Keep Indianapolis Beautiful

Planted Tree Re-Inventory Report:

Survival, Condition, and Benefits of Recently Planted Trees

Prepared by Sarah Widney
Bloomington Urban Forestry Research Group at CIPEC
Indiana University – Bloomington
February 2015

February 2015

Table of Contents

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 Keep Indianapolis Beautiful, Inc., with emphasis on benefit estimates generated using i-Tree Streets.

Summary of Results

Teams of volunteers, supervised by Keep Indianapolis Beautiful, Inc. (KIB), re-inventoried 1,076 trees in Indianapolis in June and July of 2014. These trees were selected from a list of 11,240 trees planted by KIB from 2009 to 2011. At the time of re-inventory, 80% of these recently planted trees had survived. Highlights of the tree analysis are:

- Most (64% of) re-inventoried trees were found to be in good condition.
- Average diameter at breast height (DBH) of surviving trees was 3.8 cm (1.5 inches).
- Re-inventoried trees provide almost $16,000 in annual benefits, an average of $20 per tree.
- Re-inventoried trees provide more than 2,000 m^2 (23,000 ft^2) of canopy cover.
- American elm (*Ulmus americana*) was the most common species of surviving re-inventoried trees (Figure 1).
- Oak (*Quercus*) was the most common genus of surviving re-inventoried trees (Figure 2).
- American elms provide the most canopy cover and highest total benefits.
- All 11,240 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 $182,000 in total annual benefits.

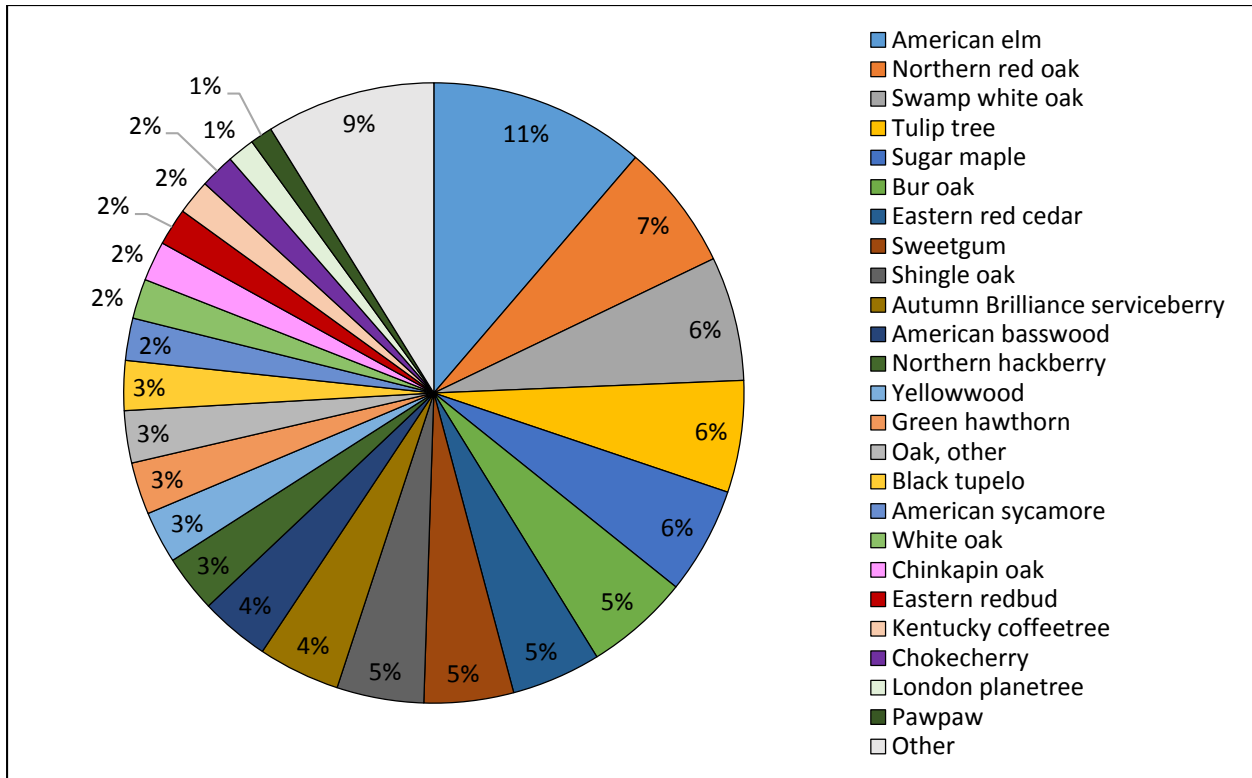**Figure 1. Species distribution of surviving re-inventoried trees planted by KIB from 2009 to 2011. "Other" includes species that each make up less than 1% of the population – see Appendix Table A1 for a full list of species.**
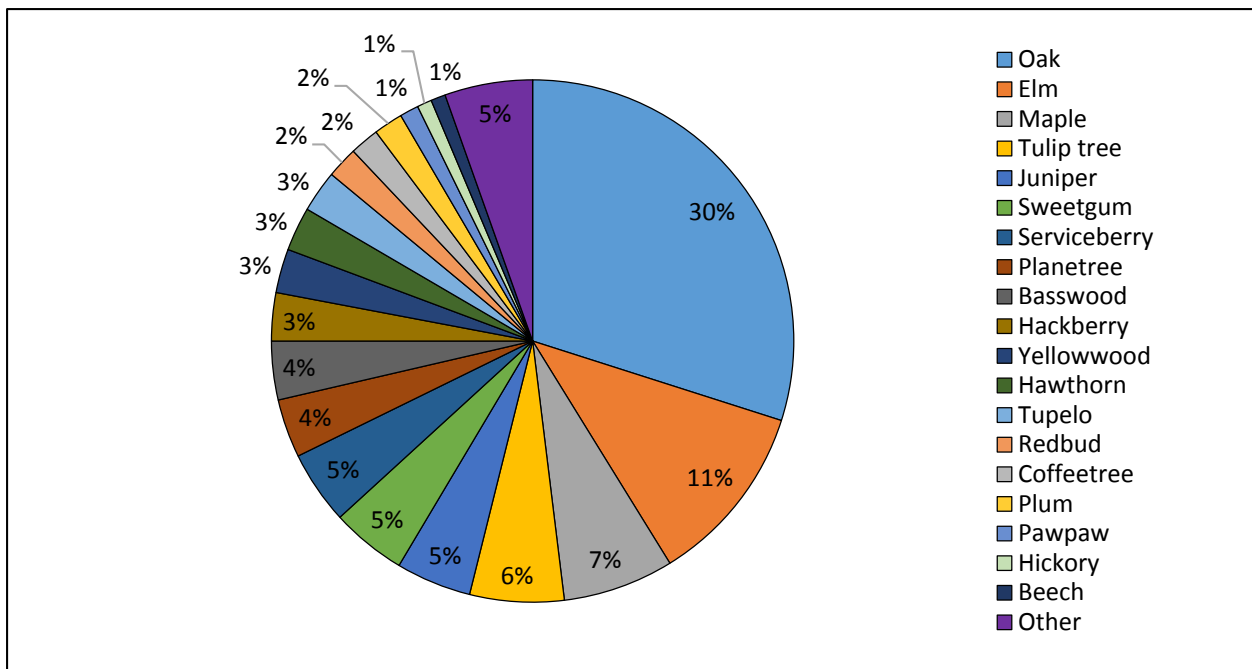

Figure 2. Genus distribution of surviving re-inventoried trees planted by KIB from 2009 to 2011. "Other" includes genera that each make up less than 1% of the population.

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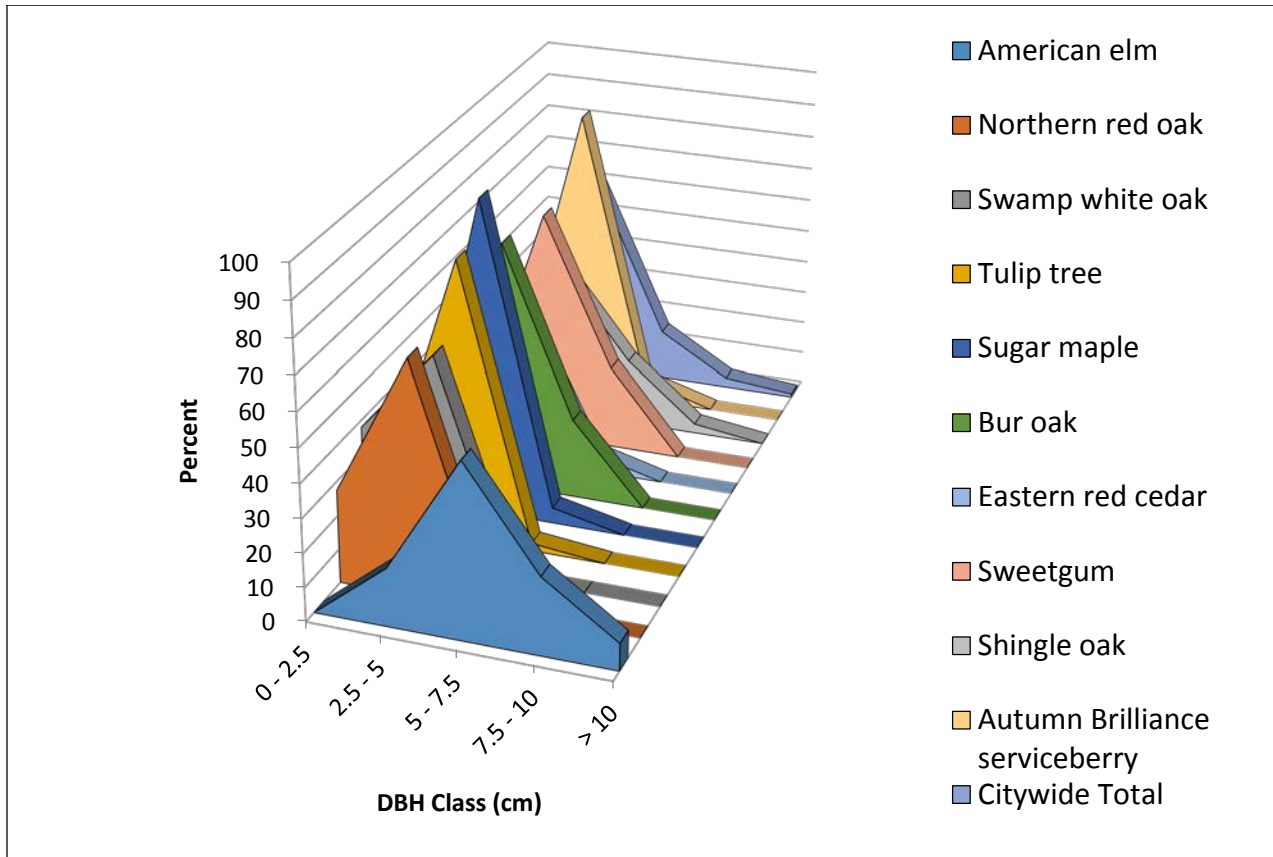
Figure 3. Size distributions of the ten most common surviving tree species.

Most (60% of) surviving re-inventoried trees were in the 2.5-5.0 cm size class (Figure 3). However, more than half of re-inventoried American elms were in the 5.0-7.5 cm size class. The 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 15 cm.
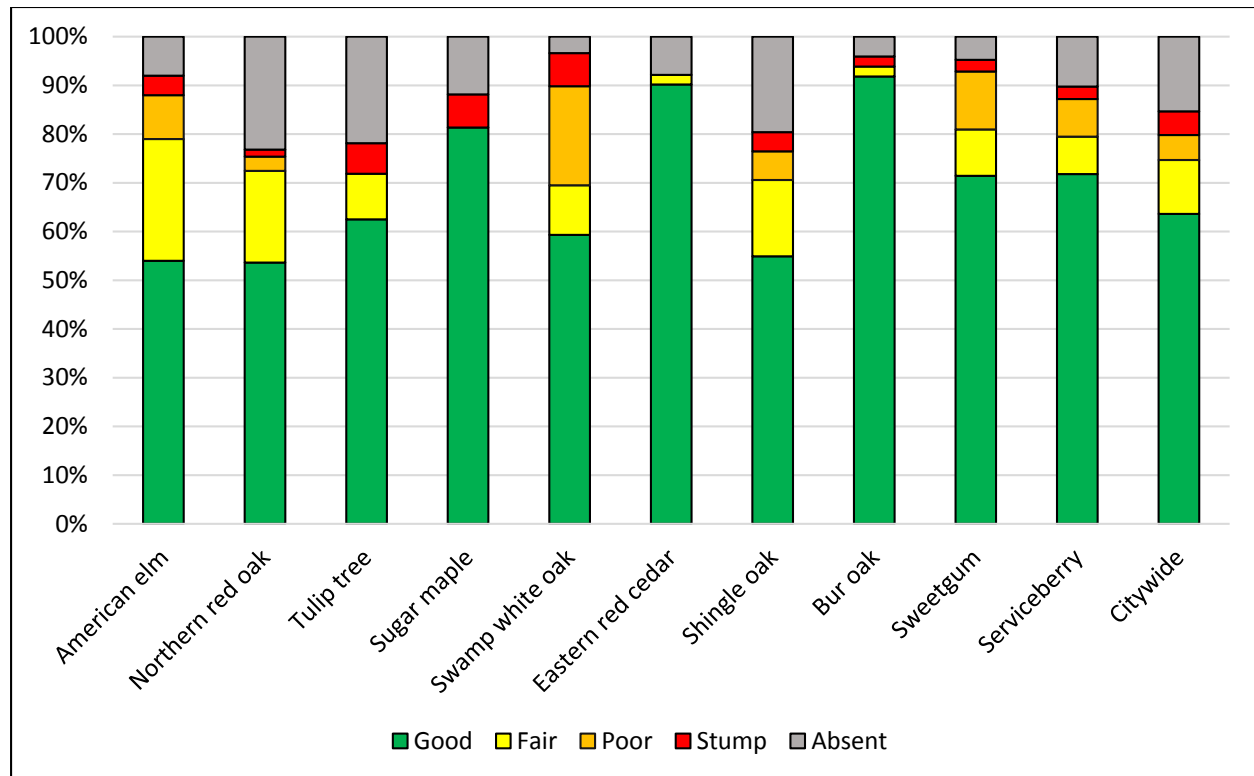
Overall Condition

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-four percent of all re-inventoried trees were in good condition, 11% were in fair condition, 5% were in poor condition, 5% only had a stump present, and 15% were absent (Figure 4). Overall condition ratings varied considerably among species; only 54% of re-inventoried Northern red oak (*Quercus rubra*) trees were in good condition, while more than 90% of re-inventoried Eastern red cedars (*Juniperus virginiana*) and bur oaks (*Quercus macrocarpa*) 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:
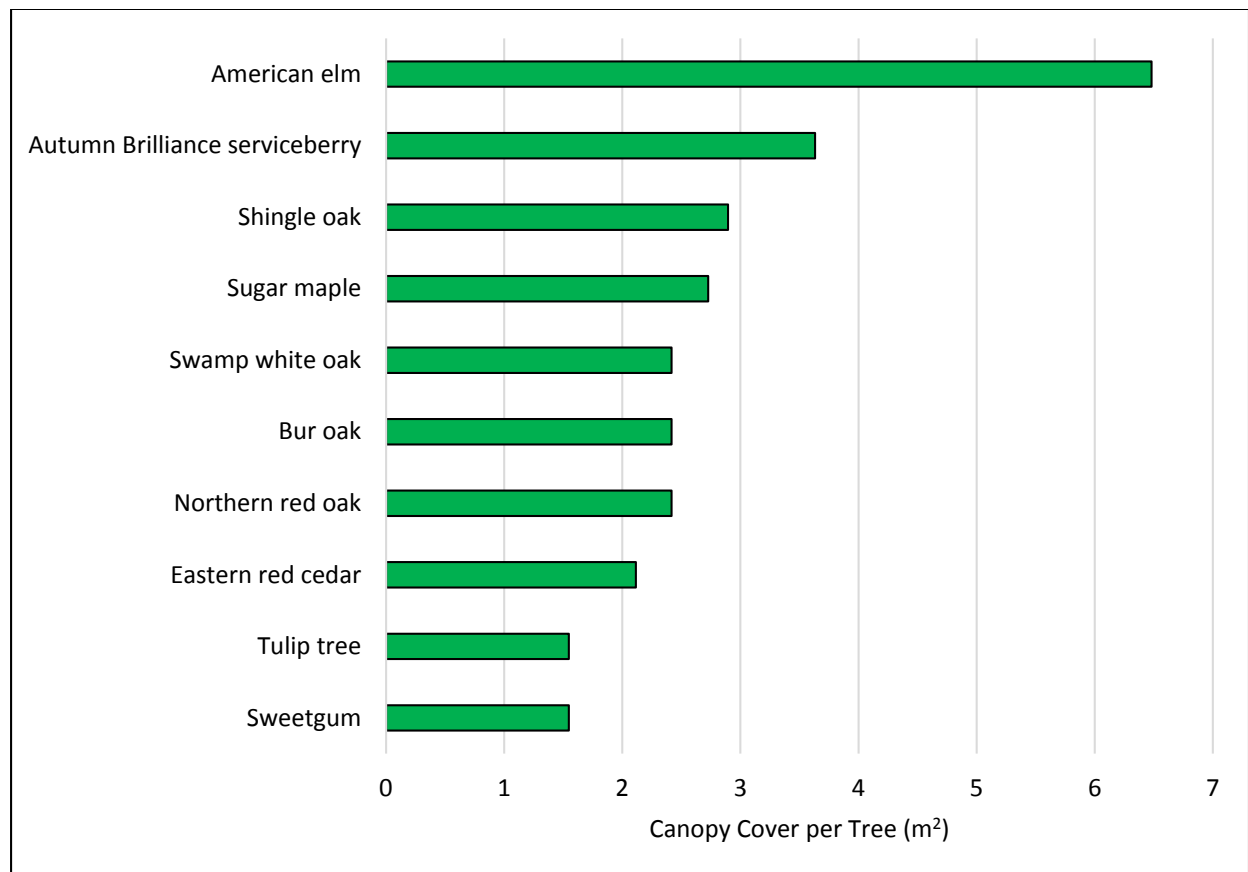
Figure 5. Average estimated canopy cover per tree (m^2) of the ten most common surviving tree species.

Re-inventoried trees provide 2,000 m^2 (23,000 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 2.8 m^2 (30 ft^2) of canopy cover. Of the ten most common surviving tree species, American elms provide the most canopy cover per tree, while sweetgums and tulip trees 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. Annual aesthetic value is calculated based on the tree's expected annual increase in leaf surface area and the expected property value increase per square foot of leaf surface area. The method used to calculate benefit estimates is detailed by Peper and colleagues (2009).

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

Benefit Type	Total Benefits	$/Tree	Percent of Total Benefits
Energy	$152	$0.20	1.0%
CO_2	$56	$0.07	0.4%
Air Quality	$70	$0.09	0.4%
Stormwater	$529	$0.69	3.4%
Aesthetic/Other	$14,828	$19.21	94.8%
Total Benefits	$15,635	$20.25	100%

Most (95%) 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 had a disproportionately large contribution 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.
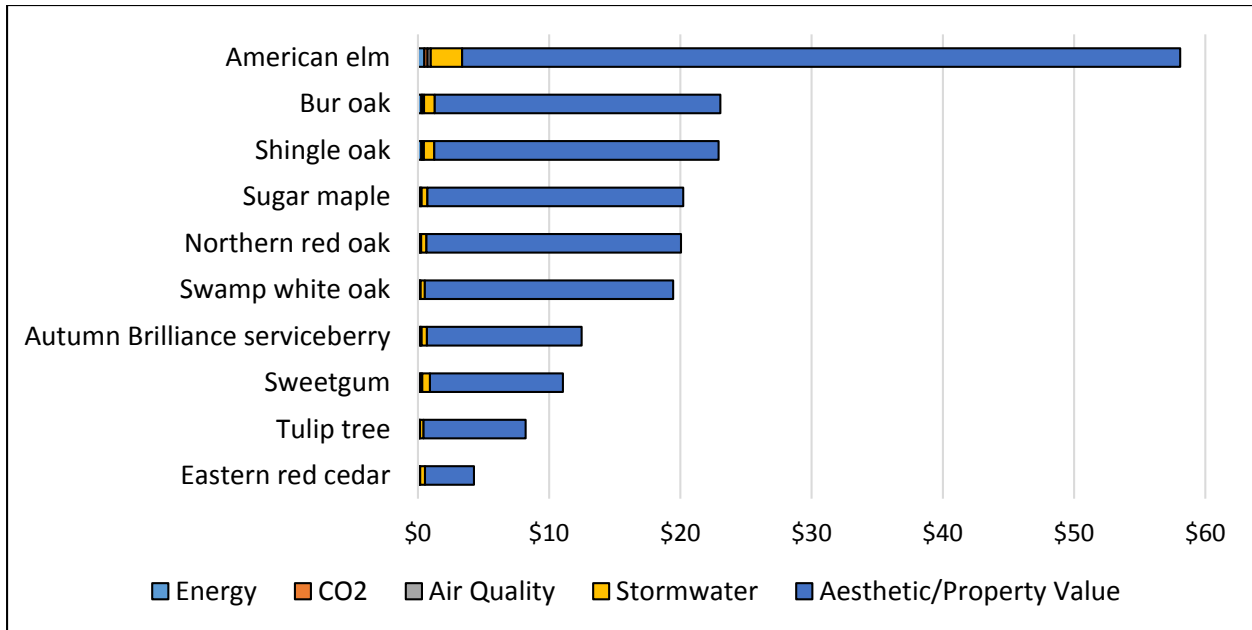
Figure 6. Estimated annual benefits per tree, by type, provided by the ten most common surviving tree species.
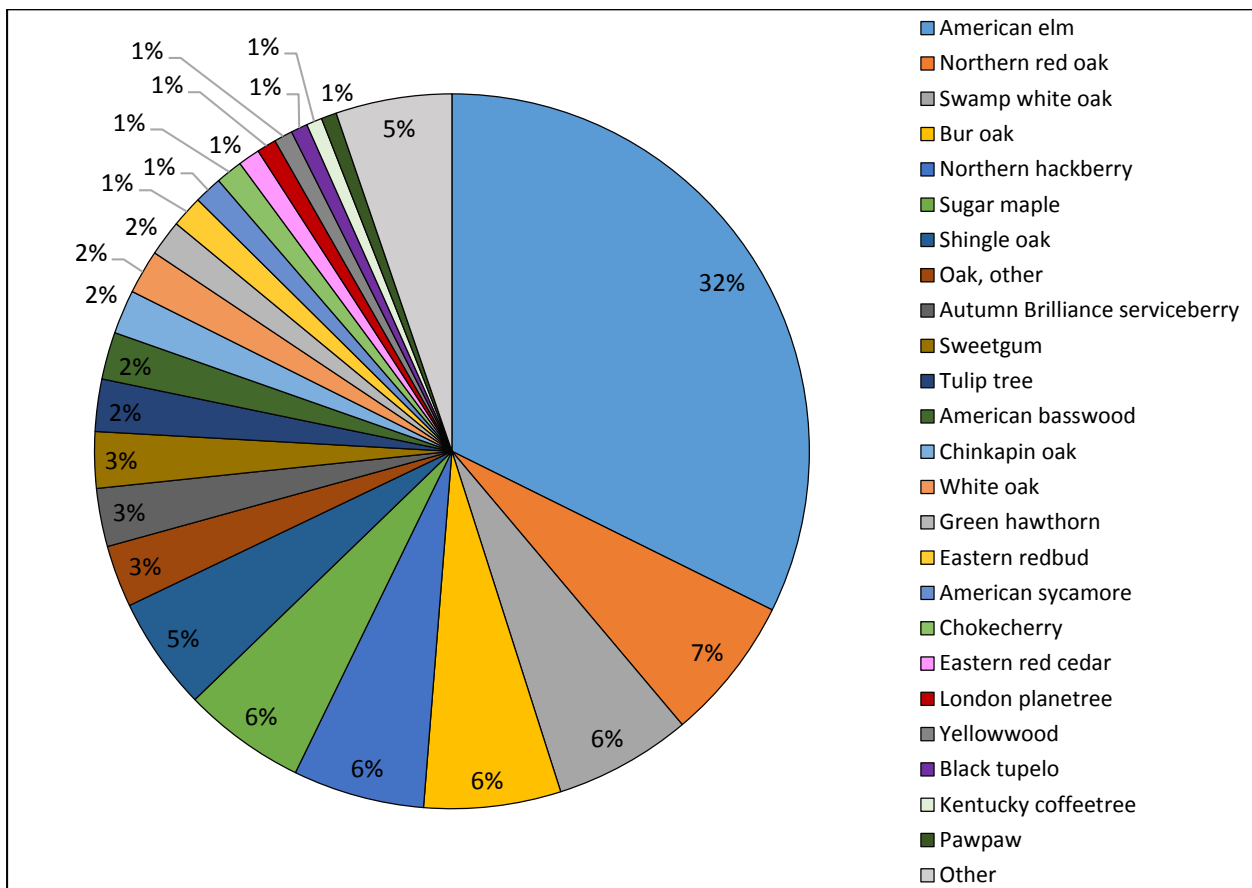

Figure 7. Each species' contribution to estimated total annual benefits. American elms provide 32% of estimated total annual benefits though they make up only 11% of total trees.

Tree Benefits: A Closer Look

Energy Benefits:

Re-inventoried trees provide an estimated $152 in annual energy benefits (Table 2). American elms (*Ulmus americana*), bur oaks, and shingle oaks contribute more energy benefits per tree than other species (Figure 8). The top three contributors to estimated energy benefits are American elms (28% of total energy benefits), bur oaks (7% of total energy benefits), and shingle oaks (6% of total energy benefits).
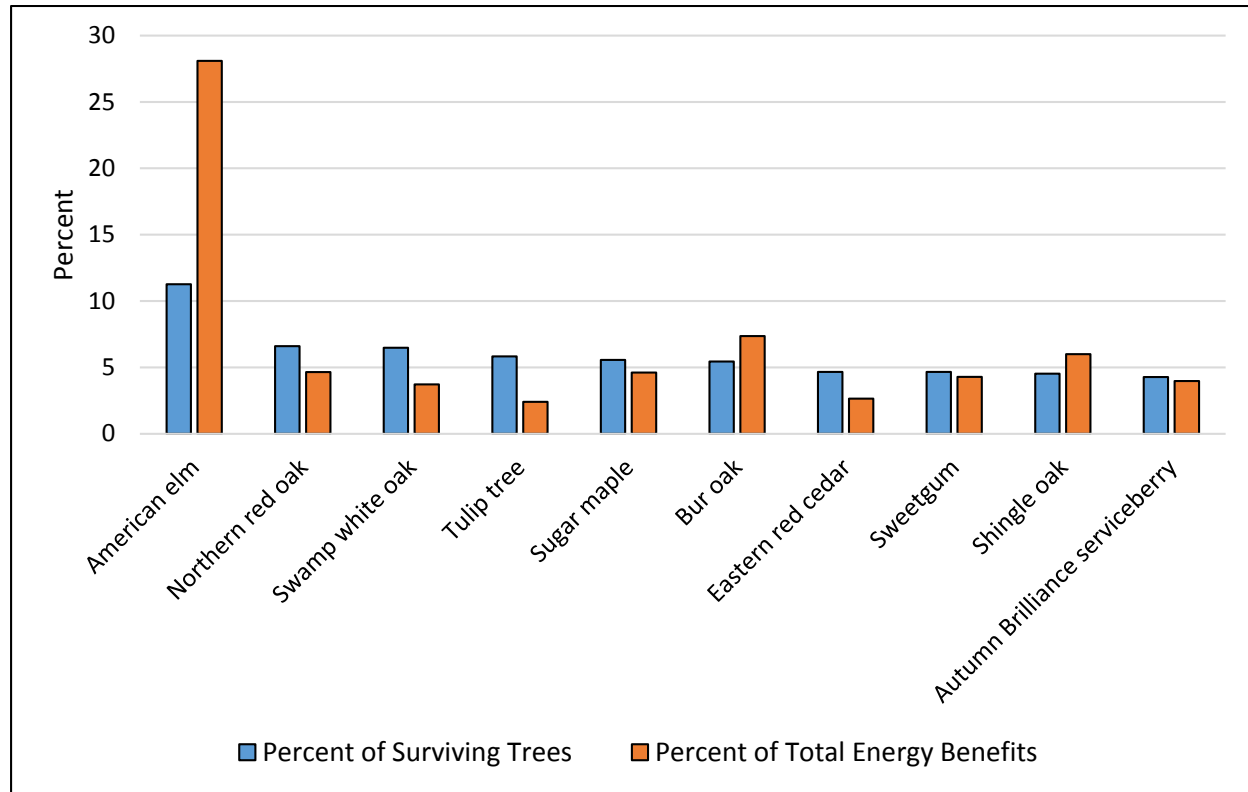
Figure 8. Percent of surviving trees compared to percent of estimated total annual energy benefits provided by the ten most common surviving tree species.

CO_2 Benefits:

All together, re-inventoried trees provide an estimated $56 in annual CO_2 benefits, which corresponds to 7,700 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 (87 trees with an average DBH of 2.6 in) sequester or avoid 2,860 kg of CO_2 (worth $21) each year. All bur oaks in the re-inventory sample (42 trees with an average DBH of 1.6 in) sequester or avoid 500 kg of CO_2 (worth $4) each year.

Air Quality Benefits:

All together, re-inventoried trees provide an estimated $70 in annual air quality benefits, representing uptake or avoidance of 7 kg of ozone, 4 kg of NO_2, 4 kg of PM_{10}, and 13 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 (Peper et al. 2009). These functions are dependent on tree size and leaf area, so annual air quality benefits will increase as the trees grow larger. American elms, bur oaks, and shingle oaks contribute most to estimated air quality benefits at 31%, 7%, and 5% of total air quality benefits, respectively.

Stormwater Benefits:
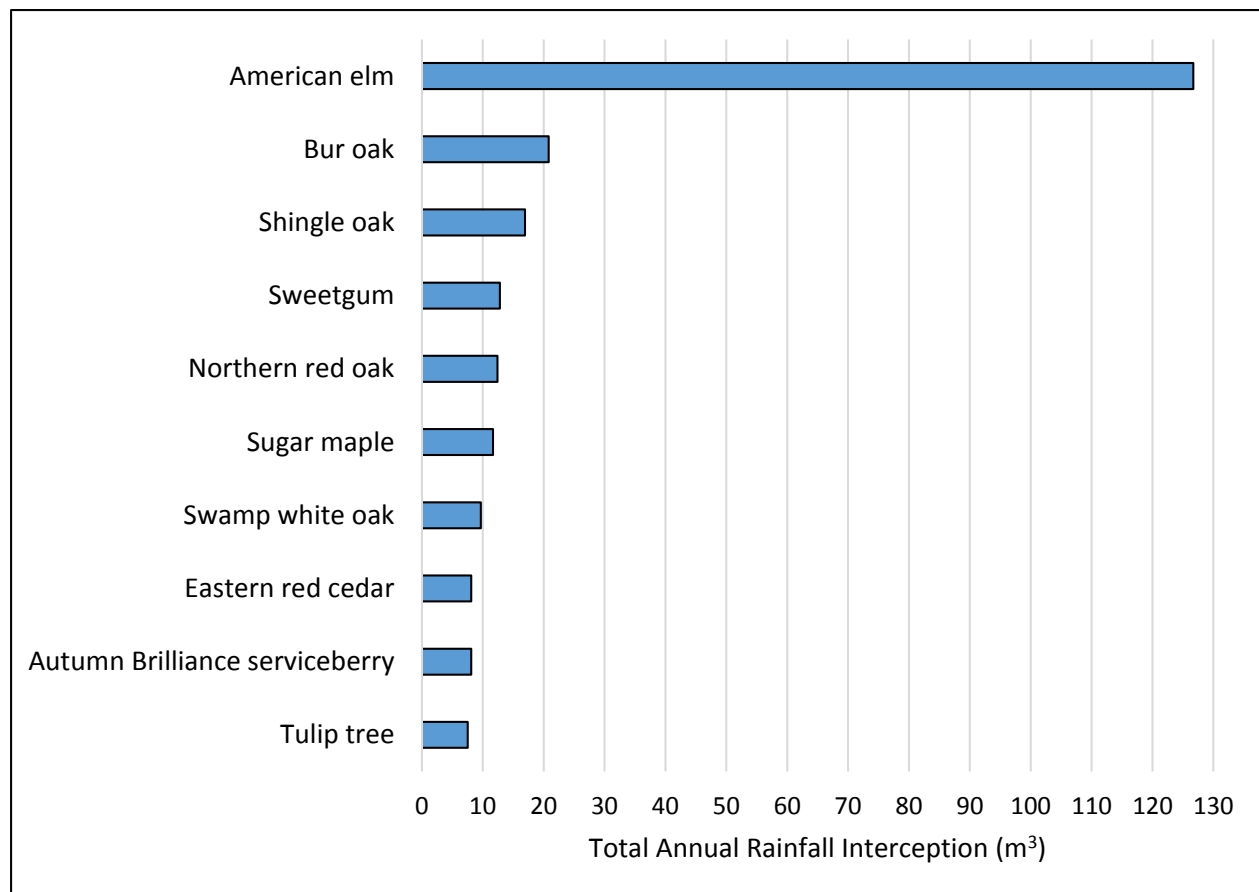
Figure 9. Estimated total rainfall (m³) intercepted annually by the ten most common surviving tree species.

Re-inventoried trees intercept an estimated 320 m³ (11,000 ft³) of rainfall each year and provide $530 in annual stormwater benefits. American elm, bur oak, and shingle oak trees together provide more than half of total stormwater benefits. American elms alone provide more than a third of total stormwater benefits, collectively intercepting 127 m³ (4,480 ft³) of rainfall and providing $208 in estimated annual stormwater benefits (Figure 9).

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 total leaf area, which is estimated based on DBH, but do not take into account whether a tree flowers or not (see Anderson and Cordell 1988 for supporting research). American elms contribute most to total aesthetic benefits (Table 3). The total annual aesthetic value of all re-inventoried trees was $14,828, an average of $19 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 annual aesthetic benefits of re-inventoried trees.

Species	Average Aesthetic Benefits per Tree	Total Aesthetic Benefits	Percent of Total Aesthetic Benefits
American elm	$55	$4,760	32%
Northern hackberry	$40	$917	6%
Bur oak	$22	$914	6%
Shingle oak	$22	$758	5%
Oak	$20	$421	3%
Sugar maple	$19	$838	6%
Northern red oak	$19	$989	7%
Swamp white oak	$19	$946	6%
Autumn Brilliance serviceberry	$12	$389	3%
Sweetgum	$10	$365	2%

Structural/Replacement Value

A tree's structural (also called replacement) value is the amount it would cost to replace the planted tree and depends on the tree's species, size, and condition rating. The total replacement value of the surviving re-inventoried trees is $223,000. American elms and Northern red oaks contribute most to the replacement value at $23,000 and $16,000, respectively. Assuming each tree costs $155 to plant (Peper et al. 2009), the initial cost of the re-inventoried trees would be $167,000. At this price, the value of trees planted from 2009-2011 exceed the costs after only 3-5 years of growth.

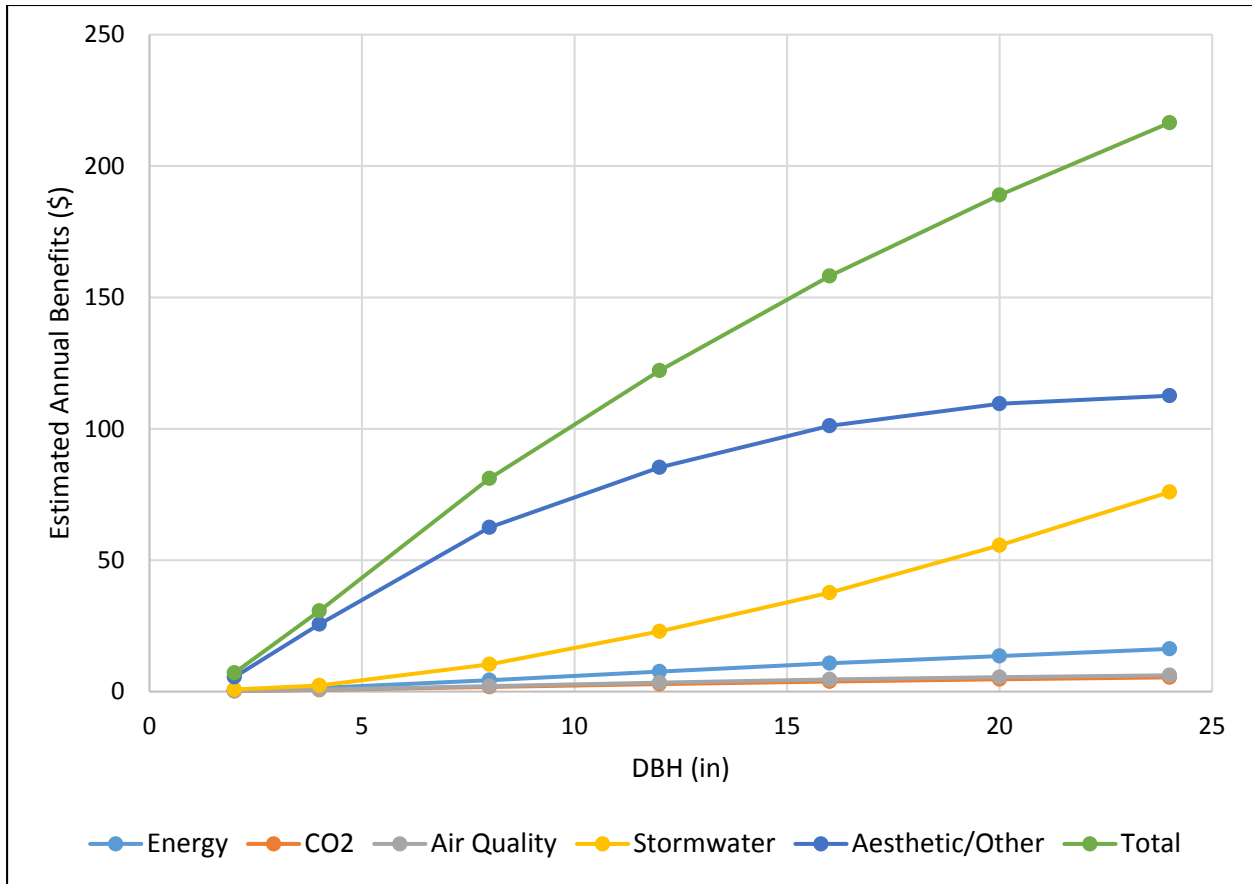**How Annual Benefits Change over a Tree's Lifetime**

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 (Peper et al. 2009). 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

Anderson, L.M. and Cordell, H.K. 1988. Influence of trees on residential property values in Athens, Georgia (U.S.A.): a survey based on actual sales prices. Landscape and Urban Planning 15: 153-164. Available from http://www.srs.fs.usda.gov/pubs/ja/ja_anderson003.pdf.

i-Tree Streets. i-Tree Software Suite v6.0.7. n.d. Available from http://www.itreetools.org.

Peper, P.J., McPherson, E.G., Simpson, J.R., Vargas, K.E., and Xiao, Q. 2009. Lower Midwest community tree guide: benefits, costs, and strategic planting. United States Department of Agriculture Forest Service Pacific Southwest Research Station General Technical Report PSW-GTR-219. Available from www.itreetools.org/streets/resources/Streets_CTG/PSW_GTR219_Lower_Midwest_CTG.pdf.

Vogt, J.M. and Fischer, B.C. 2014. A protocol for citizen science monitoring of recently-planted urban trees. Cities and the Environment (CATE) 7(2): Article 4. Available from http://digitalcommons.lmu.edu/cate/vol7/iss2/4/.

Vogt, J.M., Mincey, S.K., Fischer, B.C., and Patterson, M. 2014. Planted tree re-inventory protocol. Version 1.1. Bloomington, IN: Bloomington Urban Forestry Research Group at the Center for the Study of Institutions, Population and Environmental Change, Indiana University. Available from http://www.indiana.edu/~cipec/research/bufrg_protocol.php.

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)
Acer nigrum	Black maple	5	1.7
Acer rubrum	Red maple	4	2.2
Acer saccharum	Sugar maple	43	1.5
Acer spp.	Maple, other	1	2.0
Aesculus glabra	Ohio buckeye	1	1.0
Aesculus spp.	Buckeye	1	0.9
Amelanchier canadensis	Eastern serviceberry	2	1.9
Amelanchier x grandiflora	Autumn brilliance serviceberry	33	1.3
Asimina triloba	Pawpaw	9	0.9
Betula nigra	River birch	3	2.9
Carpinus caroliniana	American hornbeam	5	0.8
Carya cordiformis	Bitternut hickory	7	1.2
Catalpa speciosa	Northern catalpa	4	1.1
Celtis occidentalis	Northern hackberry	23	1.1
Cercis canadensis	Eastern redbud	15	1.7
Cladrastis kentukea	Yellowwood	21	1.1
Cornus florida	Flowering dogwood	1	1.2
Cornus spp.	Alternateleaf dogwood	3	0.7
Crataegus viridis	Green hawthorn	21	1.2
Diospyros virginiana	Common persimmon	3	1.1
Fagus grandifolia	American beech	7	1.0
Ginkgo biloba	Ginkgo	1	1.0
Gleditsia triacanthos	Honeylocust	2	2.2
Gymnocladus dioicus	Kentucky coffeetree	14	0.9
Halesia tetraptera	Carolina silverbell	1	0.6
Juglans nigra	Black walnut	1	2.6
Juniperus virginiana	Eastern red cedar	36	1.1
Liquidambar styraciflua	Sweetgum	36	1.6
Liriodendron tulipifera	Tulip tree	45	1.3
Metasequoia glyptostroboides	Dawn redwood	2	1.2
Nyssa sylvatica	Black tupelo	20	1.1
Ostrya virginiana	Eastern hophornbeam	5	1.3
Physocarpus opulifolius	Common ninebark	1	0.7
Pinus strobus	Eastern white pine	2	1.2
Platanus occidentalis	American sycamore	17	1.6
Platanus x acerifolia	London planetree	11	1.7
Prunus spp.	Chokecherry	14	1.7
Quercus alba	White oak	16	1.3

Quercus bicolor	Swamp white oak	50	1.0
Quercus imbricaria	Shingle oak	35	1.4
Quercus macrocarpa	Bur oak	42	1.6
Quercus muehlenbergii	Chinkapin oak	16	1.2
Quercus rubra	Northern red oak	51	1.2
Quercus spp.	Oak, other *	21	1.4
Rhus typhina	Skunkbush sumac	1	0.6
Taxodium distichum	Baldcypress	4	1.2
Tilia americana	American basswood	28	1.9
Ulmus americana	American elm	87	2.6
Viburnum spp.	Viburnum	1	0.7
Citywide Total	Citywide Total	772	1.5

*Oak, other includes overcup oak (*Quercus lyrata*), blackjack oak (*Q. marilandica*), swamp chestnut oak (*Q. michauxii*), willow oak (*Q. phellos*), and Shumard oak (*Q. shumardii*).

Table A2. Estimated annual 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
Acer nigrum	$0.17	$0.05	$0.07	$0.60	$15.25	$16.13
Acer rubrum	$0.50	$0.10	$0.21	$1.45	$19.22	$21.47
Acer saccharum	$0.16	$0.05	$0.07	$0.45	$19.49	$20.22
Acer spp.	$0.64	$0.12	$0.26	$1.85	$22.04	$24.92
Aesculus glabra	$0.05	$0.02	$0.02	$0.17	$5.62	$5.88
Aesculus spp.	$0.05	$0.02	$0.02	$0.17	$5.62	$5.88
Amelanchier canadensis	$0.35	$0.05	$0.17	$1.14	$13.97	$15.69
Amelanchier x *grandiflora*	$0.18	$0.02	$0.08	$0.40	$11.79	$12.47
Asimina triloba	$0.16	$0.02	$0.07	$0.30	$11.48	$12.03
Betula nigra	$0.58	$0.20	$0.26	$1.78	$17.03	$19.85
Carpinus caroliniana	$0.05	$0.02	$0.02	$0.17	$5.62	$5.88
Carya cordiformis	$0.07	$0.04	$0.03	$0.24	$7.55	$7.93
Catalpa speciosa	$0.10	$0.01	$0.04	$0.21	$25.71	$26.07
Celtis occidentalis	$0.10	$0.07	$0.04	$0.31	$39.89	$40.42
Cercis canadensis	$0.32	$0.04	$0.15	$0.97	$13.47	$14.95
Cladrastis kentukea	$0.07	$0.02	$0.03	$0.22	$5.91	$6.25
Cornus florida	$0.16	$0.02	$0.07	$0.30	$11.48	$12.03
Cornus spp.	$0.16	$0.02	$0.07	$0.30	$11.48	$12.03
Crataegus viridis	$0.16	$0.02	$0.07	$0.30	$11.48	$12.03
Diospyros virginiana	$0.05	$0.02	$0.02	$0.17	$5.62	$5.88
Fagus grandifolia	$0.07	$0.04	$0.03	$0.24	$7.55	$7.93

Ginkgo biloba	$0.07	$0.04	$0.03	$0.24	$7.55	$7.93
Gleditsia triacanthos	$0.44	$0.13	$0.22	$1.28	$13.07	$15.15
Gymnocladus dioicus	$0.07	$0.04	$0.03	$0.24	$7.55	$7.93
Halesia tetraptera	$0.05	$0.02	$0.02	$0.17	$5.62	$5.88
Juglans nigra	$0.44	$0.12	$0.23	$1.87	$36.86	$39.52
Juniperus virginiana	$0.11	$0.01	$0.05	$0.37	$3.72	$4.27
Liquidambar styraciflua	$0.18	$0.08	$0.08	$0.58	$10.13	$11.05
Liriodendron tulipifera	$0.08	$0.04	$0.04	$0.27	$7.78	$8.21
Metasequoia glyptostroboides	$0.07	$0.04	$0.03	$0.24	$7.55	$7.93
Nyssa sylvatica	$0.05	$0.02	$0.02	$0.17	$5.62	$5.88
Ostrya virginiana	$0.05	$0.02	$0.02	$0.17	$5.62	$5.88
Physocarpus opulifolius	$0.16	$0.02	$0.07	$0.30	$11.48	$12.03
Pinus strobus	$0.07	$0.01	$0.03	$0.40	$9.02	$9.52
Platanus occidentalis	$0.20	$0.08	$0.09	$0.64	$10.58	$11.60
Platanus x *acerifolia*	$0.23	$0.09	$0.11	$0.74	$11.30	$12.47
Prunus spp.	$0.24	$0.03	$0.11	$0.66	$12.55	$13.60
Quercus alba	$0.11	$0.05	$0.05	$0.32	$18.93	$19.45
Quercus bicolor	$0.11	$0.05	$0.05	$0.32	$18.93	$19.45
Quercus imbricaria	$0.26	$0.09	$0.11	$0.79	$21.66	$22.91
Quercus macrocarpa	$0.27	$0.09	$0.11	$0.81	$21.77	$23.05
Quercus muehlenbergii	$0.11	$0.05	$0.05	$0.32	$18.93	$19.45
Quercus rubra	$0.14	$0.05	$0.06	$0.40	$19.40	$20.05
Quercus spp.	$0.18	$0.06	$0.07	$0.51	$20.06	$20.89
Rhus typhina	$0.16	$0.02	$0.07	$0.30	$11.48	$12.03
Taxodium distichum	$0.07	$0.04	$0.03	$0.24	$7.55	$7.93
Tilia americana	$0.21	$0.09	$0.10	$0.68	$10.86	$11.94
Ulmus americana	$0.49	$0.24	$0.25	$2.39	$54.71	$58.08
Viburnum spp.	$0.16	$0.02	$0.07	$0.30	$11.48	$12.03
Citywide Total	$0.20	$0.07	$0.09	$0.69	$19.21	$20.25