	**100%**	**100%**	**$2.09**

Air Quality Improvement

Urban trees improve air quality in five fundamental ways:

- Absorption of gaseous pollutants such as ozone (O_3), sulfur dioxide (SO_2), 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
- Transpiration of water and shade provision, resulting in lower local air temperatures, thereby reducing ozone (0_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 are statistically associated with increased tree mortality for 95 large US cities (Bell and others, 2004).

However, it should be noted that while trees do a great deal to absorb air pollutants (especially ozone and particulate matter); they also negatively contribute to air pollution. Trees emit various biogenic volatile organic compounds (BVOCs), such as isoprene's and monoterpenes, which also contribute to ozone formation. i-Tree *Streets* analysis accounts for these BVOC emissions in the air quality net benefit.

Deposition, Interception, and Avoided Pollutants

Each year, approximately 4,586 kg of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), small particulate matter (PM_{10}), and ozone (O_3) are intercepted or absorbed by the inventoried trees in Victoria, for a value of $23,010 (Table 8). As a population, Garry oak (*Quercus garryana*) provide the largest proportion of deposition benefits, accounting for 9.2% while representing 4.3% of the population.

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, 4,431 kg of pollutants, valued at $17,037, are avoided annually through the shading effects of Victoria's inventoried trees.

BVOC Emissions

Biogenic volatile organic compound (BVOC) emissions from trees, which negatively affect air quality, must also be considered. Approximately 3,186 kg of BVOCs are emitted annually from Victoria's inventoried trees, offsetting the total air quality benefit by -$8,133. Among the most common species, the genus *Quercus* produces the most BVOCs. The population of English oak (*Quercus robur*) produce 207 kg, valued at -$1,189, and Garry oak (*Quercus garryana*) produces 138 kg, valued at -$795. The positive air quality impacts of Garry oak outweigh the BVOC release for a net positive impact of $3.45 per tree while English oak has a net negative air quality impact valued at -$0.19 annually.

Net Air Quality Improvement

The net value of air pollutants removed, avoided, and released by Victoria's inventoried street tree population is $31,914 annually. The average net benefit per tree is $1.69. Trees vary dramatically in their ability to produce 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, London plane (*Platanus acerifolia*, $6.89) and tulip tree (*Liriodendron tulipifera*, $4.47) currently produce the greatest per tree net air quality improvements (Figure 8).

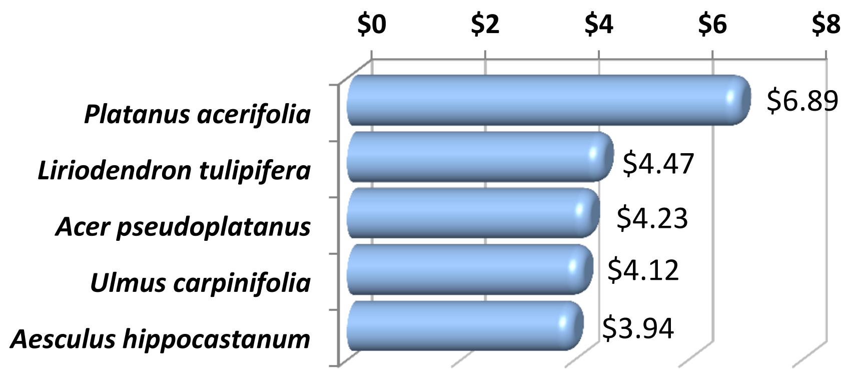


Figure 8. Annual Improvement to Air Quality - Top Five Species

Table 8. Annual Air Quality Improvements Provided by Victoria's Inventoried Street Trees

Species	Deposition					Avoided					Emissions			Total ($)	% of Pop.	Avg. $/tree
	O3 (kg)	NO2 (kg)	PM10 (kg)	SO2 (kg)	Total ($)	NO2 (kg)	PM10 (kg)	VOC (kg)	SO2 (kg)	Total ($)	BVOC (kg)	BVOC ($)	Total (kg)			
Prunus cerasifera	168.2	41.6	41.8	19.6	1,368.41	49.4	9.8	9.1	55.3	484.13	-1.3	-7.42	393.5	1,845.12	10.3	**0.95**
Prunus serrulata	132.6	32.8	33.0	15.5	1,079.22	39.3	7.8	7.3	44.0	385.28	-1.0	-5.88	311.3	1,458.63	8.3	**0.94**
Crataegus oxyacantha	139.7	34.9	37.7	17.5	1,144.29	64.3	13.4	12.6	77.8	647.85	-1.2	-6.86	396.6	1,785.29	6.3	**1.51**
Acer rubrum	110.1	27.2	28.7	11.8	895.23	108.8	22.9	21.5	133.0	1,100.01	0.0	0.00	464.0	1,995.24	5.1	**2.07**
Quercus garryana	261.4	63.7	66.7	29.4	2,121.22	146.1	31.4	29.4	183.9	1,493.03	-138.1	-794.91	674.0	2,819.34	4.3	**3.45**
Betula papyrifera	68.0	16.6	18.8	7.6	553.55	78.0	16.2	15.2	93.6	783.35	-56.8	-326.76	257.3	1,010.14	4.0	**1.33**
Prunus yedoensis	61.1	15.1	15.2	7.1	497.58	17.6	3.5	3.3	19.8	172.81	-0.5	-2.70	142.3	667.68	3.8	**0.94**
Carpinus betulus	67.0	16.3	18.9	7.5	545.70	76.2	15.9	14.9	92.0	766.80	-54.4	-313.30	254.2	999.20	3.7	**1.44**
Aesculus hippocastanum	239.9	58.5	61.5	27.0	1,946.81	131.8	28.3	26.6	165.9	1,346.62	-122.3	-703.72	617.0	2,589.71	3.5	**3.94**
Aesculus carnea	134.1	33.5	34.7	16.8	1,096.77	52.9	11.2	10.4	64.8	535.04	-1.1	-6.52	357.2	1,625.29	3.0	**2.85**
Acer campestre	97.8	23.8	26.5	11.0	795.07	78.9	16.6	15.6	96.8	798.82	-61.1	-351.55	305.9	1,242.34	3.0	**2.18**
Betula pendula	45.3	11.0	12.8	5.1	368.70	55.8	11.6	10.9	67.0	560.18	-39.3	-226.42	180.0	702.46	2.7	**1.38**
Ulmus carpinifolia	184.1	44.9	46.9	20.7	1,493.52	98.5	21.2	19.9	124.3	1,007.80	-93.6	-538.41	466.9	1,962.92	2.5	**4.12**
Fraxinus ornus	78.8	19.7	20.5	9.9	644.53	32.0	6.7	6.3	38.9	323.24	-0.7	-4.05	212.1	963.71	2.3	**2.23**
Prunus accolade	28.4	7.0	7.1	3.3	230.92	9.0	1.8	1.7	10.1	88.65	-0.2	-1.27	68.2	318.30	1.8	**0.93**
Quercus robur	85.7	24.7	27.7	11.2	728.65	40.3	8.4	7.8	48.4	404.97	-206.6	-1,188.88	47.7	-55.25	1.5	**-0.19**

Species	Deposition					Avoided					Emissions			Total ($)	% of Pop.	Avg. $/tree
	O3 (kg)	NO2 (kg)	PM10 (kg)	SO2 (kg)	Total ($)	NO2 (kg)	PM10 (kg)	VOC (kg)	SO2 (kg)	Total ($)	BVOC (kg)	BVOC ($)	Total (kg)			
Fagus sylvatica	14.8	3.7	3.9	1.6	120.52	19.0	4.0	3.7	23.0	191.08	0.0	0.00	73.6	311.60	1.3	**1.31**
Platanus acerifolia	120.1	29.7	29.0	13.0	974.13	60.8	13.1	12.3	77.3	623.37	0.0	0.00	355.4	1,597.50	1.2	**6.89**
Acer pseudoplatanus	63.6	15.7	15.9	6.9	516.38	44.1	9.4	8.8	54.9	448.96	0.0	0.00	219.3	965.34	1.2	**4.23**
Liquidambar styraciflua	36.5	9.0	9.4	3.9	296.30	33.1	7.0	6.5	40.6	335.26	0.0	0.00	146.1	631.56	1.2	**2.91**
Crataegus x lavallei	31.5	7.9	8.2	3.9	257.55	13.2	2.8	2.6	16.1	132.95	-0.3	-1.54	85.8	388.96	1.2	**1.79**
Liriodendron tulipifera	62.6	15.5	15.4	6.8	508.27	39.2	8.4	7.9	49.1	399.80	0.0	0.00	204.8	908.07	1.1	**4.47**
Magnolia kobus	6.8	1.7	1.8	0.8	55.59	7.1	1.5	1.4	8.4	70.85	-5.9	-34.12	23.5	92.32	1.0	**0.48**
Other Species	581.5	148.0	156.0	68.2	4,770.98	390.4	81.8	76.6	473.6	3,936.16	-628.9	-3,618.49	1,347.2	5,088.65	25.8	**1.05**
Citywide Total	**2,820**	**702**	**738**	**326**	**$23,010**	**1,686**	**355**	**332**	**2,059**	**$17,037**	**-1,413**	**-$8,133**	**7,604**	**$31,914**	**100 %**	**$1.69**

Stormwater Runoff Reductions

Rainfall interception by trees reduces 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. Healthy urban trees 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 bare soil.

Victoria's inventoried trees intercept 93,683 cubic meters of stormwater annually for an average of 4.96 cubic meters per tree (Table 9). That total amount of stormwater would fill more than 37 Olympic-sized swimming pools. The total value of this benefit to the City is $267,282, an average of $14.17 per tree. London plane (*Platanus acerifolia*) are currently providing the highest per tree benefit, valued at $42.26. The population of Garry oak (*Quercus garryana*) are providing the greatest proportion of the stormwater benefit, at 8.3% of the benefit, while representing 4.3% of the population.

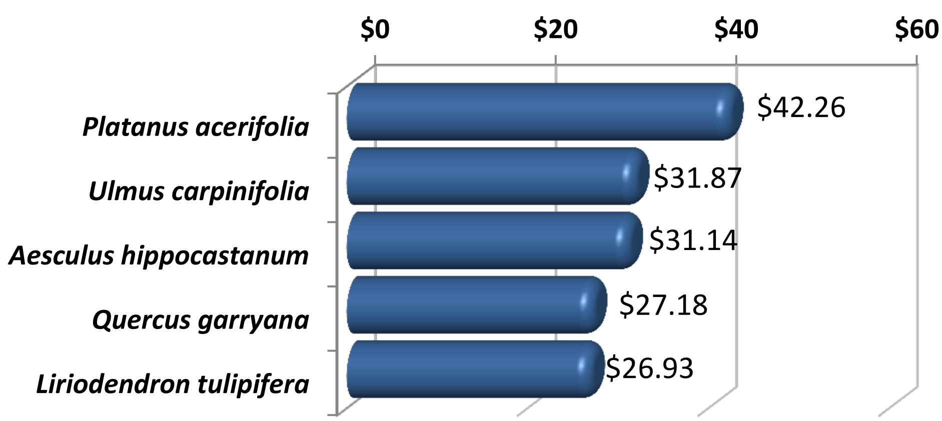


Figure 9. Annual Reduction in Stormwater Runoff - Top Five Species

Table 9. Annual Stormwater Runoff Reduction Benefits Provided by Victoria's Inventoried Street Trees

Species	Total Rainfall Interception (m^3)	Total ($)	% of Pop.	% of Total $	Avg. $/tree
Prunus cerasifera	5,591	15,951	10.3	5.97	**8.22**
Prunus serrulata	4,305	12,283	8.3	4.60	**7.89**
Crataegus oxyacantha	1,577	4,500	6.3	1.68	**3.80**
Acer rubrum	4,729	13,491	5.1	5.05	**13.98**
Quercus garryana	7,785	22,210	4.3	8.31	**27.18**
Betula papyrifera	3,837	10,947	4.0	4.10	**14.37**
Prunus yedoensis	2,071	5,909	3.8	2.21	**8.28**
Carpinus betulus	3,819	10,896	3.7	4.08	**15.66**
Aesculus hippocastanum	7,171	20,461	3.5	7.66	**31.14**
Aesculus carnea	1,243	3,547	3.0	1.33	**6.21**
Acer campestre	4,193	11,962	3.0	4.48	**21.02**
Betula pendula	2,773	7,912	2.7	2.96	**15.58**
Ulmus carpinifolia	5,329	15,203	2.5	5.69	**31.87**
Fraxinus ornus	813	2,320	2.3	0.87	**5.37**
Prunus accolade	811	2,314	1.8	0.87	**6.75**
Quercus robur	2,076	5,924	1.5	2.22	**20.86**
Fagus sylvatica	868	2,477	1.3	0.93	**10.41**
Platanus acerifolia	3,436	9,804	1.2	3.67	**42.26**
Acer pseudoplatanus	2,014	5,747	1.2	2.15	**25.21**
Liquidambar styraciflua	1,440	4,109	1.2	1.54	**18.94**
Crataegus x lavallei	307	875	1.2	0.33	**4.03**
Liriodendron tulipifera	1,916	5,467	1.1	2.05	**26.93**
Magnolia kobus	338	963	1.0	0.36	**4.96**
Other Species	25,239	72,009	25.8	26.94	**14.80**
Citywide total	**93,683**	**$267,282**	**100%**	**100%**	**$14.17**

Aesthetic, Property Value and Socioeconomic Benefits

Trees provide beauty in the urban landscape, privacy to homeowners, improved human health, a sense of comfort and place, and habitat for urban wildlife. Research shows that trees promote better business by stimulating more frequent and extended shopping and a willingness to pay more for goods and parking (Wolf, 1999). Some of these benefits are captured as a percentage of the value of the property on which a tree stands. To determine the value of these less tangible benefits, i-Tree *Streets* uses research that compares differences in sales prices of homes to estimate the contribution associated with trees. Differences in housing prices in relation to the presence (or lack) of a street tree help define the aesthetic value of street trees in the urban environment.

The calculation of annual aesthetic and other benefits corresponds with a tree's annual increase in leaf area. When a tree is actively growing, leaf area may increase dramatically. Once a tree is mature, there may be little or no net increase in leaf area from one year to the next; thus, there is little or no incremental annual aesthetic benefit for that year, although the cumulative benefit over the course of the entire life of the tree may be large. Since this report represents a one-year sample snapshot of the inventoried tree population, **aesthetic benefits reflect the increase in leaf area for each species population over the course of a single year.**

The total annual benefit associated with property value increases and other less tangible benefits is $2,313,335, an average of $122.60 per tree (Table 10). Tree species that produce the highest average per tree aesthetic benefits are sweetgum (*Liquidambar styraciflua*, $287.28), and sycamore maple (*Acer pseudoplatanus*, $273.26). The population of red maple (*Acer rubrum*) provides the largest proportion of the benefit, at 9.1% while representing just 5.1% of the population.

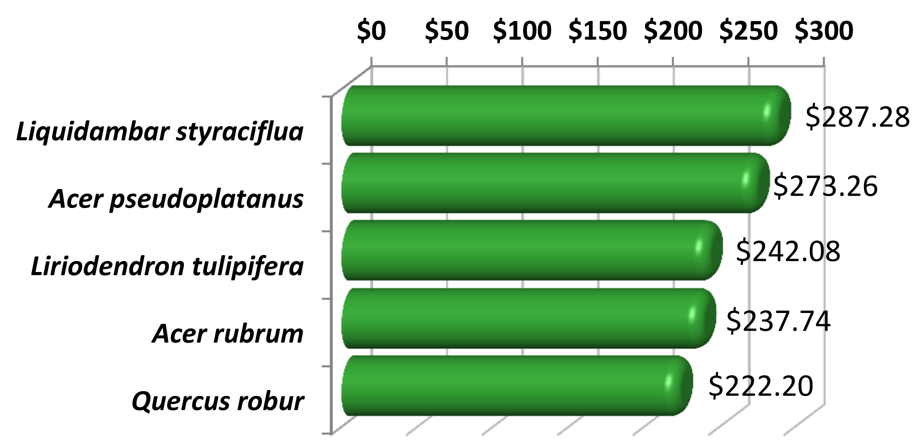


Figure 10. Annual Increase in Property and Socioeconomic Values - Top Five Species

Table 10. Annual Property Value, Aesthetic, and Socioeconomic Benefits Provided by Victoria's Inventoried Tree Resource

Species	Total ($)	% of Pop.	% of Total $	Avg. $/tree
Prunus cerasifera	33,078	10.3	1.4	**17.05**
Prunus serrulata	29,867	8.3	1.3	**19.18**
Crataegus oxyacantha	132,627	6.3	5.7	**112.11**
Acer rubrum	229,417	5.1	9.9	**237.74**
Quercus garryana	128,373	4.3	5.5	**157.13**
Betula papyrifera	120,741	4.0	5.2	**158.45**
Prunus yedoensis	12,842	3.8	0.6	**17.99**
Carpinus betulus	112,745	3.7	4.9	**161.99**
Aesculus hippocastanum	107,624	3.5	4.7	**163.81**
Aesculus carnea	73,334	3.0	3.2	**128.43**
Acer campestre	96,497	3.0	4.2	**169.59**
Betula pendula	81,806	2.7	3.5	**161.03**
Ulmus carpinifolia	75,551	2.5	3.3	**158.39**
Fraxinus ornus	43,201	2.3	1.9	**100.00**
Prunus accolade	8,305	1.8	0.4	**24.21**
Quercus robur	63,103	1.5	2.7	**222.20**
Fagus sylvatica	52,359	1.3	2.3	**220.00**
Platanus acerifolia	37,056	1.2	1.6	**159.72**
Acer pseudoplatanus	62,303	1.2	2.7	**273.26**
Liquidambar styraciflua	62,340	1.2	2.7	**287.28**
Crataegus x lavallei	23,141	1.2	1.0	**106.64**
Liriodendron tulipifera	49,143	1.1	2.1	**242.08**
Magnolia kobus	29,335	1.0	1.3	**151.21**
Other Species	648,547	25.8	28.0	**133.31**
Citywide Total	**$2,313,335**	**100%**	**100%**	**$122.60**

Figure 11. Summary of Annual per Tree Benefits

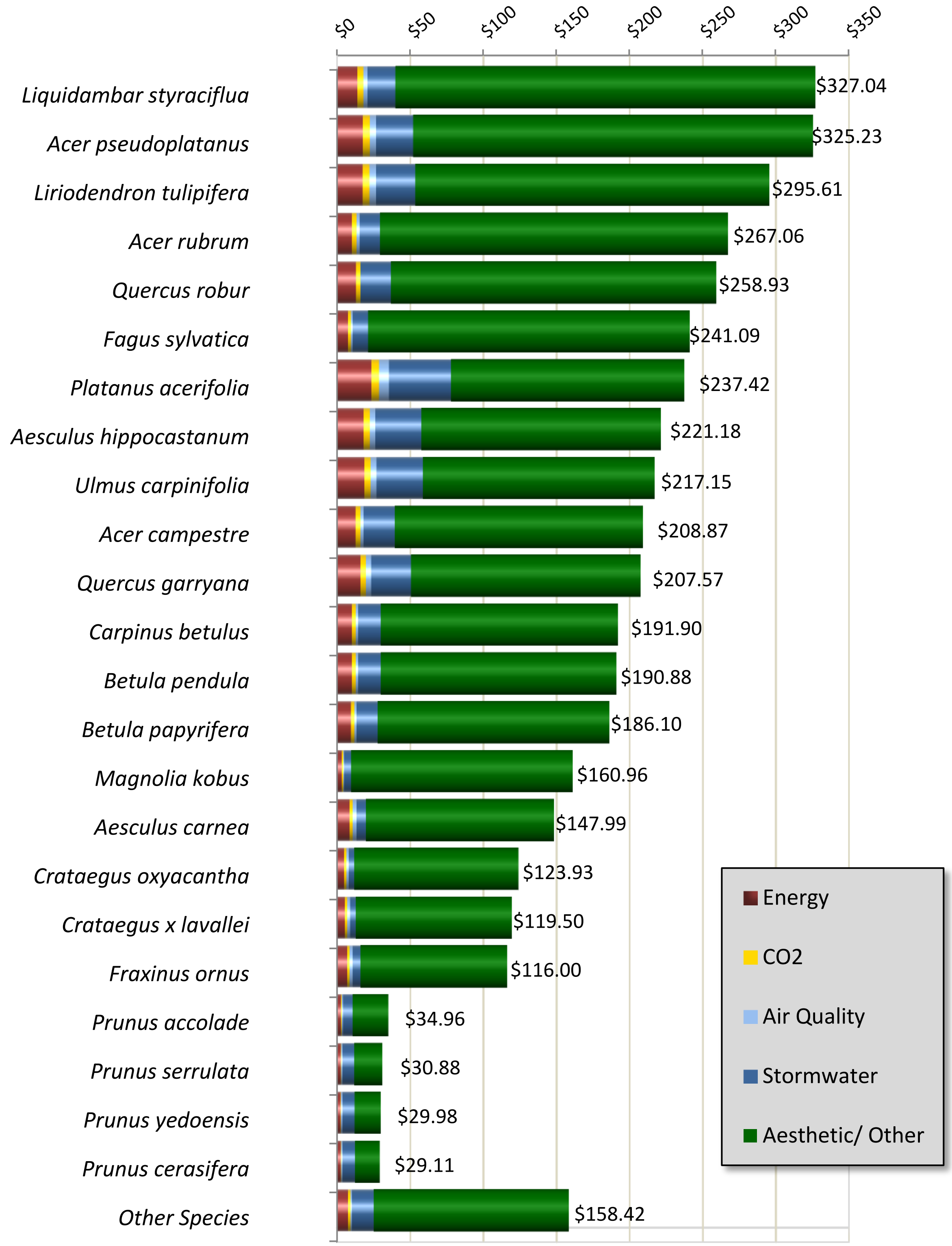


Table 11. Summary of Current Annual Average per Tree Benefits ($/Tree/yr.) from

Species	Energy	CO2	Air Quality	Stormwater	Aesthetic/ Other	Total
Prunus cerasifera	2.46	0.42	0.95	8.22	17.05	**29.11**
Prunus serrulata	2.44	0.44	0.94	7.89	19.18	**30.88**
Crataegus oxyacantha	4.93	1.58	1.51	3.80	112.11	**123.93**
Acer rubrum	10.26	3.01	2.07	13.98	237.74	**267.06**
Quercus garryana	16.01	3.77	3.45	27.18	157.13	**207.54**
Betula papyrifera	9.37	2.59	1.33	14.37	158.45	**186.10**
Prunus yedoensis	2.39	0.40	0.94	8.28	17.99	**29.98**
Carpinus betulus	9.99	2.83	1.44	15.66	161.99	**191.90**
Aesculus hippocastanum	17.94	4.35	3.94	31.14	163.81	**221.18**
Aesculus carnea	8.36	2.14	2.85	6.21	128.43	**147.99**
Acer campestre	12.56	3.52	2.18	21.02	169.59	**208.87**
Betula pendula	10.05	2.84	1.38	15.58	161.03	**190.88**
Ulmus carpinifolia	18.46	4.32	4.12	31.87	158.39	**217.15**
Fraxinus ornus	6.73	1.67	2.23	5.37	100.00	**116.00**
Prunus accolade	2.54	0.53	0.93	6.75	24.21	**34.96**
Quercus robur	12.99	3.08	-0.19	20.86	222.20	**258.93**
Fagus sylvatica	7.28	2.10	1.31	10.41	220.00	**241.09**
Platanus acerifolia	23.30	5.25	6.89	42.26	159.72	**237.42**
Acer pseudoplatanus	17.45	5.08	4.23	25.21	273.26	**325.23**
Liquidambar styraciflua	13.83	4.08	2.91	18.94	287.28	**327.04**
Crataegus x lavallei	5.51	1.52	1.79	4.03	106.64	**119.50**
Liriodendron tulipifera	17.34	4.78	4.47	26.93	242.08	**295.61**
Magnolia kobus	3.36	0.95	0.48	4.96	151.21	**160.96**
Other Species	7.35	1.91	1.05	14.80	133.31	**158.42**
Citywide Average	**$8.13**	**$2.09**	**$1.69**	**$14.17**	**$122.60**	**$148.68**

The property value benefit of Victoria’s trees is relatively high, accounting for 82.5% of the benefits. Stormwater benefits comprise 9.5% of the benefit while energy savings account for 5.5%. The air quality and carbon dioxide benefits are valued substantially lower, accounting for 1.1% and 1.4% of the benefits respectively. (Table 11)

Net Benefits and Benefit-Investment Ratio (BIR)

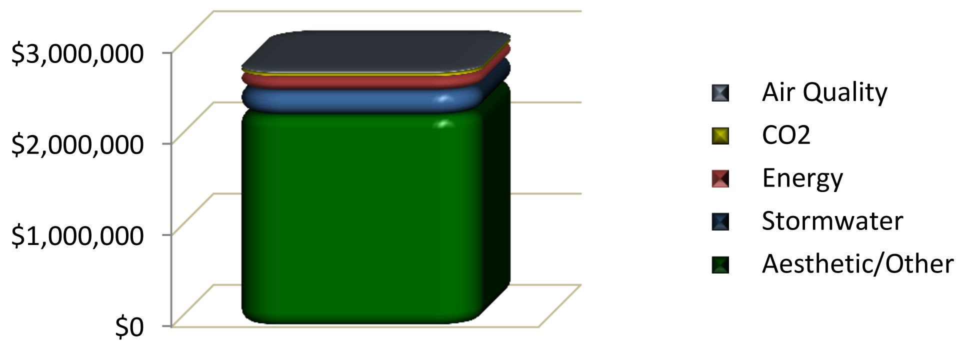
Victoria receives substantial benefits from their street trees; however, the City must also consider their investments in maintaining this resource. Applying a *benefit-investment ratio* (BIR) is a useful way to evaluate the public investment in the community tree population. A BIR is an indicator used to summarize the overall value compared to the investments of a given resource. Specifically, in this analysis, BIR is the ratio of the total value of benefits provided by the City's inventoried trees compared to the cost (investment) associated with their management.

The total estimated benefits provided by Victoria's inventoried tree resource is $2,805,508, a value of $148.68 per tree and $35.05 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 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 the complex nature of interactions make quantification imprecise. Tree growth and mortality rates are highly variable. A true and full accounting of benefits and investments must consider variability among sites (e.g., tree species, growing conditions, maintenance practices) throughout the City, as well as variability in tree growth.

When the City's annual tree related expenditure (or investment) of $741,171 in this resource is considered, the net annual benefit (benefits minus investment) to the City is $2,064,337. The average net value for an individual street tree in Victoria is $109.40 and the per capita net value is $25.79. Based on the inventory of 18,869 street trees, **Victoria is currently receiving $3.79 in benefits for every $1 invested in its urban forest resource** (Table 12).

As existing trees mature and vacant planting sites are filled, the benefits from this resource will increase. Over time, with proactive and timely management, Victoria's urban forest is likely to continue to provide positive net benefits to the community. Furthermore, considering the vital importance of trees to the quality of life in Victoria, the true value of the urban forest is incalculable.

Figure 12. Total Annual Benefits from Victoria's Inventoried Trees



Total Annual Benefit: $2,805,508
Average Annual per Tree Benefit: $148.68
Annual Value of Benefits per Capita: $35.05

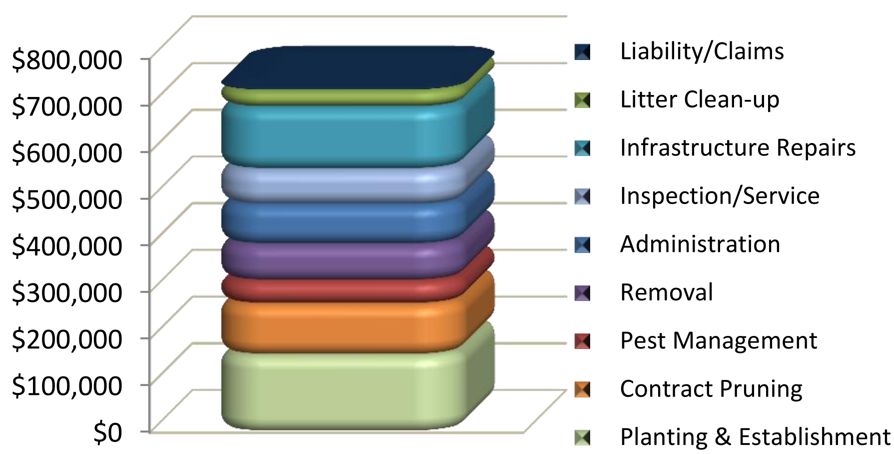


Figure 13. Total Annual Investment to Maintain Victoria's Inventoried Trees

Total Annual Investment: $741,171
Average Annual per Tree Investment: $39.28
Annual Investment per Capita: $9.26

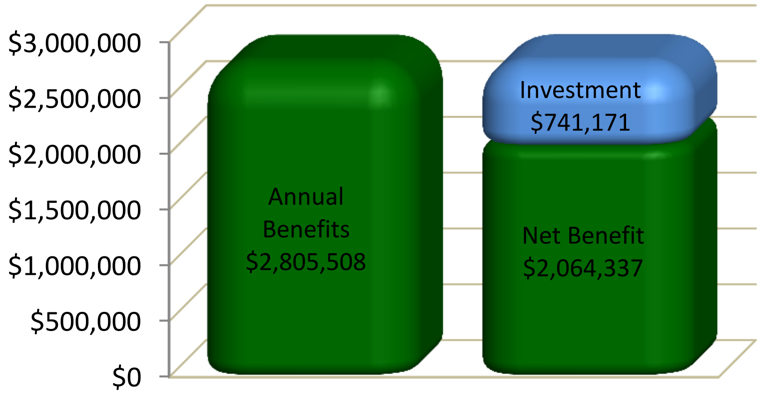


Figure 14. Benefit versus Investment Ratio

Annual Net Benefit from Victoria's Inventoried Tree Resource: $2,064,337

For EVERY $1 invested in trees, Victoria receives $3.79 in benefits.

Table 12. Annual Benefit versus Investment Summary for Victoria's Inventoried Tree Resource

Benefits	Total ($)	$/tree	$/capita
Energy	153,484	8.13	1.92
CO2	39,493	2.09	0.49
Air Quality	31,914	1.69	0.40
Stormwater	267,282	14.17	3.34
Aesthetic/Other	2,313,335	122.60	28.91
Total Benefits	**$2,805,508**	**$148.68**	**$35.05**
Investment			
Planting & Establishment	164,698	8.73	2.06
Contract Pruning	109,170	5.79	1.36
Pest Management	49,833	2.64	0.62
Removal	78,080	4.14	0.98
Administration	85,069	4.51	1.06
Inspection/Service	75,405	4.00	0.94
Infrastructure Repairs	133,000	7.05	1.66
Litter Clean-up	37,376	1.98	0.47
Liability/Claims	8,540	0.45	0.11
Total Investment	**$741,171**	**$39.28**	**$9.26**
Net Benefit	**$2,064,337**	**$109.40**	**$25.79**
Benefit-Investment Ratio	**$3.79**		

Conclusion

This analysis describes the current structural characteristics of Victoria's inventoried street tree resource using established tree sampling, numerical modeling, and statistical methods to provide a general accounting of the benefits. The analysis provides a "snapshot" of this resource at its current population, structure, and condition. 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. Victoria's inventoried trees are providing quantifiable benefits including energy savings, stormwater runoff reduction, reduction in atmospheric CO_2, and aesthetic benefits. The City's 18,869 inventoried trees are providing $2,805,508 in annual gross benefits. That is an average of $146.68 per tree and $35.05 per capita.

The trees inventoried in this project are primarily mature, established trees with high diversity of 238 different species. Although it is critical to maintain an adequate level of resources to protect and nurture this resource, Victoria's 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:

Victoria's trees are providing an average benefit of $35.05 per capita.

- Maintain an appropriate age distribution by continuing to plant new trees to improve long-term resource sustainability and greater canopy coverage. To maximize benefits, focus on medium to large-stature trees where conditions are sustainable.
- Maximize the condition of the existing tree resource through comprehensive tree maintenance and a cyclical pruning schedule.
- Continue annual tree planting efforts with the goal of achieving a 100% stocking rate, utilizing available planting sites identified by the inventory. Exclude or greatly reduce planting the three overrepresented species in new planting areas.
- Formalize a structural pruning program for young and establishing trees to promote healthy structure, extend life expectancy, and reduce future costs and liability.
- Maintain and update the inventory database.

Urban forest managers can better anticipate future trends with an understanding of the current status of the City's tree population. Managers can also anticipate challenges and devise plans to increase the current level of benefits. Performance data from the analysis can be used to make determinations regarding species selection, distribution, and maintenance policies. 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. An urban forest master plan is a critical tool for successful urban forest management, inspiring commitment and providing vision for communication with key decision-makers both inside and outside the organization.

Victoria's trees are of vital importance to the environmental, social, and economic well-being of the community. Victoria has demonstrated that street 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 may use this inventory to take a proactive and forward-looking approach to caring for the community's trees in the future. Updates should be incorporated into the inventory as work is performed. 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 proactive management, Victoria's urban forest can be expected to produce an even greater flow of benefits as this resource continues to mature. By maintaining a commitment to planting, maintaining, and preserving these trees, the community will continue to be a healthy, safe, and enjoyable place to live.

Victoria's trees are of vital importance to the environmental, social, and economic well-being of the community.

Appendix A: Methods and Procedures

Certified Arborists collected Victoria's tree inventory using ArcPad software to assist the inventory arborist in locating the sample plots on the ground and inputting tree attributes (details about each tree's species, size, and condition). The data was formatted for use in i-Tree's tree population assessment tool, i-Tree *Streets*, a STRATUM Analysis Tool (Streets v 5.1.2; i-Tree v 6.0.0). 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 Victoria's trees, i-Tree *Streets* calculates the dollar value of annual resource functionality. This analysis combines the results of the City's tree inventory with benefit 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 (Victoria is located in the Pacific Northwest Climate Zone).

An annual resource unit was determined on a per tree basis for each of the modeled benefits. Resource units are measured as gigajoules of electricity saved per tree; gigajoules of natural gas conserved per tree; kilograms of atmospheric CO_2 reduced per tree; kilograms of NO_2,SO_2, O_3, PM_{10}, and VOCs reduced per tree; cubic meters of stormwater runoff reduced per tree; and cubic meters of leaf area added per tree to increase benefit 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 provided the investment of planting, pruning, irrigation, removal, and other investments. These investments were adjusted to reflect the fact that the inventoried trees comprise just 70% of the estimated citywide inventory. For the purpose of this analysis, the investments were reduced to 70% of the total investments provided. During the course of the inventory, the US – Canada exchange rate varied, but remained close to equal. For the purpose of this model, the exchange rate was assumed to be at parity and the reported monetary values were expressed in Canadian currency.

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 13. Victoria Benefit Prices Used In This Analysis

Benefits	Price	Unit*	Source
Electricity	$0.069	$/Kwh	Residential rates from BC Hydro
Natural Gas	$0.345	$/therm	Residential rates from Fortis BC
CO_2	$0.0075	$/lb	*Streets* default – Pacific Northwest
PM_{10}	$0.49	$/lb	*Streets* default – Pacific Northwest
NO_2	$2.77	$/lb	*Streets* default – Pacific Northwest
SO_2	$0.98	$/lb	*Streets* default – Pacific Northwest
VOC	$2.61	$/lb	*Streets* default – Pacific Northwest
Stormwater Interception	$0.0108	$/gallon	*Streets* default – Pacific Northwest
Median Home Value	$526,000	$	Times Colonist

*i-Tree default values are entered in standard units and converted by the model to metric units for data export.

i-Tree *Streets* default values (Table 13) from the Pacific Northwest Climate Zone were used for all benefit prices except for median home values and electric and natural gas rates. Electric rates and natural gas rates are residential rates from BC Hydro and Fortis BC. Median home value for Victoria was estimated to be $526,000 by the City of Victoria based on information from the Times Colonist. Using these rates, the magnitude of the benefits provided by the inventoried tree resource was calculated using i-Tree *Streets*. Program budget values used in benefit versus investment ratio calculations were supplied by the City of Victoria, and reduced to 70% because only that portion of city trees were estimated to be included in the inventory.

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Appendix C: Common and Botanical Names

Common and Botanical Names for Victoria's Most Common Street Tree Species

Common Name	Species
purple plum	*Prunus cerasifera*
flowering cherry	*Prunus serrulata*
hawthorn	*Crataegus oxyacantha*
maple, red	*Acer rubrum*
Garry oak	*Quercus garryana*
birch, paper	*Betula papyrifera*
Yoshino cherry	*Prunus yedoensis*
hornbeam	*Carpinus betulus*
horse chestnut	*Aesculus hippocastanum*
horse chestnut, red	*Aesculus carnea*
maple, hedge	*Acer campestre*
birch, European white	*Betula pendula*
Elm, field	*Ulmus carpinifolia*
flowering ash	*Fraxinus ornus*
Accolade cherry	*Prunus accolade*
oak, English	*Quercus robur*
beech	*Fagus sylvatica*
London plane	*Platanus acerifolia*
maple, sycamore	*Acer pseudoplatanus*
sweetgum	*Liquidambar styraciflua*
Lavalle hawthorn	*Crataegus x lavallei*
tulip tree	*Liriodendron tulipifera*
Kobus magnolia	*Magnolia kobus*