The Greening of Detroit

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

Funders:
USDA Forest Service
National Urban & Community Forestry Advisory Council (NUCFAC)
USDA Forest Service, Northern Research Station

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 trees planted 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 through projects funded by these nonprofits from 2009 to 2011. This report presents the results of the re-inventory data analysis for The Greening of Detroit, with emphasis on benefit estimates generated using i-Tree Streets.

Summary of Results

Teams of volunteers, supervised by the Greening of Detroit, re-inventoried 1,241 trees in Detroit in June and July of 2014. These trees were selected from a list of 7,040 trees planted by the Greening of Detroit from 2009 to 2011. At the time of re-inventory, 79% of these recently planted trees had survived. Highlights of the tree analysis are:

- Most (72 % of) re-inventoried trees were found to be in good condition.
- Average diameter at breast height (DBH) of surviving trees was 5.2 cm (2 inches).
- Re-inventoried trees provide $8,500 in annual benefits, an average of $9 per tree.
- Re-inventoried trees provide almost 5,000 m^2 (50,000 ft^2) of canopy cover.
- Maple cultivars (Autumn Blaze maple) were the most common tree species (Figure 1).
- *Acer* was the most common genus of surviving trees (Figure 2).
- Northern hackberry (*Celtis occidentalis*) trees provide the most total annual benefits.
- London plane trees (*Platanus* x *acerifolia*) provide the most canopy cover.
- All 7,040 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 $50,000 in total annual benefits.

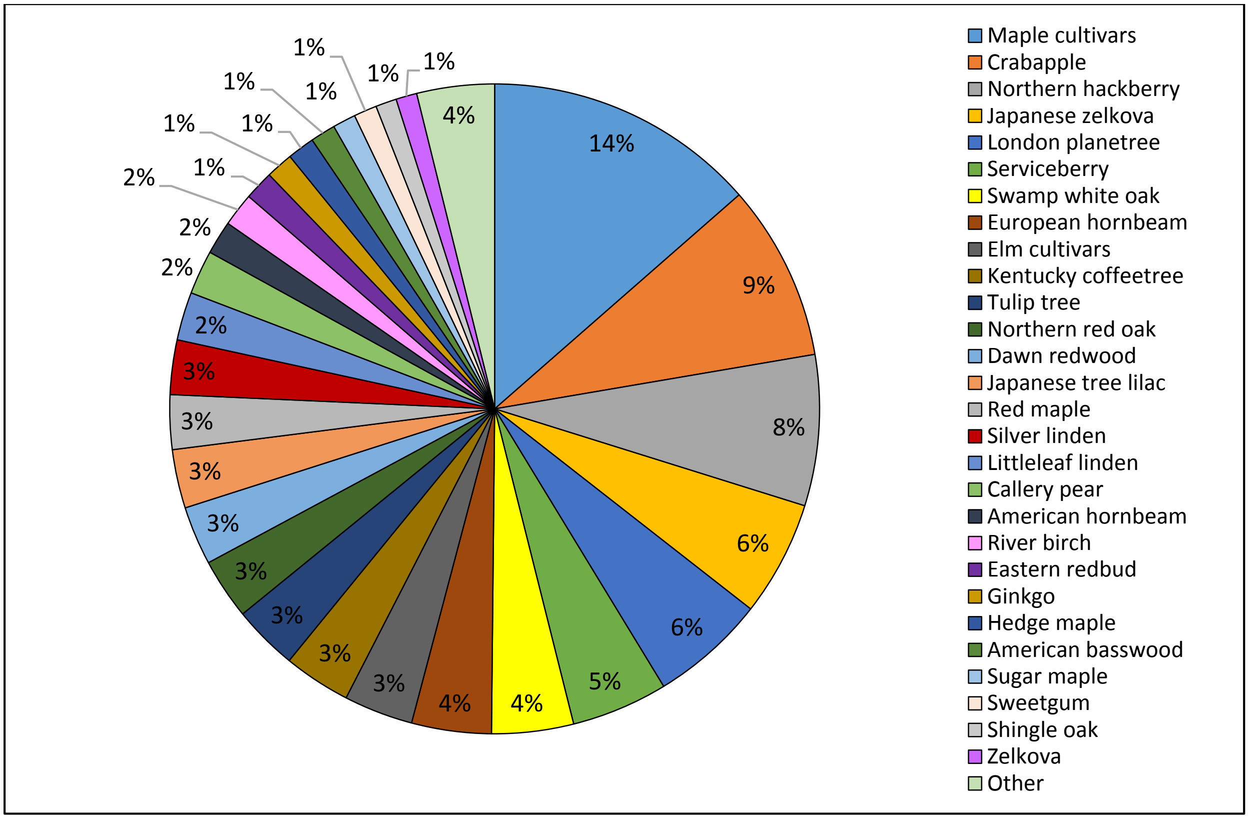

Figure 1. Species distribution of surviving re-inventoried trees planted by The Greening of Detroit from 2009 to 2011. "Other" includes species that each make up less than 1% of the population – see Appendix Table A1 for a full list of species.

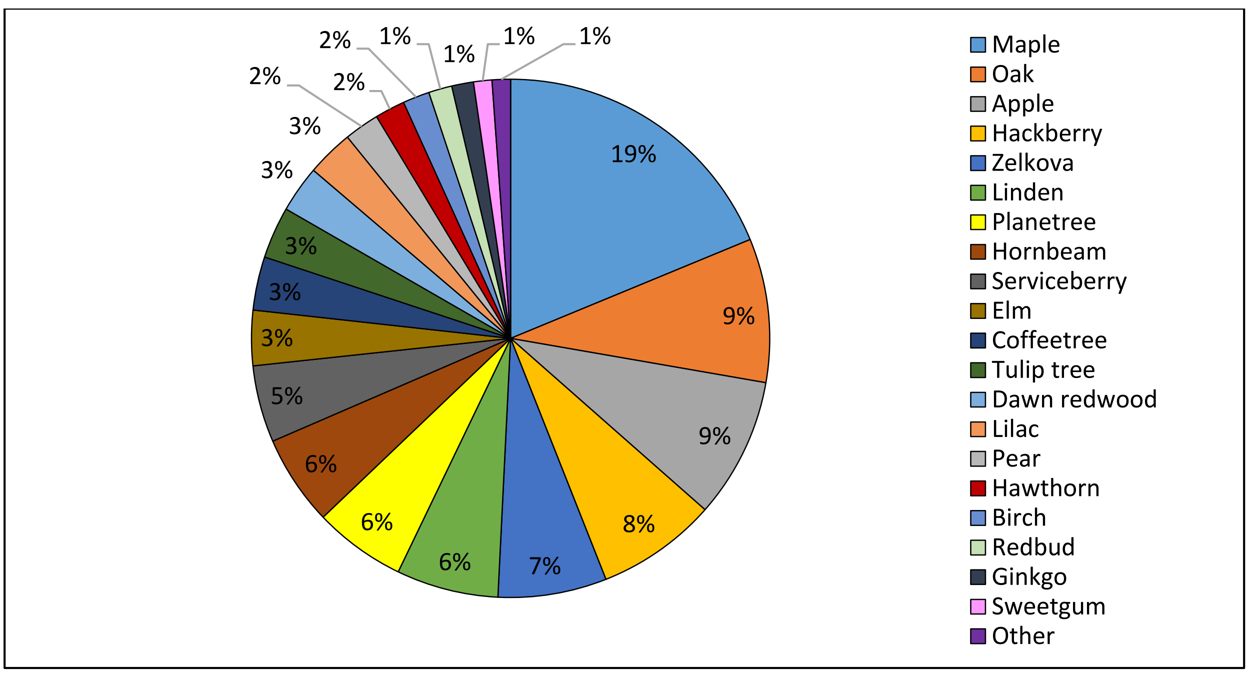

Figure 2. Genera of surviving re-inventoried trees planted by the Greening of Detroit from 2009 to 2011. "Other" includes genera that each make up less than 1% of the population.

Size Distribution

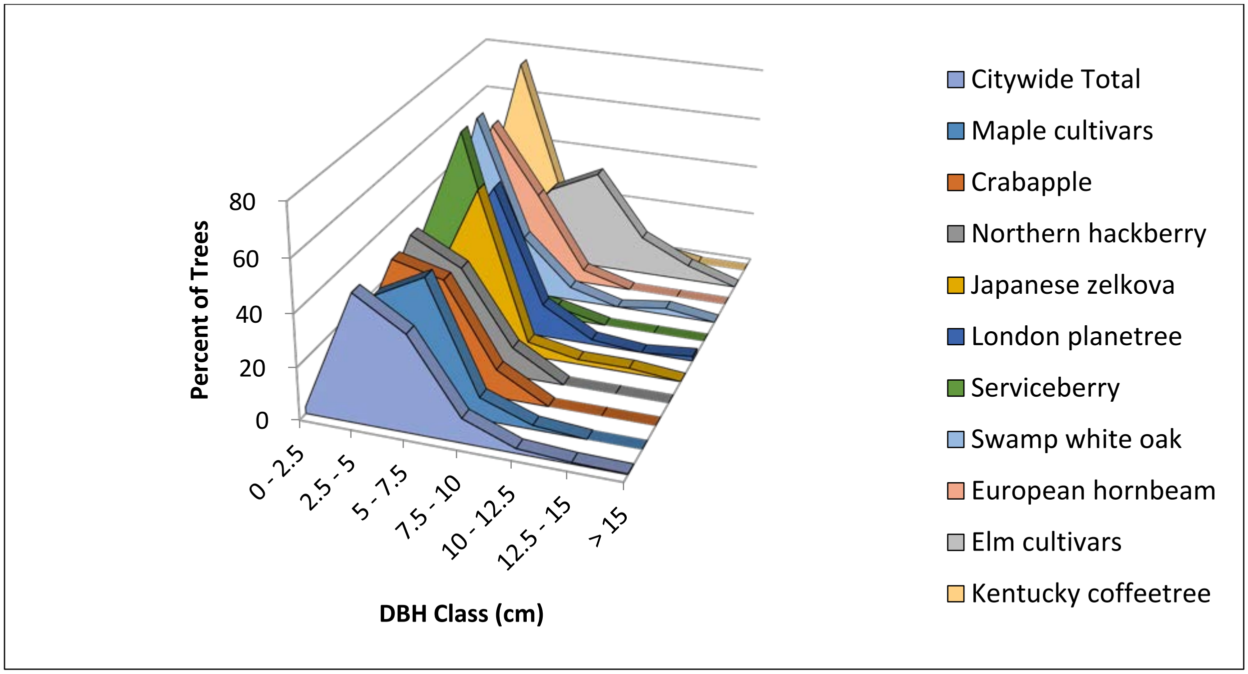

Figure 3. Size distribution of the ten most common surviving re-inventoried tree species.

Half of the surviving re-inventoried trees were in the 2.5-5 cm size class and 37% were in the 5-7.5 cm size class (Figure 3). Of the ten most common re-inventoried species, elm cultivars were the largest, with 30% of re-inventoried trees in the 5.0-7.5 cm size class, 40% of trees in the 7.5-10 cm size class, and an average DBH of 3.3 inches (8.3 cm).

Overall Condition

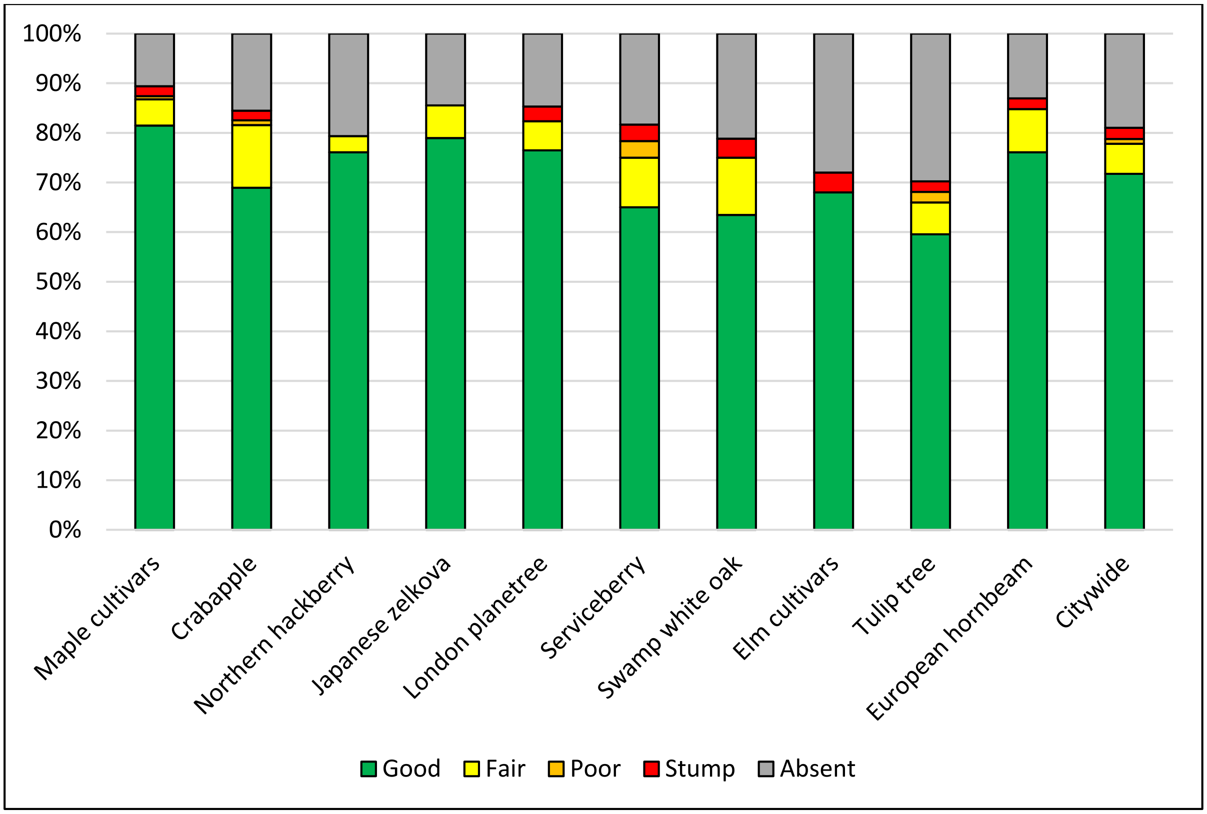

Figure 4. Frequency of overall condition ratings of the ten most common re-inventoried tree species.

Overall condition of living trees was rated in three categories: good, fair, and poor (Table 1). Seventy-one percent of all re-inventoried trees were in good condition, 6% were in fair condition, 1% were in poor condition, 2% only had a stump present, and 19% were absent (Figure 4). Overall condition varied among tree species; only 60% of tulip trees (*Liriodendron tulipifera*) were in good condition, while more than 80% of maple cultivars 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.

<u>Leaf Area and Canopy Cover Estimates:</u>

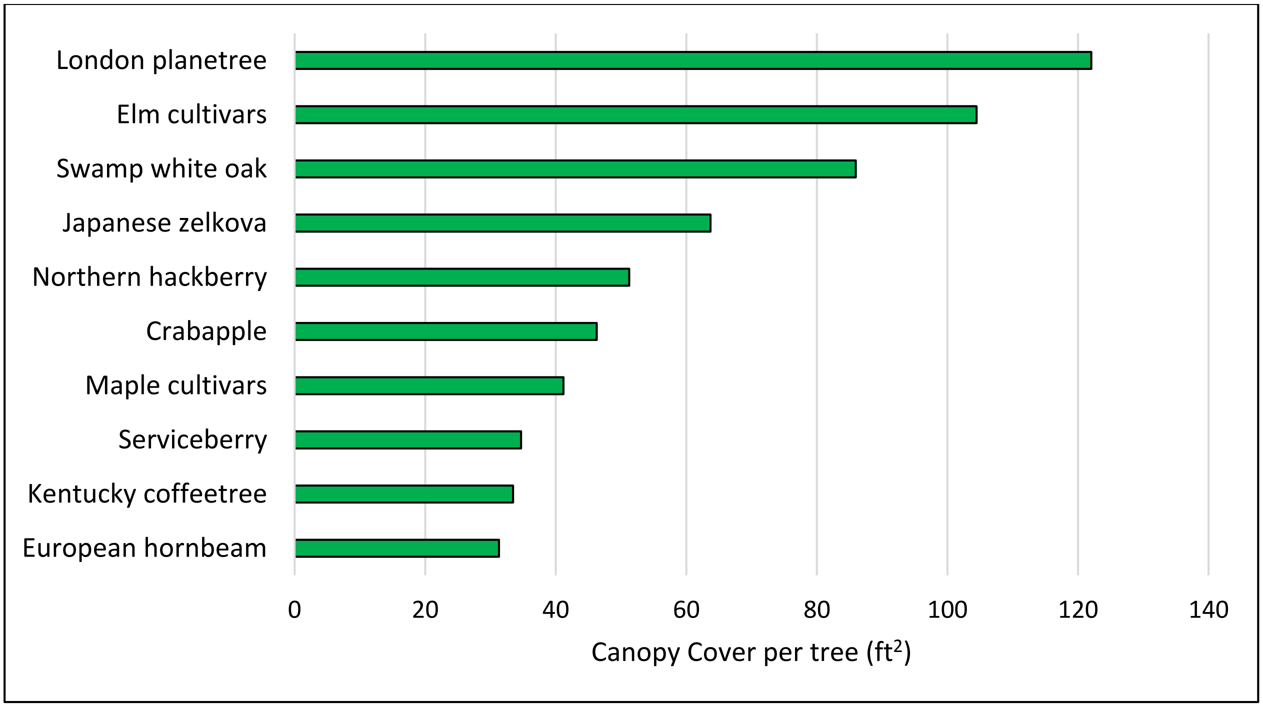

Figure 5. Average estimated canopy cover per tree (ft^2) of the ten most common surviving re-inventoried trees.

Re-inventoried trees provide 5,000 m^2 (54,000 ft^2) of canopy cover and almost 17,000 m^2 (180,000 ft^2) of total leaf area. Canopy cover is the area of land 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 5 m^2 (54 ft^2) of canopy cover. Of the ten most common surviving re-inventoried tree species, London planetrees provide the most canopy cover per tree and European hornbeams provide the least canopy cover per tree (Figure 5).

Tree size makes a big difference in the canopy cover estimated by i-Tree. Compared to the citywide average, relatively more London planetrees, elm cultivars, swamp white oaks, and Japanese zelkovas were in larger size classes (Figure 3). As a result, they had above-average canopy cover per tree as estimated by i-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 (2007).

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

Benefit Type	Total Benefits	$/Tree	Percent of Total Benefits
Energy	$3,824	$3.99	45%
CO_2	$117	$0.12	1%
Air Quality	$849	$0.89	10%
Stormwater	$800	$0.83	9%
Aesthetic/Other	$2,958	$3.08	35%
Total Benefits	$8,548	$8.91	100%

Most of the estimated benefits provided by the re-inventoried trees are energy benefits (Table 2; Figure 6). Currently, Northern hackberries (*Celtis occidentalis*) provide the most total estimated benefits (Figure 7). See Appendix Table A2 for a full list of benefits per tree, by type, provided by each re-inventoried species.

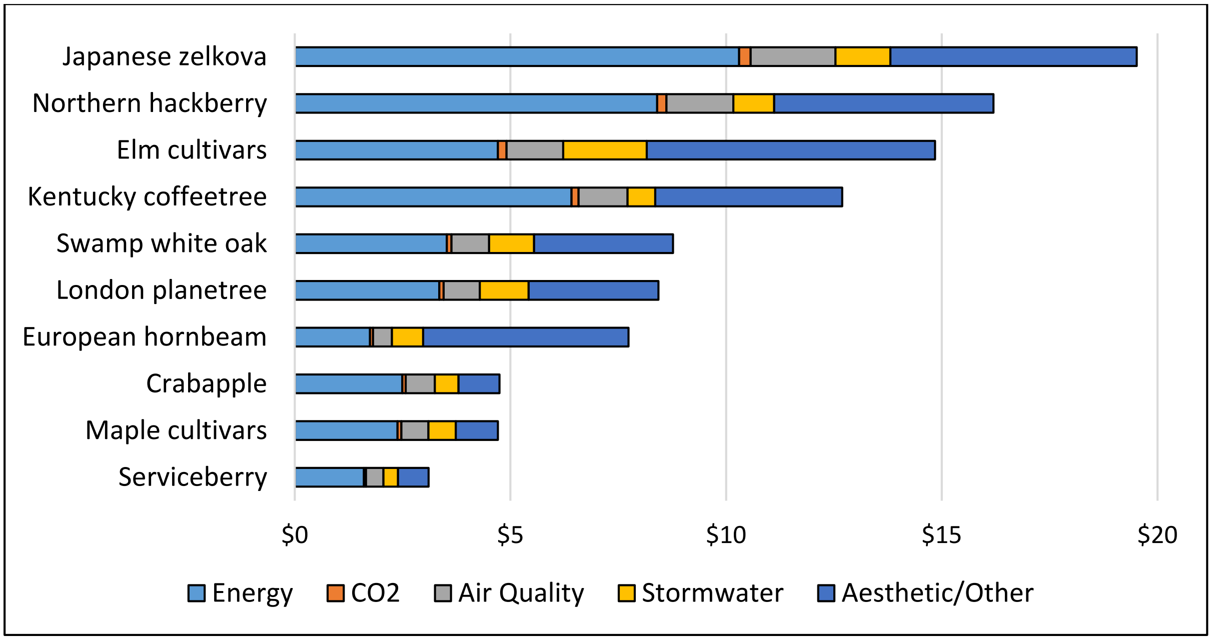

Figure 6. Estimated annual benefits per tree, by type, provided by the ten most common surviving tree species.

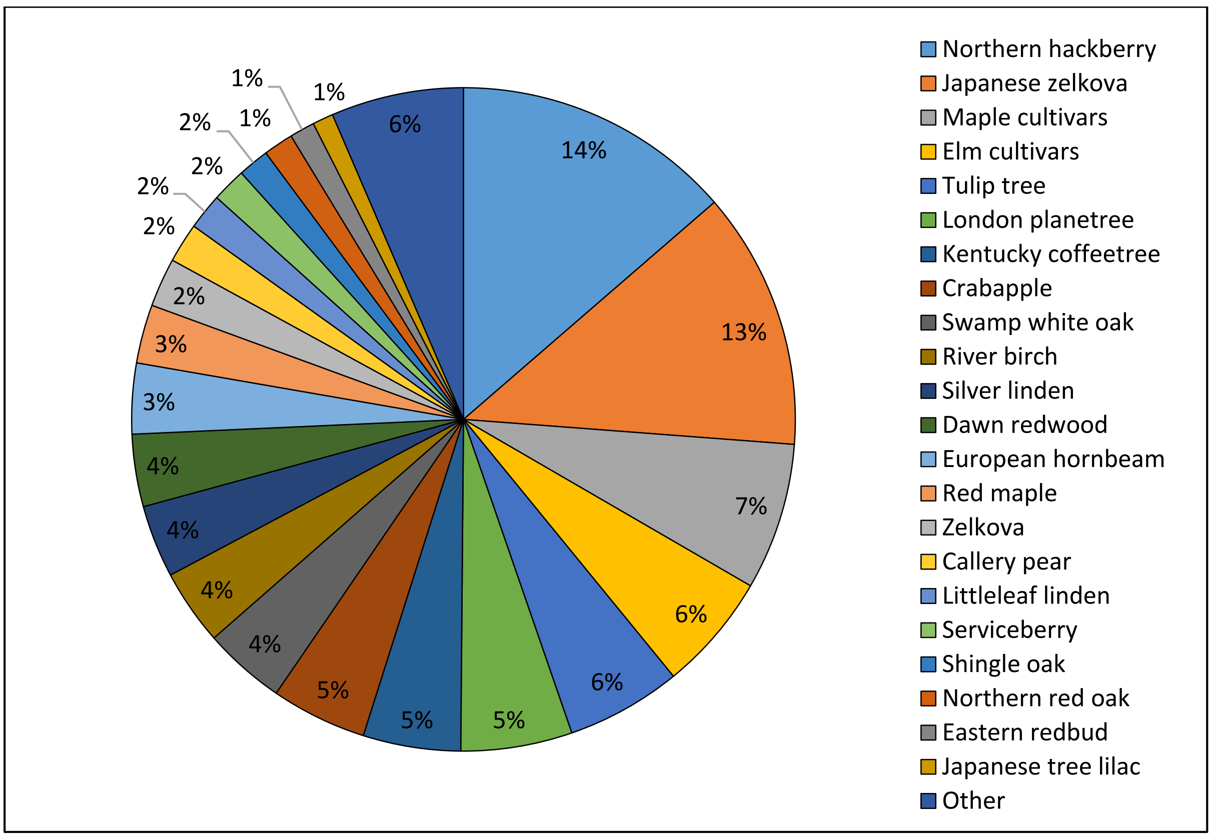

Figure 7. Each species' contribution to estimated total annual benefits. Northern hackberries provide 14% of estimated total annual benefits though they make up only 8% of surviving re-inventoried trees.

Tree Benefits: A Closer Look

Energy Benefits:

Re-inventoried trees provide an estimated $3,824 in annual energy benefits (Table 1). Northern hackberries and Japanese zelkovas contribute more energy benefits per tree than average, while maple cultivars and crabapples contribute less than average per tree (Figure 8). The top three contributors to estimated energy benefits are Northern hackberry, Japanese zelkova (*Zelkova serrata*), and maple cultivars (*Acer* spp.).

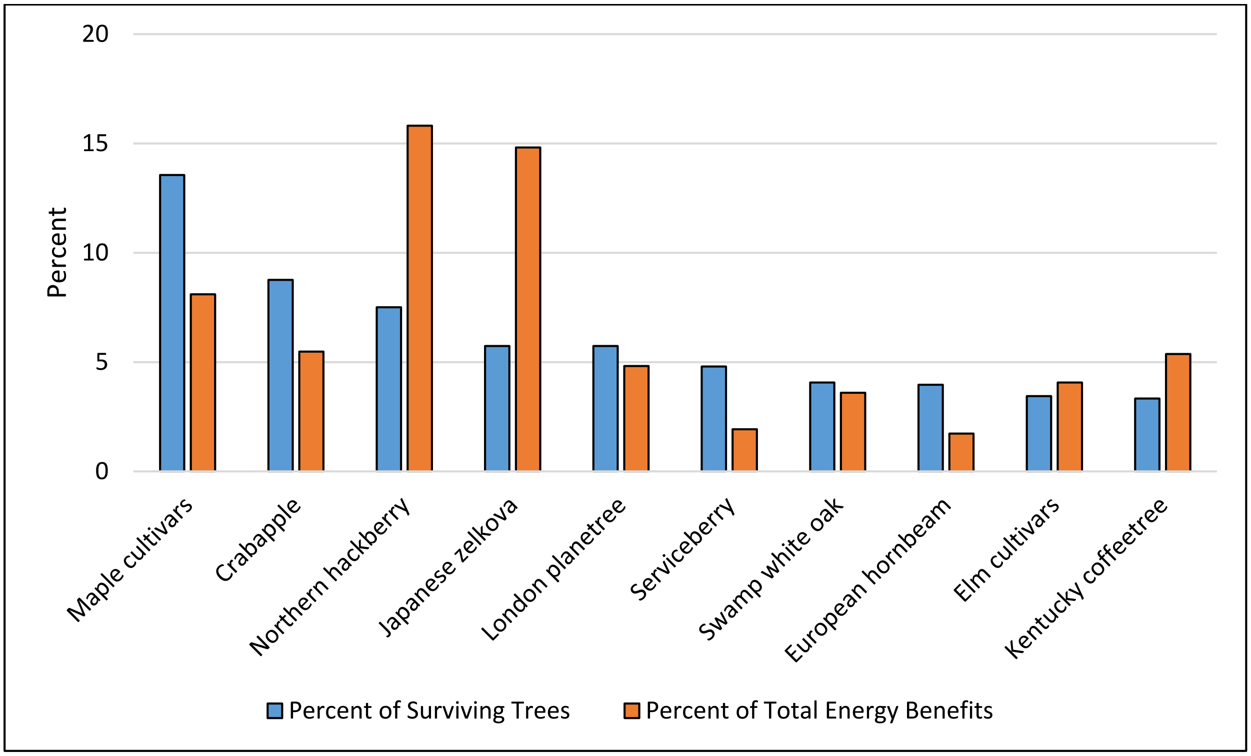

Figure 8. Percent of surviving trees compared to percent of estimated total annual energy benefits provided by the ten most common surviving tree species.

CO_2 Benefits:

All together, re-inventoried trees provide an estimated $117 in annual CO_2 benefits, which corresponds to 16,000 kg of CO_2 sequestered or avoided each year. 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.

Northern hackberry and Japanese zelkova trees provide the most CO_2 benefits, together sequestering or avoiding more than 4,000 kg of CO_2 annually. All Northern hackberries (72 trees with an average DBH of 2.1 in) sequester or avoid 2,100 kg of CO_2 (worth $16) each year, and all Japanese zelkovas (55 trees with an average DBH of 2.1 in) sequester or avoid 2,000 kg of CO_2 (worth $15) each year.

Air Quality Benefits:

All together, re-inventoried trees provide an estimated $849 in annual air quality benefits, representing uptake or avoidance of 13 kg of ozone, 43 kg of NO_2, 9 kg of PM_{10}, and 19 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. 2007). These functions are dependent on tree size and leaf area, so annual air quality benefits will increase as the trees grow larger. Northern hackberry and Japanese zelkova trees provide the most air quality benefits; together they account for more than 25% of total air quality benefits.

Stormwater Benefits:

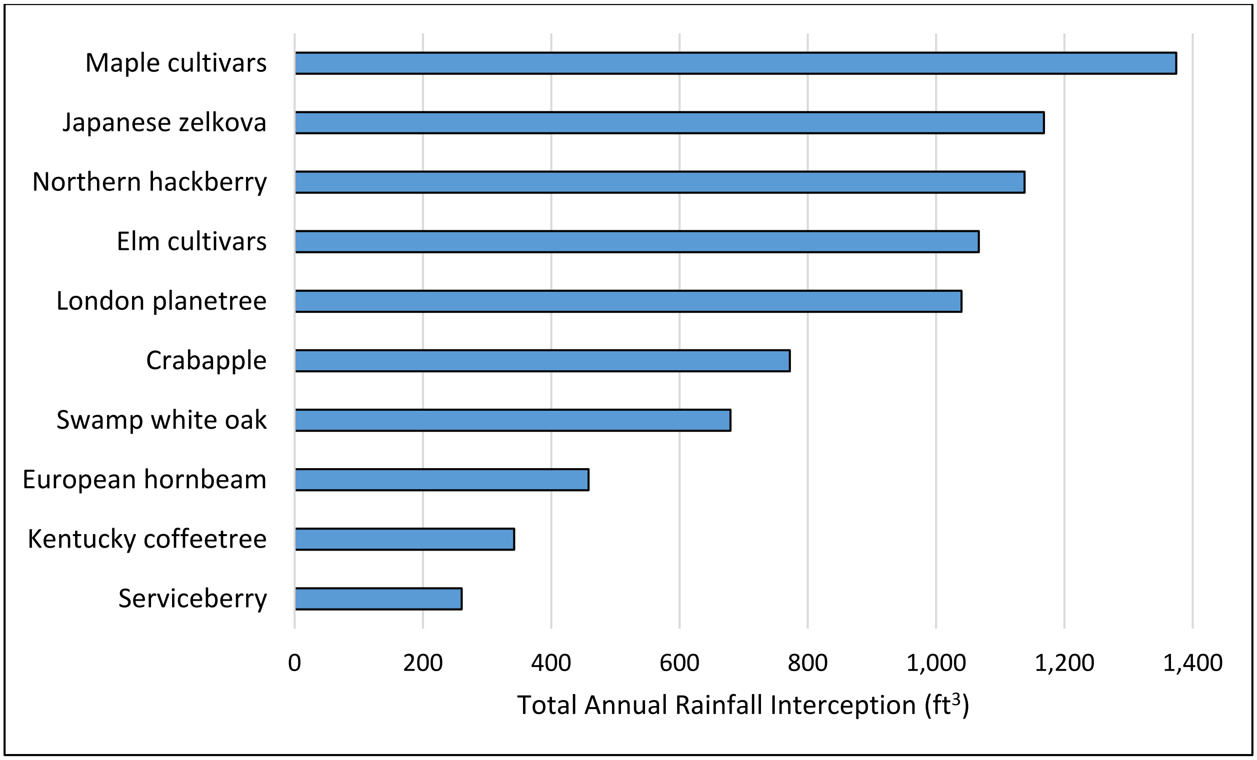

Figure 9. Estimated total rainfall (ft^3) intercepted annually by the ten most common surviving tree species.

Re-inventoried trees intercept an estimated 380 m^3 (13,000 ft^3) of rainfall each year and provide $800 in annual stormwater benefits. Maple cultivars provide 10% of total stormwater benefits, collectively intercepting almost 1,400 ft^3 of rainfall per year, more than 10 ft^3 per tree (Figure 9).

Aesthetic/Property Value Benefits:

Thirty-five percent of the benefits provided by the re-inventoried trees ($2,958) are aesthetic benefits, quantified by an increase in property value. Aesthetic/property value benefits 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). Northern hackberries and Japanese zelkovas contribute most to aesthetic benefits (Table 3). The average annual aesthetic value of re-inventoried trees was $3 per tree.

Table 3. Summary of the ten tree species that contribute most to estimated annual aesthetic benefits.

Species	Average Aesthetic Benefits per Tree	Total Aesthetic Benefits	Percent of Total Aesthetic Benefits
Northern hackberry	$5.08	$366	12%
Japanese zelkova	$5.71	$314	11%
Elm cultivars	$6.68	$221	7%
European hornbeam	$4.76	$181	6%
London planetree	$3.01	$166	6%
Tulip tree	$4.90	$152	5%
Kentucky coffeetree	$4.33	$139	5%
Red maple	$5.06	$131	4%
Maple cultivars	$0.98	$127	4%
Swamp white oak	$3.22	$126	4%

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 $215,000. Maple cultivars, crabapples, and Northern hackberries contribute most to the replacement value at $33,000, $18,000, and $18,000, respectively. Assuming each tree costs $155 to plant (Peper et al. 2009), the initial cost of the re-inventoried trees would be $192,000. 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

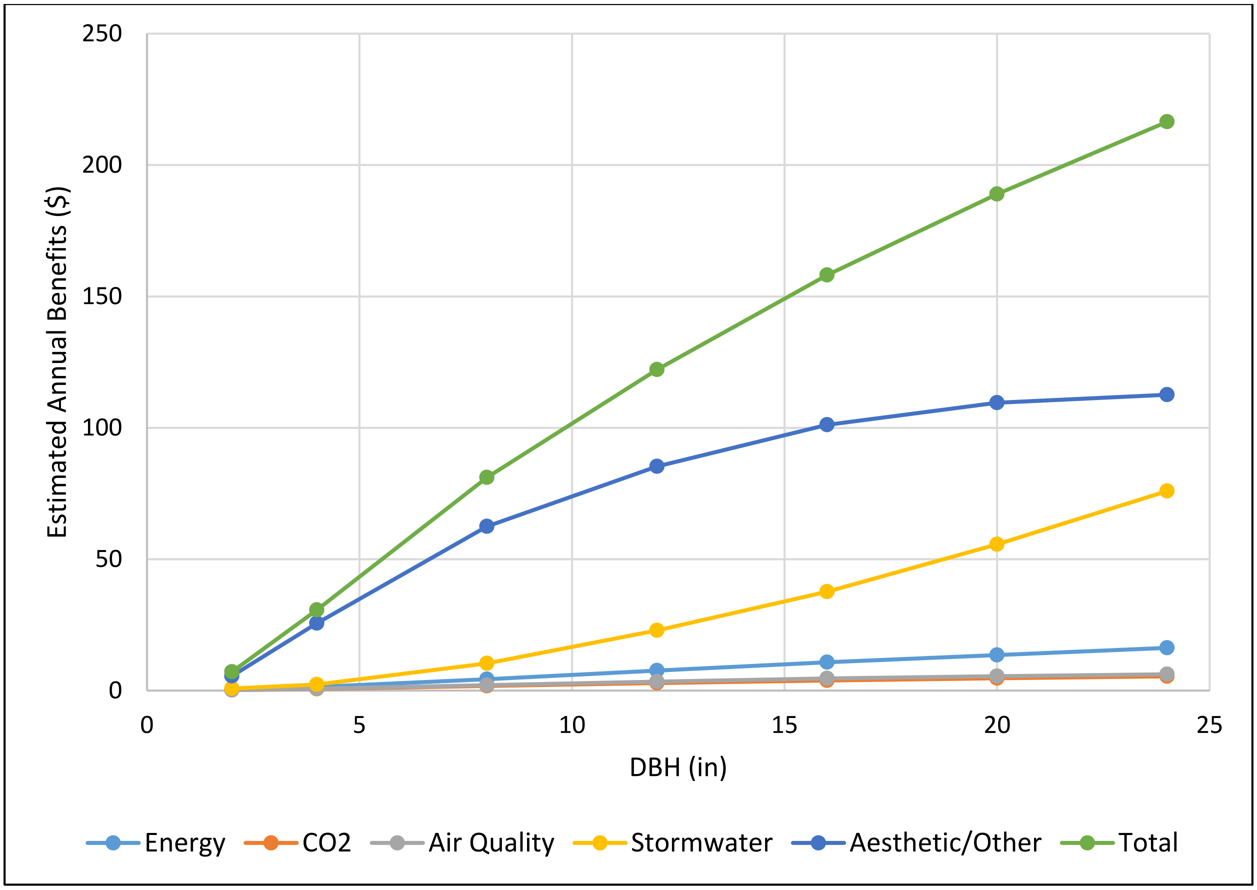

Figure 10. Estimated annual benefits of a sugar maple at different sizes up to 24 inches DBH in the South climate region.

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. 2007). 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.

McPherson, E.G., Simpson, J.R., Peper, P.J., Gardner, S.L., Vargas, K.E., and Xiao, Q. 2007. Northeast community tree guide: benefits, costs, and strategic planting. United States Department of Agriculture Forest Service, Pacific Southwest Research Station. General Technical Report PSW-GTR-202. Available from www.itreetools.org/streets/resources/Streets_CTG/PSW_GTR202_Northeast_CTG.pdf.

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)
Tilia americana	American basswood	12	1.9
Carpinus caroliniana	American hornbeam	16	1.3
Nyssa sylvatica	Black tupelo	9	1.4
Quercus macrocarpa	Bur oak	1	2.5
Pyrus calleryana	Callery pear	21	2.3
Crataegus crus-galli	Cockspur hawthorn	7	1.4
Cornus mas	Cornelian cherry	2	1.2
Malus spp.	Crabapple	84	2.0
Metasequoia glyptostroboides	Dawn redwood	28	1.3
Cercis canadensis	Eastern redbud	14	2.6
Ulmus spp.	Elm cultivars	33	3.3
Quercus robur	English oak	2	4.2
Carpinus betulus	European hornbeam	38	1.9
Ginkgo biloba	Ginkgo	13	1.3
Crataegus viridis	Green hawthorn	4	1.2
Crataegus spp.	Hawthorn	7	2.2
Acer campestre	Hedge maple	13	1.8
Syringa reticulata	Japanese tree lilac	28	1.6
Zelkova serrata	Japanese zelkova	55	2.1
Gymnocladus dioicus	Kentucky coffeetree	32	1.7
Tilia cordata	Littleleaf linden	23	2.1
Platanus x *acerifolia*	London planetree	55	2.3
Acer spp.	Maple cultivars	130	2.2
Celtis occidentalis	Northern hackberry	72	2.1
Quercus rubra	Northern red oak	29	1.6
Quercus spp.	Oak, other	2	2.4
Acer rubrum	Red maple	26	2.0
Betula nigra	River birch	16	2.6
Quercus coccinea	Scarlet oak	3	2.3
Amelanchier spp.	Serviceberry	46	1.3
Quercus imbricaria	Shingle oak	10	2.2
Tilia tomentosa	Silver linden	26	3.0
Acer saccharum	Sugar maple	11	2.2
Quercus bicolor	Swamp white oak	39	1.8
Liquidambar styraciflua	Sweetgum	11	1.7
Lirodendron tulipifera	Tulip tree	31	1.9
Zelkova spp.	Zelkova	10	2.6
Citywide Total	Citywide Total	959	2.0

Table A2. Estimated benefits per tree, by type, for surviving re-inventoried trees.

Species	Energy Benefits	CO_2 Benefits	Air Quality Benefits	Stormwater Benefits	Aesthetic Benefits	Total Benefits
American basswood	$1.50	$0.08	$0.39	$0.53	$3.02	$5.53
American hornbeam	$0.69	$0.03	$0.17	$0.24	$4.08	$5.21
Black tupelo	$1.55	$0.07	$0.39	$0.63	$4.64	$7.27
Bur oak	$5.73	$0.20	$1.44	$1.86	$4.50	$13.73
Callery pear	$2.30	$0.14	$0.72	$0.91	$3.79	$7.86
Cockspur hawthorn	$1.26	$0.03	$0.31	$0.26	$0.66	$2.53
Cornelian cherry	$1.26	$0.03	$0.31	$0.26	$0.66	$2.53
Crabapple	$2.50	$0.08	$0.68	$0.55	$0.95	$4.75
Dawn redwood	$5.32	$0.13	$0.90	$0.45	$3.99	$10.78
Eastern redbud	$4.24	$0.14	$1.13	$0.92	$1.04	$7.47
Elm cultivars	$4.71	$0.20	$1.32	$1.93	$6.68	$14.84
English oak	$7.27	$0.25	$1.84	$2.66	$4.03	$16.04
European hornbeam	$1.74	$0.07	$0.44	$0.72	$4.76	$7.74
Ginkgo	$0.29	$0.01	$0.07	$0.08	$0.46	$0.90
Green hawthorn	$1.26	$0.03	$0.31	$0.26	$0.66	$2.53
Hawthorn	$3.08	$0.10	$0.81	$0.66	$0.92	$5.57
Hedge maple	$1.89	$0.07	$0.50	$0.51	$0.86	$3.83
Japanese tree lilac	$1.60	$0.05	$0.40	$0.34	$0.71	$3.10
Japanese zelkova	$10.30	$0.27	$1.97	$1.27	$5.71	$19.52
Kentucky coffeetree	$6.42	$0.16	$1.14	$0.64	$4.33	$12.69
Littleleaf linden	$1.29	$0.09	$0.36	$0.60	$4.19	$6.53
London planetree	$3.35	$0.10	$0.84	$1.13	$3.01	$8.43
Maple cultivars	$2.38	$0.09	$0.63	$0.63	$0.98	$4.71
Northern hackberry	$8.40	$0.22	$1.55	$0.95	$5.08	$16.20
Northern red oak	$1.09	$0.04	$0.24	$0.41	$2.51	$4.29
Oak, other	$4.08	$0.13	$1.01	$1.24	$3.56	$10.04
Red maple	$2.53	$0.10	$0.64	$1.08	$5.06	$9.40
River birch	$10.36	$0.27	$1.97	$1.26	$5.78	$19.65
Scarlet oak	$4.63	$0.16	$1.16	$1.45	$3.87	$11.27
Serviceberry	$1.61	$0.05	$0.41	$0.34	$0.71	$3.10
Shingle oak	$5.40	$0.19	$1.36	$1.73	$4.31	$12.99
Silver linden	$4.45	$0.17	$1.40	$2.26	$3.36	$11.62
Sugar maple	$2.74	$0.10	$0.71	$0.84	$2.12	$6.52
Swamp white oak	$3.53	$0.11	$0.87	$1.04	$3.22	$8.77
Sweetgum	$0.89	$0.03	$0.15	$0.31	$1.55	$2.94
Tulip tree	$8.00	$0.21	$1.48	$0.90	$4.90	$15.47
Zelkova	$10.75	$0.28	$2.05	$1.33	$5.92	$20.34
Citywide Total	$3.99	$0.12	$0.89	$0.83	$3.08	$8.91