# Forest ReLeaf of Missouri

## Planted Tree Re-Inventory Report:

## Survival, Condition, and Benefits of Recently Planted Trees

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## 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 Forest ReLeaf of Missouri, with emphasis on benefit estimates generated using i-Tree Streets.

## Summary of Results

Teams of volunteers, supervised by Forest ReLeaf of Missouri, re-inventoried 101 trees in St. Louis, Missouri in June, July, and August of 2014. These trees were selected from a list of planting projects in which 2,171 trees were planted by Forest ReLeaf in the St. Louis area from 2009 to 2011. Eighty-six percent of the re-inventoried trees (87 out of 101 re-inventoried trees) had survived at the time of re-inventory. However, we are unable to calculate a true mortality rate due to the uncertainty of tree locations based on data-keeping methods that keep track of the approximate locations of tree-planting projects rather than individual tree locations. Highlights of the tree analysis are:

- Most (70% of) re-inventoried trees were found to be in good condition.
- Average diameter at breast height (DBH) of surviving trees was 3.9 cm (1.5 inches).
- Re-inventoried trees provide almost $1,400 in annual benefits, an average of $17.60 per tree.
- Re-inventoried trees provide more than 300 $m^2$ (3,000 $ft^2$) of canopy cover.
- Bald cypress (*Taxodium distichum*) was the most common species of surviving re-inventoried trees (Figure 1).
- *Taxodium* was the most common genus of surviving re-inventoried trees (Figure 2).
- River birches (*Betula nigra*) provide the most canopy cover and total benefits.
- All 2,171 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 $33,000 in total annual benefits.

## Species & Genus Distributions

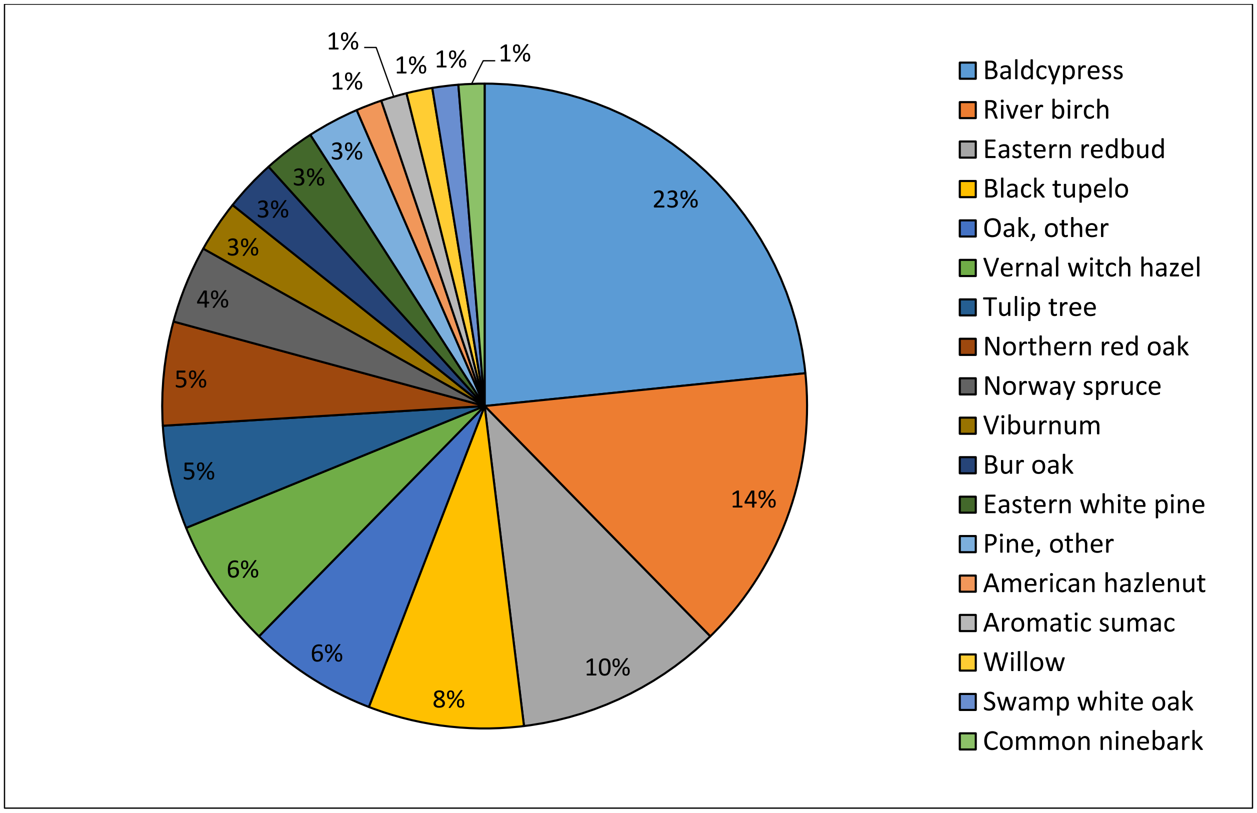


**Figure 1. Species distribution of surviving re-inventoried trees planted by Forest ReLeaf of Missouri from 2009 to 2011. See Appendix Table A1 for a list of scientific and common names.**

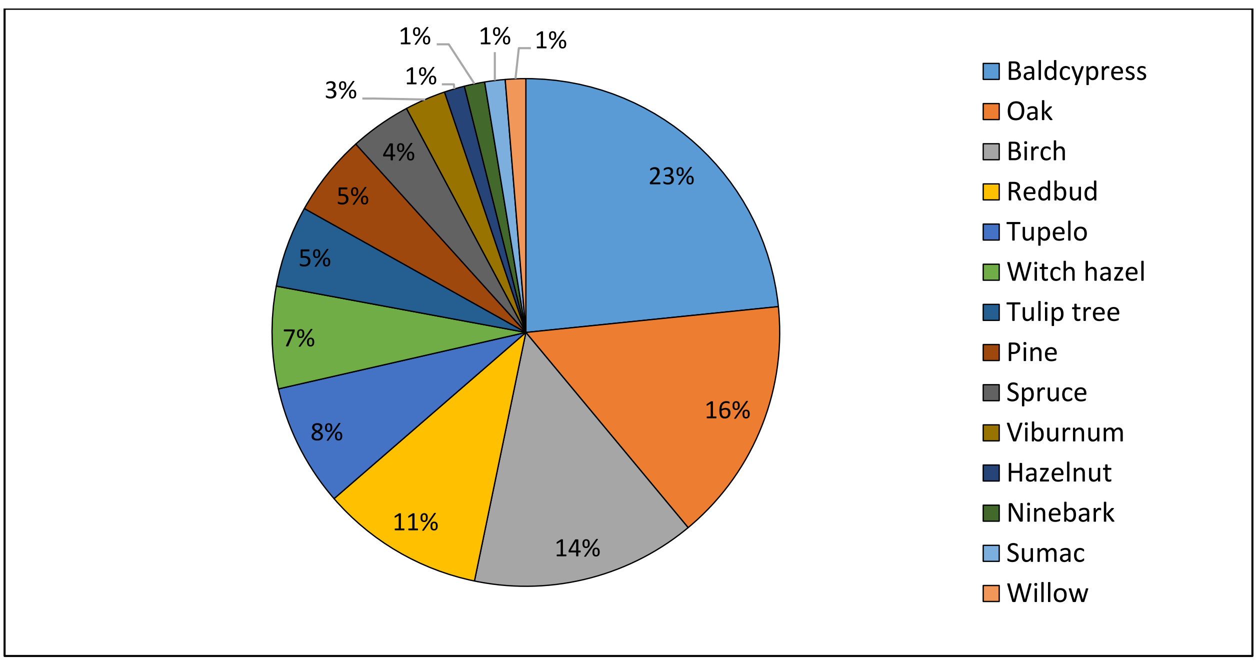


**Figure 2. Genus distribution of surviving re-inventoried trees planted by Forest ReLeaf of Missouri from 2009 to 2011.**

## Size Distribution

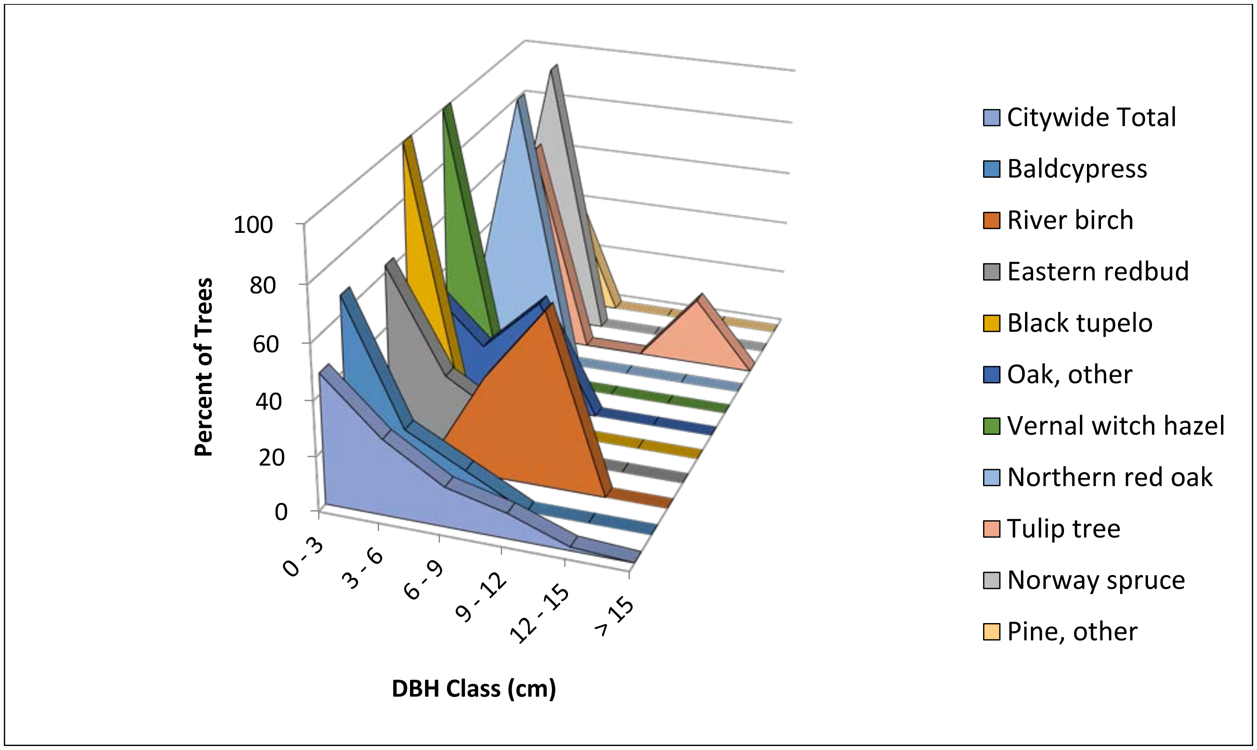


**Figure 3. Size distributions of the ten most common surviving tree species.**

Half of re-inventoried trees were in the 0-3 cm size class, 25% were in the 3-6 cm size class, 15% were in the 6-9 cm size class, and 10% had a DBH of 9 cm or greater (Figure 3). However, more than half of all river birches (*Betula nigra*) were in the 9-12 cm size class. No trees in the re-inventory sample were larger than 15 cm (5.9 inches).

## Overall Condition

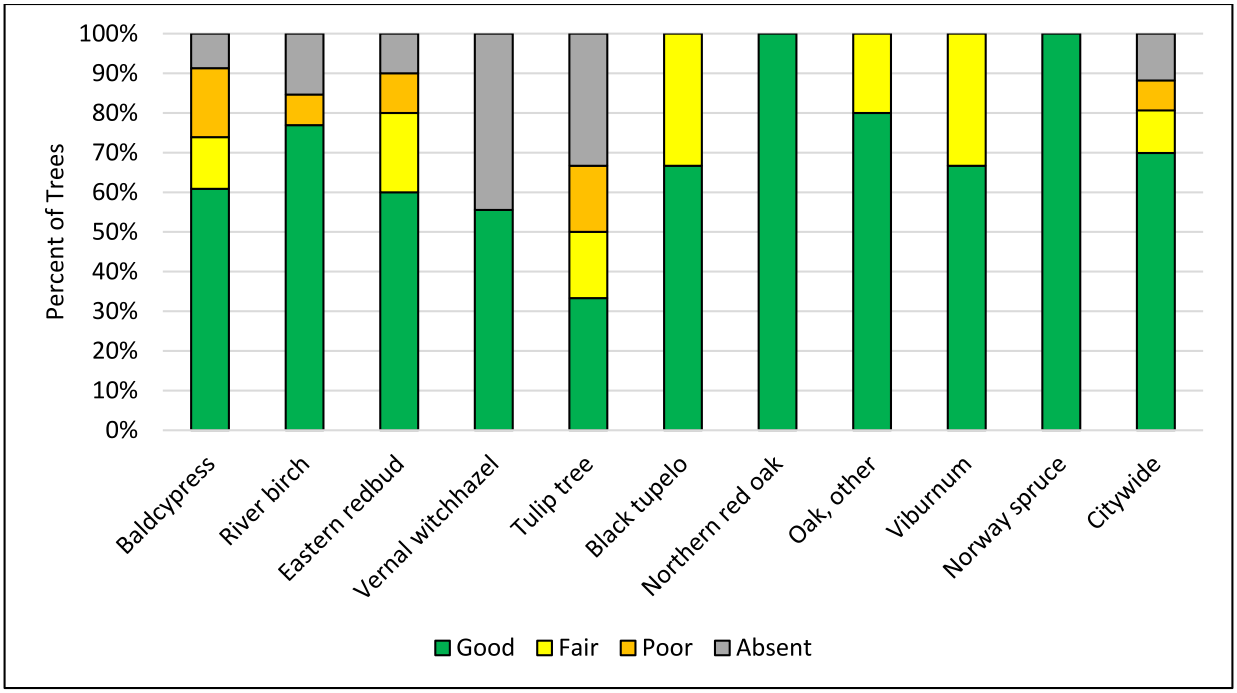


**Figure 4. Frequency of overall condition ratings of the ten most common re-inventoried tree species.**

Overall condition of living trees was rated in three categories: good, fair, and poor (Table 1). Seventy percent of all re-inventoried trees were in good condition, 11% were in fair condition, 8% were in poor condition, and 12% were absent (Figure 4). Overall condition ratings varied among species; only 33% of tulip trees (*Liriodendron tulipifera*) were in good condition, while 100% of Northern red oaks (*Quercus rubra*) and Norway spruces (*Picea abies*) 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:

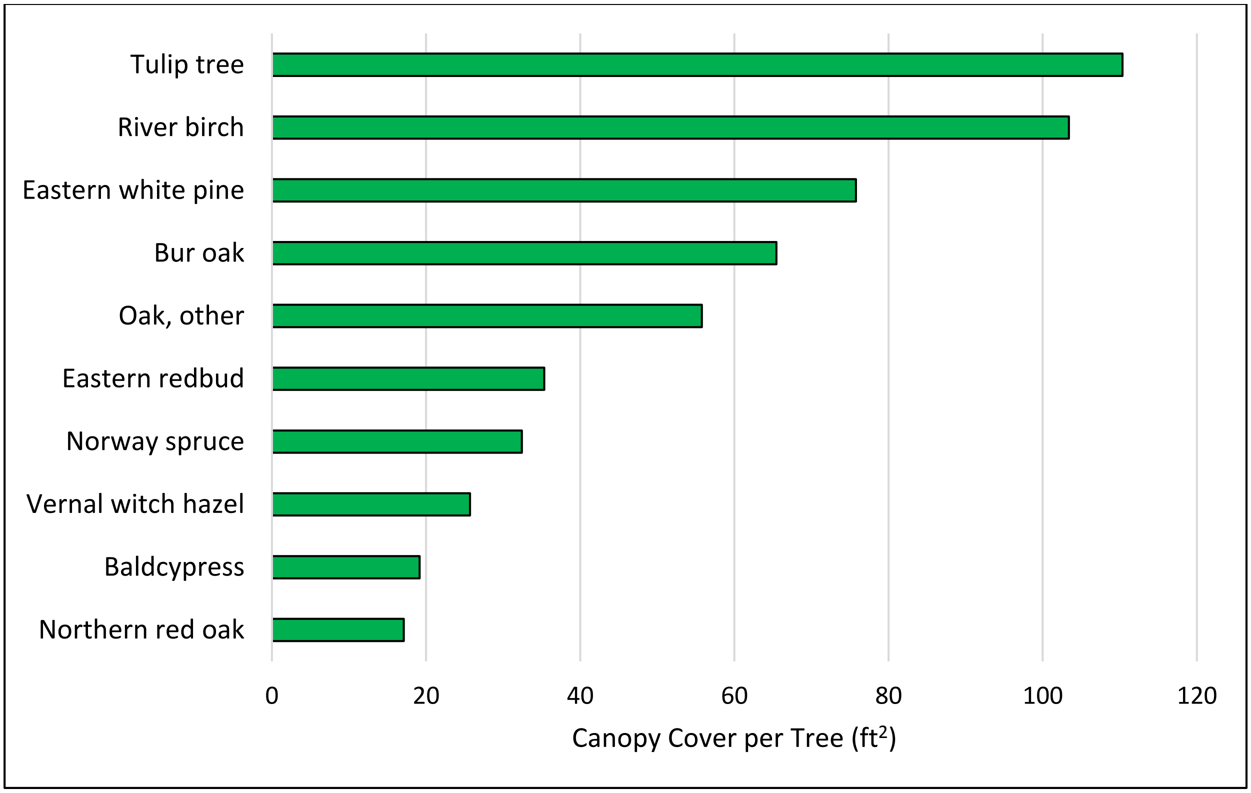


**Figure 5. Average estimated canopy cover per tree (ft$^2$) of the ten most common surviving tree species.**

Re-inventoried trees provide 3,200 ft$^2$ (306 m$^2$) of canopy cover and 9,000 ft$^2$ (840 m$^2$) 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 43 ft$^2$ (4 m$^2$) of canopy cover. Of the ten most common surviving re-inventoried tree species, tulip trees provide the most canopy cover per tree, while Northern red oaks 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 tulip trees and river birches 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 Peper and colleagues (2009).

**Table 2. Estimated total annual benefits provided by re-inventoried trees in St. Louis.**

| Benefits | Total Benefits | $/Tree | Percent of Total Benefits |
|---|---|---|---|
| Energy | $35 | $0.45 | 2.6% |
| $CO_2$ | $6 | $0.08 | 0.5% |
| Air Quality | $9 | $0.12 | 0.7% |
| Stormwater | $65 | $0.84 | 4.8% |
| Aesthetic/Other | $1,242 | $16.13 | 91.5% |
| Total Benefits | $1,357 | $17.62 | 100.0% |

Most (91.5%) 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, river birches (*Betula nigra*) contribute most to the 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.

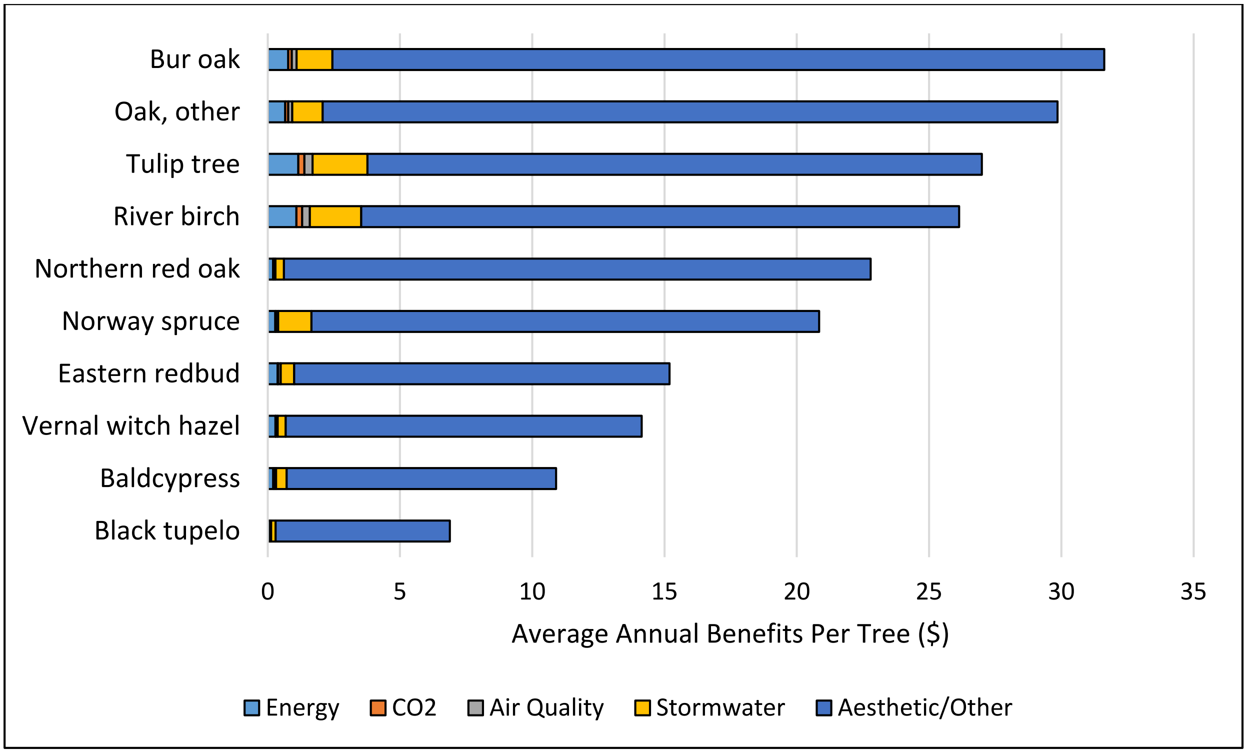


**Figure 6. Estimated benefits per tree, by type, provided by the ten most common surviving tree species.**

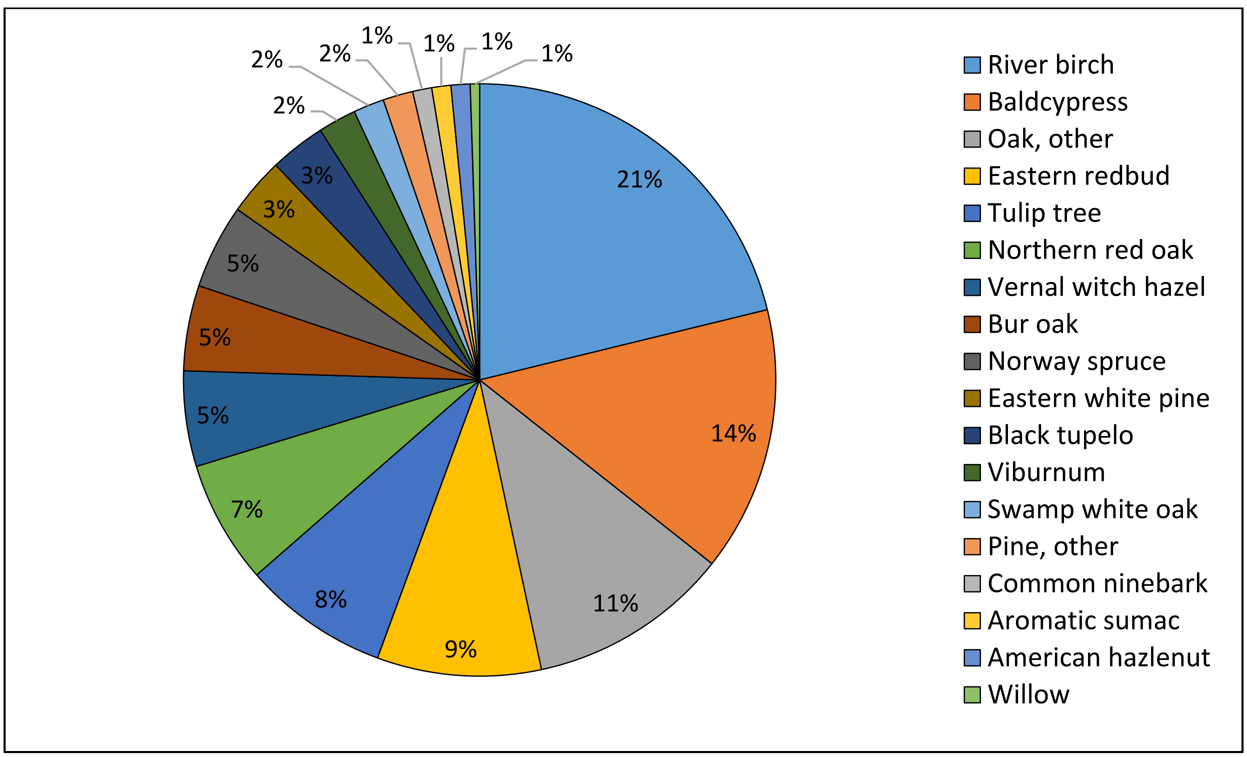


**Figure 7. Each species' contribution to estimated total benefits. River birches provide 21% of estimated total benefits though they make up only 14% of total trees.**

**Tree Benefits: A Closer Look**

Energy Benefits:

Re-inventoried trees provide an estimated $35 in annual energy benefits (Table 2). River birches and tulip trees contribute more energy benefits per tree than other species (Figure 8). The top three contributors to estimated energy benefits are river birches (34% of total energy benefits), tulip trees (13% of total energy benefits), and bald cypress trees (11% of total energy benefits).

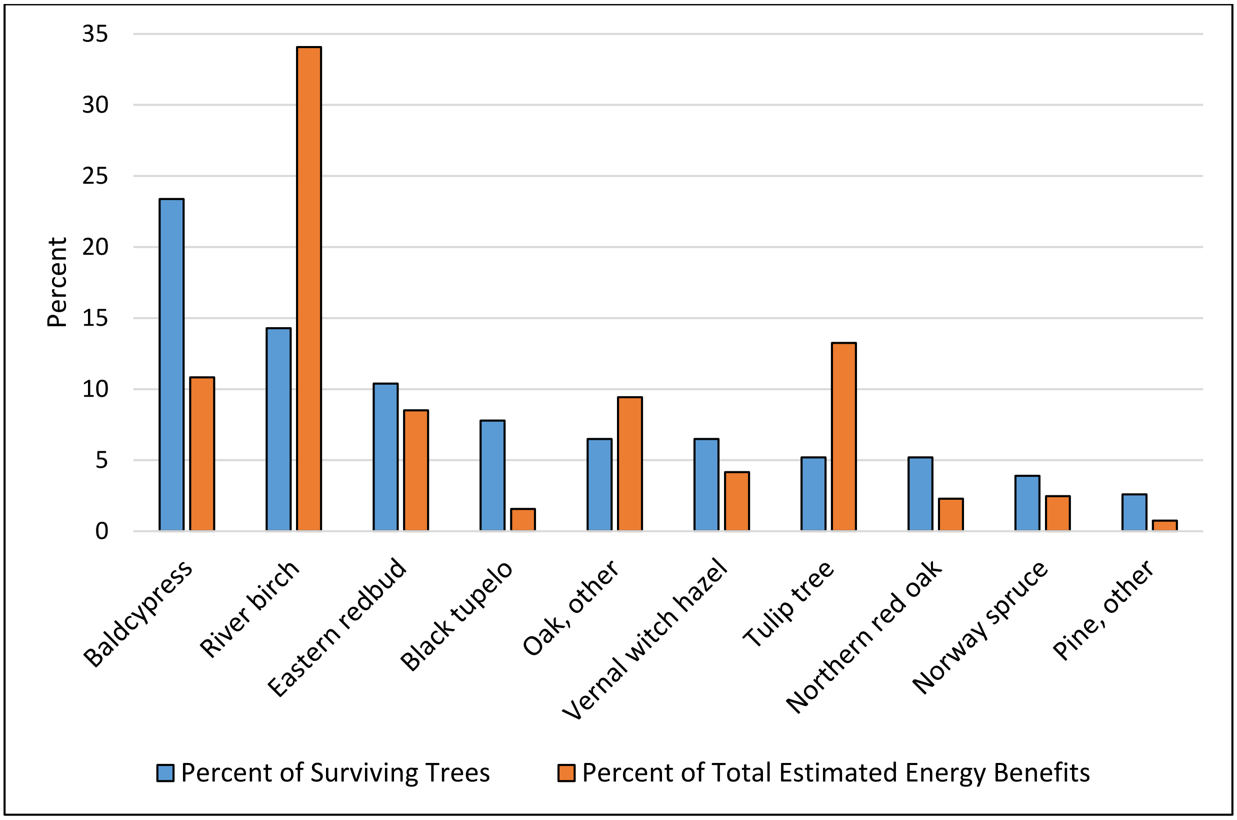


**Figure 8. Percent of surviving trees compared to percent of estimated total energy benefits provided by the ten most common surviving tree species.**

$CO_2$ Benefits:

All together, re-inventoried trees provide an estimated $6 in annual $CO_2$ benefits, which corresponds to 840 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 river birches in the re-inventory sample (11 trees with an average DBH of 3.5 in) sequester or avoid 330 kg of $CO_2$ (worth $2) each year. All bald cypress trees in the re-inventory sample (18 trees with an average DBH of 0.9 in) sequester or avoid 140 kg of $CO_2$ (worth $1) each year.

Air Quality Benefits:

All together, re-inventoried trees provide an estimated $9 in annual air quality benefits, representing uptake or avoidance of 1 kg of ozone, 1 kg of $NO_2$, 0.5 kg of $PM_{10}$, and 2 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. River birches, tulip trees, and bald cypress trees contribute most to estimated air quality benefits at 35%, 14%, and 11% of total air quality benefits, respectively.

Stormwater Benefits:

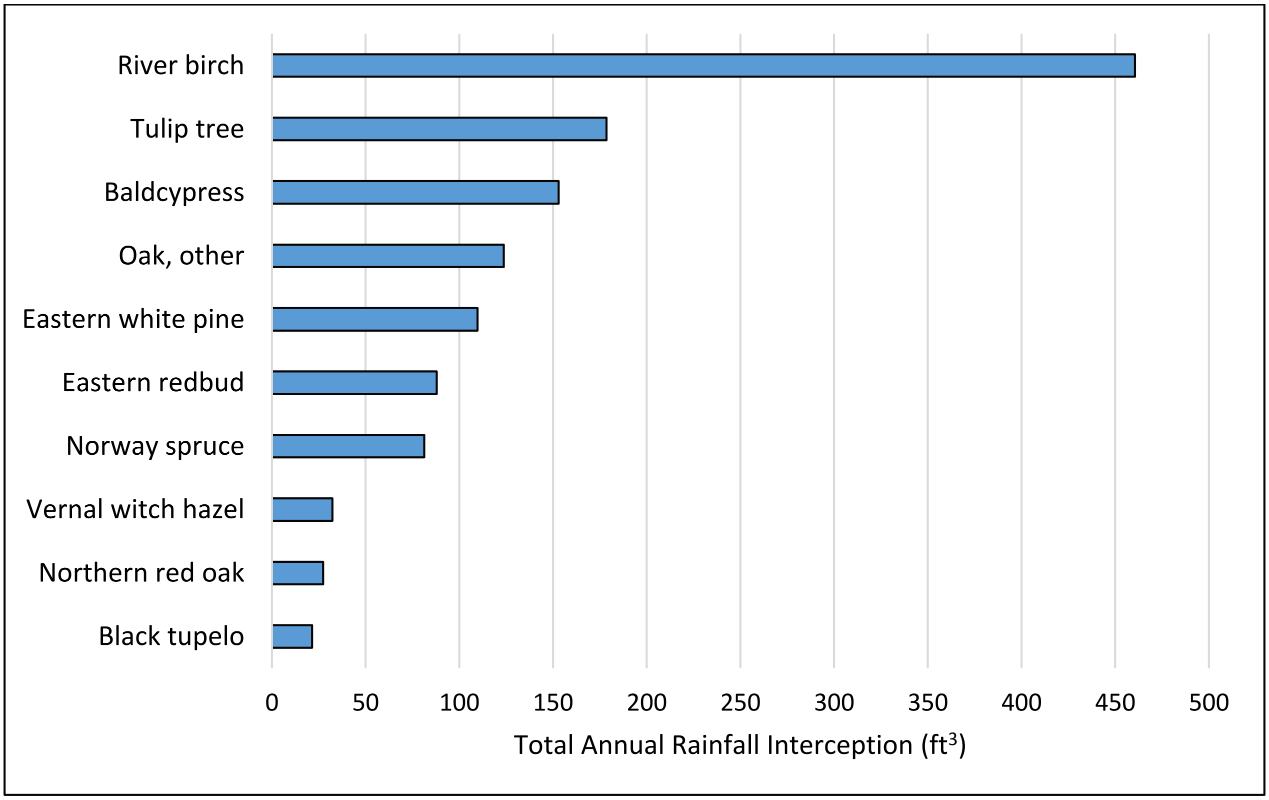


**Figure 9. Estimated total rainfall ($ft^3$) intercepted annually by the ten most common surviving tree species.**

Re-inventoried trees intercept an estimated 40 $m^3$ (1,400 $ft^3$) of rainfall each year and provide $65 in annual stormwater benefits. River birches, tulip trees, and bald cypress trees together provide more than half of total stormwater benefits. River birches alone provide 33% of total stormwater benefits, collectively intercepting 13 $m^3$ (460 $ft^3$) and providing $21 in 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 tree size, but do not take into account whether a tree flowers or not (see Anderson and Cordell 1988 for supporting research). Bald cypress trees contribute most to total aesthetic benefits (Table 3). The total annual aesthetic value of all re-inventoried trees was $1,242, an average of $16 per tree.

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

| Species | Average Aesthetic Benefits per Tree | Total Aesthetic Benefits | Percent of Total Aesthetic Benefits |
|---|---|---|---|
| Bur oak | $29 | $58 | 5% |
| Oak, other | $28 | $139 | 11% |
| Tulip tree | $23 | $93 | 7% |
| River birch | $23 | $249 | 20% |
| Northern red oak | $22 | $89 | 7% |
| Norway spruce | $19 | $58 | 5% |
| Eastern redbud | $14 | $113 | 9% |
| Vernal witch hazel | $13 | $67 | 5% |
| Bald cypress | $10 | $183 | 15% |
| Black tupelo | $7 | $40 | 3% |

### 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 $23,000. Bald cypress trees and river birches contribute most to the replacement value at $5,500 and $3,400, respectively. Assuming each tree costs $155 to plant (Peper et al. 2009), the initial cost of the re-inventoried trees would be $15,500. 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**

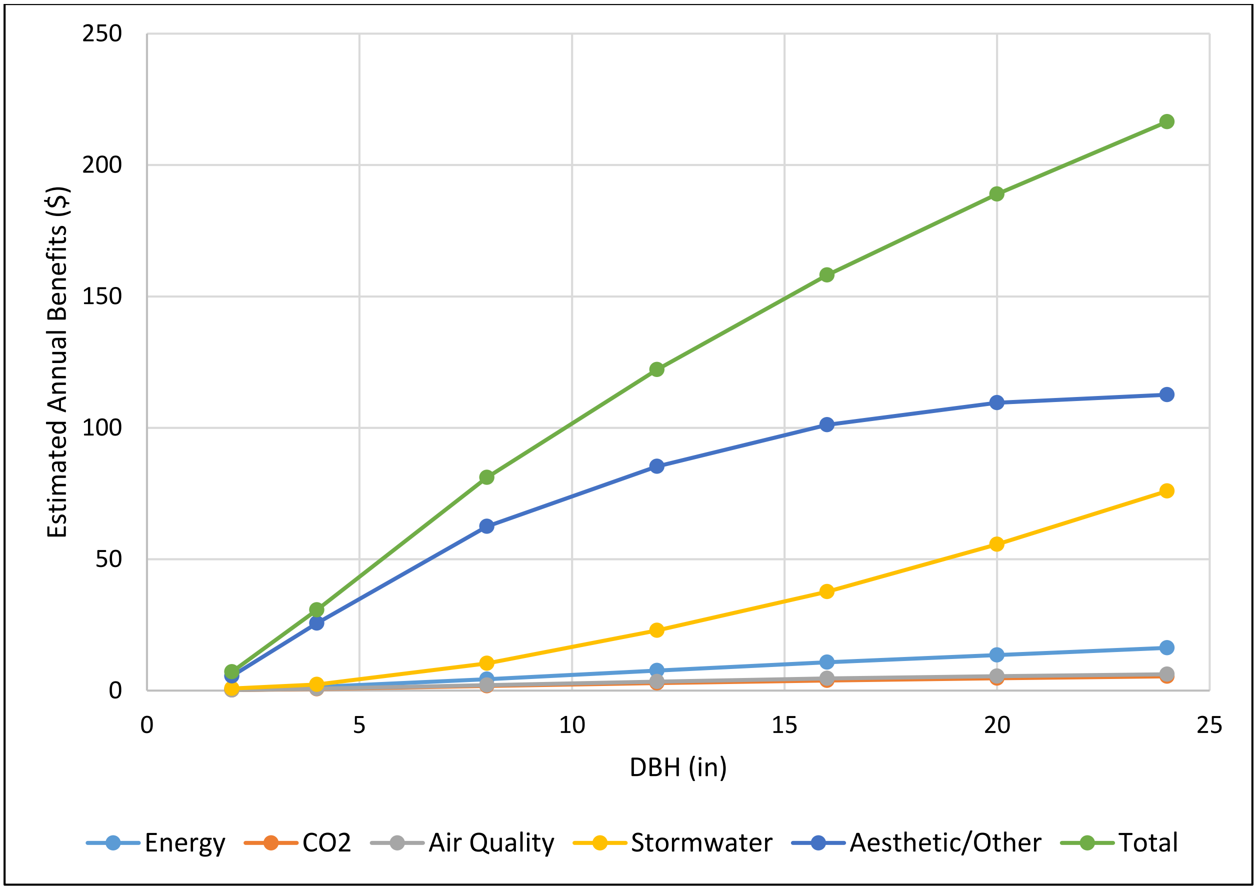


**Figure 10. Estimated annual benefits of a sugar maple at different sizes up to 24 inches DBH in the South climate region.**

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.

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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) |
|---|---|---|---|
| *Corylus americana* | American hazelnut | 1 | 0.1 |
| *Rhus aromatica* | Aromatic sumac | 1 | 0.7 |
| *Taxodium distichum* | Bald cypress | 18 | 0.9 |
| *Nyssa sylvatica* | Black tupelo | 6 | 0.4 |
| *Quercus macrocarpa* | Bur oak | 2 | 2.1 |
| *Physocarpus opulifolius* | Common ninebark | 1 | 0.04 |
| *Cercis canadensis* | Eastern redbud | 8 | 1.1 |
| *Pinus strobus* | Eastern white pine | 2 | 2.4 |
| *Quercus rubra* | Northern red oak | 4 | 1.4 |
| *Picea abies* | Norway spruce | 3 | 2.0 |
| *Quercus* spp. | Oak, other* | 5 | 1.7 |
| *Pinus* spp. | Pine, other* | 2 | 1.1 |
| *Betula nigra* | River birch | 11 | 3.5 |
| *Quercus bicolor* | Swamp white oak | 1 | 0.9 |
| *Liriodendron tulipifera* | Tulip tree | 4 | 3.0 |
| *Hamamelis vernalis* | Vernal witch hazel | 5 | 0.3 |
| *Viburnum* spp. | Viburnum | 2 | 0.1 |
| *Salix* spp. | Willow | 1 | 1.9 |
| Citywide Total | Citywide Total | 77 | 1.5 |

*Oak, other includes overcup oak (*Quercus lyrata*), swamp chestnut oak (*Q. michauxii*), and willow oak (*Q. phellos*). Pine, other includes pitlolly pine (pitch x loblolly pine).

**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 hazelnut | $0.29 | $0.02 | $0.07 | $0.30 | $13.46 | $14.14 |
| Aromatic sumac | $0.29 | $0.02 | $0.07 | $0.30 | $13.46 | $14.14 |
| Bald cypress | $0.21 | $0.05 | $0.05 | $0.39 | $10.19 | $10.90 |
| Black tupelo | $0.09 | $0.02 | $0.02 | $0.17 | $6.59 | $6.89 |
| Bur oak | $0.77 | $0.13 | $0.18 | $1.36 | $29.18 | $31.62 |
| Common ninebark | $0.29 | $0.02 | $0.07 | $0.30 | $13.46 | $14.14 |
| Eastern redbud | $0.37 | $0.03 | $0.10 | $0.51 | $14.19 | $15.19 |
| Eastern white pine | $0.57 | $0.05 | $0.21 | $2.55 | $18.02 | $21.39 |
| Northern red oak | $0.20 | $0.05 | $0.05 | $0.32 | $22.18 | $22.79 |
| Norway spruce | $0.29 | $0.02 | $0.08 | $1.26 | $19.19 | $20.84 |
| Oak, other | $0.66 | $0.12 | $0.15 | $1.15 | $27.78 | $29.86 |
| Pine, other | $0.13 | $0.01 | $0.03 | $0.40 | $10.57 | $11.13 |
| River birch | $1.08 | $0.22 | $0.29 | $1.94 | $22.60 | $26.13 |
| Swamp white oak | $0.20 | $0.05 | $0.05 | $0.32 | $22.18 | $22.79 |
| Tulip tree | $1.16 | $0.23 | $0.31 | $2.07 | $23.23 | $27.00 |
| Vernal witch hazel | $0.29 | $0.02 | $0.07 | $0.30 | $13.46 | $14.14 |
| Viburnum | $0.29 | $0.02 | $0.07 | $0.30 | $13.46 | $14.14 |
| Willow | $0.09 | $0.02 | $0.02 | $0.17 | $6.59 | $6.89 |
| Citywide Total | $0.45 | $0.08 | $0.12 | $0.84 | $16.13 | $17.62 |