Trees Atlanta

Planted Tree Re-Inventory Report:

Survival, Condition, and Benefits of Recently Planted Trees

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Funders:
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Background

The Bloomington Urban Forestry Research Group (BUFRG) at Indiana University was funded by the U.S. Forest Service's National Urban and Community Forestry Advisory Council (NUCFAC) to conduct a five-city study of tree planting projects supported by nonprofit organizations in urban settings. BUFRG partnered with Trees Atlanta, The Greening of Detroit, Keep Indianapolis Beautiful, Inc., the Pennsylvania Horticultural Society, Forest ReLeaf of Missouri, and the Alliance for Community Trees to conduct this research. The study included a re-inventory of trees planted in projects funded by these nonprofits from 2009 to 2011. This report presents the results of the re-inventory data analysis for Trees Atlanta, with emphasis on benefit estimates generated using i-Tree Streets.

Summary of Results

Teams of volunteers, supervised by Trees Atlanta, re-inventoried 577 trees in Atlanta in June and July of 2014. These trees were selected from a list of 4,741 trees planted by Trees Atlanta from 2009 to 2011. At the time of re-inventory, 78% of these recently planted trees had survived. Highlights of the tree analysis are:

- Most (79% of) surviving trees were found to be in good condition.
- Average diameter at breast height (DBH) of surviving trees was 7.3 cm (2.9 inches).
- Re-inventoried trees provide almost $7,000 in annual benefits, an average of $15 per tree.
- Re-inventoried trees provide almost 4,000 m^2 (43,000 ft^2) of canopy cover.
- Crape myrtle (*Lagerstroemia* spp) was the most common species of surviving re-inventoried trees (Figure 1).
- *Magnolia* was the most common genus of surviving trees (Figure 2).
- American elms (*Ulmus americana*) provide the most canopy cover and highest total annual benefits.
- All 4,741 trees planted from 2009 to 2011 have a species composition similar to the re-inventoried trees; if all trees planted from 2009 to 2011 had the same average DBH and mortality rates as the re-inventoried trees, they would provide approximately $55,500 in total annual benefits.

Species and Genus Distributions

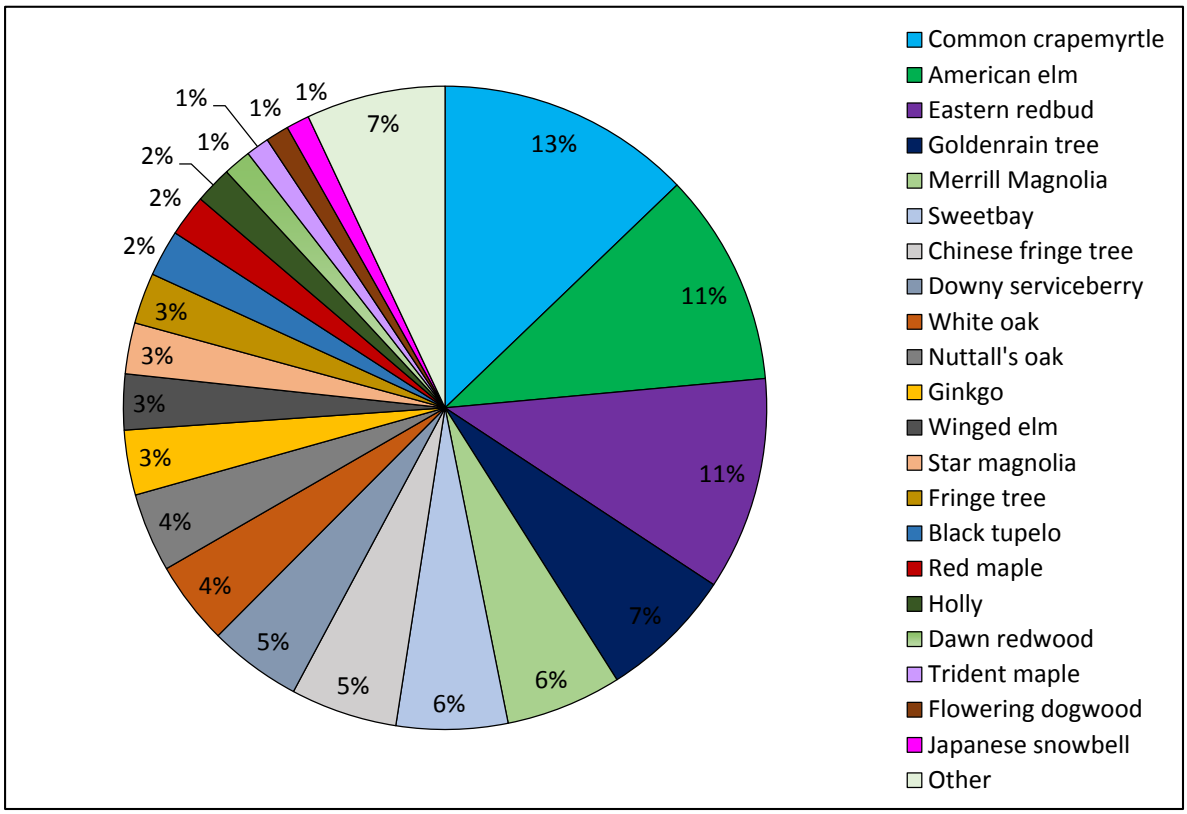

Figure 1. Species distribution of surviving re-inventoried trees planted by Trees Atlanta from 2009 to 2011. "Other" includes species that each make up less than 1% of the population - see Appendix Table A1 for a full list of species.

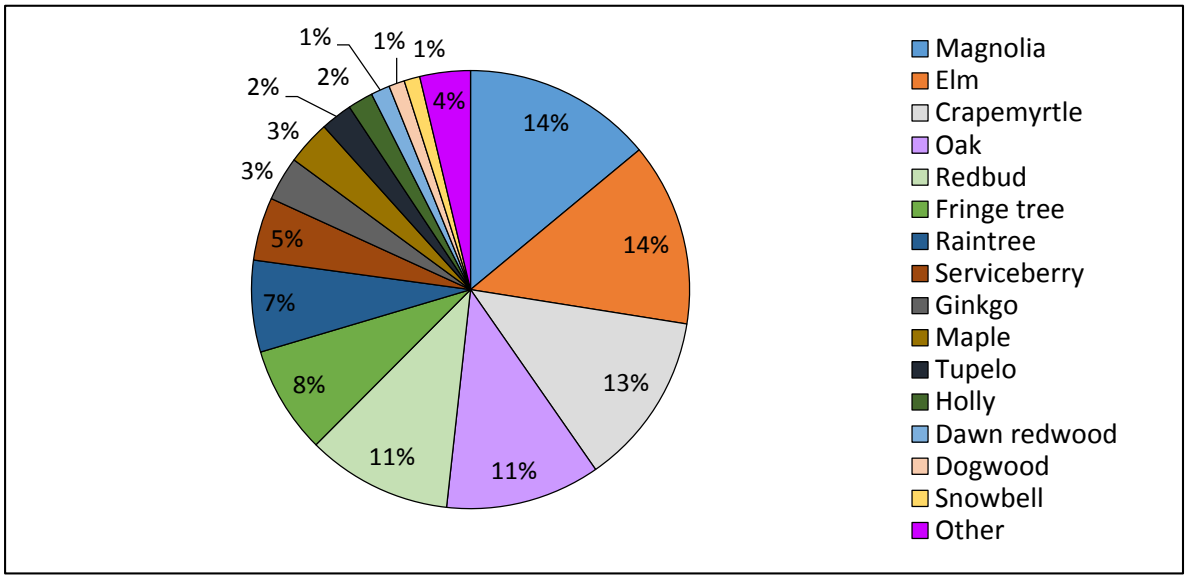

Figure 2. Genus distribution of surviving re-inventoried trees planted by Trees Atlanta from 2009 to 2011. "Other" includes genera that each make up less than 1% of the population.

Size Distribution

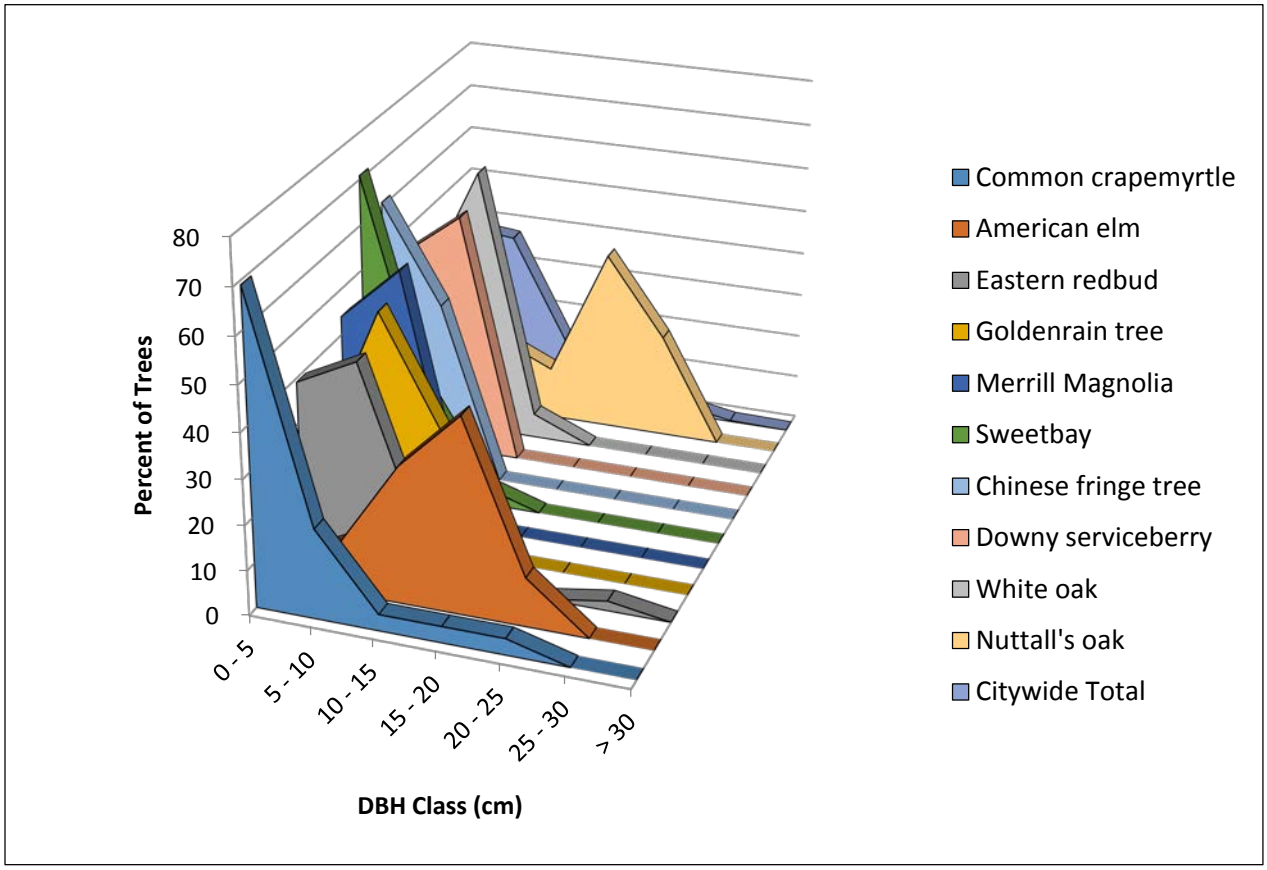

Figure 3. Size distributions of the ten most common surviving tree species.

Most (76% of) surviving re-inventoried trees were in the 0-5 or 5-10 cm size class (Figure 3). However, more than 40% of re-inventoried American elms and Nuttall's oaks were in the 15-20 cm size class. Interestingly, the Nuttall's oaks and American elms were not older than trees of other species, so they were either larger at planting or grew faster relative to other species. No trees in the re-inventory sample were larger than 30 cm (11.8 inches).

Overall Condition

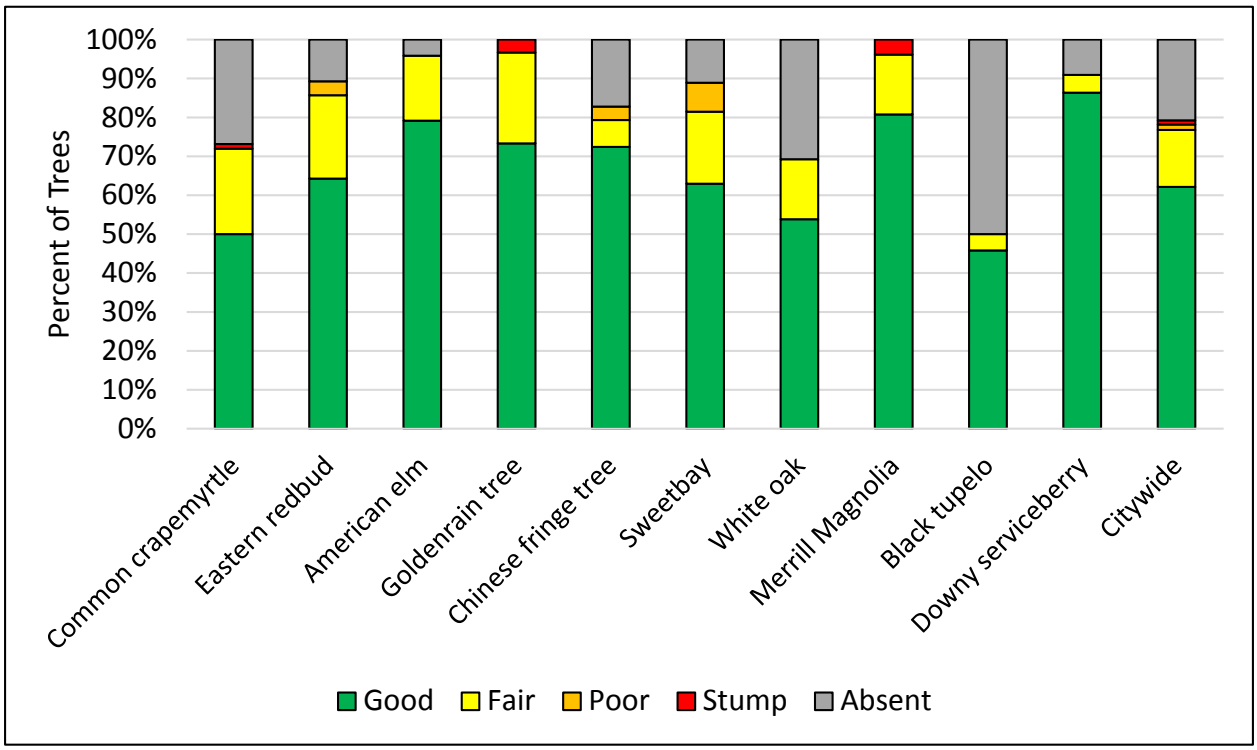

Figure 4. Frequency of overall condition ratings of the ten most common re-inventoried tree species.

Overall condition of living trees was rated in three categories: good, fair, and poor (Table 1). Sixty-two percent of all re-inventoried trees were in good condition, 15% were in fair condition, 1% were in poor condition, 1% only had a stump present, and 21% were absent (Figure 4). Overall condition ratings varied considerably among species; half of all black tupelo (*Nyssa sylvatica*) trees re-inventoried were absent, while more than 80% of all American elms, Merrill magnolia (*Magnolia* x *loebneri* 'Merrill'), and downy serviceberry (*Amelanchier arborea*) trees re-inventoried were in good condition.

Table 1. Explanation of overall condition ratings. From Vogt et al. 2014.

Rating	Explanation
Good	Full canopy, minimal to no mechanical damage to trunk, no branch dieback over 5 cm (2”) in diameter, no suckering (root or water sprouts), form is characteristic of species.
Fair	Thinning canopy, new growth in medium to low amounts, tree may be stunted, significant mechanical damage to trunk (new or old), insect/disease is visibly affecting the tree, form not representative of species, premature fall coloring on foliage, needs training pruning.
Poor	Tree is declining, visible dead branches over 5 cm (2”) in diameter in canopy, significant dieback of other branches in inner and outer canopy, severe mechanical damage to trunk usually including decay from damage, new foliage is small, stunted or minimum amount of new growth, needs priority pruning of dead wood.

Leaf Area, Canopy Cover, and Benefit Estimates from i-Tree Streets

Quantification of the canopy cover and other benefits provided by trees can help justify the costs of tree plantings. We used i-Tree Streets, a program developed by the U.S. Forest Service and Davey Resource Group, to estimate the total leaf area, canopy cover, and benefits provided by the re-inventoried trees. i-Tree Streets takes into account the species and size class of each tree in calculating leaf area and canopy cover and incorporates the energy costs and climate of the region in calculating benefits.

Leaf Area and Canopy Cover Estimates:

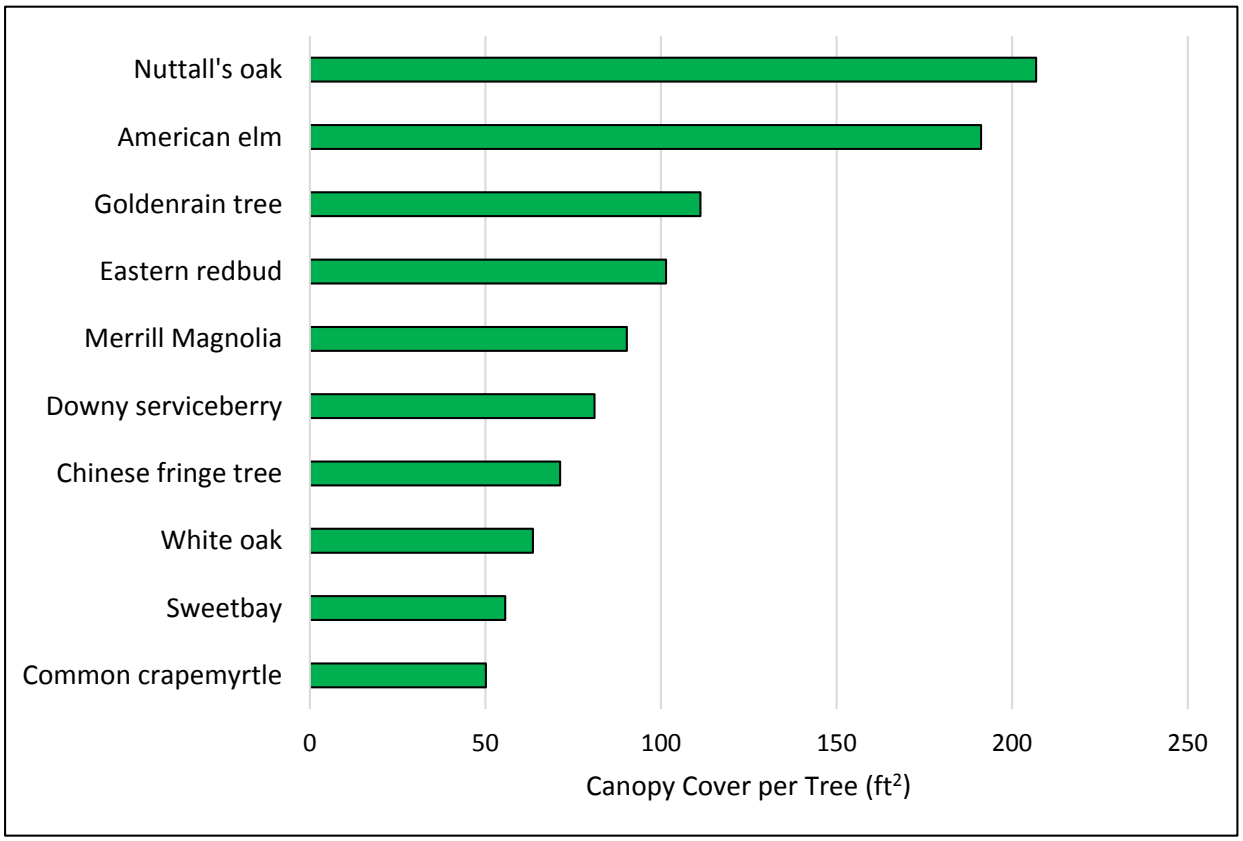

Figure 5. Average estimated canopy cover per tree (ft^2) of the ten most common surviving tree species.

Re-inventoried trees provide 4,000 m^2 (43,000 ft^2) of canopy cover and 5,600 m^2 (60,000 ft^2) of total leaf area. Canopy cover is the area of ground shaded by the tree, while leaf area is the total surface area of all the leaves in a tree's crown. Leaf area can be significantly larger than canopy cover because additional vertical layers of leaves increase leaf area without increasing canopy cover. The average re-inventoried tree currently provides 9.3 m^2 (100 ft^2) of canopy cover. Of the ten most common surviving re-inventoried tree species, Nuttall's oaks and American elms provide the most canopy cover per tree, while sweetbay and common crape myrtle provide the least canopy cover per tree (Figure 5).

Benefit Estimates:

i-Tree Streets estimates benefits in five categories: energy, CO_2, air quality, stormwater, and aesthetic/other benefits. Energy benefits are the reduced building heating and cooling costs provided by the tree. CO_2 benefits value the carbon sequestered by the tree and CO_2 emissions avoided due to reduced energy usage. Air quality benefits take into account ozone, NO_2, SO_2, PM_{10}, and VOC uptake and avoidance. Stormwater benefits quantify the value of reduced stormwater runoff due to rain interception by the tree. Aesthetic benefits take into account the increase in property value associated with the tree. The method used to calculate benefit estimates is detailed by McPherson and colleagues (2006).

Table 2. Estimated total annual benefits provided by re-inventoried trees in Atlanta.

Benefit Type	Total Benefits	$/Tree	Percent of Total Benefits
Energy	$378	$0.88	6%
CO_2	$142	$0.33	2%
Air Quality	$154	$0.36	2%
Stormwater	$874	$2.04	13%
Aesthetic/Other	$5,089	$11.86	77%
Total Benefits	$6,637	$15.47	100%

Most of the estimated benefits provided by the re-inventoried trees are aesthetic (Table 2; Figure 6). We expect the aesthetic benefits to become relatively less important over time as the trees grow larger and contribute more to energy, stormwater, CO_2, and air quality benefits. Currently, American elms (*Ulmus americana*) contribute most to the total estimated benefits (Figure 7). Tree size makes a big difference in the leaf area, canopy cover, and benefits estimated by i-Tree. American elms and Nuttall's oaks had disproportionately large contributions to the estimated total benefits provided by re-inventoried trees because they were larger than other trees in the re-inventoried sample (Figure 3). See Appendix Table A2 for a full list of benefits per tree, by type, provided by each re-inventoried species.

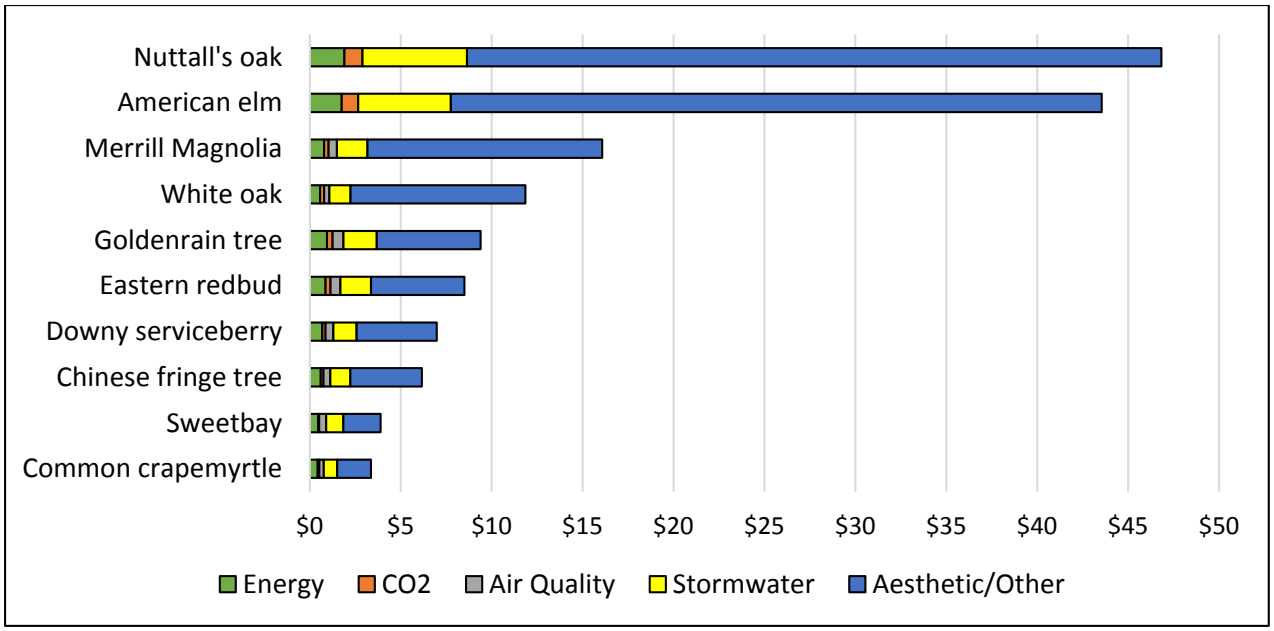

Figure 6. Estimated annual benefits per tree, by type, provided by the ten most common surviving tree species.

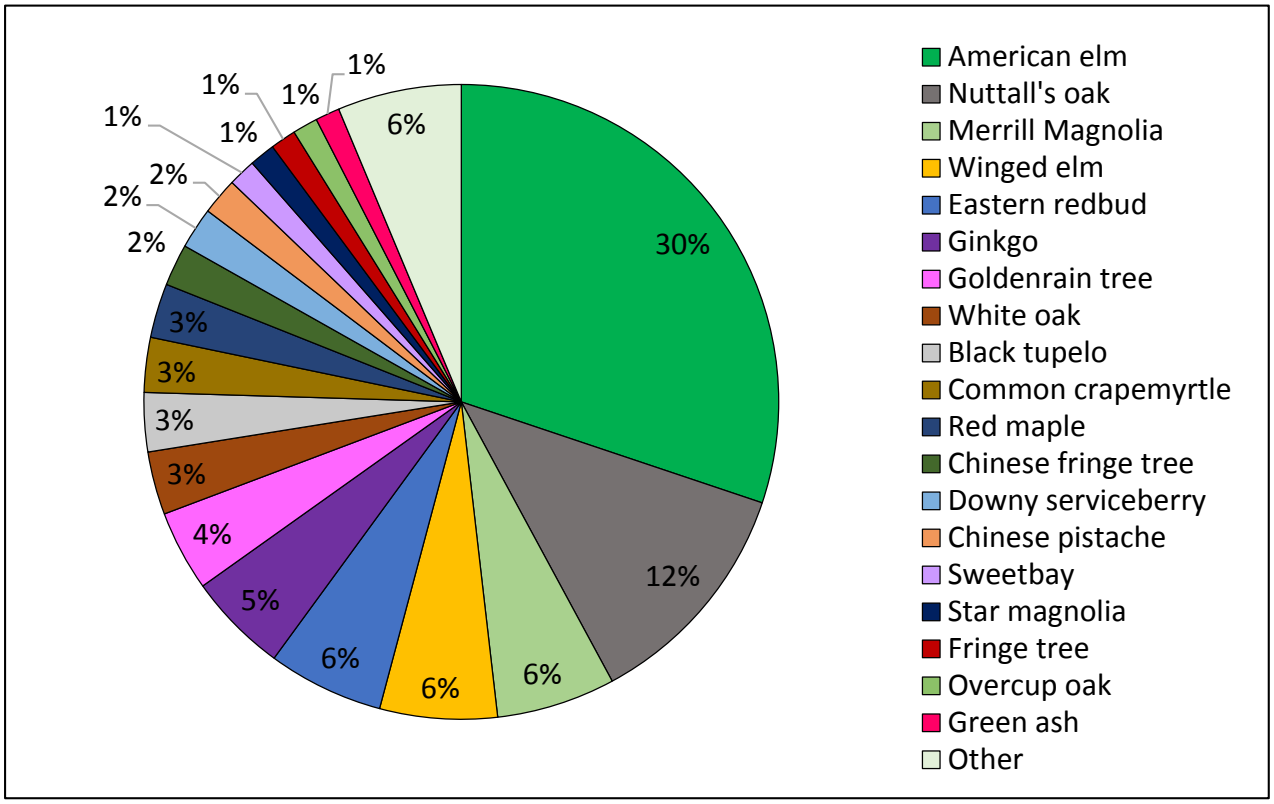

Figure 7. Each species' contribution to estimated total annual benefits. American elms provide 30% of estimated total annual benefits though they make up only 11% of total trees.

Tree Benefits: A Closer Look

Energy Benefits:

Re-inventoried trees provide an estimated $378 in annual energy benefits (Table 2). American elms (*Ulmus americana*) and Nuttall's oaks (*Quercus nuttallii*) both contribute disproportionately to total energy benefits (Figure 8). The top three contributors to estimated energy benefits are American elms (21% of total energy benefits), Eastern redbuds (11% of total energy benefits), and Nuttall's oaks (8% of total energy benefits).

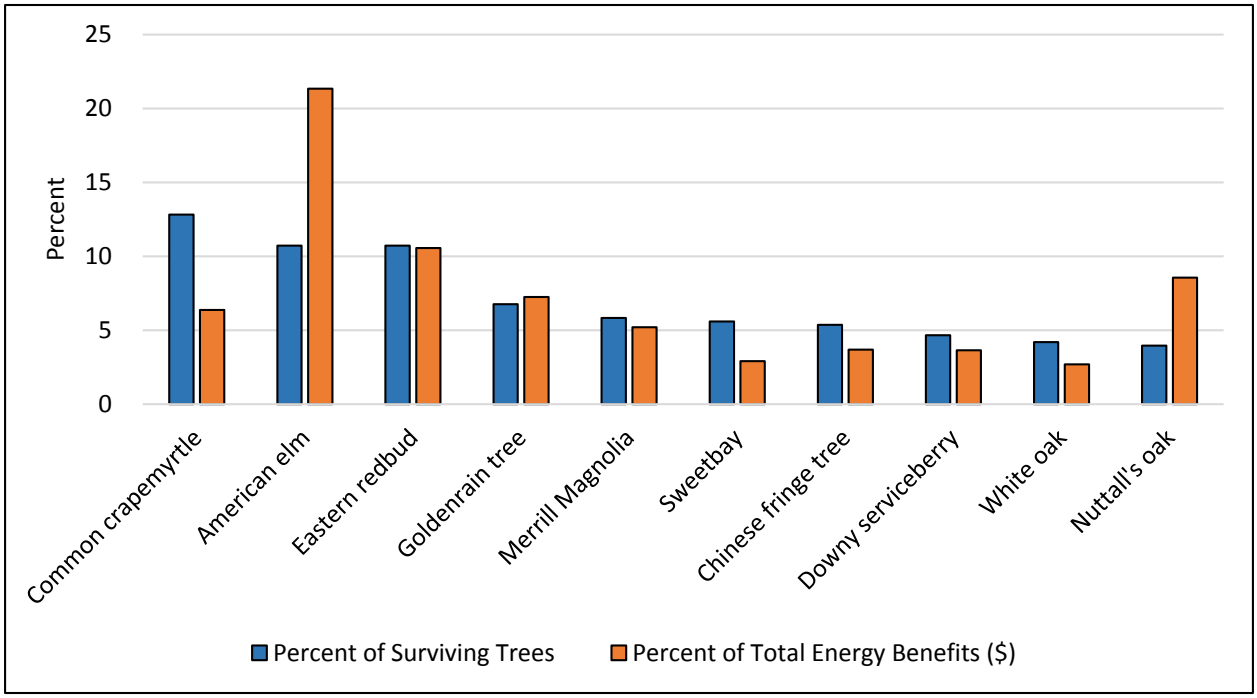

Figure 8. Percent of surviving trees compared to percent of estimated total annual energy benefits provided by the ten most common surviving tree species.

CO_2 Benefits:

All together, re-inventoried trees provide an estimated $142 in annual CO_2 benefits, which corresponds to 8,600 kg of CO_2 sequestered or avoided annually. Sequestered CO_2 refers to the volume of carbon stored in the tree as it grows larger each year, while avoided CO_2 refers to the carbon emissions avoided through reduced heating and cooling energy usage. Re-inventoried trees have been in the ground only 3-5 years and are therefore still relatively small in size, and small trees put on (sequester) less additional volume per year than larger trees.

All American elms in the re-inventory sample (46 trees with an average DBH of 5.7 in) sequester or avoid 2,500 kg of CO_2 (worth $42) each year. All Nuttall's oaks in the re-inventory sample (17 trees with an average DBH of 5.9 in) sequester or avoid 1,000 kg of CO_2 (worth $17) each year.

Air Quality Benefits:

All together, re-inventoried trees provide an estimated $154 in annual air quality benefits, representing uptake or avoidance of 4 kg of ozone, 6 kg of NO_2, 5 kg of PM_{10}, and 10 kg of SO_2 each year. Trees reduce air pollution directly by absorbing gaseous pollutants and intercepting small particles and indirectly by reducing energy usage, thereby reducing emissions from power plants (McPherson et al. 2006). These functions are dependent on tree size and leaf area, so annual air quality benefits will increase as the trees grow larger. Eastern redbuds, goldenrain trees, and common crape myrtle contribute most to estimated air quality benefits at 16%, 11%, and 9% of total air quality benefits, respectively.

Stormwater Benefits:

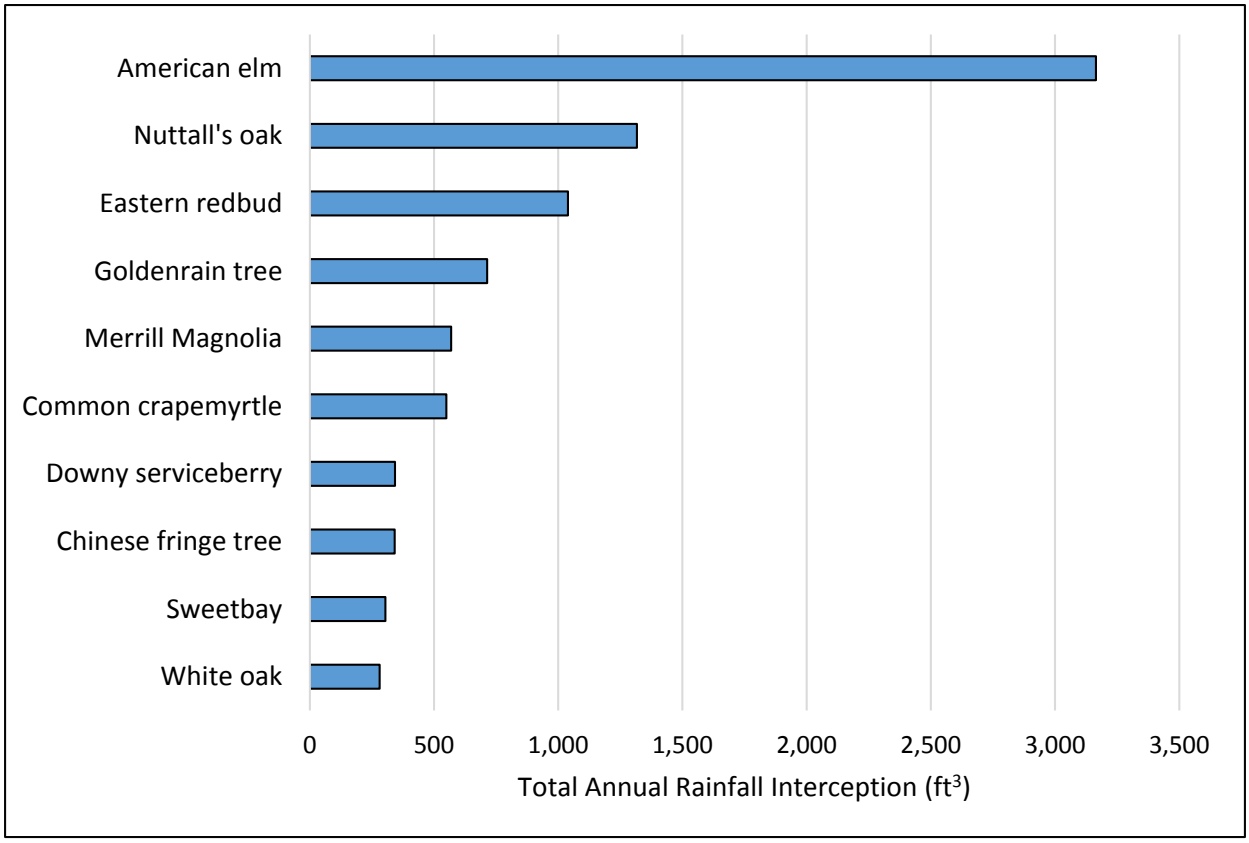

Figure 9. Estimated total rainfall (ft^3) intercepted annually by the ten most common surviving tree species.

Re-inventoried trees intercept an estimated 330 m^3 (12,000 ft^3) of rainfall each year and provide $874 in annual stormwater benefits. All American elm, Nuttall's oak, eastern redbud, and goldenrain trees together provide more than half of total stormwater benefits. American elms alone provide more than a quarter of total stormwater benefits, intercepting 90 m^3 (3,200 ft^3) of rainfall and providing $234 in estimated annual stormwater benefits each year.

Aesthetic/Property Value Benefits:

Most of the benefits provided by the re-inventoried trees are aesthetic benefits, quantified by an increase in property value. Aesthetic/property value benefit estimates in i-Tree Streets are dependent on tree size, but do not take into account whether a tree flowers or not (see Anderson and Cordell 1988 for supporting research). American elms and Nuttall's oaks contribute most to total aesthetic benefits (Table 3). The total annual aesthetic value of all re-inventoried trees was $5,089, an average of $11.86 per tree.

Table 3. Summary of the ten tree species that contribute most to estimated annual aesthetic benefits. American elms provide almost 1/3 of the total aesthetic benefits of re-inventoried trees.

Species	Average Aesthetic Benefits per Tree ($)	Total Aesthetic Benefits ($)	Percent of Total Aesthetic Benefits
Nuttall's oak	$38.19	$649	13%
American elm	$35.78	$1,646	32%
Winged elm	$28.88	$347	7%
Ginkgo	$18.73	$262	5%
Red maple	$16.79	$151	3%
Black tupelo	$15.57	$156	3%
Merrill Magnolia	$12.91	$323	6%
White oak	$9.61	$173	3%
Goldenrain tree	$5.71	$166	3%
Eastern redbud	$5.15	$237	5%

Structural/Replacement Value

A tree's structural (also called replacement) value is the amount it would cost to replace the planted tree and it depends on the tree's species, size, and condition rating. The total replacement value of the surviving re-inventoried trees is $147,000. American elms, Nuttall's oaks, and common crape myrtles contribute most to the replacement value at $28,000, $21,000, and $15,000, respectively. Assuming each tree costs $155 to plant (Peper et al. 2009), the initial cost of the re-inventoried trees would be $90,000. At this price, the value of trees planted from 2009 to 2011 exceed the costs after only 3-5 years of growth.

How Annual Benefits Change over a Tree's Lifetime

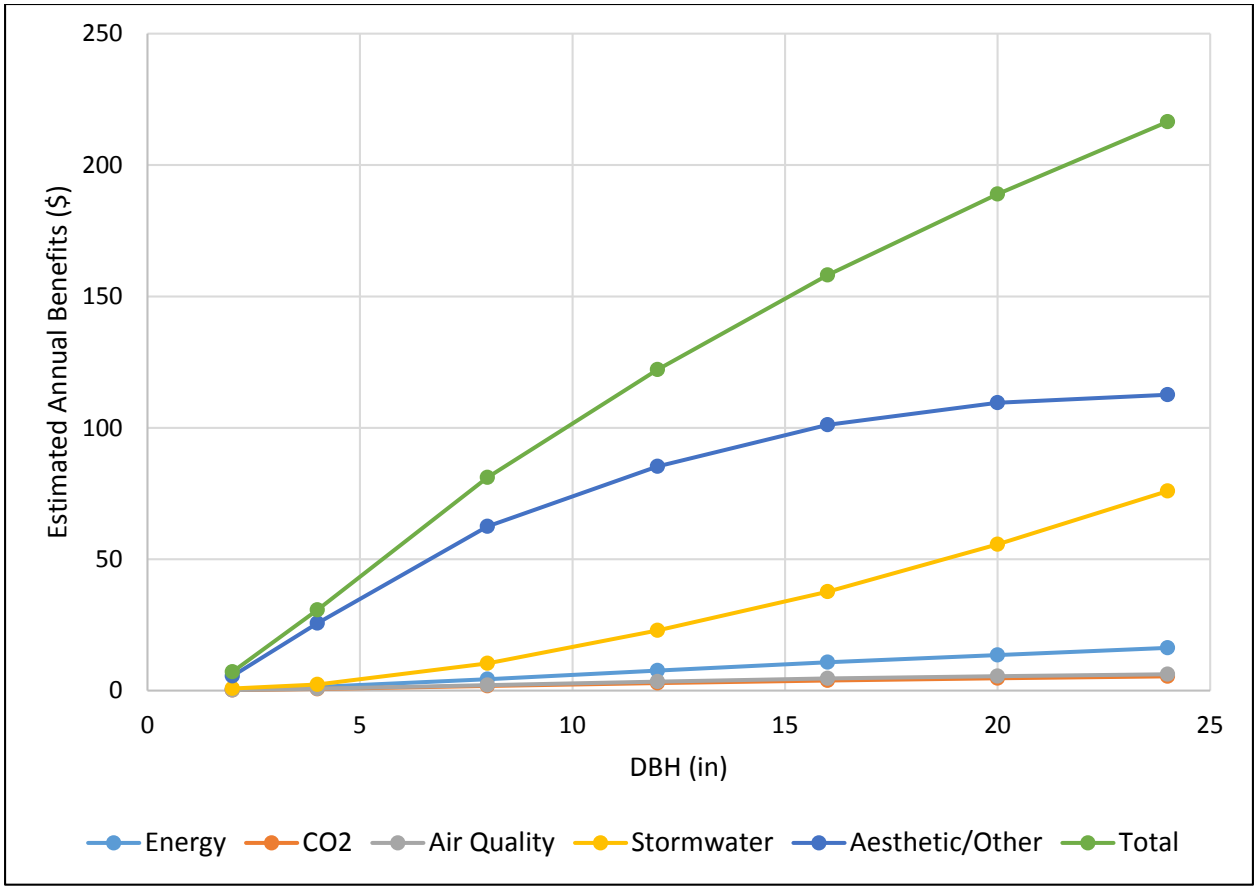

Figure 10. Estimated annual benefits of a sugar maple at different sizes up to 24 inches DBH in the South climate region.

We expect annual benefits to change over the lifetime of a tree in two ways: the total benefits increase, and the aesthetic benefits become relatively less important as stormwater and other benefit types become more important. Benefit types that are related to tree growth, such as CO_2 benefits, decline as the tree's growth slows. Energy, CO_2, and air quality benefits remain small relative to other benefit types because of the low cost of electricity and natural gas, carbon emissions, and air pollutants. i-Tree uses growth models based on urban tree data to predict how a tree's height, crown diameter, and leaf area will change over its lifetime (McPherson et al. 2006). For the hypothetical tree modeled in Figure 10, 52% of total benefits are aesthetic benefits, 35% are stormwater benefits, 7% are energy benefits, 3% are air quality benefits, and 3% are CO_2 benefits at 24 inches DBH.

Resources

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Appendix

Table A1. Scientific and common names, average DBH (inches) of surviving re-inventoried trees.

Scientific Name	Common Name	Number of Trees	Average DBH (in)
Tilia americana	American basswood	1	2.0
Ulmus americana	American elm	46	5.7
Carpinus caroliniana	American hornbeam	1	1.1
Taxodium distichum	Bald cypress	1	3.0
Nyssa sylvatica	Black tupelo	10	2.7
Chionanthus retusus	Chinese fringe tree	23	1.7
Pistacia chinensis	Chinese pistache	4	3.6
Lagerstroemia spp.	Common crape myrtle	55	2.2
Metasequoia glyptostroboides	Dawn redwood	6	1.7
Amelanchier arborea	Downy serviceberry	20	2.1
Cercis canadensis	Eastern redbud	46	2.6
Cornus florida	Flowering dogwood	5	1.1
Chionanthus virginicus	Fringe tree	11	2.2
Ginkgo biloba	Ginkgo	14	3.3
Koelreuteria paniculata	Goldenrain tree	29	2.9
Fraxinus pennsylvanica	Green ash	3	4.2
Crataegus viridis	Green hawthorn	1	2.2
Ilex spp.	Holly	8	1.5
Styrax japonicus	Japanese snowbell	5	1.1
Zelkova serrata	Japanese zelkova	1	7.2
Magnolia spp.	Merrill Magnolia	25	2.0
Quercus rubra	Northern red oak	2	2.0
Quercus nuttallii	Nuttall's oak	17	5.9
Quercus lyrata	Overcup oak	3	3.7
Quercus stellata	Post oak	2	1.3
Acer rubrum	Red maple	9	3.7
Quercus shumardii	Shumard oak	3	2.2
Quercus falcata	Southern red oak	3	2.5
Magnolia stellata	Star magnolia	11	2.2
Magnolia virginiana	Sweetbay	24	1.7
Acer buergeranum	Trident maple	5	4.5
Liriodendron tulipifera	Tulip tree	1	3.1
Quercus alba	White oak	18	2.4
Quercus phellos	Willow oak	1	3.0
Ulmus alata	Winged elm	12	2.9
Hamamelis virginiana	Witch hazel	2	1.6
Cladrastis kentukea	Yellowwood	1	2.0
Citywide Total	Citywide Total	429	2.9

Table A2. Estimated energy, CO_2, air quality, stormwater, aesthetic, and total benefits per tree for surviving re-inventoried trees.

Species	Energy Benefits	CO_2 Benefits	Air Quality Benefits	Stormwater Benefits	Aesthetic Benefits	Total Benefits
American basswood	$0.68	$0.29	$0.21	$1.44	$13.47	$16.08
American elm	$1.75	$0.91	-$0.04	$5.10	$35.78	$43.50
American hornbeam	$0.23	$0.04	$0.13	$0.49	$6.35	$7.24
Bald cypress	$0.68	$0.29	$0.21	$1.44	$13.47	$16.08
Black tupelo	$1.06	$0.36	$0.61	$2.33	$15.57	$19.94
Chinese fringe tree	$0.61	$0.14	$0.38	$1.10	$3.93	$6.16
Chinese pistache	$1.82	$0.66	$1.05	$4.03	$23.54	$31.10
Common crape myrtle	$0.44	$0.08	$0.25	$0.74	$1.86	$3.37
Dawn redwood	$0.19	$0.05	$0.08	$0.36	$2.19	$2.87
Downy serviceberry	$0.69	$0.18	$0.43	$1.27	$4.41	$6.98
Eastern redbud	$0.87	$0.28	$0.55	$1.67	$5.15	$8.51
Flowering dogwood	$0.40	$0.06	$0.25	$0.68	$2.76	$4.15
Fringe tree	$0.78	$0.22	$0.49	$1.46	$4.94	$7.89
Ginkgo	$1.34	$0.47	$0.77	$2.92	$18.73	$24.23
Goldenrain tree	$0.94	$0.31	$0.60	$1.82	$5.71	$9.39
Green ash	$1.08	$0.51	$0.21	$2.57	$23.01	$27.38
Green hawthorn	$0.92	$0.28	$0.58	$1.75	$5.75	$9.29
Holly	$0.29	$0.08	$0.27	$0.45	$1.00	$2.08
Japanese snowbell	$0.40	$0.06	$0.25	$0.68	$2.76	$4.15
Japanese zelkova	$2.18	$1.15	-$0.16	$6.61	$44.15	$53.92
Merrill Magnolia	$0.79	$0.25	$0.45	$1.69	$12.91	$16.08
Northern red oak	$0.24	$0.23	$0.09	$0.59	$6.97	$8.11
Nuttall's oak	$1.90	$1.00	-$0.13	$5.74	$38.19	$46.70
Overcup oak	$1.62	$0.58	$0.94	$3.56	$21.71	$28.41
Post oak	$0.19	$0.05	$0.08	$0.36	$2.19	$2.87
Red maple	$0.85	$0.44	$0.45	$1.87	$16.79	$20.40
Shumard oak	$0.51	$0.21	$0.16	$1.08	$9.71	$11.68
Southern red oak	$0.72	$0.32	$0.17	$1.64	$14.48	$17.33
Star magnolia	$0.78	$0.22	$0.49	$1.46	$4.94	$7.89
Sweetbay	$0.46	$0.06	$0.39	$0.94	$2.05	$3.89
Trident maple	$1.30	$0.51	$0.82	$2.61	$7.44	$12.68
Tulip tree	$0.68	$0.29	$0.21	$1.44	$13.47	$16.08
White oak	$0.57	$0.22	$0.30	$1.16	$9.61	$11.85
Willow oak	$0.68	$0.29	$0.21	$1.44	$13.47	$16.08
Winged elm	$0.70	$0.37	$0.42	$2.70	$28.88	$33.06
Witch hazel	$0.66	$0.17	$0.42	$1.22	$4.26	$6.72
Yellowwood	$1.22	$0.41	$0.71	$2.63	$18.06	$23.02
Citywide Total	$0.88	$0.33	$0.36	$2.04	$11.86	$15.47