City of Boise, Idaho
Municipal Forest Resource Analysis

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

Technical Report to:
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—June 2007—





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Executive Summary

Boise, the capital and largest city in the state of Idaho, maintains parks and street trees as an integral component of the urban infrastructure (*Figure 1*). Located along the Boise River and nestled against foothills of the Rocky Mountains, Boise is renowned for its unique blend of natural beauty and urban comforts.

Trees are a critical component of the city in general. Research indicates that healthy trees can lessen im-pacts associated with the built environment by reducing stormwater runoff, energy consumption, and air pollutants. Trees improve urban life, making Boise a more enjoyable place to live, work, and play, while mitigating the city's environmental impact. Over the past century, Boise residents and the City have been developing their urban forest on public and private properties. This report evaluates Boise street and park trees on the street public right-of-way only. The primary question that this study asks is whether the accrued benefits from Boise's right-of-way trees justify the annual expenditures?

This analysis combines results of a citywide inventory with benefit–cost modeling data to produce four types of information on the city-managed ROW tree resource:

- Structure (species composition, diversity, age distribution, condition, etc.)
- Function (magnitude of annual environmental and aesthetic benefits)
- Value (dollar value of benefits minus management costs)
- Management needs (sustainability, planting, maintenance)

Resource Structure

Boise's tree inventory includes 23,262 publicly managed trees along the right of way (ROW).

Figure 1—Trees shade a Boise neighborhood. Street trees in Boise provide great benefits, improving air quality, sequestering carbon dioxide, reducing stormwater runoff and beautifying the city. The trees of Boise return $1.30 in benefits for every $1 spent on tree care

These include 179 tree species with Norway maple (*Acer platanoides*), silver maple (*Acer saccharinum*), honeylocust (*Gleditsia triacanthos*), green ash (*Fraxinus pennsylvanica*), and crabapple (*Malus* spp.) the predominant species. The managers of the city's street trees can be commended for the overall diversity of the tree population in terms of the number of species and distribution of trees among the species.

There is approximately one ROW tree for every nine residents, and these trees shade approximately 0.74% of the city or 6.52% of the city's streets and sidewalks.

Boise divides its tree population into three mature size classes. Class I trees are small species, growing to 30 ft tall. Class II represents shade trees that mature to a maximum height of 40–60 ft while Class III shade trees grow to 60–90 ft.

The age structure of Boise's ROW tree population appears fairly close to the desired "ideal" distribution in having a high proportion (48%) of young trees (0–6 inch diameter at breast height [DBH] or 4.5 ft above the ground) and fewer mature and old trees. The largest size classes are represented almost entirely by silver maple, American sycamore, London planetree (*Platanus acerifolia*), and elm species (*Ulmus* spp.), many of which are nearing the end of their natural life spans. Loss of these trees before the large young tree population matures could represent a sizeable impact on the flow of benefits the city currently receives from street trees. Conversely, if the young trees survive and grow to full maturity, Boise can look forward to greater benefits in the future.

Resource Function and Value

The ROW trees of Boise provide great benefits to the citizens. Their ability to moderate climate—thereby reducing energy use—is substantial. Electricity saved annually in Boise from both shading and climate effects of the ROW trees totals 3,021 MWh ($184,117), and annual natural gas saved totals 129,230 therms ($147,639) for a total energy cost savings of $331,756 or $14 per tree.

Citywide, annual carbon dioxide (CO_2) sequestration and emission reductions due to energy savings by ROW trees are 1,122 lbs and 1,743 lbs, respectively. CO_2 released during decomposition and tree-care activities is 1,440 lbs. Net CO_2 reduction is 907 tons, valued at $6,060 or $0.26 per tree.

Net annual air pollutants removed, released, and avoided average 0.20 lbs per tree and are valued at $6,292 or $0.27 per tree. Ozone ($O_3$) is the most significant pollutant intercepted by trees, with 6,939 lbs per year removed from the air ($3,539), while nitrogen dioxide (NO_2) is the most economically significant air pollutant whose production is avoided at the power plant, due to reduced energy needs (1,353 lbs) per year ($690).

Boise's ROW trees intercept rain, reducing stormwater runoff by 19,246,286 gallons annually, with an estimated value of $96,238. Citywide, the average tree intercepts 827 gallons of stormwater each year, valued at $4 per tree.

The estimated total annual benefits associated with aesthetics, property value increases, and other less tangible improvements are approximately $561,917 or $24 per tree on average.

The grand total for all annual benefits – environmental and aesthetic – provided by ROW trees is $1,002,263, an average of $43 per street tree. The city's 1,926 silver maples produce the highest total level of benefits at $173,990, annually ($90 per tree, 17.4% of total benefits). On a per tree basis, American sycamore (*Platanus occidentalis*, $87 per tree) and English elm (*Ulmus procera*, $85 per tree) also produce significant benefits. Small-stature species, such as the crabapple ($17 per tree), the Callery pear (*Pyrus calleryana*, $19 per tree), and the hawthorn (*Crataegus* spp., $19 per tree) provide the lowest benefits.

Boise spends approximately $770,784 in a typical year maintaining its public ROW trees ($33.13/tree). The highest single cost is tree removal ($141,417), followed by administration ($124,494).

Silver maple, due to age and structural problems, accounts for significant proportion of maintenance costs associated with tree removal, storm cleanup, and property and infrastructure damage.

Subtracting Boise's total expenditures on ROW trees from total costs shows that Boise's municipal ROW tree population is a valuable asset, providing approximately $231,479 or $9.95 per tree ($1.11 per capita) in net annual benefits to the community. Over the years, the city has invested millions in its urban forest. Citizens are now receiving a return on that investment—ROW trees are providing $1.30 in benefits for every $1 spent on tree care. Boise's benefit-cost ratio of 1.30 is similar to those reported for Berkeley, CA (1.37), Charleston, SC (1.34), and Albuquerque (1.31), but is below those reported for Fort Collins, CO (2.18), Cheyenne, WY (2.09), and Bismarck, ND (3.09). A variety of factors can contribute to the benefit-cost ratio being lower than other communities, but key is the fact that the majority of the trees are still immature and have not yet reached full potential for producing benefits.

Another way of describing the worth of trees is their replacement value, which assumes that the value of a tree is equal to the cost of replacing it in its current condition. Replacement value is a function of the number, stature, placement and condition of the cities' trees and reflects their value over a lifetime. As a major component of Boise's green infrastructure, the 23,262 street trees are estimated to have a replacement value of $88,266,102 or $3,794 per tree.

Resource Management

Boise's ROW trees are a dynamic resource. Managers of the urban forest and the community alike can take pride in knowing that these trees greatly improve the quality of life in the city. However, the trees are also a fragile resource needing constant care to maximize and sustain production of benefits into the future while also protecting the public from potential hazard. The challenge as the city continues to grow will be to sustain and expand the existing canopy cover to take advantage of the increased environmental and aesthetic benefits the trees can provide to the community.

In 2006, Boise Mayor David Bieter signed the U.S. Mayors Climate Protection Agreement making Boise the 1st city in Idaho to endorse the agreement. Street ROW trees contribute more to reducing heat island effects, energy consumption, and ground-level ozone by shading the gray infrastructure than trees in backyards and parks. By acting now to implement the recommendations in this report, Boise will be better able to meet its 7% emission reduction target by 2012 and generally benefit from a more functional and sustainable urban forest in the future.

Management recommendations focused on sustaining existing benefits and increasing future benefits include the following:

1. To help meet Boise's Climate Protection Agreement goals to reduce greenhouse gases and emissions:
    - Develop programs and policies to encourage and significantly increase shade tree planting along streets, in parking lots, and near buildings in and adjacent to public rights-of-way.
    - Increase ROW stocking and canopy cover, setting an initial goal of planting one ROW tree for every five residents. This represents an increase of over 18,000 ROW trees (41,600 total compared to 23,262 currently) for a 25% stocking level and 10.5% canopy cover over streets and sidewalks.
    - Increase stocking level with larger-growing (Class II and III) shade tree species where conditions are suitable to maximize benefits. Consider adopting front-yard easements for new tree planting and maintenance where parkway planting strips are absent.
    - Plan for adequate care and pruning to reduce tree mortality and insure survival.

2. Develop a strong young-tree care program that emphasizes reducing mortality. Irrigation along with inspection and pruning at least twice during the initial five years after planting will provide a good foundation for the trees. Expansion of the Tree Steward program is a cost-effective approach to accomplishing this goal.

3. Track the success of the newly planted trees to determine those most adaptable to the difficult growing conditions in Boise. Continue planting a diverse mix of tree species to guard against catastrophic losses due to storms, pests or disease while concentrating the species choice on those that have proven most successful.

4. Sustain current benefits by investing in programmed maintenance of mature trees (e.g., silver maple, American basswood, elms, Norway maple, American sycamore) to prolong the functional life spans of these trees. This includes developing a planned replacement program designed to gradually and systematically replace senescent trees with trees that will grow to similar stature.

5. Continue working with the Ada County Highway District to develop planting space and tree guidelines in new developments and when retrofitting existing streets. Adequate space for Class II and III trees should be a priority.

6. Implement Forestry Management Plan priority recommendations including the development and im-plementation of a public education and volunteer program to demonstrate the link between basic tree care – irrigation frequencies and appropriate maintenance levels – and the resultant benefits provided to the homeowner, neighborhood, and community. This should assist in increasing available planting space and improving tree longevity, functionality, and overall benefits.

7. Develop, implement, and enforce a landscaping ordinance for Boise that creates specific public and private street and parking lot shade guidelines to promote tree canopy cover and associated benefits.

The challenge ahead is to better integrate Boise's green infrastructure with its gray infrastructure. This can be achieved by including green space and trees in the planning phase of development projects, providing space for trees through adequate ROW design or property easements, planting that available space, and designing and maintaining plantings to maximize net benefits over the long term.

Chapter One—Introduction

Located along the Boise River where the desert plateau meets the Rocky Mountains, Boise is the capital and largest city in the State of Idaho. It is the hub of commerce, banking and government for the state. This "City of Trees" (Boise derives its name from the French 'le bois' or 'the woods') maintains its trees as an integral component of the urban infrastructure. Over the past century, Boise residents and the city have been planting trees on public and private properties. Long before Idaho received its statehood, early residents began planting trees to improve community appearance and provide cool shade in an otherwise harsh desert plateau environment. The city's Community Forestry Unit of the Parks and Recreation Department actively manages more than 41,000 trees (Boise Parks & Recreation Dept. Community Forestry Unit 2003). It is estimated that there are over 200,000 trees on private properties within the city. The city believes that the public's investment in stewardship of the urban forest produces benefits that far outweigh the costs to the community and that investing in Boise's green infrastructure makes sense economically, environmentally, and socially.

Research indicates that healthy trees can mitgate impacts associated with urban environs: polluted stormwater runoff, poor air quality, high energy use for heating and cooling buildings, and heat islands. Healthy trees increase real estate values, provide neighborhood residents with a sense of place, and foster psychological, social, and physical health. Street and park trees are associated with other intangibles, too, such as increasing community attractiveness for tourism and business and providing wildlife habitat and corridors. The municipal forest makes Boise a more enjoyable place to visit, live, work, and play while mitigating the environmental impacts of the city (*Figure 2*).

In an era of decreasing public funds and rising costs, however, there is a need to scrutinize public expenditures that are often viewed as "nonessential," such as planting and maintaining street trees. Some may question the need for the level of service presently provided. Hence, the primary question that this study asks is *whether the accrued benefits from Boise's ROW trees justify the annual expenditures?*

In answering this question, information is provided to do the following:

- Assist decision-makers to assess and justify the degree of funding and type of management program appropriate for Boise's urban forest.
- Provide critical baseline information for evaluating program cost-efficiency and alternative management structures.
- Highlight the relevance and relationship of Boise's street trees to local quality of life issues such as environmental health, economic development, and psychological well-being.

Figure 2—Stately trees shade a residential street in Boise

- Provide quantifiable data to assist in developing alternative funding sources through utility purveyors, air quality districts, federal or state agencies, legislative initiatives, or local assessment fees.

This report includes six chapters and three appendices:

Chapter One—Introduction: Describes the purpose of the study.

Chapter Two—Boise's Municipal Tree Resource: Describes the current structure of the street ROW tree resource.

Chapter Three—Costs of Managing Boise's Municipal Trees: Details management expenditures for publicly managed right-of-way trees.

Chapter Four—Benefits of Boise's Municipal Trees: Quantifies the estimated value of tangible benefits and calculates net benefits and a benefit–cost ratio for street ROW trees.

Chapter Five—Management Implications: Evaluates relevancy of this analysis to current programs and describes management challenges for street ROW tree maintenance.

Chapter Six—Conclusions: Final word on the use of this analysis.

Appendix A—Tree Distribution: Lists species and tree numbers in the population of street ROW trees.

Appendix B—Replacement Values: Lists replacement values for the entire street ROW tree population.

Appendix C—Describes procedures and methodology for calculating structure, function, and value of the street ROW tree resource.

References—Lists publications cited in the study.

Chapter Two—Boise's Municipal Tree Resource

Many of Boise's citizens are passionate about their trees, believing that they add character, beauty, and serenity to the city (*Figure 3*). With increasing focus on species diversity, residents and city government have been planting trees on public and private property over the past century. Today thousands of trees grace Boise, earning the city recognition as a National Arbor Day Foundation "Tree City USA" for 29 years and receiving the Foundation's Growth Award six times in the past 12 years. The Parks & Recreation Department Community Forestry Unit is an accredited urban forestry program with the Society of Municipal Arborists. Community Forestry is responsible for the preservation, protection and management of more than 41,000 publicly owned trees in the City of Boise and sponsors a ReLeaf Boise tree-planting event, free tree steward classes and other educational opportunities for the community. Their published *Tree Selection Guide for Street and Landscapes throughout Idaho* includes planting and maintenance information for residents as well as botanical drawings to assist residents and visitors with tree identification. In 2006, the Community Forestry staff and members of the community reviewed and updated the Community Forestry Management Plan, assessing Boise's urban forest and formalizing recommendations for the planting, care and maintenance of the tree resource. Additionally, in 2003, the Community Forestry Unit produced the Tree Statistics Report, evaluating the diversity, size, and age distribution of the urban forest. Cooperatively, citizens and the Community Forestry Unit are striving to monitor and improve all aspects of their urban forest, continuing to make Boise an enjoyable and healthy place to live.

Tree Numbers

Begun in 1981, the Boise tree inventory is used as a management tool and continually updated. At the

Figure 3—Boise's substantial canopy cover provides citizens with many environmental and aesthetic benefits

time of this study the ROW trees along streets tallied 23,262 trees, distributed among eight management districts (*Figure 4*).

The municipal ROW tree population is dominated by deciduous trees (91.75% of the total). There are no broadleaf evergreen street trees. Conifers account for the remaining 8.25% of the ROW tree population. Deciduous trees provide protection against the harsh summer sun, while still allowing the sun's warming rays to reach buildings during winter months.

Street Tree Stocking Level

Although the inventory on which our study is based did not sample all potential public right-of-way planting sites in Boise, stocking level can be estimated based on total street miles and the city's inventory of 23,262 street trees. Assuming there are 800 linear miles of streets in Boise (Jorgenson 2006), on average there are 29 street trees per mile. A fully stocked city would have one tree on each side of the street every 50 feet or 211 trees per mile. By this measure, Boise's street tree stocking level is 14%, and there is room, theoretically, for as many as another 145,000 trees. The actual number of street tree plantings sites may be significantly less due to inadequate planting spaces, presence of privately owned trees, and utility conflicts. Boise's current stocking level compares favorably with Cheyenne, WY (12%), Glendale, AZ (9%), and Charleston, SC (8%), but is significantly less than Bismarck, ND (37%), and the mean stocking level for 22 U.S. cities (38.4%) (McPherson et al. 2005; McPherson and Rowntree 1989).

One significant challenge to increasing the street tree stocking levels in Boise is the lack of public right of way available for tree planting in areas developed after 1970. Historically, Boise's street development always included parkway planting strips on public right of way between curbs and sidewalks. About midway through the 1900s, that changed as land prices increased and public coffers for purchasing street rights of way dwindled. Streets and sidewalks also became wider, leaving little space for landscaping of any kind, especially trees. In the 1970s, public street trees all but disappeared from residential and commercial street planning. Those neighborhoods that chose to incorporate parkway strips were left with space enough for 3- to 5-ft wide planters – inadequate for growth of Class II and III shade trees without disrupting sidewalks and curbs caused by roots and trunks. The result was several decades when Boise's public tree canopy was not increased. Public tree planting will likely never be possible in these areas unless the city works with the community to develop policies establishing tree easements on properties adjacent to these rights of way. Of course, the private citizens in these areas may plant their

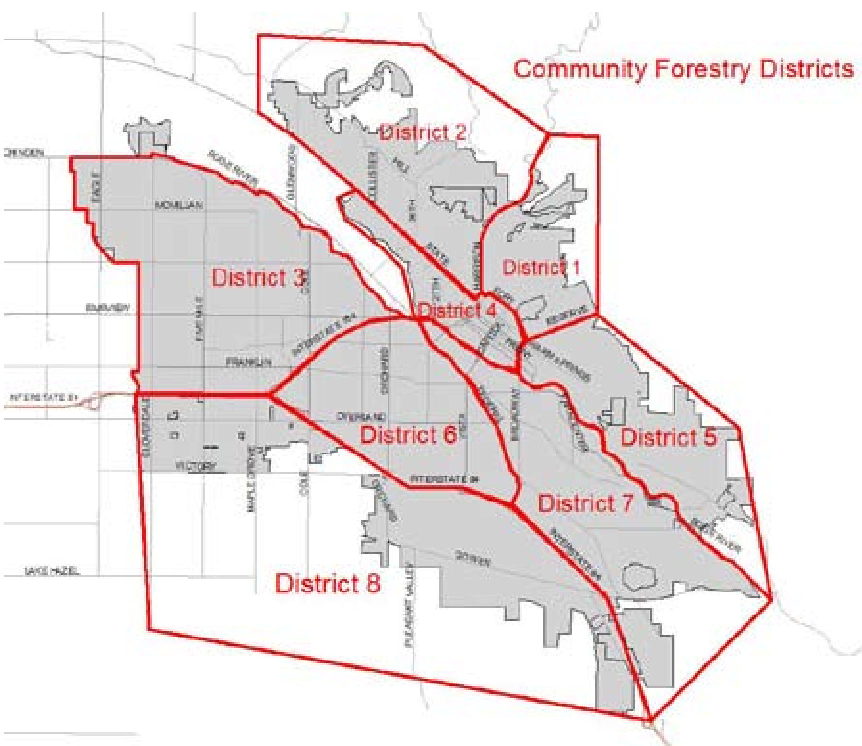

Figure 4—Urban forest management districts in Boise. In District 8, public trees are limited to parks

trees adjacent to streets, but consistent planting of shade trees is not likely in these areas without established programs to encourage neighborhood planting.

Recently, citizens, planners and developers have started to swing the pendulum back toward reintroducing the public right of way tree parkways, at least in residential neighborhoods. The Ada County Highway District has recently approved a policy that will require minimum 8' parkway strips in new developments in Ada County that choose to incorporate them into their street design. This will provide new potential for Boise and all Ada County communities to increase the street tree stocking levels. Wider parkway strips should allow for planting and growth of large shade trees, while decreasing damage to sidewalks and curbs as trees approach maturity.

Municipal ROW Trees Per Capita

Calculations of street trees per capita are important in determining how well-forested a city is. Assuming a human population of 208,000 (Jorgenson 2006) and a street ROW tree population of 23,262, Boise's number of ROW trees per capita is 0.11 – approximately one tree for every nine people – significantly below the mean ratio of 0.37 reported for 22 U.S. cities (McPherson and Rowntree 1989). More recent research shows Boise's ratio similar to Fort Collins, CO (0.12 or one tree per eight residents) but significantly lower than Cheyenne, WY (one tree per six residents) and Bismarck, ND (one tree per three residents) (McPherson et al. 2003; Peper et al. 2004a, b).

Species Richness, Composition and Diversity

The ROW tree population in Boise includes a mix of 179 different species—more than three times the mean of 53 species reported by McPherson and Rowntree (1989) in their nationwide survey of street tree populations in 22 U.S. cities. This is especially impressive considering the challenging growing conditions in a high desert plateau community.

The predominant municipal ROW tree species are Norway maple (*Acer platanoides*, 10.4%), silver maple (*Acer saccharinum*, 8.3%), honeylocust (*Gleditsia triacanthos*, 6.9%), green ash (*Fraxinus pennsylvanica*, 4.5%), and crabapple (*Malus* spp., 4.1%) (*Table 1*; see also *Appendix A*).

The Community Forestry Unit, focused on species diversification, is working to conform to the general idea that no single species should represent more than 10% of the population and no genus more than 20% (Clark et al. 1997). Norway maple barely exceeds the 10% species level, and only one genus, maple (*Acer* spp.), surpasses the 20% threshold at 23.6%. In 2000, maples constituted 29% of the forest, but when maples die or require removal, the Community Forestry staff encourages replacement with nonmaple species, thereby reducing the predominance of this genus. The Community Forestry Unit is clearly aware of the impact that drought, disease, pests, or other stressors can have on an urban forest dominated by one species or genus. Providing a wide variety of species will reduce the loss of canopy due to such catastrophic events.

Although ROW tree species diversity at the city level is good, at the district level, there are some areas for concern (*Table 2*; see *Figure 4* for districts). In District 4, for example, 18.8% of the street trees are Norway maple. In District 6, silver maples represent 13.6% of the population and Scotch pine (*Pinus sylvestris*) 13.7% in District 7.

Species Importance

Importance values (IV) are particularly meaningful to managers because they indicate a community's reliance on the functional capacity of particular species. For this study, IV takes into account not only total tree numbers, but canopy cover and leaf area, providing a useful comparison with the total population distribution.

IV, a mean of three relative values, can in theory

Table 1*—Most abundant ROW tree species in order of predominance by DBH class and tree type*

	DBH class (in)									
Species	**0–3**	**3–6**	**6–12**	**12–18**	**18–24**	**24–30**	**30–36**	**36–42**	**>42**	**Total**	**% of total**
Broadleaf deciduous large (BDL)											
Silver maple	52	46	98	173	347	577	381	160	92	1,926	8.3
Honeylocust	484	324	535	218	23	18	3	2	-	1,607	6.9
Green ash	307	351	202	92	46	32	12	3	1	1,046	4.5
White ash	499	267	86	17	-	2	4	-	-	875	3.8
American sycamore	61	23	34	61	139	195	145	44	11	713	3.1
American basswood	209	122	141	96	67	26	9	1	1	672	2.9
Ash	58	134	128	131	98	55	15	1	1	621	2.7
Sweetgum	282	120	128	72	11	3	-	-	-	616	2.6
Black locust	36	74	113	108	116	110	29	13	2	601	2.6
Elm	53	61	64	18	34	76	108	68	18	500	2.1
Northern red oak	187	66	51	48	61	38	13	1	-	465	2.0
Black walnut	13	30	106	134	84	34	5	4	2	412	1.8
Sugar maple	248	38	26	22	10	7	1	-	-	352	1.5
Northern catalpa	13	40	47	65	66	73	33	7	1	345	1.5
London planetree	140	55	85	27	13	15	4	2	2	343	1.5
Siberian elm	19	21	56	49	58	66	24	12	2	307	1.3
English elm	-	1	4	1	28	67	110	69	23	303	1.3
Cottonwood	36	78	35	18	10	24	24	18	29	272	1.2
BDL other	294	150	144	154	142	166	87	38	26	1,201	5.2
Total	2,991	2,001	2,083	1,504	1,353	1,584	1,007	443	211	13,177	56.6
Broadleaf deciduous medium (BDM)											
Norway maple	669	505	607	421	162	57	7	2	-	2,430	10.4
Maple	239	135	203	130	51	9	1	2	-	770	3.3
Callery pear	377	256	106	5	1	-	-	-	-	745	3.2
Littleleaf linden	208	62	17	4	4	-	-	-	-	295	1.3
BDM other	669	317	216	129	64	28	18	6	5	1,452	6.2
Total	2,162	1,275	1,149	689	282	94	26	10	5	5,692	24.5
Broadleaf deciduous small (BDS)											
Crabapple	424	329	155	34	2	-	-	-	-	944	4.1
Hawthorn	117	75	128	63	7	-	-	-	-	390	1.7
Plum	51	141	88	7	3	-	-	-	-	290	1.2
BDS other	419	172	168	82	7	2	-	-	-	850	3.7
Total	1,011	717	539	186	19	2	-	-	-	2,474	10.6
Conifer evergreen large (CEL)											
Blue spruce	57	168	86	99	29	10	1	-	1	451	1.9
CEL other	41	87	121	91	47	22	8	-	-	417	1.8
Total	98	255	207	190	76	32	9	-	1	868	3.7
Conifer evergreen medium (CEM)											
Scotch pine	174	212	67	8	2	4	-	-	-	467	2.0
Austrian pine	28	135	139	47	7	5	-	-	-	361	1.6
CEM other	66	65	46	18	6	2	-	-	-	203	0.9
Total	268	412	252	73	15	11	-	-	-	1,031	4.4
Conifer evergreen small (CES)											
CES other	4	2	10	3	1	-	-	-	-	20	0.1
Citywide total	6,534	4,662	4,240	2,645	1,746	1,723	1,042	453	217	23,262	100.0

Table 2—Most abundant right-of-way tree species by district with percentage of totals in parenthesis

District	1st (%)	2nd (%)	3rd (%)	4th (%)	5th (%)	# of trees
Not assigned	Honeylocust (10.2)	Norway maple (9.7)	Green ash (6.6)	Crabapple (5.6)	Silver maple (4.9)	1,054
1	Norway maple (10.7)	Silver maple (9.3)	Honeylocust (6.8)	Maple (6.3)	Green ash (5.2)	3,529
2	Silver maple (11)	Norway maple (10.9)	Honeylocust (4.3)	Maple (3.9)	Elm (3.8)	4,956
3	Green ash (7.1)	Silver maple (6.7)	Norway maple (6.4)	Ash (5.9)	White ash (4.3)	1,293
4	Norway maple (18.8)	White ash (6.3)	White ash (6.3)	Green ash (6.3)	Silver maple (5.2)	4,538
5	Norway maple (9.3)	Honeylocust (8.4)	Silver maple (7.4)	Maple (5)	White ash (4.8)	3,132
6	Silver maple (13.6)	Black locust (9.7)	Siberian elm (6)	Green ash (5.2)	Crabapple (4.9)	1,839
7	Scotch pine (13.7)	Crabapple (7.4)	Honeylocust (6.8)	Silver maple (6.6)	Austrian pine (6.3)	2,921
Citywide total	Norway maple (10.4)	Silver maple (8.3)	Honeylocust (6.9)	Green ash (4.5)	Crabapple (4.1)	23,262

range between 0 and 100, where an IV of 100 implies total reliance on one species and an IV of 0 suggests no reliance. Urban tree populations with one dominant species (IV>25%) may have low maintenance costs due to the efficiency of repetitive work, but may still incur large costs if decline, disease, or senescence of the dominant species results in large numbers of removals and replacements. When IVs are more evenly dispersed among five to ten leading species, the risks of a catastrophic loss of a single dominant species are reduced. Of course, suitability of the dominant species is an important consideration. Planting short-lived or poorly adapted trees can result in short rotations and increased long-term management costs.

The 28 most abundant ROW tree species listed in *Table 3* constitute 82% of the total population, 86% of the total leaf area, and 86% of total canopy cover, for an IV of 85. As *Table 3* illustrates, Boise is relying most on the functional capacity of silver maple. Though the species accounts for just over 8% of all public ROW trees, because of the trees' large size, the amount of leaf area and canopy cover provided is great, increasing their importance value to 18.62 when all components are considered. This makes them 2.3 times more significant than Norway maple and 2.5 times more significant than American sycamore (*Platanus occidentalis*), the next closest species.

The main reason why silver maple are highest in importance value is that the majority of the trees are old and fully mature; therefore, they have reached their full structural and functional capacity. Maple, as a genus, contributes 32% of the leaf area and 34% of Boise's canopy cover. Other large trees – honeylocust, green ash, and white ash (*Fraxinus americana*) – appear to have significantly lower importance values; however, more than half of their populations are young trees (<6 inches DBH) and will continue to grow in importance as they age. For example, white ash's current importance value is only 1.87, but nearly 90% of its population is less than 6 inches DBH. If white ash increase in size and number they are likely to become as important as the older species.

Age Structure

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

Citywide, the overall age structure, represented here in terms of DBH, for ROW trees in Boise appears fairly similar to the ideal with the exception of trees in the 6–12 inch DBH class where the proportion is 7% below the ideal (*Figure 5*) . Closer examination, however, shows that the results differ greatly by species. Norway maple comes closest to ideal distributions across DBH classes. Four

Table 3—Importance values (IV) indicate which species dominate the population based on numbers and size

Species	% of total trees	Leaf area (ft^2)	% of total leaf area	Canopy cover (ft^2)	% of total canopy cover	Importance value
Silver maple	8.3	13,300,478	23.8	3,602,907	23.8	18.62
Norway maple	10.4	3,427,328	6.1	1,110,360	7.3	7.97
American sycamore	3.1	5,668,569	10.1	1,438,316	9.5	7.57
Honeylocust	6.9	2,382,679	4.3	903,552	6.0	5.71
Elm	2.1	3,221,936	5.8	579,637	3.8	3.91
English elm	1.3	2,947,684	5.3	530,133	3.5	3.36
Green ash	4.5	1,438,364	2.6	437,499	2.9	3.32
Ash	2.7	1,781,251	3.2	539,219	3.6	3.14
Maple	3.3	1,201,394	2.1	369,241	2.4	2.63
Black walnut	1.8	1,430,379	2.6	463,421	3.1	2.46
Northern red oak	2.0	1,410,519	2.5	395,024	2.6	2.38
Black locust	2.6	1,224,755	2.2	356,163	2.4	2.38
American basswood	2.9	991,999	1.8	286,878	1.9	2.19
Siberian elm	1.3	1,634,050	2.9	295,987	2.0	2.07
Crabapple	4.1	335,031	0.6	147,613	1.0	1.88
White ash	3.8	468,885	0.8	150,796	1.0	1.87
Cottonwood	1.2	1,122,196	2.0	308,663	2.0	1.74
Northern catalpa	1.5	880,510	1.6	229,941	1.5	1.53
Sweetgum	2.6	544,285	1.0	137,392	0.9	1.51
Callery pear	3.2	290,363	0.5	82,894	0.5	1.42
London planetree	1.5	713,931	1.3	205,402	1.4	1.37
Blue spruce	1.9	509,810	0.9	106,098	0.7	1.18
Hawthorn	1.7	256,311	0.5	114,678	0.8	0.96
Austrian pine	1.6	328,771	0.6	82,594	0.5	0.90
Sugar maple	1.5	350,606	0.6	80,020	0.5	0.89
Scotch pine	2.0	165,596	0.3	44,537	0.3	0.87
Plum	1.2	148,401	0.3	65,711	0.4	0.65
Littleleaf linden	1.3	78,716	0.1	23,817	0.2	0.52

species are heavily represented in the smaller size classes, reflecting the city's recent efforts to plant new Class I, II, and III species including green ash, white ash, Callery pear (*Pyrus calleryana*), and crabapple. As relatively new introductions to the planting palette, these species have 63-87% of their populations in the 0–6 inch DBH class and little or no representation as of yet in mature size classes. For mature size classes, Boise ROW trees exceed ideal numbers only because of two species – American sycamore and silver maple – with heavy representation in DBH classes greater than 24 inches. The middle size classes (18–30 inch DBH) are less well-represented, probably a result of fewer trees being planted during that time period, coupled with high mortality rates. Records maintained by Community Forestry indicate the tree mortality of new plantings in Boise at around 2% per year for the first five years and 0.8% per year thereafter, suggesting that 30% of all trees planted do not live beyond 30 years (Jorgenson 2006). Many trees simply do not live long enough to grow large. Poor maintenance through inadequate watering or overwatering by adjacent property owners is the main contributing factor to early mortality. Where growing conditions are good, removed trees are replaced with new trees.

It is interesting to note that Boise has a relatively high percentage of very old street ROW trees (2.9%

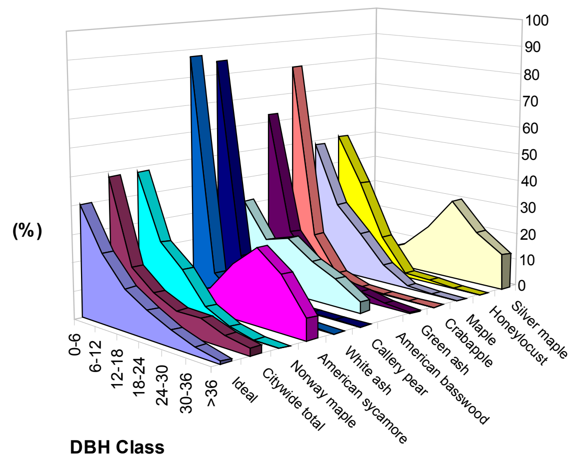

Figure 5—Relative age distribution for Boise's 10 most abundant street tree species citywide shown with an ideal distribution

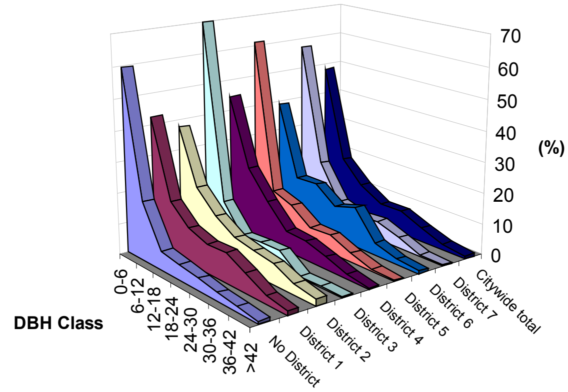

Figure 6—Relative age distribution of all street trees by management district

in DBH classes greater than 36 inches). These large trees are almost entirely elms (data not shown), silver maple and American sycamore. Most of the other large trees are cottonwoods or were heavily planted in the past.

Figure 6 shows age distribution of ROW trees by district. The desired pattern (a high proportion of new trees and numbers that decline with age) holds true at the district level. Some small differences can be noted: Districts 3 and 5 have a markedly high proportion of trees in the youngest class while Districts 1, 2, and 6 surpass the ideal representation for the larger DBH classes. No district was assigned to 1,054 trees in the inventory and that is also shown in *Figure 6*.

Again, it is important to note that these findings are proportionate to the number of ROW trees present in each district, not total number of ROW trees. Districts undergoing expansion and development have significantly fewer trees than older, established districts due to exclusion of tree space from planned rights-of-way (*Figure 4*).

Tree Condition

Tree condition indicates both how well trees are managed and how well they perform given site-specific conditions. About 57% of ROW trees in Boise are in good or better condition, with over 16% in poor or worse condition (*Figure 7*). The relative performance index (RPI) of each species provides an indication of its suitability to local growing conditions, as well as its performance. A species whose trees are in average condition compared to all other species in the city has an RPI of 1.0. Species that perform above the average have an RPI greater than 1.0, and those species with below average performance have RPIs below 1.0. Part of Boise's higher percentage of trees in good condition may be due to the fact that 66% of the ROW population is relatively young, under 12 inches DBH.

Condition varies greatly from species to species, however (*Table 4*). Looking at species with 100 or more trees planted, Boise species with the lowest RPI (highest percentage in poor or worse condition)

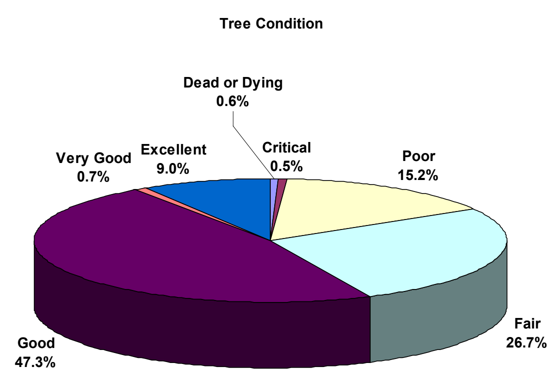

Figure 7—Boise's street trees are assigned one of seven condition ratings. The majority of the city's trees are in fair or better condition

Table 4*—Relative performance index (RPI) for Boise's predominant right-of-way species*

Species	Dead	Critical	Poor	Fair	Good	Very good	Excellent	RPI	# of trees	% of pop'n
Northern hackberry	0.9	0.0	1.9	8.3	59.3	0.0	29.6	1.24	108	0.5
White ash	0.3	0.5	2.7	17.1	52.5	2.2	24.7	1.19	875	3.8
London planetree	0.0	0.0	2.6	13.1	65.3	0.9	18.1	1.17	343	1.5
Callery pear	0.5	0.3	3.2	13.5	62.4	1.6	18.4	1.16	743	3.2
White oak	0.0	0.0	1.1	18.4	62.1	1.1	17.2	1.16	174	0.7
Northern red oak	0.6	0.0	3.2	9.5	71.0	1.1	14.6	1.15	465	2.0
American basswood	0.4	0.1	7.0	22.3	45.1	0.0	25.0	1.15	672	2.9
Crabapple	0.2	0.3	5.4	23.5	50.8	1.0	18.8	1.13	942	4.1
Green ash	0.6	0.5	4.4	21.8	54.7	1.0	17.0	1.12	1,045	4.5
Maple	1.4	0.4	7.6	21.5	48.6	0.0	20.6	1.11	768	3.3
Sugar maple	0.3	0.9	5.1	9.1	71.9	6.3	6.5	1.11	352	1.5
Honeylocust	0.3	0.2	4.5	20.5	60.8	1.3	12.4	1.10	1,607	6.9
Silver linden	0.0	0.0	2.2	8.1	86.8	0.0	2.9	1.10	136	0.6
Sweetgum	0.7	0.3	3.4	18.6	66.1	0.2	10.7	1.10	614	2.6
Japanese pagoda tree	0.0	0.7	9.9	19.2	55.0	0.0	15.2	1.09	151	0.7
Ginkgo	0.0	0.7	3.4	12.8	77.9	0.0	5.4	1.09	149	0.6
Austrian pine	0.0	0.0	1.9	12.7	83.9	0.0	1.4	1.08	361	1.6
Bur oak	0.8	0.0	2.5	12.6	79.8	1.7	2.5	1.08	119	0.5
Scotch pine	0.0	0.0	0.2	17.4	82.4	0.0	0.0	1.07	466	2.0
Plum	1.4	0.7	14.8	26.2	34.8	0.0	22.1	1.07	290	1.2
Blue spruce	0.4	0.0	1.8	21.1	73.8	0.0	2.9	1.06	451	1.9
Littleleaf linden	0.0	0.3	3.1	25.4	62.7	5.1	3.4	1.06	295	1.3
Hawthorn	0.5	0.8	5.4	39.7	40.3	0.0	13.3	1.04	390	1.7
Pine	0.9	0.0	3.6	17.9	77.7	0.0	0.0	1.04	112	0.5
Norway maple	0.6	0.7	9.4	25.0	56.9	0.5	7.0	1.02	2,428	10.5
Red maple	0.0	1.8	5.3	20.4	71.7	0.0	0.9	1.02	113	0.5
Basswood	0.7	1.4	9.5	19.0	63.3	2.0	4.1	1.02	147	0.6
Ash	0.3	0.0	19.3	35.7	41.2	0.0	3.4	0.93	621	2.7
American sycamore	0.3	0.4	21.2	45.4	23.3	0.4	8.9	0.92	711	3.1
Northern catalpa	0.0	0.3	15.1	47.8	34.8	0.6	1.4	0.91	345	1.5
Tree of heaven	0.0	0.0	13.5	64.3	22.2	0.0	0.0	0.86	126	0.5
American elm	0.0	0.6	27.5	60.5	9.6	0.0	1.8	0.80	167	0.7
Black walnut	2.0	1.5	28.1	46.9	21.0	0.0	0.5	0.80	409	1.8
Cottonwood	4.1	0.0	35.1	32.1	28.4	0.0	0.4	0.79	271	1.2
Elm	1.4	0.4	37.6	37.0	23.0	0.0	0.6	0.79	500	2.2
Silver maple	0.8	0.9	42.6	42.6	12.5	0.1	0.5	0.75	1,919	8.3
Siberian elm	0.0	0.0	55.4	34.5	6.5	0.0	3.6	0.73	307	1.3
English elm	0.0	1.0	49.5	38.9	10.6	0.0	0.0	0.72	303	1.3
Black locust	2.3	1.7	71.4	19.6	3.5	0.0	1.5	0.63	601	2.6
Citywide total	0.64	0.49	15.20	26.72	47.32	0.65	8.98	1.00	23,220	100.0

are black locust (*Robinia pseudoacacia*, 75%), Siberian elm (*Ulmus pumila*, 55%), and English elm (*Ulmus procera*, 50%). Species with the largest percentage of trees in good or better condition include northern hackberry (*Celtis occidentalis*, 90%), London planetree (*Platanus acerifolia*, 85%), and Callery pear (82%). Note that these values reflect condition as reported in the 2005 inventory and may not reflect current conditions for all species.

Care should be taken when analyzing tree condition to ensure that relevant factors such as age are taken into consideration. For example, 80% or more of Callery pear, white ash, and crabapple are young trees under 6 inches DBH. It is important to compare relative age (*Figure 5*) with RPI (*Table 4*) to determine whether various species have actually stood the test of time. Conclusions about their suitability to the region as ROW trees should be postponed until the trees have matured.

Tree Canopy

Canopy cover, or more precisely, the amount and distribution of leaf surface area, is the driving force behind the urban forest's ability to produce benefits for the community. As canopy cover increases, so do the benefits afforded by leaf area. It is important to remember that street and park trees throughout the United States—and those of Boise—likely represent less than 20% of the entire urban forest (Moll and Kollin 1993) within a city. Overall tree cover for the City of Boise (public and private trees) was reported as 28.6% (Dwyer et al. 2000). Public ROW trees canopy cover is only 0.74%, given a city land area of 46,720 acres (73 mi^2) and our estimated ROW tree canopy of 347.6 acres. The ROW trees cover 6.5% of city streets and sidewalks. Shading of streets and sidewalks decreases urban heat island effects as well as asphalt maintenance costs. Boise's street and sidewalk canopy coverage exceeds that of Glendale, AZ (1.8%), Charleston, SC (2.5%), and Cheyenne, WY (5.2%), but is significantly less than Fort Collins, CO (11.8%), Bismarck, ND (23.8%), and Minneapolis, MN (35.2%). Although canopy coverage will increase in certain portions of the city as all the young trees planted in recent years mature, overall canopy cover may not increase unless space is created for street ROW trees in new developments and existing developments currently lacking tree ROW space or easements.

Replacement Value

Replacement value is a way of describing the value of trees at a given time, reflecting their current number, stature, placement, and condition. There are several methods that arborists employ to develop a fair and reasonable perception of a tree's value (CTLA 1992, Watson 2002). The cost approach is widely used today and assumes that value equals the cost of production, or in other words, the cost of replacing a tree in its current state (Cullen 2002).

Replacing Boise's 23,262 municipal ROW trees with trees of similar size, species, and condition if, for example, all were destroyed by a catastrophic storm, would cost approximately $88 million (*Table 5*; see also *Appendix B*). Boise's ROW trees are a valuable legacy, and as a central component of the city's green infrastructure can be considered a public asset with a value of $88,266,102, with most of this value in the older and larger trees. The average replacement value per tree is $3,794.

Replacement value should be distinguished from the value of annual benefits produced by the ROW trees. The latter will be described in *Chapter 4* as a "snapshot" of benefits during one year, while the former accounts for the historical investment in trees over their lifetimes. Hence, the replacement value of Boise's municipal ROW tree population is many times greater than the value of annual benefits it produces.

__Table 5__—Replacement values, summed by DBH class, for the 40 most valuable species of street trees in Boise. See Appendix B for complete listing

Species	0–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total	% of total
Silver maple	28,505	137,676	611,029	2,392,822	6,662,492	6,348,965	3,463,423	2,357,652	22,002,562	24.9
American sycamore	19,963	46,893	226,683	990,527	2,354,429	2,592,123	1,090,125	280,837	7,601,581	8.6
Norway maple	338,113	1,010,245	1,950,829	1,418,823	834,526	146,852	59,605	-	5,758,993	6.5
Elm	34,268	82,497	55,920	213,017	765,365	1,636,198	1,457,405	402,179	4,646,849	5.3
English elm	506	4,970	3,978	180,390	670,634	1,689,091	1,425,427	480,592	4,455,587	5.0
Northern catalpa	21,955	78,967	315,748	612,742	1,094,941	756,575	199,965	30,086	3,110,980	3.5
Black locust	36,068	133,021	334,423	666,072	1,051,526	406,209	231,586	42,580	2,901,485	3.3
Honeylocust	229,053	946,600	1,047,467	226,481	294,462	70,826	69,689	-	2,884,578	3.3
Ash	69,974	198,456	554,975	840,089	730,531	295,597	20,940	23,402	2,733,966	3.1
American elm	-	-	31,543	114,325	689,649	902,183	650,683	230,872	2,619,255	3.0
American basswood	86,210	245,752	485,897	662,020	428,405	199,650	34,845	32,075	2,174,852	2.5
Green ash	211,228	317,559	397,233	406,472	441,062	268,862	75,423	24,084	2,141,923	2.4
Black walnut	16,344	152,455	523,405	608,443	416,337	93,797	97,084	61,477	1,969,343	2.2
Northern red oak	55,393	94,037	242,873	598,861	596,881	301,450	26,120	-	1,915,614	2.2
Siberian elm	11,563	57,590	132,469	294,997	559,408	311,233	212,475	37,608	1,617,342	1.8
Maple	94,843	304,255	540,269	433,814	124,116	22,289	44,050	-	1,563,636	1.8
Cottonwood	39,135	40,285	53,705	52,477	205,188	244,860	285,801	515,505	1,436,956	1.6
White oak	8,990	44,747	109,480	315,767	512,863	215,904	55,670	-	1,263,421	1.4
Blue spruce	90,049	144,424	456,913	251,521	145,673	20,823	-	30,086	1,139,490	1.3
London planetree	44,579	156,598	131,454	129,354	264,027	104,359	67,476	68,126	965,972	1.1
Sweetgum	96,335	224,473	346,168	107,110	51,026	-	-	-	825,112	0.9
Crabapple	221,301	277,953	173,914	18,067	-	-	-	-	691,235	0.8
Austrian pine	70,218	239,090	221,335	64,217	73,622	-	-	-	668,482	0.8
Hawthorn	52,756	221,326	297,376	58,840	-	-	-	-	630,298	0.7
Tree of heaven	7,472	45,077	78,079	127,050	189,702	93,475	21,033	-	561,888	0.6
Norway spruce	5,940	22,208	75,524	151,364	159,454	143,415	-	-	557,905	0.6
White ash	198,596	141,862	75,580	-	27,937	95,616	-	-	539,591	0.6
Horsechestnut	2,677	17,704	124,300	101,215	64,854	90,572	65,373	-	466,694	0.5
Boxelder	4,859	11,939	49,574	85,621	161,182	68,273	17,321	35,933	434,701	0.5
Ponderosa pine	2,758	53,259	126,785	134,211	75,476	-	-	-	392,487	0.4
Eastern cottonwood	-	1,084	31,119	20,672	85,450	37,253	-	213,421	388,999	0.4
Callery pear	174,986	179,743	22,730	7,461	-	-	-	-	384,919	0.4
Sugar maple	52,813	39,112	95,440	76,622	87,374	18,904	-	-	370,264	0.4
Scotch pine	127,773	111,696	39,664	18,788	61,861	-	-	-	359,781	0.4
Willow	3,080	8,817	6,445	40,886	113,827	81,632	48,196	53,844	356,727	0.4
Japanese pagoda tree	25,264	66,419	62,729	160,020	27,639	-	-	-	342,072	0.4
English oak	24,390	14,194	45,864	81,953	46,834	114,699	-	-	327,933	0.4
Basswood	29,011	49,249	67,375	89,044	27,639	-	-	-	262,317	0.3
Bur oak	13,754	8,502	10,619	113,942	112,747	-	-	-	259,564	0.3
White fir	2,630	19,684	90,883	106,063	39,910	-	-	-	259,170	0.3
Other trees	586,407	940,371	1,148,534	584,988	324,036	376,202	161,841	159,188	4,281,578	5.0
Citywide total	3,139,759	6,890,789	11,396,330	13,557,148	20,573,085	17,747,887	9,881,556	5,079,547	88,266,102	100.0

Chapter Three—Costs of Managing Boise's Municipal Trees

The benefits that Boise's ROW trees provide come, of course, at a cost. This chapter presents a breakdown of annual expenditures for fiscal year 2005. *Table 6* shows that total annual tree-related expenditures for Boise's ROW trees are approximately $770,784 (Jorgenson 2007). This represents 0.35% of the City of Boise's total operating budget ($222 million) or $4 per person.

The city spends about $33 per street ROW tree on average during the year, 1.7 times the 1997 mean value of $19 per tree reported for 256 California cities after adjusting for inflation (Thompson and Ahern 2000). However, nonprogram expenditures (e.g., sidewalk repair, litter clean-up) were not included in the California survey. Boise's annual expenditure is approximately equal to that of Fort Collins, CO ($32), far less than Santa Monica, CA ($53), and Berkeley, CA ($65), and significantly more than Cheyenne WY ($19), Bismarck, ND ($18) and Boulder, CO ($21) (McPherson et al. 2005a, e).

Forestry program expenditures fall into three general categories: tree planting and establishment, pruning and general tree care, and administration.

Tree Planting and Establishment

Quality nursery stock, careful planting, and follow-up care are critical to perpetuation of a healthy urban forest. By planting new trees that are relatively large, with DBH of 2 inches, the City of Boise is giving its urban forest a healthy start. In a typical year, the Community Forestry Unit plants about 250 ROW trees (*Figure 8*). In an average year, street ROW tree planting activities including materials, labor, administration, and equipment costs, account for 9% of the program budget or approximately $68,000.

Pruning, Removals, and General Tree Care

Pruning accounts for about 15% of the annual expenditures, at $115,000 ($4.96 per tree). New trees do not receive training pruning. Regardless of tree size, all Class I, II, and III trees are pruned on a 7-year cycle.

Although there is currently no schedule for pruning young trees, Boise Community Forestry has a group of trained volunteers – the Tree Stewards – who prune street and park trees every year for the city. Currently, a group of about 15 volunteers works about 30 weeks in a year pruning trees along Boise's streets. City crews follow close behind chipping brush created by the pruning. Volunteers are currently pruning about 1,000 trees each year. The main focus of their work is structural pruning of juvenile trees and crown-raising over streets and sidewalks. Costs are low as this program only requires one staff person to direct the pruning on site

Table 6—*Boise's annual municipal forestry-related expenditures*

Street tree expenditures	Total ($)	$/Tree	$/Capita	% of total
Purchasing trees and planting	67,728	2.91	0.33	8.8
Pruning	115,356	4.96	0.55	15.0
Pest management	2,336	0.10	0.01	0.3
Removal	141,417	6.08	0.68	18.3
Administration	124,494	5.35	0.60	16.2
Inspection/service	70,831	3.04	0.34	9.2
Infrastructure repairs	87,780	3.77	0.42	11.4
Litter clean-up	45,270	1.95	0.22	5.9
Liability/claims	825	0.04	0.00	0.1
Other costs	114,747	4.93	0.55	14.9
Total expenditures	770,784	33.13	3.71	100.0

and two field staff and equipment for brush chipping. Without the Tree Stewards, Boise's young tree pruning program would be nonexistent.

While the city does irrigate its park trees, there is no budget for street tree irrigation.

Tree and stump removal accounts for about 18% of tree-related expenses ($141,000 or $6 per tree). About 290 street trees are removed each year, predominantly by contractors. Approximately 90% of the removed wood is chipped and dumped at city facilities for use as mulch in city parks and by citizens. Contractors also sell about 10% of the removed wood for use by citizens as firewood.

Administration

About $71,000 (9%) is spent annually on inspection and answering calls from the public on ROW trees. An additional $124,500 (16%) is spent on administrative expenses including administrative salary, meetings, continuing education, and in-house safety inspections.

Other Tree-Related Expenditures

In a typical year, Boise spends about $45,000 (6%) on limb calls associated with storm and litter clean-up and $2,300 (0.3%) on pest management for ROW trees. Liability or claim costs attributed to trees were minimal in 2005 at $825 (0.1%). However, it was estimated that, annually, about $88,000 (11%) is spent by on infrastructure repair related to ROW tree roots. The Ada County Highway District and adjacent residents pay the majority of these costs. Lastly, other costs – special projects, other equipment costs, payouts for employee leave, on-call costs, and miscellaneous tree care expenses – totaled $115,000 (15%).

Figure 8— A young sugar maple in full fall color

Chapter Four—Benefits of Boise's Municipal Trees

City trees work ceaselessly, providing ecosystem services that directly improve human health and quality of life. In this section, the benefits of Boise's municipal ROW trees are described. It should be noted that this is not a full accounting because some benefits are intangible or difficult to quantify (e.g., impacts on psychological and physical health, crime, and violence). Also, our limited knowledge about the physical processes at work and their interactions makes these estimates imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Tree growth and mortality rates are highly variable. A true and full accounting of benefits and costs must consider variability among sites throughout the city (e.g., tree species, growing conditions, maintenance practices), as well as variability in tree growth.

For these reasons, the estimates given here provide first-order approximations of tree value. Our approach is a general accounting of the benefits produced by municipal ROW trees in Boise—an accounting with an accepted degree of uncertainty that can nonetheless provide a platform from which decisions can be made (Maco and McPherson 2003). Methods used to quantify and price these benefits are described in more detail in *Appendix C.*

Energy Savings

Trees modify climate and conserve energy in three principal ways (*Figure 9*):

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

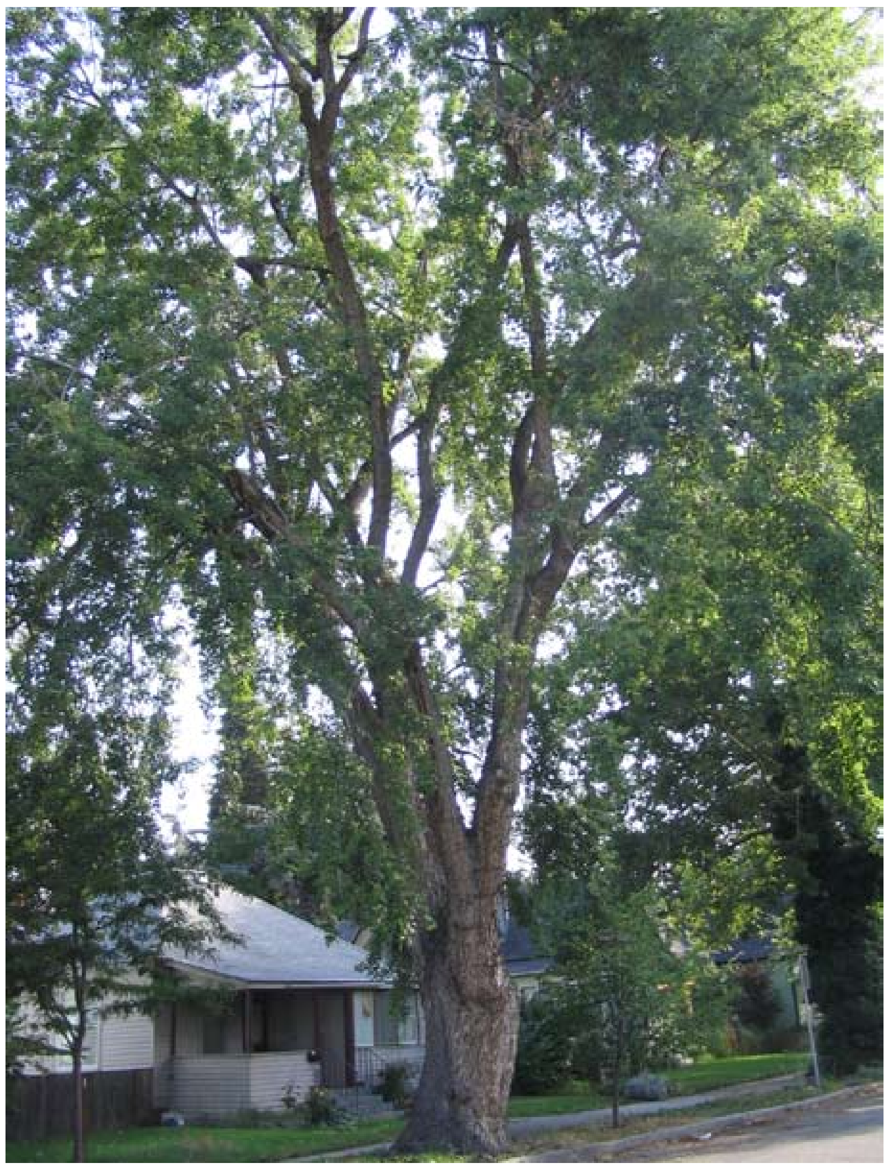

Figure 9—Trees in Boise neighborhoods reduce energy use for cooling and cleaning the air

Table 7—Net annual energy savings produced by Boise street trees

Species	Electricity (MWh)	Electricity ($)	Natural gas (therms)	Natural gas ($)	Total ($)	% of total trees	Avg. $/tree
Norway maple	241	14,714	11,736	13,407	28,121	10.4	11.57
Silver maple	675	41,136	25,784	29,456	70,593	8.3	36.65
Honeylocust	184	11,236	6,167	7,046	18,282	6.9	11.38
Green ash	91	5,572	4,572	5,224	10,796	4.5	10.32
Crabapple	31	1,907	2,204	2,518	4,425	4.1	4.69
White ash	32	1,980	1,868	2,134	4,114	3.8	4.70
Maple	81	4,946	4,292	4,903	9,849	3.3	12.79
Callery pear	19	1,142	1,014	1,158	2,300	3.2	3.09
American sycamore	263	16,002	8,559	9,778	25,779	3.1	36.16
American basswood	62	3,774	2,883	3,294	7,067	2.9	10.52
Ash	110	6,702	5,103	5,830	12,532	2.7	20.18
Sweetgum	32	1,946	1,588	1,814	3,760	2.7	6.10
Black locust	78	4,749	4,630	5,290	10,039	2.6	16.70
Elm	113	6,864	4,377	5,000	11,864	2.2	23.73
Scotch pine	9	566	488	558	1,124	2.0	2.41
Northern red oak	76	4,620	2,989	3,415	8,035	2.0	17.28
Blue spruce	23	1,431	1,056	1,206	2,637	1.9	5.85
Black walnut	96	5,860	4,130	4,718	10,578	1.8	25.67
Hawthorn	24	1,490	1,510	1,725	3,214	1.7	8.24
Austrian pine	18	1,084	824	942	2,026	1.5	5.61
Sugar maple	17	1,030	841	961	1,990	1.5	5.65
Northern catalpa	49	2,958	2,526	2,886	5,844	1.5	16.94
London planetree	41	2,513	1,697	1,939	4,452	1.5	12.98
Siberian elm	60	3,680	2,479	2,832	6,512	1.3	21.21
English elm	101	6,169	3,817	4,361	10,530	1.3	34.75
Littleleaf linden	5	326	293	335	661	1.3	2.24
Plum	14	849	972	1,110	1,959	1.3	6.76
Cottonwood	58	3,550	2,249	2,570	6,120	1.2	22.50
Other street trees	416	25,324	18,582	21,229	46,553	17.8	11.24
Citywide total	3,021	184,117	129,230	147,639	331,756	100.0	14.26

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

Trees reduce air movement into buildings and conductive heat loss from buildings. Trees can reduce wind speed and resulting air infiltration by up to 50%, translating into potential annual heating savings of 25% (Heisler 1986). Decreasing wind speed reduces heat transfer through conductive materials as well. *Appendix C* provides additional information on specific contributions that trees make toward energy savings.

Electricity and Natural Gas Results

Electricity and natural gas saved annually in Boise from both shading and climate effects equal 3,021

MWh ($184,117) and 129,230 therms ($147,639), respectively, for a total retail savings of $331,756 or a citywide average of $14.26 per tree (*Table 7*). Silver maple provides 21.3% of the energy savings although it accounts for only 8.3% of total tree numbers, as expected for a tree species with such a high importance value. Norway maple (8.5%) and American sycamore (7. 8%) make the next greatest contributions to overall energy savings. On a per tree basis, silver maples again are the greatest contributors, reducing energy needs by approximately $36.65 per tree annually. American sycamore and English elm provide the next greatest savings on a per tree basis ($36.16 and $34.75).

It should be noted again that this analysis describes the ROW tree population as it exists at the time of the inventory. This explains why the energy benefits of silver maple on a per tree basis ($36.65) are so much greater than, for instance, other large species like white ash ($4.70) or green ash ($10.32). Over 80% of Boise's silver maples are greater than 18 inches DBH, while the ashes have mostly been planted in recent years. As these younger species age and their size increases, the benefits that they provide will increase as well.

***Table 8**—CO_2 reductions, releases, and net benefits produced by street trees*

Species	Sequestered (lb)	Decomp. release (lb)	Maint. release (lb)	Avoided (lb)	Net total (lb)	Total ($)	% of trees	% of total $	Avg. $/tree
Norway maple	320,152	-21,942	-2,640	139	295,710	988	10.4	16.3	0.41
Silver maple	20,374	-144,704	-6,446	389	-130,386	-435	8.3	-7.2	-0.23
Honeylocust	120,533	-8,169	-1,484	106	110,987	371	6.9	6.1	0.23
Green ash	60,318	-5,833	-991	53	53,546	179	4.5	3.0	0.17
Crabapple	44,776	-1,610	-528	18	42,656	142	4.1	2.3	0.15
White ash	26,592	-1,038	-411	19	25,161	84	3.8	1.4	0.10
Maple	47,298	-6,534	-802	47	40,009	134	3.3	2.2	0.17
Callery pear	32,507	-811	-145	11	31,562	105	3.2	1.7	0.14
American sycamore	173,282	-31,471	-2,157	151	139,805	467	3.1	7.7	0.65
American basswood	45,173	-5,919	-787	36	38,503	129	2.9	2.1	0.19
Ash	70,858	-8,511	-1,031	63	61,380	205	2.7	3.4	0.33
Sweetgum	20,100	-1,244	-456	18	18,419	62	2.7	1.0	0.10
Black locust	155,069	-16,756	-1,298	45	137,060	458	2.6	7.6	0.76
Elm	161,776	-24,141	-1,429	65	136,270	455	2.2	7.5	0.91
Scotch pine	8,737	-320	-271	5	8,151	27	2.0	0.4	0.06
Northern red oak	58,330	-8,038	-589	44	49,746	166	2.0	2.7	0.36
Blue spruce	16,905	-1,434	-527	14	14,958	50	1.9	0.8	0.11
Black walnut	80,647	-8,829	-808	55	71,067	237	1.8	3.9	0.58
Hawthorn	26,614	-2,111	-358	14	24,159	81	1.7	1.3	0.21
Austrian pine	14,917	-710	-375	10	13,842	46	1.5	0.8	0.13
Sugar maple	18,012	-1,556	-200	10	16,265	54	1.5	0.9	0.15
Northern catalpa	34,143	-5,043	-827	28	28,302	95	1.5	1.6	0.27
London planetree	22,809	-2,141	-339	24	20,353	68	1.5	1.1	0.20
Siberian elm	85,187	-8,531	-743	35	75,948	254	1.3	4.2	0.83
English elm	148,099	-24,419	-1,275	58	122,464	409	1.3	6.8	1.35
Littleleaf linden	8,032	-371	-115	3	7,549	25	1.3	0.4	0.09
Plum	19,712	-714	-217	8	18,788	63	1.3	1.0	0.22
Cottonwood	22,513	-7,885	-604	34	14,057	47	1.2	0.8	0.17
Other street trees	380,362	-47,561	-4,896	240	328,145	1,096	17.8	18.1	0.26
Citywide total	2,243,828	-398,346	-32,751	1,743	1,814,474	6,060	100.0	100.0	0.26

Atmospheric Carbon Dioxide Reduction

Urban forests can reduce atmospheric carbon dioxide in two ways:

- Trees directly sequester CO_2 as woody and foliar biomass as they grow.
- Trees near buildings can reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production and consumption of natural gas.

At the same time, however, CO_2 is released by vehicles, chainsaws, chippers, and other equipment during the process of planting and maintaining trees. Also, eventually all trees die and most of the CO_2 that has accumulated in their woody biomass is released into the atmosphere as they decompose unless it is recycled. These factors must be taken into consideration when calculating the carbon dioxide benefits of trees.

Avoided and Sequestered Carbon Dioxide

Citywide, Boise's municipal ROW trees reduce atmospheric CO_2 by a net of 907 tons annually (*Table 8*). This benefit was valued at \$6,060 or \$0.26 per tree and is equivalent to storing enough carbon in 2005 (year of the inventory) to counteract carbon production for over 2 million (2,043,710) driving miles (assuming average vehicle fuel economy is 23 miles per gallon). Reduced CO_2 emissions from power plants due to cooling energy savings totaled 1,743 lbs, while CO_2 sequestered by trees was 1,122 tons. CO_2 released through decomposition and tree care activities totaled 1,440 lbs, or 0.08% of the net total benefit. Net sequestration was over 1,000 times the avoided emissions. This is largely due to the relatively clean resource mix for electrical generation in Boise; over 50% of energy is provided by natural gas, geothermal, biomass, and hydro/renewable sources (US EPA 2003).

On a per tree basis, English elm (\$1.35), elm species (*Ulmus* spp., \$0.91) and Siberian elm (\$0.83) provide the greatest CO_2 benefits (*Table 8*). Because of its predominance, the Norway maple population provides the greatest total CO_2 benefits, accounting for over 16% of citywide CO_2 reduction.

Air Quality Improvement

Urban trees improve air quality in five main ways:

- Absorbing gaseous pollutants (ozone, nitrogen oxides) through leaf surfaces
- Intercepting particulate matter (e.g., dust, ash, dirt, pollen, smoke)
- Reducing emissions from power generation by reducing energy consumption
- Releasing oxygen through photosynthesis
- Transpiring water and shading surfaces, resulting in lower local air temperatures, thereby reducing ozone levels

In the absence of the cooling effects of trees, higher temperatures contribute to ozone formation. On the other hand, most trees emit biogenic volatile organic compounds (BVOCs) such as isoprenes and monoterpenes that can also contribute to ozone formation. The ozone-forming potential of different species varies considerably (Benjamin and Winer 1998). The contribution of BVOC emissions from trees to ozone formation depends on complex geographic and atmospheric interactions that have not been studied in most cities.

Deposition and Interception

Each year 4,752 lbs (\$6,292) of nitrogen dioxide (NO_2), small particulate matter (PM_{10}), ozone (O_3), and sulfur dioxide (SO_2) are intercepted or absorbed by ROW trees (pollution deposition and particulate interception) in Boise (*Table 9*). The trees are most effective at removing O_3 and PM_{10}, with an implied annual value of \$6,168. Due to their substantial leaf area and predominance, silver maple contributes the most to pollutant uptake, removing 2,231 lbs each year.

***Table 9*—Pollutant deposition, avoided and BVOC emissions, and net air-quality benefits produced by predominant street tree species**

	Deposition				Avoided					BVOC emissions		Net total			
Species	O_3 (lb)	NO_2 (lb)	PM_{10} (lb)	Total ($)	NO_2 (lb)	PM_{10} (lb)	VOC (lb)	SO_2 (lb)	Total ($)	(lb)	($)	(lb)	($)	% of trees	Avg. $/tree
Norway maple	453	40	170	408	122	9	6	1	72	−173	−24	629	455	10.45	0.19
Silver maple	1,491	142	599	1,383	271	19	14	2	158	−846	−118	1691	1423	8.28	0.74
Honeylocust	374	36	150	347	65	5	3	1	38	−296	−41	338	344	6.91	0.21
Green ash	301	33	130	290	48	3	2	0	28	0	0	517	318	4.50	0.30
Crabapple	61	6	25	57	23	2	1	0	13	−1	−0	117	70	4.06	0.07
White ash	104	11	45	100	19	1	1	0	11	0	0	182	111	3.76	0.13
Maple	153	15	61	142	45	3	2	0	26	−76	−11	203	157	3.31	0.20
Callery pear	34	3	14	32	11	1	1	0	6	0	0	63	38	3.20	0.05
American sycamore	522	55	233	509	90	6	5	1	53	−2334	−327	−1422	235	3.07	0.33
American basswood	197	22	85	190	30	2	2	0	18	−78	−11	260	197	2.89	0.29
Ash	370	41	160	357	53	4	3	0	31	0	0	632	388	2.67	0.63
Sweetgum	57	5	23	53	17	1	1	0	10	−471	−66	−367	−4	2.65	-0.01
Black locust	245	27	106	236	48	3	3	0	28	−250	−35	181	229	2.58	0.38
Elm	240	23	96	223	46	3	2	0	27	0	0	411	249	2.15	0.50
Scotch pine	31	3	13	29	5	0	0	0	3	−172	−24	−119	8	2.01	0.02
Northern red oak	150	14	60	139	31	2	2	0	18	−377	−53	−118	104	2.00	0.22
Blue spruce	73	8	32	70	11	1	1	0	6	−338	−47	−213	29	1.94	0.07
Black walnut	192	18	77	178	43	3	2	0	25	−68	−10	267	194	1.77	0.47
Hawthorn	43	4	17	40	16	1	1	0	9	−1	0	82	49	1.68	0.13
Austrian pine	57	6	25	55	9	1	0	0	5	−341	−48	−244	12	1.55	0.03
Sugar maple	33	3	12	29	9	1	0	0	5	−27	−4	31	31	1.51	0.09
Northern catalpa	87	8	35	81	26	2	1	0	15	0	0	160	96	1.48	0.28
London planetree	78	7	31	72	18	1	1	0	10	−237	−33	−101	49	1.47	0.14
Siberian elm	122	12	49	114	26	2	1	0	15	0	0	213	129	1.32	0.42
English elm	219	21	88	204	40	3	2	0	23	0	0	374	227	1.30	0.75
Littleleaf linden	16	2	7	16	3	0	0	0	2	−6	−1	22	17	1.27	0.06
Plum	27	3	11	25	10	1	1	0	6	0	0	52	31	1.25	0.11
Cottonwood	212	23	92	204	24	2	1	0	14	0	0	354	218	1.17	0.80
Other street trees	998	100	411	938	194	14	10	1	113	−1171	−164	558	887	17.81	0.21
Citywide total	6,939	689	2,858	6,519	1,353	97	71	10	790	−7,265	−1,017	4,752	6,292	100	0.27

Avoided Pollutants

Energy savings result in reduced air pollutant emissions of NO_2, PM_{10}, volatile organic compounds (VOCs), and SO2 (*Table 9*). Together, 1,531 lbs of pollutants are avoided annually with an implied value of $790. In terms of amount and dollar, avoided emissions of NO_2 are greatest (1,353 lb, $690). Silver maples have the greatest impact on reducing energy needs; by moderating the climate they account for 306 lbs of pollutants whose production is avoided in power plants each year.

BVOC Emissions

Biogenic volatile organic compound (BVOC) emissions from trees must be considered. At a total of 3.6 tons, these emissions offset about one-quarter of air quality improvements and are calculated as a cost to the city of $1,017. American sycamore and silver maple are the higher emitters of BVOCs among Boise's predominant tree species with sycamore accounting for about 32% of the urban forest's emissions and silver maple 12%.

Table 10*—Annual stormwater reduction benefits of Boise's street trees by species*

Species	Rainfall interception (gal)	Total ($)	% of trees	% of total $	Avg. $/tree
Silver maple	3,949,263	19,748	8.3	20.5	10.25
American sycamore	2,022,156	10,111	3.1	10.5	14.18
Norway maple	1,291,287	6,457	10.4	6.7	2.66
Honeylocust	1,104,942	5,525	6.9	5.7	3.44
Elm	1,025,054	5,126	2.2	5.3	10.25
English elm	937,647	4,689	1.3	4.9	15.47
Ash	590,787	2,954	2.7	3.1	4.76
Siberian elm	523,227	2,616	1.3	2.7	8.52
Black walnut	490,958	2,455	1.8	2.5	5.96
Blue spruce	488,669	2,444	1.9	2.5	5.42
Green ash	479,254	2,396	4.5	2.5	2.29
American basswood	410,149	2,051	2.9	2.1	3.05
Maple	404,768	2,024	3.3	2.1	2.63
Northern red oak	386,295	1,932	2.0	2.0	4.15
Cottonwood	338,295	1,692	1.2	1.8	6.22
Austrian pine	337,251	1,686	1.5	1.8	4.67
London planetree	288,615	1,443	1.5	1.5	4.21
Northern catalpa	274,489	1,373	1.5	1.4	3.98
Scotch pine	177,845	889	2.0	0.9	1.90
White ash	165,143	826	3.8	0.9	0.94
Sweetgum	140,220	701	2.7	0.7	1.14
Hawthorn	129,447	647	1.7	0.7	1.66
Black locust	117,980	590	2.6	0.6	0.98
Callery pear	116,255	581	3.2	0.6	0.78
Sugar maple	53,015	265	1.5	0.3	0.75
Crabapple	48,917	245	4.1	0.3	0.26
Littleleaf linden	34,031	170	1.3	0.2	0.58
Plum	21,774	109	1.3	0.1	0.38
Other street trees	2,898,557	14,494	17.8	15.1	3.50
Citywide total	19,246,286	96,238	100	100	4.14

Net Air Quality Improvement

Net air pollutants removed, released, and avoided are valued at $6,292 annually. The average benefit per ROW tree is $0.27 (0.2 lb). Trees vary dramatically in their ability to produce net air-quality benefits. Large-canopied trees with large leaf surface areas that are not high emitters generally produce the greatest benefits. Although silver maples are classified as moderate emitters for Boise, the large amount of leaf area associated with the numerous large, old silver maple population counteracts the overall effect. In this case, silver maple produces the greatest benefits ($1,423 total; $0.74 per tree) even as the second highest emitter among the predominant ROW species in Boise.

Stormwater Runoff Reductions

According to Clean Water Act regulations, municipalities must obtain a permit for managing their stormwater discharges into water bodies. Each city must identify the Best Management Practices (BMPs) it will implement to reduce its pollutant discharge. Trees are minireservoirs, controlling runoff at the source. Healthy trees can reduce the amount of runoff and pollutant loading in receiving waters in three primary ways:

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

Boise's municipal ROW trees intercept 19,246,286 gal of stormwater annually, or 827 gal per tree on average (*Table 10*). The total value of this benefit to the city is $96,238 or $4.14 per tree.

Certain species are much better at reducing stormwater runoff than others. Leaf type and area, branching pattern and bark, as well as tree size and shape all affect the amount of precipitation trees can intercept and hold to reduce runoff. Trees that perform well include English elm ($15.47 per tree), American sycamore ($14.18 per tree), and silver maple ($10.25 per tree). Interception by silver maple alone accounts for over 20% of the total dollar benefit from ROW trees. Comparatively poor performers are species with relatively small leaf and stem surface areas, such as crabapple, plum (*Prunus* spp.), littleleaf linden (*Tilia cordata*), and white ash. Small species like the plum and crabapple simply do not intercept as much due to less leaf and bark surface area. Although large-growing, the littleleaf linden and white ash currently are young and small. It is expected that the stormwater benefit value these species produce will increase as their populations mature.

Aesthetic, Property Value, Social, Economic and Other Benefits

Many benefits attributed to urban trees are difficult to translate into economic terms. Wildlife habitat, beautification, privacy, shade that increases human comfort, sense of place, and well-being are difficult to price. However, the value of some of these benefits may be captured in the property values of the land on which trees stand (*Figure 10*). To estimate the value of these "other" intangible benefits, research comparing differences in sales prices of houses was used to estimate the contribution associated with trees. The difference in sales price

Figure 10—Trees add beauty and value to residential property

reflects the willingness of buyers to pay for the benefits and costs associated with trees. This approach has the virtue of capturing what buyers perceive as both the benefits and costs of trees in the sales price. One limitation of using this approach is the difficulty associated with extrapolating results from front-yard trees on residential properties to trees in other locations (e.g., commercial vs. residential) (see *Appendix C* for more details).

The estimated total annual benefit associated with property value increases and other less tangible benefits attributable to Boise ROW trees is $561,917 or $24.16 per tree on average (*Table 11*). Generally, the larger the tree, the more benefits provided. Therefore, the Boise ROW species that produce the highest average annual benefits are among the largest trees currently in the population. These include silver maple ($42.92 per tree), London planetree ($42.18 per tree), and Siberian elm ($40.62). As species diversity increases, other large-growing tree species will no doubt provide similar benefits. Conversely, small trees like hawthorn (*Crataegus* spp., $9.14 per tree), crabapple ($11.53 per tree) and Scotch pine ($13.17 per tree) produce the least benefits.

***Table 11**—Total annual increases in property value produced by street trees*

Species	Total ($)	% of trees	% of total $	Avg. $/tree
Silver maple	82,663	8.3	14.7	42.92
Norway maple	51,322	10.4	9.1	21.12
Honeylocust	48,432	6.9	8.6	30.14
American sycamore	25,418	3.1	4.5	35.65
Maple	25,086	3.3	4.5	32.58
White ash	22,004	3.8	3.9	25.15
Green ash	21,963	4.5	3.9	21.00
Elm	18,060	2.2	3.2	36.12
Ash	15,412	2.7	2.7	24.82
London planetree	14,467	1.5	2.6	42.18
Northern red oak	14,191	2.0	2.5	30.52
American basswood	13,770	2.9	2.5	20.49
Siberian elm	12,472	1.3	2.2	40.62
Black walnut	11,784	1.8	2.1	28.60
Callery pear	11,137	3.2	2.0	14.95
Sweetgum	10,960	2.7	2.0	17.79
Crabapple	10,881	4.1	1.9	11.53
English elm	9,775	1.3	1.7	32.26
Black locust	9,638	2.6	1.7	16.04
Austrian pine	7,280	1.5	1.3	20.17
Blue spruce	7,180	1.9	1.3	15.92
Littleleaf linden	6,812	1.3	1.2	23.09
Scotch pine	6,151	2.0	1.1	13.17
Northern catalpa	5,823	1.5	1.0	16.88
Sugar maple	5,289	1.5	0.9	15.03
Cottonwood	5,239	1.2	0.9	19.26
Plum	4,282	1.3	0.8	14.77
Hawthorn	3,563	1.7	0.6	9.14
Other street trees	80,863	17.8	14.4	19.52
Citywide total	561,917	100.0	100.0	24.16

Total Annual Net Benefits and Benefit–Cost Ratio

Total annual benefits produced by Boise's municipal ROW trees are estimated at $1,002,263 ($43.09 per tree, $4.78 per capita) (*Table 12*). Over the same period, tree-related expenditures are estimated to be $770,784 ($33.13 per tree, $3.71 per capita). Net annual benefits (benefits minus costs) are $231,479 or $9.95 per tree and $1.11 per capita. Boise's ROW trees currently return $1.30 to the community for every $1 spent on their management. Boise's benefit-cost ratio (BCR) of 1.30 is similar to those reported for Berkeley, CA (1.37), Charleston, SC (1.34), and Albuquerque (1.31), but is below those reported for Fort Collins, CO (2.18), Cheyenne, WY (2.09), and Bismarck, ND (3.09) (Maco et al. 2005; Vargas et al. 2006; McPherson et al. 2006, 2005a).

Boise's ROW trees have beneficial effects on the environment. Nearly half (44%) of the annual benefits provided to residents of the city are environmental services. Energy savings represents 75% of environmental benefits, with stormwater runoff reduction accounting for another 22%. Air quality improvement (1.4%) and carbon dioxide reduction (1.4%) provide the remaining environmental benefits. Annual increases in property value by street ROW trees provide the largest benefit, accounting for 56% of total annual benefits.

Table 13 shows the distribution of total annual benefits in dollars for the predominant municipal ROW tree species in Boise. On a per tree basis, American sycamore ($87 per tree) and English elm ($85 per tree) produced second and third largest benefits next to silver maple at $90. However, at the species level, four species account for nearly 40% of all benefits – silver maple (17.4%), Norway maple (8.7%), honeylocust (7.3%), and American sycamore (6.2%). It should be noted once again that this analysis provides benefits for a snapshot in time. White and green ash are the third and fourth most predominant tree species, but they are young populations with over 80% of trees measuring less than 12 inches DBH. They are poised to become

Table 12—*Benefit–cost summary for all street trees*

Benefits	Total ($)	$/tree	$/capita
Energy	331,756	14.26	1.59
Carbon dioxide	6,060	0.26	0.03
Air Quality	6,292	0.27	0.03
Stormwater	96,238	4.14	0.46
Aesthetic/other	561,917	24.16	2.70
Total Benefits	1,002,263	43.09	4.82
Costs			
Planting	67,728	2.91	0.33
Pruning	115,356	4.96	0.55
Pest management	2,336	0.10	0.01
Removal	141,417	6.08	0.68
Administration	124,494	5.35	0.60
Inspection/service	70,831	3.04	0.34
Infrastructure repairs	87,780	3.77	0.42
Litter clean-up	45,270	1.95	0.22
Liability/claims	825	0.04	0.00
Other costs	114,747	4.93	0.55
Total costs	770,784	33.13	3.71
Net benefits	231,479	9.95	1.11
Benefit-cost ratio		1.30	

Table 13—Average annual benefits ($ per tree) of street trees by species

Species	Energy	CO_2	Air quality	Stormwater	Aesthetic/other	$/tree	Total ($)	% of total $
Silver maple	36.65	−0.23	0.74	10.25	42.92	90.34	173,990	17.4
Norway maple	11.57	0.41	0.19	2.66	21.12	35.94	87,343	8.7
Honeylocust	11.38	0.23	0.21	3.44	30.14	45.40	72,954	7.3
American sycamore	36.16	0.65	0.33	14.18	35.65	86.97	62,011	6.2
Maple	12.79	0.17	0.20	2.63	32.58	48.38	37,250	3.7
Elm	23.73	0.91	0.50	10.25	36.12	71.51	35,754	3.6
Green ash	10.32	0.17	0.30	2.29	21.00	34.08	35,651	3.6
Ash	20.18	0.33	0.63	4.76	24.82	50.71	31,491	3.1
White ash	4.70	0.10	0.13	0.94	25.15	31.02	27,140	2.7
English elm	34.75	1.35	0.75	15.47	32.26	84.59	25,630	2.6
Black walnut	25.67	0.58	0.47	5.96	28.60	61.28	25,248	2.5
Northern red oak	17.28	0.36	0.22	4.15	30.52	52.53	24,428	2.4
American basswood	10.52	0.19	0.29	3.05	20.49	34.54	23,213	2.3
Siberian elm	21.21	0.83	0.42	8.52	40.62	71.60	21,982	2.2
Black locust	16.70	0.76	0.38	0.98	16.04	34.86	20,953	2.1
London planetree	12.98	0.20	0.14	4.21	42.18	59.71	20,480	2.0
Crabapple	4.69	0.15	0.07	0.26	11.53	16.70	15,763	1.6
Sweetgum	6.10	0.10	-0.01	1.14	17.79	25.13	15,479	1.5
Callery pear	3.09	0.14	0.05	0.78	14.95	19.01	14,161	1.4
Cottonwood	22.50	0.17	0.80	6.22	19.26	48.95	13,315	1.3
Northern catalpa	16.94	0.27	0.28	3.98	16.88	38.35	13,230	1.3
Blue spruce	5.85	0.11	0.07	5.42	15.92	27.36	12,340	1.2
Austrian pine	5.61	0.13	0.03	4.67	20.17	30.61	11,050	1.1
Scotch pine	2.41	0.06	0.02	1.90	13.17	17.56	8,200	0.8
Littleleaf linden	2.24	0.09	0.06	0.58	23.09	26.05	7,685	0.8
Sugar maple	5.65	0.15	0.09	0.75	15.03	21.68	7,630	0.8
Hawthorn	8.24	0.21	0.13	1.66	9.14	19.37	7,554	0.8
Plum	6.76	0.22	0.11	0.38	14.77	22.22	6,444	0.6
Other street trees	11.24	0.26	0.21	3.50	19.52	34.73	143,894	14.4

the city's most beneficial species in the future, with benefit production increasing every year. This is important because over 60% of the city's current most beneficial trees (silver maple) are mature or senescent and smaller species, such as crabapple ($17 per tree), Callery pear ($19 per tree), and hawthorn ($19 per tree) will provide correspondingly lower benefits despite increased new plantings.

This is not to insist that large trees are always the best option. Numerous considerations drive species choice, including planting site, potential conflicts with infrastructure, maintenance concerns, water use, and design considerations. In some cases, small trees (Class I) are the best or only option. Nonetheless, the results of this analysis emphasize that large trees (Class II and III) should be planted wherever possible to increase the benefits to the citizens of Boise.

Figure 11 illustrates the average annual benefits per tree by district and reflects differences in tree types and ages. The trees of District 2 provide $49.59 in benefits on average each year, which can be attributed to the predominant species (see *Table 2*) – all of which are large-stature trees – and the number of trees within the district. The trees of District 3, in contrast, provide only $33.69 in benefits on average, due to the low numbers of trees within the district (about 1,300 compared to 5,000 in District 2) and the fact that the majority are young – very few trees are within the largest size class (only 1.3% are larger than 30-inch DBH compared to over 10% in District 2).

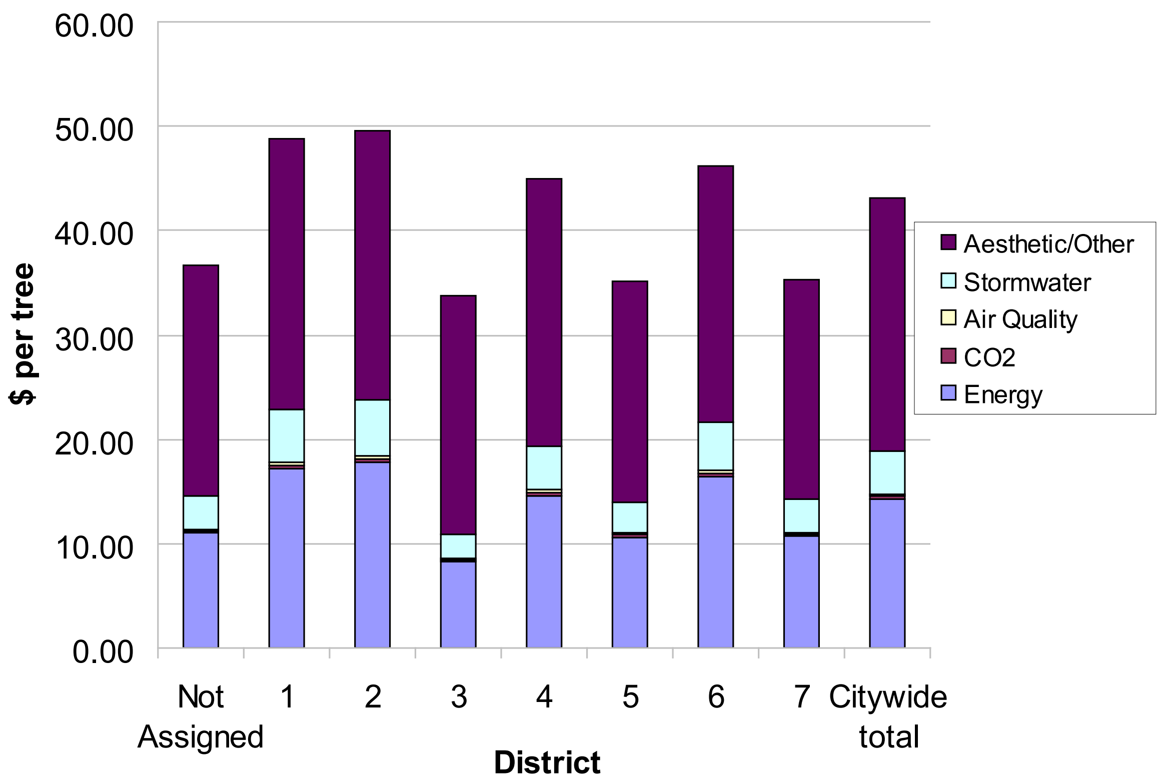

Figure 11—Average annual street tree benefits per tree by management district

Chapter Five—Management Implications

Boise's urban forest reflects the values, lifestyles, preferences, and aspirations of current and past residents. It is a dynamic legacy whose character will change greatly over the next decades. Although this study provides a "snapshot" in time of the municipal ROW tree resource, it also serves as an opportunity to speculate about the future. Given the status of Boise's ROW tree population, what future trends are likely and what management challenges will need to be met to sustain or increase this level of benefits?

Focusing on three components—resource complexity, resource extent, and maintenance—will help refine broader municipal tree management goals. Achieving resource sustainability will produce long-term net benefits to the community while reducing the associated costs incurred in managing the resource.

Resource Complexity

The Parks and Recreation Department, Community Forestry Unit of Boise is to be commended for its commitment to increasing the diversity of the urban forest. The number of ROW species (179) is excellent, particularly considering the desert plateau climate. It is evident that there has been increased effort to both diversify and improve the age structure of the public right of way trees. The distribution of trees across species, with no one species representing significantly more than 10% of the total is fairly unique among the cities we have studied. However, there is reason to remain concerned over the predominance of maples generally. As a genus, these trees represent 24% of the total ROW tree population and produce 30.1% of all benefits enjoyed by residents of Boise. Ash species represent another 11% of the population and currently produce 9.5% of the benefits. As previously mentioned, with 80% of the ash under 12-inch DBH, these species are poised to become the next generation of major benefit producers within the city. Care must be taken to maintain and monitor these two genera to protect them from disease and pest infestations now occurring in other parts of the nation. New York City has removed over 5,000 maples in the past few years due to Asian longhorn beetle (ALB) infestation. Emerald ash borers (EAB) have killed more than 20 million ash trees in Michigan, Ohio, and Indiana. Boise's ash trees currently suffer infestations of ash-lilac borers and Pacific flathead borers.

Figure 12 displays large- and medium-growing trees in the smallest DBH size classes, indicat-

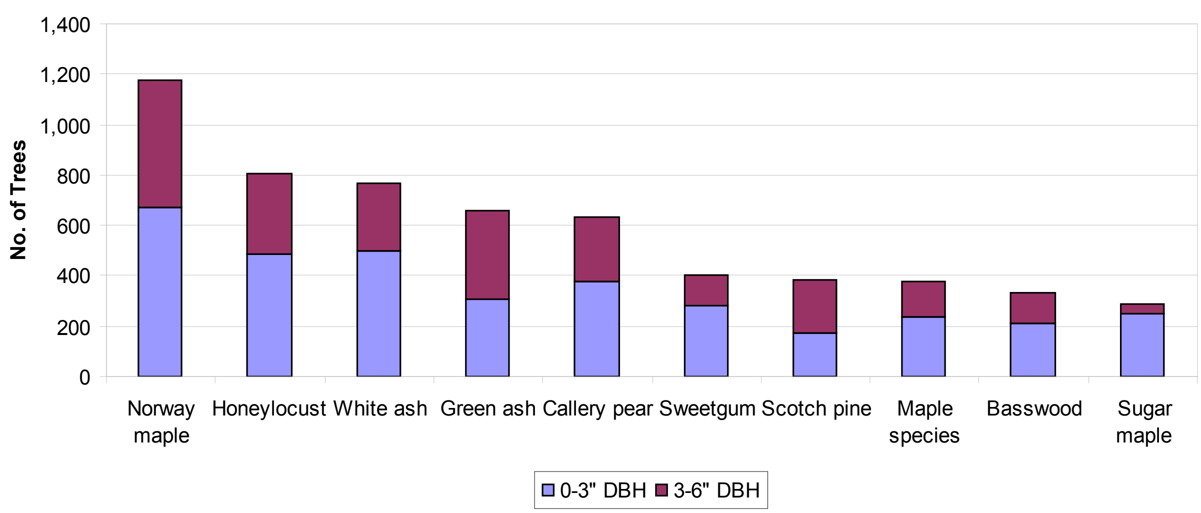

Figure 12—Predominant species in the smallest diameter classes (0-6" DBH) indicating relatively recent tree planting and survival trend

ing trends in new and replacement trees. Norway maples predominate and the maple genus accounts for 23% of all relatively recent plantings (0–3 inch DBH). Ash, as a genus, composes another 17% of the 5,500 0–3 inch trees. These two genera account for 40% of the new tree population in the 2005 inventory, and their popularity could increase their susceptibility pests and diseases. Aware of the importance of reducing the number of potential host species for ash-lilac and Pacific flathead borers, as well as ALB and EAB, the Community Forestry staff is carefully monitoring further municipal plantings of these species.

Increasing the planting of high benefit species like Northern red oak (*Quercus rubra*) and American basswood (*Tilia americana)* is possible. Both species had above-average relative performance indices. Both produced significant benefits although they remain relatively young populations. The performance of littleleaf linden should be followed as well, as it may become a high benefit tree. Of the 295 trees planted, over 91% are in the smallest DBH class, yet the species still produces nearly 1% of the city's benefits. Expanding upon the planting of species with high relative performance and leaf area but low susceptibility to pests and disease will be vital to maintaining the flow of benefits through time as well as insuring the health of the urban forest.

Resource Extent

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

From 2000–2006, the Community Forestry Unit planted (including replacements) about 250 trees annually. Over the same 7-year period removals averaged 288 trees annually. Tree planting is expected to increase over the next few years to about 270 new trees annually. Given that the current mortality rate is 30% over the first 40 years of growth, we would expect 81 of these trees to die before reaching maturity, leaving 189 to continue growing and producing benefits. This removal rate combined with mortality numbers indicates a net loss in Boise tree numbers and canopy cover over time unless the city acts to reverse the current trend.

Any tree added to a city adds benefits in terms of air quality improvement, climate moderation, reductions in energy use, stormwater management and aesthetic improvement—benefits that have been described in detail above. Planting trees along streets and in parking lots, however, offers additional benefits beyond those that come from planting trees in parks. Most importantly, trees located along streets and in parking lots are more likely to shade structures. By moderating the immediate climate around a building, energy use is reduced, lowering costs for building owners and simultaneously reducing air pollutants and CO_2.

Trees along streets have also been shown to reduce the wear on asphalt by lowering surface temperatures and thereby reducing maintenance costs (McPherson and Muchnick 2005). A study comparing several blocks in Modesto, CA, demonstrated that streets shaded by large trees required fewer than half the number of slurry seals (2.5 vs. 6 on an unshaded street) over a 30-year period, with associated savings of $0.66/ft2. In areas with on-street parking, trees can have an additional benefit of reducing pollutant emissions from parked cars by lowering local air temperature (Scott et al. 1999). Evaporative emissions from parked vehicles account for 16% of total vehicular emissions; lowering the air temperature by increasing shade cover in Sacramento parking lots to 50% from 8% was estimated to reduce overall emissions by 2% (0.85 tons per day). Although seemingly modest, many existing programs to improve air quality have similar goals.

The importance of size in achieving high levels of benefits should also not be forgotten. Large-growing trees should be planted wherever possible. In Boise this translates into planting Class II and III trees wherever possible.

Currently trees are planted and replanted in the same ROW locations they have been in for years with few new plantings in new locations. Planting is limited for a variety of reasons, but predominantly due reduced space for trees in new developments and drought conditions. Trees have been struggling with recent droughts and warm, dry winters, and water availability has become a deciding factor in whether to replace dead and dying trees. More people are deciding not to water city right-of-way tree lawns in front of their homes either to conserve water or reduce their water expenditures. This reduction in watering is currently the largest factor in the decline of many existing public street trees and a huge challenge to increasing street tree presence.

Additionally, as development has occurred in Boise, the local highway district has generally only purchased enough right-of-way to build a road and sidewalk, leaving few locations where new trees can be planted. A few local developers increasingly want to return to more classical neighborhoods and streetscapes with tree lawns, allowing for the planting of more trees. In 2005, at the urging of the Community Forestry Unit, the highway district created policies setting size standards for tree lawns in the right-of-way and these standards are now in place. This, coupled with pro-tree developers may assist the city in turning around a trend toward net losses in tree cover. Further education for citizens and local governmental entities in charge of development is recommended to increase awareness of the environmental value of street trees.

ROW Canopy Cover

In 2006, Boise Mayor David Beiter signed the U.S. Mayors Climate Protection Agreement, making Boise the first city in Idaho and the 280th city in the nation to endorse the agreement. Boise will strive to meet or exceed a 7% reduction from the 1990 greenhouse gas emission level through such measures as energy-efficient building practices, alternative fuels, improved transportation, and improved land-use planning.

By shading the gray infrastructure, canopy cover over streets and sidewalks contributes directly to reducing urban heat island effects, reducing energy consumption, ground level ozone, and the formation of greenhouse gases. As cities grow, carbon emissions, and air and water pollution typically increase. However, the value of the benefits that trees provide typically also increase. The mayor of New York City has recently acknowledged this and increased funding for the planting and care of trees by $37 million per year, establishing a long-term commitment in using the green infrastructure to mitigate the impact of a vast gray infrastructure.

As Boise has grown in recent years, public right-of-way planning in new neighborhoods has not allocated adequate space for trees, a contributing factor to the 14% stocking level citywide (29 trees/mile; one tree for every nine residents), one of the lowest levels among cities studied thus far. Boise's tree canopy currently shades 6.5% of the city's streets and sidewalks. We recommend that the city focus on increasing stocking and canopy cover, setting an initial goal of planting one ROW tree for every five residents. This represents an increase of over 18,000 ROW trees (41,600 total compared to 23,262 currently) for a 25% stocking level and 10.5% canopy cover over streets and sidewalks. Planning for planting new trees must also include planning for adequate care and maintenance to reduce mortality rates and insure survival.

Maintenance

Boise's maintenance challenges in the coming years will be to establish and care properly for the many new trees that have been planted and to maintain and eventually remove the old silver maples, American sycamores, and elms as they continue to decline. With 270 new trees planted each year, a strong young-tree care program is imperative to insure, first, that the trees survive, and second, that they transition into well-structured, healthy mature trees requiring minimal pruning. Investing in the young-tree care program will reduce costs for routine maintenance as trees mature and reduce removal and replacement costs for dead trees.

It will be a significant challenge, but the Parks and Recreation Department should work to secure funding to increase the young tree maintenance cycle to at least two visits during the first 5 years of establishment. Funding for establishment irrigation should also be considered, and inspection and pruning of young trees should be a priority. Expansion and enhancement of the Tree Steward volunteer program to take advantage of citizens willing to give time to improve the community forest could significantly reduce potential increases in costs associated with improving tree care.

The older silver maples, American sycamores, and elms are reaching the end of their natural life spans and are in decline. Like people, older trees tend to develop problems that younger trees do not; Boise's silver maples often develop significant internal decay, which can result in dangerous loss of large branches. Silver maples are also cause significant damage when planted too near gray infrastructure because they have shallow root systems and large root crowns. Boise's silver maples will require increased maintenance as they age and eventually they will have to be removed. The future of these species, which provide an enormous share of the benefits of the urban forest, should be considered with special care. Additionally, because of their stature and grace they tend to be especially beloved by residents (*Figure 13*). For these reasons, a careful plan should be developed to begin planting similarly beneficial and beautiful trees *before* all of the older trees have to be removed. The trees in the worst condition should be replaced first, while treating the others to prolong their lifespan. Planned replacement involves assessing the tree population, particularly in those neighborhoods dominated by even-aged trees of the same species, and establishing a program of systematic removal and replacement so that the neighborhood will not suffer suddenly from a complete die-off or removal of hazardous trees.

Additionally, if the city decides to increase canopy cover along public ROW, it is vital that an adequate maintenance program be funded to care for the increased number of trees and better insure their survival.

Figure 13—Old trees grace a residential neighborhood

Chapter Six—Conclusion

This analysis describes structural characteristics of the municipal tree population and uses tree growth and geographic data for Boise to model the ecosystem services trees provide the city and its residents. In addition, the benefit–cost ratio has been calculated and management needs identified. The approach is based on established tree sampling, numerical modeling, and statistical methods and provides a general accounting of the benefits produced by municipal trees in Boise that can be used to make informed decisions.

Boise's 23,262 ROW trees are a valuable asset, providing over $1 million ($43 per tree) in annual gross benefits. Benefits to the community are most pronounced for energy savings and aesthetic and other benefits. Thus, municipal street ROW trees play a particularly important role in maintaining the environmental and aesthetic qualities of the city (*Figure 14*). Boise spends approximately $771 thousand maintaining these ROW trees or $33.13 per tree.

After expenditures are taken into account, Boise's ROW tree resource currently provides approximately $231,479 or $9.95 per tree ($1.11 per capita) in net annual benefits to the community. Over the years, Boise has invested millions of dollars in these trees. **Citizens are seeing a return on that investment—receiving $1.30 in benefits for every $1 spent on tree care**. The fact that Boise's benefit–cost ratio exceeds 1.0 indicates that the program is not only operationally efficient, but is capitalizing on the functional services its trees can produce. Over 66% of the tree population is relatively young – under 12 inches DBH – and nearly 75% of these trees are medium to large-growing (Class II and III) trees. The value of Boise's ROW trees will increase if the many young trees planted by the Community Forestry Unit can survive and mature. As the resource grows, continued investment in management is critical, insuring that the trees are properly cared for so residents receive a high return on investment in the future.

Boise's ROW trees are a dynamic resource. Managers of the urban forest and the community alike can take pride in knowing that these trees greatly improve the quality of life in the city. However, the trees are also a fragile resource needing constant care to maximize and sustain production of benefits into the future while also protecting the public from potential hazard. The challenge as the city continues to grow will be to sustain and expand the existing canopy cover to take advantage of the increased environmental and aesthetic benefits the trees can provide to the community.

Management recommendations focused on sustaining existing benefits and increasing future benefits include the following:

Figure 14—Norway maple leaves. Tree leaves help clean the air by absorbing pollutants, reduce stormwater runoff by intercepting rainfall, and reduce energy use by shading homes and businesses

1. To help meet Boise's Climate Protection Agreement goals to reduce greenhouse gases and emissions:
    - Develop programs and policies to encourage and significantly increase shade tree planting along streets, in parking lots, and near buildings in and adjacent to public rights-of-way.
    - Increase ROW stocking and canopy cover, setting an initial goal of planting one ROW tree for every five residents. This represents an increase of over 18,000 ROW trees (41,600 total compared to 23,262 currently) for a 25% stocking level and 10.5% canopy cover over streets and sidewalks.
    - Increase stocking level with larger-growing (Class II and III) shade tree species where conditions are suitable to maximize benefits. Consider adopting front-yard easements for new tree planting and maintenance where parkway planting strips are absent.
    - Plan for adequate care and pruning to reduce tree mortality rates and insure survival.
2. Develop a strong young-tree care program that emphasizes reducing mortality. Irrigation along with inspection and pruning at least twice during the initial five years after planting will provide a good foundation for the trees. Expansion of the Tree Steward program is a cost-effective approach to accomplishing this goal.
3. Track the success of the newly planted trees to determine those most adaptable to the difficult growing conditions in Boise. Continue planting a diverse mix of tree species to guard against catastrophic losses due to storms, pests or disease while concentrating the species choice on those that have proven most successful.
4. Sustain current benefits by investing in programmed maintenance of mature trees (e.g., silver maple, American basswood, elms, Norway maple, American sycamore) to prolong the functional life spans of these trees. This includes developing a planned replacement program designed to gradually and systematically replace senescent trees with trees that will grow to similar stature.
5. Continue working with the Ada County Highway District to develop planting space and tree guidelines in new developments and when retrofitting existing streets. Adequate space for Class II and III trees should be a priority.
6. Implement Forestry Management Plan priority recommendations including the development and implementation of a public education and volunteer program to demonstrate the link between basic tree care – irrigation frequencies and appropriate maintenance levels – and the resultant benefits provided to the homeowner, neighborhood, and community. This should assist in increasing available planting space and improving tree longevity, functionality, and overall benefits.
7. Develop, implement, and enforce a landscaping ordinance for Boise that creates specific public and private street and parking lot shade guidelines to promote tree canopy cover and associated benefits.

These recommendations build on a history of dedicated management and commitment to natural resource preservation that has put Boise on course to provide an urban forest resource that is both functional and sustainable.

Appendix A—Tree Distribution

***Table A1**—Tree numbers by size class (DBH in inches) for all street trees*

Species	0–3	3–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total
Broadleaf deciduous large (BDL)										
Acer saccharinum	52	46	98	173	347	577	381	160	92	1,926
Gleditsia triacanthos	484	324	535	218	23	18	3	2	-	1,607
Fraxinus pennsylvanica	307	351	202	92	46	32	12	3	1	1,046
Fraxinus americana	499	267	86	17	-	2	4	-	-	875
Platanus occidentalis	61	23	34	61	139	195	145	44	11	713
Tilia americana	209	122	141	96	67	26	9	1	1	672
Fraxinus species	58	134	128	131	98	55	15	1	1	621
Liquidambar styraciflua	282	120	128	72	11	3	-	-	-	616
Robinia pseudoacacia	36	74	113	108	116	110	29	13	2	601
Ulmus species	53	61	64	18	34	76	108	68	18	500
Quercus rubra	187	66	51	48	61	38	13	1	-	465
Juglans nigra	13	30	106	134	84	34	5	4	2	412
Acer saccharum	248	38	26	22	10	7	1	-	-	352
Catalpa speciosa	13	40	47	65	66	73	33	7	1	345
Platanus acerifolia	140	55	85	27	13	15	4	2	2	343
Ulmus pumila	19	21	56	49	58	66	24	12	2	307
Ulmus procera	-	1	4	1	28	67	110	69	23	303
Populus species	36	78	35	18	10	24	24	18	29	272
Quercus alba	18	14	28	25	38	38	11	2	-	174
Ulmus americana	-	-	-	9	16	57	49	27	9	167
Ailanthus altissima	7	14	35	25	20	19	6	1	-	127
Quercus macrocarpa	86	5	5	2	13	8	-	-	-	119
Acer negundo	14	5	11	18	16	20	5	2	2	93
Quercus robur	17	42	8	9	8	3	5	-	-	92
Quercus species	29	18	6	8	4	1	2	-	-	68
Liriodendron tulipifera	16	14	8	6	2	1	2	-	-	49
Quercus palustris	3	7	15	5	5	2	-	-	-	37
Gymnocladus dioicus	17	2	4	8	2	2	-	-	-	35
Ulmus parvifolia	21	11	1	-	-	-	-	-	-	33
Populus deltoides	-	-	1	8	3	8	2	-	9	31
Fraxinus quadrangulata	-	1	7	15	2	2	-	-	-	27
Populus × canadensis	-	2	6	6	7	-	1	1	3	26
Taxodium distichum	8	5	2	3	2	-	-	-	-	20
Betula nigra	19	-	-	-	-	-	-	-	-	19
Quercus bicolor	13	2	-	-	1	-	1	1	-	18
Populus trichocarpa	5	2	-	-	-	-	-	2	3	12
Quercus coccinea	1	4	4	-	1	1	1	-	-	12
Betula papyrifera	8	-	1	-	-	-	-	-	-	9
Populus alba	2	-	-	1	-	2	1	1	-	7
Quercus velutina	6	-	-	-	-	-	-	-	-	6
Acer nigrum	-	-	1	1	1	-	-	-	-	3
Carya species	1	-	-	2	-	-	-	-	-	3
Castanea dentata	-	1	1	-	-	1	-	-	-	3

Species	0–3	3–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total
Populus nigra	-	-	-	2	-	1	-	-	-	3
Quercus falcata	2	-	-	-	-	-	-	-	-	2
Ulmus glabra	-	-	-	-	1	-	1	-	-	2
Larix decidua	1	-	-	-	-	-	-	-	-	1
Magnolia acuminata	-	-	-	1	-	-	-	-	-	1
Populus balsamifera	-	1	-	-	-	-	-	-	-	1
Quercus phellos	-	-	-	-	-	-	-	1	-	1
Total	2,991	2,001	2,083	1,504	1,353	1,584	1,007	443	211	13,177
Broadleaf deciduous medium (BDM)										
Acer platanoides	669	505	607	421	162	57	7	2	-	2,430
Acer species	239	135	203	130	51	9	1	2	-	770
Pyrus calleryana	377	256	106	5	1	-	-	-	-	745
Tilia cordata	208	62	17	4	4	-	-	-	-	295
Sophora japonica	40	41	38	13	17	2	-	-	-	151
Ginkgo biloba	65	14	39	28	3	-	-	-	-	149
Tilia species	50	46	28	14	9	2	-	-	-	149
Tilia tomentosa	105	22	1	-	1	2	4	1	-	136
Acer rubrum	37	44	26	5	1	-	-	-	-	113
Celtis occidentalis	56	46	3	-	-	1	-	-	2	108
Aesculus hippocastanum	3	5	11	28	11	4	4	2	-	68
Fraxinus oxycarpa	43	13	7	-	-	-	-	-	-	63
Corylus colurna	51	7	-	-	-	-	-	-	-	58
Fraxinus excelsior	-	2	21	23	6	1	-	-	-	53
Salix species	7	4	6	2	7	14	6	3	3	52
Carpinus betulus	48	3	-	-	-	-	-	-	-	51
Other species	21	10	9	4	2	-	-	-	-	46
Populus tremuloides	19	18	1	-	-	-	-	-	-	38
Phellodendron amurense	24	-	-	-	-	-	-	-	-	24
Fraxinus mandshurica	20	-	-	-	-	-	-	-	-	20
Juglans regia	2	4	9	2	-	-	2	-	-	19
Morus alba	1	-	6	5	3	1	1	-	-	17
Betula pendula	4	1	6	4	1	-	-	-	-	16
Catalpa bignonioides	9	4	-	-	1	-	-	-	-	14
Fagus species	10	2	1	-	1	-	-	-	-	14
Corylus species	-	12	-	-	-	-	-	-	-	12
Acer pseudoplatanus	5	3	1	1	-	1	-	-	-	11
Fagus sylvatica	9	-	-	-	-	-	1	-	-	10
Betula species	6	3	-	-	-	-	-	-	-	9
Alnus glutinosa	3	4	-	-	1	-	-	-	-	8
Eucommia ulmoides	5	-	1	-	-	-	-	-	-	6
Cercidiphyllum japonicum	4	-	1	-	-	-	-	-	-	5
Gleditsia caspica	5	-	-	-	-	-	-	-	-	5
Quercus aliena	4	-	-	-	-	-	-	-	-	4
Quercus laurifolia	-	4	-	-	-	-	-	-	-	4
Quercus glandulifera	3	1	-	-	-	-	-	-	-	4
Aesculus glabra	3	-	-	-	-	-	-	-	-	3
Salix nigra	3	-	-	-	-	-	-	-	-	3

Species	0–3	3–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total
Fraxinus nigra	-	2	-	-	-	-	-	-	-	2
Quercus acutissima	1	1	-	-	-	-	-	-	-	2
Alnus cordata	1	-	-	-	-	-	-	-	-	1
Fraxinus ornus	-	1	-	-	-	-	-	-	-	1
Morus rubra	-	-	1	-	-	-	-	-	-	1
Quercus kelloggii	1	-	-	-	-	-	-	-	-	1
Quercus muehlenbergii	1	-	-	-	-	-	-	-	-	1
Total	2,162	1,275	1,149	689	282	94	26	10	5	5,692
Broadleaf deciduous small (BDS)										
Malus species	424	329	155	34	2	-	-	-	-	944
Crataegus species	117	75	128	63	7	-	-	-	-	390
Prunus species	51	141	88	7	3	-	-	-	-	290
Koelreuteria paniculata	18	25	30	17	1	1	-	-	-	92
Crataegus phaenopyrum	69	14	2	-	-	-	-	-	-	85
Crataegus monogyna	-	5	36	23	-	-	-	-	-	64
Cercis canadensis	24	6	14	5	-	-	-	-	-	49
Acer campestre	45	-	-	-	-	-	-	-	-	45
Malus pumila	13	11	13	7	1	-	-	-	-	45
Sorbus aucuparia	9	10	12	8	1	-	-	-	-	40
Rhus species	16	17	2	-	-	1	-	-	-	36
Acer truncatum	32	1	1	-	-	-	-	-	-	34
Elaeagnus angustifolia	6	2	12	12	1	-	-	-	-	33
Crataegus laevigata	3	9	13	2	-	-	-	-	-	27
Cornus florida	12	7	4	-	-	-	-	-	-	23
Prunus cerasifera	14	8	1	-	-	-	-	-	-	23
Prunus triloba	4	9	5	1	-	-	-	-	-	19
Pyrus fauriei	19	-	-	-	-	-	-	-	-	19
Populus grandidentata	8	8	1	1	-	-	-	-	-	18
Prunus virginiana	13	1	-	-	-	-	-	-	-	14
Rhus typhina	6	7	1	-	-	-	-	-	-	14
Acer ginnala	11	2	-	-	-	-	-	-	-	13
Magnolia species	6	1	4	1	-	-	-	-	-	12
Malus ioensis	1	10	1	-	-	-	-	-	-	12
Crataegus viridis	8	3	-	-	-	-	-	-	-	11
Syringa reticulata	11	-	-	-	-	-	-	-	-	11
Cladrastis lutea	10	-	-	-	-	-	-	-	-	10
Maackia amurensis	10	-	-	-	-	-	-	-	-	10
Prunus serrulata	6	2	2	-	-	-	-	-	-	10
Carpinus caroliniana	5	4	-	-	-	-	-	-	-	9
Cornus species	5	1	3	-	-	-	-	-	-	9
Prunus persica	6	3	-	-	-	-	-	-	-	9
Diospyros virginiana	-	-	1	4	2	-	-	-	-	7
Sorbus americana	-	2	5	-	-	-	-	-	-	7
Albizia julibrissin	6	-	-	-	-	-	-	-	-	6
Laburnum × watereri	3	1	1	-	-	-	-	-	-	5
Pterostyrax corymbosa	4	-	-	-	-	-	-	-	-	4
Acer griseum	3	-	-	-	-	-	-	-	-	3

Species	0–3	3–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total
Acer grandidentatum	3	-	-	-	-	-	-	-	-	3
Cotinus coggygria	-	-	2	1	-	-	-	-	-	3
Prunus sargentii	3	-	-	-	-	-	-	-	-	3
Ptelea trifoliata	3	-	-	-	-	-	-	-	-	3
Pyrus communis	1	2	-	-	-	-	-	-	-	3
Salix matsudana	1	1	1	-	-	-	-	-	-	3
Amelanchier arborea	-	-	1	-	-	-	-	-	-	1
Cotinus obovatus	1	-	-	-	-	-	-	-	-	1
Prunus armeniaca	-	-	-	-	1	-	-	-	-	1
Prunus blieriana	1	-	-	-	-	-	-	-	-	1
Total	1,011	717	539	186	19	2	-	-	-	2,474
Conifer evergreen large (CEL)										
Picea pungens	57	168	86	99	29	10	1	-	1	451
Pinus species	17	43	40	12	2	-	1	-	-	115
Picea abies	4	11	14	19	18	12	7	-	-	85
Pinus ponderosa	5	4	31	26	14	5	-	-	-	85
Abies concolor	1	5	11	19	11	3	-	-	-	50
Pseudotsuga menziesii	-	3	3	9	1	2	-	-	-	18
Picea species	1	5	7	2	-	-	-	-	-	15
Abies species	3	4	4	2	1	-	-	-	-	14
Sequoiadendron giganteum	1	6	4	-	-	-	-	-	-	11
Abies homolepis	5	-	-	-	-	-	-	-	-	5
Pinus serotina	-	2	2	1	-	-	-	-	-	5
Picea mariana	-	1	2	-	-	-	-	-	-	3
Thuja occidentalis	1	2	-	-	-	-	-	-	-	3
Thuja plicata	3	-	-	-	-	-	-	-	-	3
Picea engelmannii	-	-	1	1	-	-	-	-	-	2
Cedrus deodara	-	-	1	-	-	-	-	-	-	1
Pinus strobus	-	1	-	-	-	-	-	-	-	1
Tsuga canadensis	-	-	1	-	-	-	-	-	-	1
Total	98	255	207	190	76	32	9	-	1	868
Conifer evergreen medium (CEM)										
Pinus sylvestris	174	212	67	8	2	4	-	-	-	467
Pinus nigra	28	135	139	47	7	5	-	-	-	361
Cedrus species	26	22	18	8	2	-	-	-	-	76
Juniperus virginiana	-	9	21	9	4	1	-	-	-	44
Juniperus species	13	14	5	-	-	-	-	-	-	32
Pinus glabra	1	4	1	1	-	1	-	-	-	8
Pinus monticola	-	7	1	-	-	-	-	-	-	8
Picea asperata	7	-	-	-	-	-	-	-	-	7
Pinus coulteri	1	5	-	-	-	-	-	-	-	6
Picea omorika	3	2	-	-	-	-	-	-	-	5
Picea orientalis	5	-	-	-	-	-	-	-	-	5
Picea glauca	2	1	-	-	-	-	-	-	-	3
Sciadopitys verticillata	3	-	-	-	-	-	-	-	-	3
Cedrus atlantica	1	1	-	-	-	-	-	-	-	2
Pinus attenuata	2	-	-	-	-	-	-	-	-	2

Species	0–3	3–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total
Pinus cembra	2	-	-	-	-	-	-	-	-	2
Total	268	412	252	73	15	11	-	-	-	1,031
Conifer evergreen small (CES)										
Pinus mugo	4	2	4	3	1	-	-	-	-	14
Juniperus scopulorum	-	-	6	-	-	-	-	-	-	6
Total	4	2	10	3	1	-	-	-	-	20
Citywide total	6,534	4,662	4,240	2,645	1,746	1,723	1,042	453	217	23,262

Appendix B—Replacement Values

***Table B1**—Replacement value for Boise's street trees*

Species	0–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total	% of Total
Silver maple	28,505	137,676	611,029	2,392,822	6,662,492	6,348,965	3,463,423	2,357,652	22,002,562	24.9
American sycamore	19,963	46,893	226,683	990,527	2,354,429	2,592,123	1,090,125	280,837	7,601,581	8.6
Norway maple	338,113	1,010,245	1,950,829	1,418,823	834,526	146,852	59,605	-	5,758,993	6.5
Elm	34,268	82,497	55,920	213,017	765,365	1,636,198	1,457,405	402,179	4,646,849	5.3
English elm	506	4,970	3,978	180,390	670,634	1,689,091	1,425,427	480,592	4,455,587	5.0
Northern catalpa	21,955	78,967	315,748	612,742	1,094,941	756,575	199,965	30,086	3,110,980	3.5
Black locust	36,068	133,021	334,423	666,072	1,051,526	406,209	231,586	42,580	2,901,485	3.3
Honeylocust	229,053	946,600	1,047,467	226,481	294,462	70,826	69,689	-	2,884,578	3.3
Ash	69,974	198,456	554,975	840,089	730,531	295,597	20,940	23,402	2,733,966	3.1
American elm	-	-	31,543	114,325	689,649	902,183	650,683	230,872	2,619,255	3.0
American basswood	86,210	245,752	485,897	662,020	428,405	199,650	34,845	32,075	2,174,852	2.5
Green ash	211,228	317,559	397,233	406,472	441,062	268,862	75,423	24,084	2,141,923	2.4
Black walnut	16,344	152,455	523,405	608,443	416,337	93,797	97,084	61,477	1,969,343	2.2
Northern red oak	55,393	94,037	242,873	598,861	596,881	301,450	26,120	-	1,915,614	2.2
Siberian elm	11,563	57,590	132,469	294,997	559,408	311,233	212,475	37,608	1,617,342	1.8
Maple	94,843	304,255	540,269	433,814	124,116	22,289	44,050	-	1,563,636	1.8
Cottonwood	39,135	40,285	53,705	52,477	205,188	244,860	285,801	515,505	1,436,956	1.6
White oak	8,990	44,747	109,480	315,767	512,863	215,904	55,670	-	1,263,421	1.4
Blue spruce	90,049	144,424	456,913	251,521	145,673	20,823	-	30,086	1,139,490	1.3
London planetree	44,579	156,598	131,454	129,354	264,027	104,359	67,476	68,126	965,972	1.1
Sweetgum	96,335	224,473	346,168	107,110	51,026	-	-	-	825,112	0.9
Crabapple	221,301	277,953	173,914	18,067	-	-	-	-	691,235	0.8
Austrian pine	70,218	239,090	221,335	64,217	73,622	-	-	-	668,482	0.8
Hawthorn	52,756	221,326	297,376	58,840	-	-	-	-	630,298	0.7
Tree of heaven	7,472	45,077	78,079	127,050	189,702	93,475	21,033	-	561,888	0.6
Norway spruce	5,940	22,208	75,524	151,364	159,454	143,415	-	-	557,905	0.6
White ash	198,596	141,862	75,580	-	27,937	95,616	-	-	539,591	0.6
Horsechestnut	2,677	17,704	124,300	101,215	64,854	90,572	65,373	-	466,694	0.5
Boxelder	4,859	11,939	49,574	85,621	161,182	68,273	17,321	35,933	434,701	0.5
Ponderosa pine	2,758	53,259	126,785	134,211	75,476	-	-	-	392,487	0.4
Eastern cottonwood	-	1,084	31,119	20,672	85,450	37,253	-	213,421	388,999	0.4
Callery pear	174,986	179,743	22,730	7,461	-	-	-	-	384,919	0.4
Sugar maple	52,813	39,112	95,440	76,622	87,374	18,904	-	-	370,264	0.4
Scotch pine	127,773	111,696	39,664	18,788	61,861	-	-	-	359,781	0.4
Willow	3,080	8,817	6,445	40,886	113,827	81,632	48,196	53,844	356,727	0.4
Japanese pagoda tree	25,264	66,419	62,729	160,020	27,639	-	-	-	342,072	0.4
English oak	24,390	14,194	45,864	81,953	46,834	114,699	-	-	327,933	0.4
Basswood	29,011	49,249	67,375	89,044	27,639	-	-	-	262,317	0.3
Bur oak	13,754	8,502	10,619	113,942	112,747	-	-	-	259,564	0.3
White fir	2,630	19,684	90,883	106,063	39,910	-	-	-	259,170	0.3
Ginkgo	14,349	74,219	138,835	28,745	-	-	-	-	256,148	0.3
Plum	72,808	139,531	19,487	20,947	-	-	-	-	252,773	0.3
Silver linden	23,523	1,554	-	8,213	29,336	92,085	37,003	-	191,714	0.2
Pine	22,931	64,953	54,586	20,340	-	20,076	-	-	182,886	0.2
Oneseed hawthorn	2,544	66,749	109,165	-	-	-	-	-	178,458	0.2
Goldenrain tree	14,952	50,312	72,556	9,904	16,296	-	-	-	164,020	0.2

Species	0–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total	% of Total
Oak	12,965	9,765	36,177	36,683	14,334	43,249	-	-	153,173	0.2
Littleleaf linden	58,971	32,226	22,569	36,134	-	-	-	-	149,898	0.2
European ash	700	26,192	68,312	37,479	11,857	-	-	-	144,540	0.2
Eastern red cedar	4,299	38,668	39,664	39,395	13,969	-	-	-	135,995	0.2
Tulip tree	8,956	14,093	26,547	16,970	13,969	45,526	-	-	126,059	0.1
Blue ash	551	11,592	63,532	15,435	25,378	-	-	-	116,488	0.1
Northern hackberry	29,247	4,618	-	-	13,055	-	-	68,238	115,157	0.1
Beech	2,129	1,685	-	10,703	-	-	-	-	14,517	0.0
Carolina poplar	776	6,725	16,948	36,364	-	1,800	2,322	46,686	111,622	0.1
Pin oak	3,423	22,862	19,943	38,587	23,566	-	-	-	108,379	0.1
Kentucky coffeetree	3,299	7,254	41,475	19,164	34,978	-	-	-	106,169	0.1
White mulberry	140	9,675	21,662	26,078	15,852	19,004	-	-	92,411	0.1
Red maple	25,714	38,470	19,120	8,972	-	-	-	-	92,276	0.1
Cedar	14,322	27,508	33,050	15,304	-	-	-	-	90,185	0.1
Black cottonwood	1,727	-	-	-	-	-	39,619	44,265	85,610	0.1
Douglas fir	1,422	5,241	40,288	8,485	27,937	-	-	-	83,374	0.1
English walnut	2,293	14,792	9,682	-	-	50,570	-	-	77,337	0.1
Russian olive	1,879	18,060	49,191	5,863	-	-	-	-	74,992	0.1
Paradise apple	7,269	22,509	34,650	9,033	-	-	-	-	73,461	0.1
Swamp white oak	2,471	-	-	9,582	-	27,954	30,473	-	70,480	0.1
Other species	7,701	14,675	19,363	14,788	-	-	-	-	56,528	0.1
Scarlet oak	2,060	6,289	-	8,485	16,962	20,343	-	-	54,140	0.1
Eastern redbud	6,025	24,575	23,111	-	-	-	-	-	53,712	0.1
White poplar	365	-	2,338	-	20,607	10,551	19,738	-	53,599	0.1
European mountain ash	5,406	15,387	26,223	5,963	-	-	-	-	52,978	0.1
Baldcypress	3,520	3,960	14,054	16,970	-	-	-	-	38,505	0.0
Common persimmon	-	1,758	17,754	16,360	-	-	-	-	35,872	0.0
Wych elm	-	-	-	10,303	-	24,703	-	-	35,006	0.0
European white birch	886	9,274	15,919	8,705	-	-	-	-	34,784	0.0
Willow oak	-	-	-	-	-	-	32,687	-	32,687	0.0
Sweet mountain pine	1,493	7,257	13,940	9,033	-	-	-	-	31,723	0.0
Smooth hawthorn	4,738	18,021	8,621	-	-	-	-	-	31,380	0.0
Sumac	10,331	3,003	-	-	11,227	-	-	-	24,561	0.0
Fir	2,200	5,655	8,035	7,498	-	-	-	-	23,388	0.0
Caucasian ash	13,299	8,855	-	-	-	-	-	-	22,154	0.0
Spruce	2,033	10,972	8,953	-	-	-	-	-	21,959	0.0
European beech	1,031	-	-	-	-	20,343	-	-	21,374	0.0
Sycamore maple	1,908	1,758	4,643	-	12,141	-	-	-	20,450	0.0
Washington hawthorn	16,593	3,611	-	-	-	-	-	-	20,204	0.0
Juniper	9,151	6,604	-	-	-	-	-	-	15,755	0.0
Flowering plum	4,105	8,050	3,419	-	-	-	-	-	15,574	0.0
American chestnut	506	1,265	-	-	12,523	-	-	-	14,294	0.0
Black maple	-	1,825	3,989	7,717	-	-	-	-	13,531	0.0
Black poplar	-	-	4,358	-	8,084	-	-	-	12,442	0.0
Quaking aspen	10,875	1,046	-	-	-	-	-	-	11,921	0.0
Flowering dogwood	5,328	5,937	-	-	-	-	-	-	11,265	0.0
Spruce pine	2,017	1,958	5,243	-	1,969	-	-	-	11,187	0.0
European alder	2,385	-	-	8,306	-	-	-	-	10,691	0.0
Giant sequoia	3,236	7,254	-	-	-	-	-	-	10,490	0.0

Species	0–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total	% of Total
Turkish hazelnut	10,118	-	-	-	-	-	-	-	10,118	0.0
Pond pine	976	3,570	5,243	-	-	-	-	-	9,789	0.0
Rocky mountain juniper	-	9,784	-	-	-	-	-	-	9,784	0.0
Chinese elm	8,268	1,448	-	-	-	-	-	-	9,716	0.0
Bigtooth aspen	4,997	1,314	2,727	-	-	-	-	-	9,039	0.0
Southern catalpa	3,172	-	-	5,863	-	-	-	-	9,035	0.0
European hornbeam	7,936	-	-	-	-	-	-	-	7,936	0.0
Hickory	148	-	7,648	-	-	-	-	-	7,796	0.0
Smoke tree	-	2,791	4,843	-	-	-	-	-	7,634	0.0
Prairie crabapple	5,458	2,091	-	-	-	-	-	-	7,548	0.0
Cherry plum	6,137	1,241	-	-	-	-	-	-	7,378	0.0
Magnolia	1,546	3,232	2,313	-	-	-	-	-	7,091	0.0
American mountain ash	681	5,936	-	-	-	-	-	-	6,617	0.0
Apricot	-	-	-	6,615	-	-	-	-	6,615	0.0
Purple blow maple	4,810	1,631	-	-	-	-	-	-	6,441	0.0
Hedge maple	5,969	-	-	-	-	-	-	-	5,969	0.0
Dogwood	1,176	4,502	-	-	-	-	-	-	5,678	0.0
Engelmann spruce	-	1,503	3,989	-	-	-	-	-	5,491	0.0
Western white pine	3,317	1,980	-	-	-	-	-	-	5,297	0.0
Kwanzan cherry	1,856	3,408	-	-	-	-	-	-	5,264	0.0
Staghorn sumac	3,964	1,265	-	-	-	-	-	-	5,230	0.0
Hazelnut	4,831	-	-	-	-	-	-	-	4,831	0.0
Cucumber tree	-	-	4,372	-	-	-	-	-	4,372	0.0
Black spruce	555	3,694	-	-	-	-	-	-	4,248	0.0
Amur corktree	3,564	-	-	-	-	-	-	-	3,564	0.0
Manchurian ash	2,843	-	-	-	-	-	-	-	2,843	0.0
Peach	2,640	-	-	-	-	-	-	-	2,640	0.0
Korean sun pear	2,610	-	-	-	-	-	-	-	2,610	0.0
Paper birch	1,233	1,356	-	-	-	-	-	-	2,589	0.0
Coulter pine	2,589	-	-	-	-	-	-	-	2,589	0.0
Green hawthorn	2,556	-	-	-	-	-	-	-	2,555	0.0
American hornbeam	2,543	-	-	-	-	-	-	-	2,543	0.0
River birch	2,521	-	-	-	-	-	-	-	2,521	0.0
Amur maple	2,342	-	-	-	-	-	-	-	2,343	0.0
Hardy rubber tree	684	1,631	-	-	-	-	-	-	2,315	0.0
Laurel oak	2,302	-	-	-	-	-	-	-	2,302	0.0
Birch	2,264	-	-	-	-	-	-	-	2,264	0.0
Common chokecherry	2,213	-	-	-	-	-	-	-	2,213	0.0
Corkscrew willow	618	1,536	-	-	-	-	-	-	2,154	0.0
Katsura tree	529	1,539	-	-	-	-	-	-	2,068	0.0
Downy serviceberry	-	1,631	-	-	-	-	-	-	1,631	0.0
Serbian spruce	1,545	-	-	-	-	-	-	-	1,544	0.0
Eastern hemlock	-	1,539	-	-	-	-	-	-	1,539	0.0
Yellowwood	1,535	-	-	-	-	-	-	-	1,535	0.0
Japanese tree lilac	1,503	-	-	-	-	-	-	-	1,503	0.0
Golden-chain tree	842	614	-	-	-	-	-	-	1,456	0.0
Deodar cedar	-	1,448	-	-	-	-	-	-	1,448	0.0
Red mulberry	-	1,448	-	-	-	-	-	-	1,448	0.0
Amur maackia	1,314	-	-	-	-	-	-	-	1,314	0.0

Species	0–6	6–12	12–18	18–24	24–30	30–36	36–42	>42	Total	% of Total
Common pear	1,087	-	-	-	-	-	-	-	1,087	0.0
Northern white cedar	1,039	-	-	-	-	-	-	-	1,039	0.0
Mimosa	993	-	-	-	-	-	-	-	993	0.0
Chinese spruce	987	-	-	-	-	-	-	-	987	0.0
Black ash	976	-	-	-	-	-	-	-	976	0.0
Konara oak	952	-	-	-	-	-	-	-	952	0.0
White spruce	903	-	-	-	-	-	-	-	903	0.0
Japanese fir	890	-	-	-	-	-	-	-	890	0.0
Black oak	787	-	-	-	-	-	-	-	787	0.0
Caspian locust	718	-	-	-	-	-	-	-	718	0.0
Oriental spruce	707	-	-	-	-	-	-	-	707	0.0
Black willow	696	-	-	-	-	-	-	-	696	0.0
Sawtooth oak	605	-	-	-	-	-	-	-	605	0.0
Atlas cedar	588	-	-	-	-	-	-	-	588	0.0
Oriental white oak	538	-	-	-	-	-	-	-	538	0.0
Umbrella pine	509	-	-	-	-	-	-	-	509	0.0
Little epaulettetree	487	-	-	-	-	-	-	-	487	0.0
Eastern white pine	474	-	-	-	-	-	-	-	474	0.0
Balsam poplar	471	-	-	-	-	-	-	-	471	0.0
Ohio buckeye	449	-	-	-	-	-	-	-	449	0.0
Sargent cherry	419	-	-	-	-	-	-	-	419	0.0
Flowering ash	388	-	-	-	-	-	-	-	388	0.0
Common hoptree	384	-	-	-	-	-	-	-	384	0.0
Western redcedar	368	-	-	-	-	-	-	-	368	0.0
Knobcone pine	323	-	-	-	-	-	-	-	323	0.0
Southern red oak	319	-	-	-	-	-	-	-	319	0.0
Paperbark maple	315	-	-	-	-	-	-	-	315	0.0
Bigtooth maple	307	-	-	-	-	-	-	-	307	0.0
Swiss stone pine	294	-	-	-	-	-	-	-	294	0.0
Blierana plum	174	-	-	-	-	-	-	-	174	0.0
American smoketree	174	-	-	-	-	-	-	-	174	0.0
California black oak	159	-	-	-	-	-	-	-	159	0.0
Chinkapin oak	131	-	-	-	-	-	-	-	131	0.0
Italian alder	127	-	-	-	-	-	-	-	127	0.0
European larch	114	-	-	-	-	-	-	-	114	0.0
Citywide total	3,139,759	6,890,789	11,396,330	13,557,148	20,573,085	17,747,887	9,881,556	5,079,547	88,266,102	100

Appendix C—Methodology and Procedures

This analysis combines results of a citywide inventory with benefit–cost modeling data to produce four types of information:

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

This Appendix describes municipal tree sampling, tree growth modeling, and the model inputs and calculations used to derive the aforementioned outputs.

Growth Modeling

A stratified random sample of 930 street trees, drawn from Boise's municipal tree database, was inventoried to establish relations between tree age, size, leaf area and biomass; subsequently, estimates for determining the magnitude of annual benefits in relation to predicted tree size were derived. The sample was composed of the 20 most abundant species; from these data, growth of all trees was inferred. The species were as follows:

- Norway maple (*Acer platanoides*)
- Silver maple (*Acer saccharinum*)
- Sugar maple (*Acer saccharum*)
- Northern catalpa (*Catalpa speciosa*)
- Hawthorn (*Crataegus* spp.)
- White ash (*Fraxinus americana*)
- Green ash (*Fraxinus pennsylvanica*)
- Honeylocust (*Gleditsia triacanthos*)
- Black walnut (*Juglans nigra*)
- Sweetgum (*Liquidambar styraciflua*)
- Apple (*Malus* spp.)
- Blue spruce (*Picea pungens*)
- Scotch pine (*Pinus sylvestris*)
- London planetree (*Platanus acerifolia*)
- American sycamore (*Platanus occidentalis*)
- Callery pear (*Pyrus calleryana*)
- Northern red oak (*Quercus rubra*)
- Black locust (*Robinia pseudoacacia*)
- American basswood (*Tilia americana*)
- Siberian elm (*Ulmus pumila*)

To obtain information spanning the life cycle of predominant tree species, the inventory was stratified into nine DBH classes:

- 0–3 in (0–7.6 cm)
- 3–6 in (7.6–15.2 cm)
- 6–12 in (15.2–30.5 cm
- 12–18 in (30.5–45.7 cm)
- 18–24 in (45.7–61.0 cm)
- 24–30 in (61.0–76.2 cm)
- 30–36 in (76.2–91.4 cm)
- 36–42 in (91.4–106.7 cm)
- >42 in (>106.7 cm)

Thirty to sixty randomly selected trees of each species were selected to survey, along with an equal number of alternative trees. Tree measurements included DBH (to nearest 0.1 cm by sonar measuring device), tree crown and crown base (to nearest 0.5 m by altimeter), crown diameter in two directions (parallel and perpendicular to nearest street to nearest 0.5 m by sonar measuring device), tree condition and location. Replacement trees were sampled when trees from the original sample population could not be located. Tree age was determined by municipal tree managers. Fieldwork was conducted in August and September 2005.

Crown volume and leaf area were estimated from computer processing of tree crown images obtained using a digital camera. The method has shown greater accuracy than other techniques (±25% of actual leaf area) in estimating crown volume and leaf area of open-grown trees (Peper and McPherson 2003).

Linear and non-linear regression was used to fit predictive models—with DBH as a function of age—for each of the 20 sampled species. Predictions of leaf surface area (LSA), crown diameter, and height metrics were modeled as a function of DBH using best-fit models (Peper et al. 2003).

Replacement Value

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 is widely used today and assumes that the cost of production equals value (Cullen 2002).

The trunk formula method (CTLA 1992), also called depreciated replacement cost, is a common approach for estimating tree value in terms of cost. 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.

We regard the terms "replacement value" and "replacement cost" as synonymous indicators of the urban forest's value. Replacement value is indicated by the cost of replacing existing trees with trees of similar size, species, and condition if all were destroyed, for example, by a catastrophic storm. Replacement cost should be distinguished from the value of annual benefits produced by the urban forest. The latter is a "snapshot" of benefits during one year, while the former 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 trunk formula method uses tree size, species, condition, and location factors to determine tree replacement value. Tree size is measured as trunk area (TA, cross-sectional area of the trunk based on DBH), while the other factors are assessed subjectively relative to a "high-quality" specimen and expressed as percentages. The trunk formula is

$$\textit{Replacement value} = \textit{Basic value} \times \textit{Condition\%} \times \textit{Location\%}$$

$$\textit{Basic value} = \textit{Replacement cost} + (\textit{Basic price} \times [TA_A - TA_{R]} \times \textit{Species\%})$$

where

Condition% = Rating of structural integrity and health; a higher percentage indicates better condition (CTLA 1992).

Location% = Rating of the site itself (relative market value), contribution of the tree in terms of its aesthetic and functional attributes, and placement, which reflects the effectiveness of realizing benefits; location is the sum of site, contribution, and placement divided by three (CTLA 1992). A higher percentage indicates better location.

Replacement cost = Sum of the cost of the replacement tree (of size TA_R) and its installation.

Basic price = Cost of the largest available transplantable tree divided by TA_R (\$/in^2).

TA_A = Trunk area of appraised tree (in^2) or height of clear trunk (linear ft) for palms.

TA_R = Trunk area of replacement tree (in^2) or height of clear trunk (linear ft) for palms.

Species% = Rating of the species's longevity, maintenance requirements, and adaptability to the local growing environment (CTLA 1992).

In this study, data from the "2006 Draft Species Evaluation Guide" were used to calculate replacement value (Pacific Northwest ISA Chapter 2006). Species rating percentages were the midpoint for the ranges reported. Tree condition ratings were based on the inventory (or set at 70% when no data were available) and location ratings were arbitrarily set at 70%, indicative of a tree located in a typical park. TA_R is 7.065 inch^2 for a 3-inch caliper tree representing the largest tree that is normally available from wholesalers; TA_A is calculated using the midpoint for each DBH class. The basic price was \$66/in^2 TA, based on the wholesale cost of a 3-inch caliper tree. Replacement costs equaled the cost for a 4-inch tree plus installation.

Replacement values were calculated using the trunk formula equation for each species by DBH class, then summed across DBH classes and species to derive total replacement value for the population.

Identifying and Calculating Benefits

Annual benefits for Boise's municipal trees were estimated for the fiscal year 2005. Growth rate modeling information was used to perform computer-simulated growth of the existing tree population for one year and account for the associated annual benefits. This "snapshot" analysis assumed that no trees were added to, or removed from, the existing population during the year. (Calculations of CO_2 released due to decomposition of wood from removed trees did consider average annual mortality.) This approach directly connects benefits with tree-size variables such as DBH and LSA. Many functional benefits of trees are related to processes that involve interactions between leaves and the atmosphere (e.g., interception, transpiration, photosynthesis); therefore, benefits increase as tree canopy cover and leaf surface area increase.

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

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

Energy Savings

Buildings and paving, along with little tree canopy cover and soil cover, increase the ambient temperatures within a city. Research shows that even in temperate climate zones temperatures in urban centers are steadily increasing by approximately 0.5°F per decade. Winter benefits of this warming do not compensate for the detrimental effects of increased summertime temperatures. Because the electricity demand of cities increases about 1–2% per 1°F increase in temperature, approximately 3–8% of the current electric demand for cooling is used to compensate for this urban heat island effect (Akbari et al. 1992).

Warmer temperatures in cities have other implications. Increases in CO_2 emissions from fossil-fuel power plants, increased municipal water demand, unhealthy ozone levels, and human discomfort and disease are all symptoms associated with urban heat islands. In Boise, there are opportunities to ameliorate the problems associated with hardscape through strategic tree planting and stewardship of existing trees thereby creating street and park landscapes that reduce stormwater runoff, conserve energy and water, sequester CO_2, attract wildlife, and provide other aesthetic, social, and economic benefits.

For individual buildings, street trees can increase energy efficiency in summer and increase or decrease energy efficiency in winter, depending on their location. During the summer, the sun is low in the eastern and western sky for several hours each day. Tree shade to protect east—and especially west—walls helps keep buildings cool. In the winter, allowing the sun to strike the southern side of buildings can warm interior spaces.

Trees reduce air movement into buildings and conductive heat loss from buildings. The rates that outside air moves into a building can increase substantially with wind speed. In cold, windy weather, the entire volume of air, even in newer or tightly sealed homes, may change every two to three hours. Trees can reduce wind speed and resulting air infiltration by up to 50%, translating into potential annual heating savings of 25% (Heisler 1986). Decreasing wind speed reduces heat transfer through conductive materials as well. Cool winter winds, blowing against single-pane windows, can contribute significantly to the heating load of homes and buildings

Calculating Electricity and Natural Gas Benefits

Calculations of annual building energy use per residential unit (unit energy consumption [UEC]) were based on computer simulations that incorporated building, climate, and shading effects, following methods outlined by McPherson and Simpson (1999). Changes in UECs due to the effects of trees (ΔUECs) were calculated on a per-tree basis by comparing results before and after adding trees. Building characteristics (e.g., cooling and heating equipment saturations, floor area, number of stories, insulation, window area, etc.) are differentiated by a building's vintage, or age of construction: pre-1950, 1950–1980, and post-1980. For example, all houses from 1950–1980 vintage are assumed to have the same floor area, and other construction characteristics. Shading effects for each of the 19 tree species were simulated at three tree-to-building distances, for eight orientations and for nine tree sizes.

The shading coefficients of the trees in leaf (gaps in the crown as a percentage of total crown silhouette) were estimated using a photographic method that has been shown to produce good estimates (Wilkinson 1991). Crown areas were obtained using the method of Peper and McPherson (2003) from digital photographs of trees from which background features were digitally removed. Values for tree species that were not sampled, and leaf-off values for use in calculating winter shade, were based on published values where available (McPherson 1984; Hammond et al. 1980). Where published values were not available, visual densities were assigned based on taxonomic considerations (trees of the same genus were assigned the same value) or observed similarity to known species. Foliation periods for deciduous trees were obtained from the literature (McPherson 1984; Hammond et al. 1980) and adjusted for Boise's climate based on consultation with foresters (Jorgenson 2006).

Average energy savings per tree were calculated as a function of distance and direction using tree location distribution data specific to Boise (i.e., frequency of trees located at different distances from buildings [setbacks] and tree orientation with respect to buildings). Setbacks were assigned to four distance classes: 0–20 ft, 20–40 ft, 40–60 ft and >60 ft. It was assumed that street trees within 60 ft of buildings provided direct shade on walls and windows. Savings per tree at each location were multiplied by tree distribution to determine location-weighted savings per tree for each species and DBH class, independent of location. Location-weighted savings per tree were multiplied by the number of trees of each species and DBH class and then summed to find total savings for the city. Tree locations were based on the stratified random sample conducted in summer 2005.

Land use (single-family residential, multifamily residential, commercial/industrial, other) for right-of-way trees was based on the same tree sample. A constant tree distribution was used for all land uses.

Three prototype buildings were used in the simulations to represent pre-1950, 1950–1980, and post-1980 construction practices for Boise (Ritschard et al. 1992). Building footprints were modeled as square, which was found to be reflective of average impacts for a large number of buildings (Simpson 2002). Buildings were simulated with 1.5-ft overhangs. Blinds had a visual density of 37%, and were assumed to be closed when the air conditioner was operating. Thermostat settings were 78°F for cooling and 68°F for heating, with a 60°F night setback in winter. Unit energy consumptions were adjusted to account for equipment saturations (percentage of structures with different types of heating and cooling equipment such as central air conditioners, room air conditioners, and evaporative coolers) (*Table C1*).

Weather data for a typical meteorological year (TMY2) from Boise were used National Solar Radiation Data Base 2006). Dollar values for energy savings were based on electricity and natural gas prices of $0.061/kWh (Idaho Power 2006) and $1.14245/therm (Intermountain Gas 2006), respectively.

Single-Family Residence Adjustments

Unit energy consumptions for simulated single-family residences were adjusted for type and saturation of heating and cooling equipment, and for various factors (F) that modify the effects of shade and climate on heating and cooling loads:

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

where

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

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

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

Changes in energy use for higher density residential and commercial structures were calculated from single-family residential results adjusted by average potential shade factors (APSF) and potential climate factors (PCF); values were set to 1.0 for single-family residential buildings.

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

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

Subscript *x* refers to residential structures with 1, 2–4 or ≥5 units, SFD to simulated single-family detached structures, sh to shade, and cl to climate effects.

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

In addition to localized shade effects, which were assumed to accrue only to street trees within 18–60 ft of buildings, lowered air temperatures and wind speeds due to neighborhood tree cover (referred to as climate effects) produce a net decrease in demand for summer cooling and winter heating. Reduced wind speeds by themselves may increase or decrease cooling demand, depending on the circumstances. To estimate climate effects on energy use, air-temperature and wind-speed reductions were estimated as a function of neighborhood canopy cover from published values following McPherson and Simpson (1999), then used as input for the building-energy-use simulations described earlier. Peak summer air temperatures were assumed to be reduced by 0.2°F for each percentage increase in canopy cover. Wind-speed reductions were based on the change in total tree plus building canopy cover resulting from the addition of the particular tree being simulated (Heisler 1990). A lot size of 10,000 ft^2 was assumed.

Cooling and heating effects were reduced based on the type and saturation of air conditioning (*Table C2*) or heating (*Table C3*) equipment by vintage. Equipment factors of 33 and 25% were assigned to homes with evaporative coolers and room air conditioners, respectively. These factors were combined with equipment saturations to account for reduced energy use and savings compared to those simulated for homes with central air conditioning ($F_{equipment}$). Building vintage distribution was combined with adjusted saturations to compute combined vintage/saturation factors for air conditioning (*Table C2*). Heating loads were converted to fuel use based on efficiencies in *Table C2*. The "other" and "fuel oil" heating equipment types were assumed to be natural gas for the purpose of this analysis. Building vintage distributions were combined with adjusted saturations to compute combined vintage/saturation factors for natural gas and electric heating (*Table C3*).

Multi-Family Residence Analysis

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

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

Commercial and Other Buildings

Reductions in unit energy consumptions for commercial/industrial (C/I) and industrial/transportation (I/T) land uses due to the presence of trees were determined in a manner similar to that used for multi-family land uses. Potential shade factors of 0.40 were assumed for small C/I, and 0.0 for large C/I. No energy impacts were ascribed to large C/I structures since they are expected to have surface-to-volume ratios an order of magnitude larger than smaller buildings and less extensive window area. Average potential shade factors for I/T structures were estimated to lie between these extremes; a value of 0.15 was used here. However, data relating I/T land use to building-space conditioning were not readily available, so no energy impacts were ascribed to I/T structures. A multiple-tree reduction factor of 0.85 was used, and no benefit was assigned for shading of buildings on adjacent lots.

Potential climate-effect factors of 0.40, 0.25 and 0.20 were used for small C/I, large C/I, and I/T, respectively. These values are based on estimates by Akbari (1992) and others who observed that commercial buildings are less sensitive to outdoor temperatures than houses.

The beneficial effects of shade on UECs tend to increase with conditioned floor area (CFA) for typi-

***Table C1**—Saturation adjustments for cooling (%)*

	Single family detached			Mobile homes			Single-family attached			Multi-family 2-4 units			Multi-family 5+ units			Commercial/ industrial		Instit./ Trans-porta-tion
	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	Small	Large	
								Cooling equipment factors										
Central air/ heat pump	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Evaporative cooler	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Wall/window unit	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
None	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
								Cooling saturations										
Central air/ heat pump	13	35	69	13	35	69	13	35	69	13	35	69	13	35	69	86	86	86
Evaporative cooler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wall/window unit	37	23	25	34	23	25	37	23	25	37	23	25	37	23	25	9	9	9
None	51	42	6	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5
Adjusted cooling saturation	22	41	75	22	41	75	22	41	75	22	41	75	22	41	75	88	88	88

Table C2*—Saturation adjustments for heating (%, except AFUE [fraction] and HSPF [kBtu/kWh)*

	Single family detached			Mobile homes			Single-family attached			Multi-family 2-4 units			Multi-family 5+ units			Commercial/ industrial		Institutional/ Transportation
	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	Small	Large	
Equipment efficiencies																		
AFUE	0.75	0.78	0.78	0.75	0.78	0.78	0.75	0.78	0.78	0.75	0.78	0.78	0.75	0.78	0.78	0.78	0.78	0.78
HSPF	6.8	6.8	8	6.8	6.8	8	6.8	6.8	8	6.8	6.8	8	6.8	6.8	8	8	8	8
HSPF	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412
Electric heat saturations																		
Electric resistance	2.4	10.9	21.4	2.4	10.9	21.4	2.4	10.9	21.4	2.4	10.9	21.4	2.4	10.9	21.4	4.9	4.9	4.9
Heat pump	0.4	1.8	3.6	0.4	1.8	3.6	0.4	1.8	3.6	0.4	1.8	3.6	0.4	1.8	3.6	5.4	5.4	5.4
Adjusted electric heat saturations	0.4	1.7	2.9	0.4	1.7	2.9	0.4	1.7	2.9	0.4	1.7	2.9	0.4	1.7	2.9	1.7	1.7	1.7
Natural gas and other heating saturations																		
Natural gas	69.0	60.8	50.0	69.0	60.8	50.0	69.0	60.8	50.0	69.0	60.8	50.0	69.0	60.8	50.0	89.7	89.7	89.7
Oil	18.3	19.0	0.0	18.3	19.0	0.0	18.3	19.0	0.0	18.3	19.0	0.0	18.3	19.0	0.0	0.0	0.0	0.0
Other	9.9	7.6	25.0	9.9	7.6	25.0	9.9	7.6	25.0	9.9	7.6	25.0	9.9	7.6	25.0	0	0	0
NG heat saturations	97	87	75	97	87	75	97	87	75	97	87	75	97	87	75	90	90	90

Table C3*—Building vintage distribution and combined vintage/saturation factors for heating and air conditioning*

	Single family detached			Mobile homes			Single-family attached			Multi-family 2-4 units			Multi-family 5+ units			Commercial/ industrial		Institutional/ Transportation
	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	Small	Large	
Vintage distribution by building type	10.8	33.4	55.8	5.0	17.2	77.8	2.3	58.3	39.4	9.4	27.3	63.3	3.6	23.2	73.2	100	100	100
Tree distribution by vintage and building type	9.4	29.0	48.4	0.3	0.9	4.1	0.2	4.7	3.2	4.0	11.7	27.2	2.0	13.2	41.8	63.0	37.0	100
Combined vintage, equipment saturation factors for cooling																		
Cooling factor: shade	2.00	11.65	35.45	0.06	0.37	3.02	0.03	1.66	2.04	0.64	3.49	14.75	0.18	2.18	12.55	19.4	5.7	0.0
Cooling factor: climate	2.04	11.92	36.27	0.06	0.36	2.95	0.03	1.56	1.92	0.40	2.17	9.17	0.21	2.51	14.42	17.4	34.1	0.0
Combined vintage, equipment saturation for heating																		
Heating factor, natural gas: shade	8.89	24.73	35.45	0.25	0.78	3.02	0.15	3.52	2.04	2.84	7.41	14.75	0.80	4.63	12.55	19.7	5.8	0.0
Heating factor, electric: shade	0.03	0.47	1.37	0.00	0.01	0.12	0.00	0.07	0.08	0.01	0.14	0.57	0.00	0.09	0.49	0.38	0.11	0.0
Heating factor, natural gas: climate	9.09	25.30	36.27	0.14	0.44	1.69	0.17	3.90	2.27	1.68	4.38	8.72	0.97	5.64	15.27	68.0	133.1	0.0
Heating factor, electric: climate	0.03	0.48	1.40	0.00	0.01	0.07	0.00	0.07	0.09	0.01	0.08	0.34	0.00	0.11	0.59	1.30	2.55	0.0

cal residential structures. As building surface area increases so does the area shaded. This occurs up to a certain point because the projected crown area of a mature tree (approximately 700–3,500 ft^2) is often larger than the building surface areas being shaded. A point is reached, however, at which no additional area is shaded as surface area increases. At this point, ΔUECs will tend to level off as CFA increases. Since information on the precise relationships between change in UEC, CFA, and tree size is not available, it was conservatively assumed that ΔUECs in *Equation 1* did not change for C/I and I/T land uses.

Atmospheric Carbon Dioxide Reduction

Sequestration (the net rate of CO_2 storage in above- and below-ground biomass over the course of one growing season) is calculated for each species using the tree-growth equations for DBH and height, described above, to calculate either tree volume or biomass. Equations from Pillsbury et al. (1998) are used when calculating volume. Fresh weight (kg/m^3) and specific gravity ratios from Alden (1995, 1997) are then applied to convert volume to biomass. When volumetric equations for urban trees are unavailable, biomass equations derived from data collected in rural forests are applied (Tritton and Hornbeck 1982; Ter-Mikaelian and Korzukhin 1997).

Carbon dioxide released through decomposition of dead woody biomass varies with characteristics of the wood itself, the fate of the wood (e.g., amount left standing, chipped, or burned), and local soil and climatic conditions. Recycling of urban waste is now prevalent, and we assume here that most material is chipped and applied as landscape mulch. Calculations were conservative because they assumed that dead trees are removed and mulched in the year that death occurs, and that 80% of their stored carbon is released to the atmosphere as CO_2 in the same year. Total annual decomposition is based on the number of trees in each species and age class that die in a given year and their biomass. Tree survival rate is the principal factor influencing decomposition. Tree mortality for Boise was 2.0% per year for the first five years after planting for street trees and 0.6% every year thereafter (Jorgenson 2006). Finally, CO_2 released during tree maintenance was estimated to be 0.89 lb CO_2 per inch DBH based on gasoline (~2,400 gal) and diesel fuel use (~8,000 gal) (Jorgenson 2006).

Table C4*—Emissions factors and monetary implied values for CO_2 and criteria air pollutants*

	Emission factor		Implied
	Electricity (lb/MWh)[a]	Natural gas (lb/MBtu)[b]	value[c] ($/lb)
CO_2	746	118	0.00334
NO_2	1.443	0.1020	0.51
SO_2	0.988	0.0006	0.06
PM_{10}	0.500	0.0075	0.92
VOCs	0.460	0.0054	0.14

[a]USEPA 1998, 2003, except Ottinger et al. 1990 for VOCs
[b]USEPA 1998
[c]CO_2 from Pearce (2003), values for all other pollutants are based on methods of Wang and Santini (1995) using emissions concentrations from U.S. EPA (2005) and population estimates from the U.S. Census Bureau (2003)

Calculating Avoided CO_2 Emissions

Reducing building energy use reduces emissions of CO_2. Emissions were calculated as the product of energy use and CO_2 emission factors for electricity and heating. Heating fuel is largely natural gas and electricity in Boise. The fuel mix for electrical generation included coal (45.5%), hydroelectric (39.3%) and natural gas (14%) (U.S. EPA 2003).

Emissions factors for electricity (lb/MWh) and natural gas (lb/MBtu) fuel mixes are given in *Table C4*. The monetary value of avoided CO_2 was $6.68/ton based on the average value in Pearce (2003).

Improving Air Quality

Calculating Avoided Emissions

Reductions in building energy use also result in reduced emissions of criteria air pollutants (those for which a national standard has been set by the EPA) from power plants and space-heating equipment. This analysis considered volatile organic hydrocarbons (VOCs) and nitrogen dioxide (NO_2)—both precursors of ozone (O_3) formation—as well as sulfur dioxide (SO_2) and particulate matter of <10 micron diameter (PM_{10}). Changes in average annual emissions and their monetary values were calculated in the same way as for CO_2, again using utility specific emission factors for electricity and heating fuels (US EPA 2003). The prices of emissions savings were derived from models that calculate the marginal cost of controlling different pollutants to meet air quality standards (Wang and Santini 1995). Emissions concentrations were obtained from the EPA (2005, *Table C4*), and population estimates from the US Census Bureau (2003).

Calculating Deposition and Interception

Trees also remove pollutants from the atmosphere. The hourly pollutant dry deposition per tree is expressed as the product of the deposition velocity Vd $=1/(R_a+R_b+R_c)$, pollutant concentration (C), canopy projection (CP) area, and time step. Hourly deposition velocities for each pollutant were calculated using estimates for the resistances R_a, R_b, and R_c estimated for each hour over a year using formulations described by Scott et al. (1998). Hourly concentrations for NO_2, SO_2, O_3 and PM_{10} for Boise were obtained from the Environmental Protection Agency (EPA 2006 and hourly meteorological data (i.e., air temperature, wind speed, solar radiation) were obtained from the Pacific Northwest Cooperative Agricultural Weather Network (U.S Department of Interior 2006). The year 2003 was chosen because data were available and it closely approximated long-term, regional climate records.

Deposition was determined for deciduous species only when trees were in-leaf. A 50% re-suspension rate was applied to PM_{10} deposition. Methods described in the section "Calculating Avoided Emissions" were used to value emissions reductions; NO_2 prices were used for ozone since ozone control measures typically aim at reducing NO_2.

Calculating BVOC Emissions

Emissions of biogenic volatile organic carbon (sometimes called biogenic hydrocarbons or BVOCs) associated with increased ozone formation were estimated for the tree canopy using methods described by Scott et al. (1998). In this approach, the hourly emissions of carbon in the form of isoprene and monoterpene are expressed as products of base emission factors and leaf biomass factors adjusted for sunlight and temperature (isoprene) or simply temperature (monoterpene). Annual dry foliar biomass was derived from field data collected in Boise during August 2006. The amount of foliar biomass present for each year of the simulated tree's life was unique for each species. Hourly air temperature and solar radiation data for 2003 described in the pollutant uptake section were used as model inputs. Hourly emissions were summed to get annual totals (*Table C4*).

The ozone-reduction benefit from lowering summertime air temperatures, thereby reducing hydrocarbon emissions from biogenic sources, was estimated as a function of canopy cover following McPherson and Simpson (1999). Peak summer air temperatures were reduced by 0.2°F for each percentage increase in canopy cover. Hourly changes in air temperature were calculated by reducing this peak air temperature at every hour based on the hourly maximum and minimum temperature for that day, the maximum and minimum values of total global solar radiation for the year.

Simulation results from Los Angeles indicate that ozone reduction benefits of tree planting with "low-emitting" species exceeded costs associated with their BVOC emissions (Taha 1996). This is a conservative approach, since the benefit associated with lowered summertime air temperatures and the resulting reduced hydrocarbon emissions from anthropogenic sources were not accounted for.

Reducing Stormwater Runoff

The social benefits that result from reduced peak runoff include reduced property damage from flooding and reduced loss of soil and habitat due to erosion and sediment flow. Reduced runoff also results in improved water quality in streams, lakes, and rivers. This can translate into improved aquatic habitats, less human disease and illness due to contact with contaminated water and reduced stormwater treatment costs.

Calculating Stormwater Runoff Reductions

A numerical simulation model was used to estimate annual rainfall interception (Xiao et al. 1998). The interception model accounts for rainwater intercepted by the tree, as well as throughfall and stem flow. Intercepted water is stored on canopy leaf and bark surfaces. Once the storage capacity of the tree canopy is exceeded, rainwater temporarily stored on the tree surface will drip from the leaf surface and flow down the stem surface to the ground. Some of the stored water will evaporate. Tree canopy parameters related to stormwater runoff reductions include species, leaf and stem surface area, shade coefficient (visual density of the crown), tree height, crown diameter, and foliation period. Wind speeds were estimated for different heights above the ground; from this, rates of evaporation were estimated.

The volume of water stored in the tree crown was calculated from crown-projection area (area under tree dripline), leaf area indices (LAI, the ratio of leaf surface area to crown projection area), the depth of water captured by the canopy surface, and the water storage capacity of the tree crown. Tree surface saturation was 0.04 in. Species-specific shading coefficient, foliation period, and tree surface saturation storage capacity influence the amount of projected throughfall.

Hourly meteorological and rainfall data for 2004 at the AgriMet Station (BOII) (The Pacific Northwest Cooperative Agricultural Weather Network, station‘s latitude: 43° 36’ 01” N, longitude: 116° 10’ 37” W, elevation: 2,720 feet) in Boise, Idaho, were used in this simulation. The year 2004 was chosen because it most closely approximated the long time average rainfall of 12.3 in (312.4 mm). Annual precipitation at BOII during 2004 was 16.4 in (417.5 mm). Storm events less than 0.1 in (2.5 mm) were assumed not to produce runoff and were dropped from the analysis. More complete descriptions of the interception model can be found in Xiao et al. (1998, 2000).

According to Johanna Bell, PE, Stormwater Program Coordinator, the City of Boise spends approximately \$1.97 million annually on operations, maintenance, and improvements to its stormwater management system (Bell 2006). To calculate annual runoff we assigned curve numbers for each land use (USDA SCS 1986). Land use percentages were obtained from the city GIS database (Wing 2006). We calculated runoff depth for each land use and found the citywide total to be 1,138 acre-feet. Given Boise’s area of 68.1 sq miles (176.4 km^2), the total annual runoff was 419.9 million gallons (1,589,486.18 m^3). The annual stormwater control cost (\$1.97 million ÷ 419.9 million gal) was estimated to be \$0.005 per gallon of runoff.

Property Value and Other Benefits

Trees provide a host of aesthetic, social, economic, and health benefits that should be included in any benefit–cost analysis. One of the most frequently cited reasons for planting trees is beautification. Trees add color, texture, line, and form to the landscape softening the hard geometry that dominates built environments. Research on the aesthetic quality of residential streets has shown that street trees are the single strongest positive influence on scenic quality (Schroeder and Cannon 1983). Consumer surveys have shown that preference ratings increase with the presence of trees in the commercial streetscape. In contrast to areas without trees, shoppers indicated that they shopped more often and longer in well-landscaped business districts, and were willing to pay more for goods and services (Wolf 1999). Research in public-housing complexes found that outdoor spaces with trees were used significantly more often than spaces without trees. By facilitating interactions among residents, trees can contribute to reduced levels of violence, as well as foster safer and more sociable neighborhood environments (Sullivan and Kuo 1996).

Well-maintained trees increase the “curb appeal” of properties. Research comparing sales prices of residential properties with different numbers and sizes of trees suggests that people are willing to pay 3–7% more for properties with ample trees versus few or no trees. One of the most comprehensive studies on the influence of trees on residential property values was based on actual sales prices and found that each large front-yard tree was associated with about a 1% increase in sales price (Anderson and Cordell 1988). Depending on average home sale prices, the value of this benefit can contribute significantly to property tax revenues.

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

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

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

Urban forests can be oases, sometimes containing more vegetative diversity than surrounding rural areas. Numerous types of wildlife inhabit cities and are generally highly valued by residents. For example, older parks, cemeteries, and botanical gardens often contain a rich assemblage of wildlife. Street-tree corridors can connect a city to surrounding wetlands, parks, and other greenspace resources that provide habitats that conserve biodiversity (Platt et al.1994).

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

Calculating Changes in Property Values and Other Benefits

In an Athens, GA, study (Anderson and Cordell 1988), a large front-yard tree was found to be associated with a 0.88% increase in average home resale values. In our study, the annual increase in leaf surface area of a typical mature large tree (30-year-old white ash, average leaf surface area 5,179 ft^2) was the basis for valuing the capacity of trees to increase property value.

Assuming the 0.88% increase in property value held true for the city of Boise, each large tree would be worth $1,329 based on the 3rd quarter, 2005, median single-family-home resale price in Boise ($151,000) (National Association of Realtors 2006). However, not all trees are as effective as front-yard trees in increasing property values. For example, trees adjacent to multifamily housing units will not increase the property value at the same rate as trees in front of single-family homes. Therefore, a citywide reduction factor (0.93) was applied to prorate trees' value based on the assumption that trees adjacent to different land uses make different contributions to property sales prices. For this analysis, the reduction factor reflects the distribution of municipal trees in Boise by land use. The overall reduction factor for street trees reflects tree distribution by land use. Reduction factors were single-home residential (100%), multi-home residential (75%), small commercial (66%), industrial/institutional/large commercial (50%), vacant/other (50%) (McPherson et al. 2001). Trees in parks were assigned a reduction factor of 0.50.

Estimating Magnitude of Benefits

Resource units describe the absolute value of the benefits of Boise's street trees on a per-tree basis. They include kWh of electricity saved per tree, kBtu of natural gas conserved per tree, lbs of atmospheric CO_2 reduced per tree, lbs of NO_2, PM_{10}, and VOCs reduced per tree, cubic feet of stormwater runoff reduced per tree, and square feet of leaf area added per tree to increase property values. A dollar value was assigned to each resource unit based on local costs.

Estimating the magnitude of the resource units produced by all street and park trees in Boise required four steps: (1) categorizing street trees by species and DBH based on the city's street-tree inventory, (2) matching other significant species with those that were modeled, (3) grouping the remaining "other" trees by type, and (4) applying resource units to each tree.

Categorizing Trees by DBH Class

The first step in accomplishing this task involved categorizing the total number of street trees by relative age (as a function of DBH class). The inventory was used to group trees into the DBH classes described at the beginning of this chapter.

Next, the median value for each DBH class was determined and subsequently used as a single value to represent all trees in each class. For each DBH value and species, resource units were estimated using linear interpolation.

Applying Resource Units to Each Tree

The interpolated resource-unit values were used to calculate the total magnitude of benefits for each DBH class and species. For example, assume that there are 300 London planetrees citywide in the 30–36 in DBH class. The interpolated electricity and natural gas resource unit values for the class midpoint (33 in) were 199.3 kWh and 6,487.9 kBtu per tree, respectively. Therefore, multiplying the resource units for the class by 300 trees equals the magnitude of annual heating and cooling benefits produced by this segment of the population: 59,790 kWh of electricity saved and 1,946,370 kBtu of natural gas saved.

Matching Significant Species with Modeled Species

To extrapolate from the 20 municipal species modeled for growth to the entire inventoried tree population, each species representing over 1% of the population was matched with the modeled species that it most closely resembled. Less abundant species that were not matched were then grouped into the "Other" categories described below. Grouping Remaining "Other" Trees by Type

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

- Broadleaf deciduous: large (BDL), medium (BDM), and small (BDS).
- Broadleaf evergreen: large (BEL), medium (BEM), and small (BES).
- Coniferous evergreen: large (CEL), medium (CEM), and small (CES).
- Palm: large (PEL), medium (PEM), and small (PES).

Large, medium, and small trees were >40 ft, 25–40 ft, and <25 ft in mature height, respectively. A typical tree was chosen to represent each of the above 15 categories to obtain growth curves for "other" trees falling into each of the categories:

BDL Other = Green ash (*Fraxinus pennsylvanica*)

BDM Other = Norway maple (*Acer platanoides*)

BDS Other = Crabapple (*Malus* spp.)

BEL Other = Not applicable

BEM Other = Not applicable

BES Other = American holly (*Ilex opaca*)

CEL Other = Blue spruce (*Picea pungens*)

CEM Other = Scotch pine (*Pinus sylvestris*)

CES Other = Pinyon pine (*Pinus edulis*)

PEL Other = Not applicable

PEM Other = Not applicable

PES Other = Not applicable

When local data were not measured for certain categories (e.g., CES), growth data from similar-sized species in a different region were used.

Calculating Net Benefits And Benefit–Cost Ratio

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

Boise residents can obtain additional economic benefits from street trees depending on tree location and condition. For example, street trees can provide energy savings by lowering wind velocities and subsequent building infiltration, thereby reducing heating costs. This benefit can extend to the neighborhood, as the aggregate effect of many street trees reduces wind speed and reduces city-wide winter energy use. Neighborhood property values can be influenced by the extent of tree canopy cover on streets. The community benefits from cleaner air and water. Reductions in atmospheric CO_2 concentrations due to trees can have global benefits.

To assess the total value of annual benefits (*B*) for each park and street tree (*i*) in each management area (j) benefits were summed:

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

Equation 3

where

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

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

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

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

p = price of aesthetics = annual increase in property value

Total net expenditures were calculated based on all identifiable internal and external costs associated with the annual management of municipal trees citywide (Koch 2004). Annual costs for the municipality (C) were summed:

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

p = annual planting expenditure
t = annual pruning expenditure
r = annual tree and stump removal and disposal expenditure
d = annual pest and disease control expenditure
e = annual establishment/irrigation expenditure
s = annual price of repair/mitigation of infrastructure damage
cl = annual price of litter/storm clean-up
l = average annual litigation and settlements expenditures due to tree-related claims
a = annual expenditure for program administration
q = annual expenditures for inspection/answer service requests

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

Citywide Net Benefits = $B - C$ *Equation 4*

BCR = B / C *Equation 5*

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