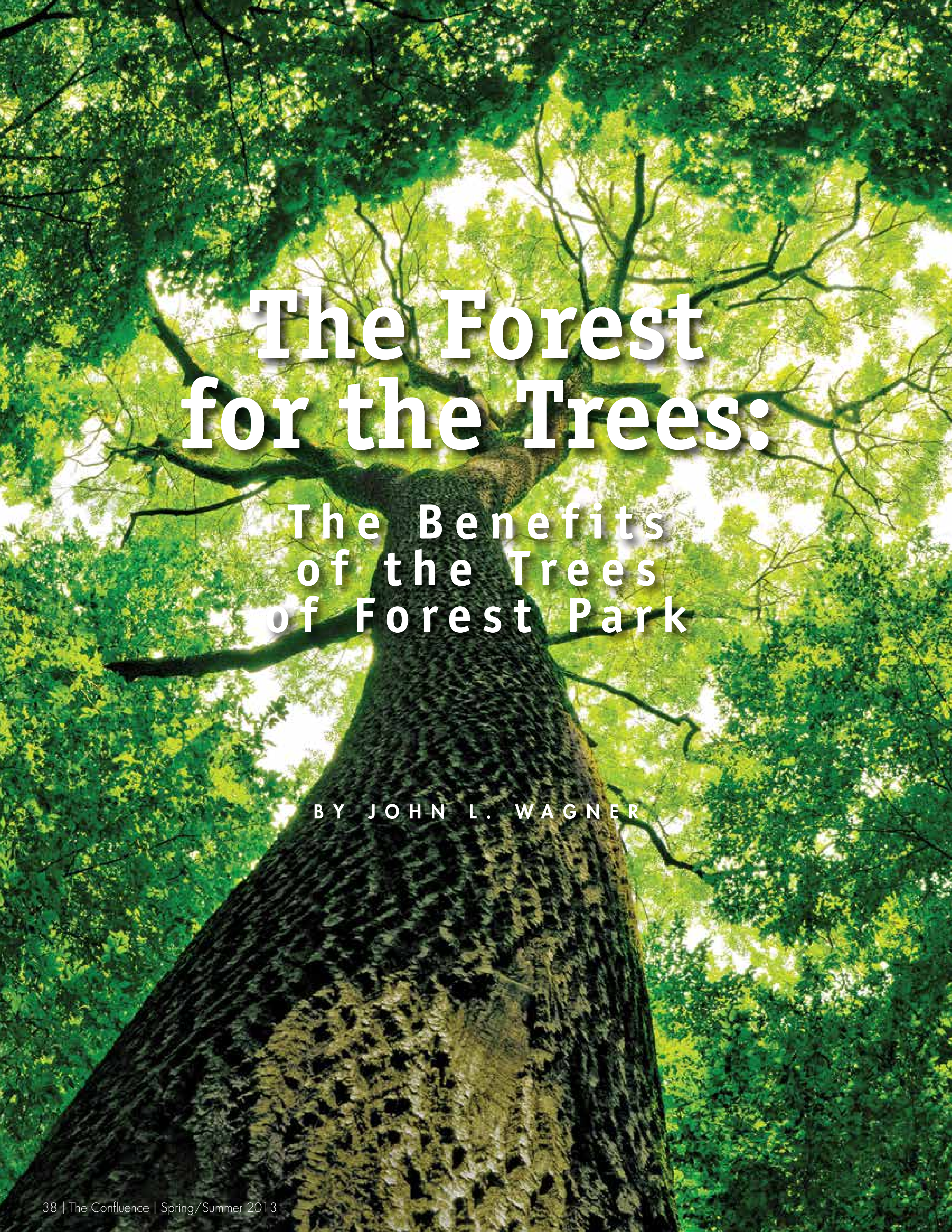


The Forest for the Trees:

The Benefits of the Trees of Forest Park

BY JOHN L. WAGNER

Forest Park in St. Louis, Missouri, has been the focus of a major restoration effort in the last decade. As part of a study on the sustainability of Forest Park, I looked closely at the trees in the park and the role they play in a sustainable urban park. I examined the benefits of the trees, from their potential to improve air quality by absorbing greenhouse gases resulting from man-made pollution, to their ability to intercept stormwater throughout the park. Another, often underappreciated aspect of trees is their aesthetic benefit, accounting for a surprising 75% of the trees' total annual benefits. My study specifically examines the distribution and the variety of the trees throughout the park, their size/age distribution, the increasing level of the park's tree biodiversity, and the evolving condition.[1] This assessment includes the trees in the "developed" portions of the park, although the forested areas are briefly mentioned. The tree canopy in the developed areas of Forest Park covers 161.2 acres, or 12.4% of the park's 1,298 acres. These developed portions comprise most of the area in the park – 92.3% – and include places such as the ground between the museums, the golf courses, picnic areas, the zoo, Art Hill, etc. The forested areas, essentially the Kennedy Forest and the Successional Forest, contribute another 73.1 acres of canopy cover, or 7.3% of the park's area. These forested areas are what we traditionally consider a "forest" to be: a large mass of trees. This distinction between the developed and forested areas of the park is important in this study as the benefits of these trees are derived differently. Just over two-thirds of the tree canopy (67.7%) lies in the developed portion of the park, with the remainder in the forested areas and the wetlands.

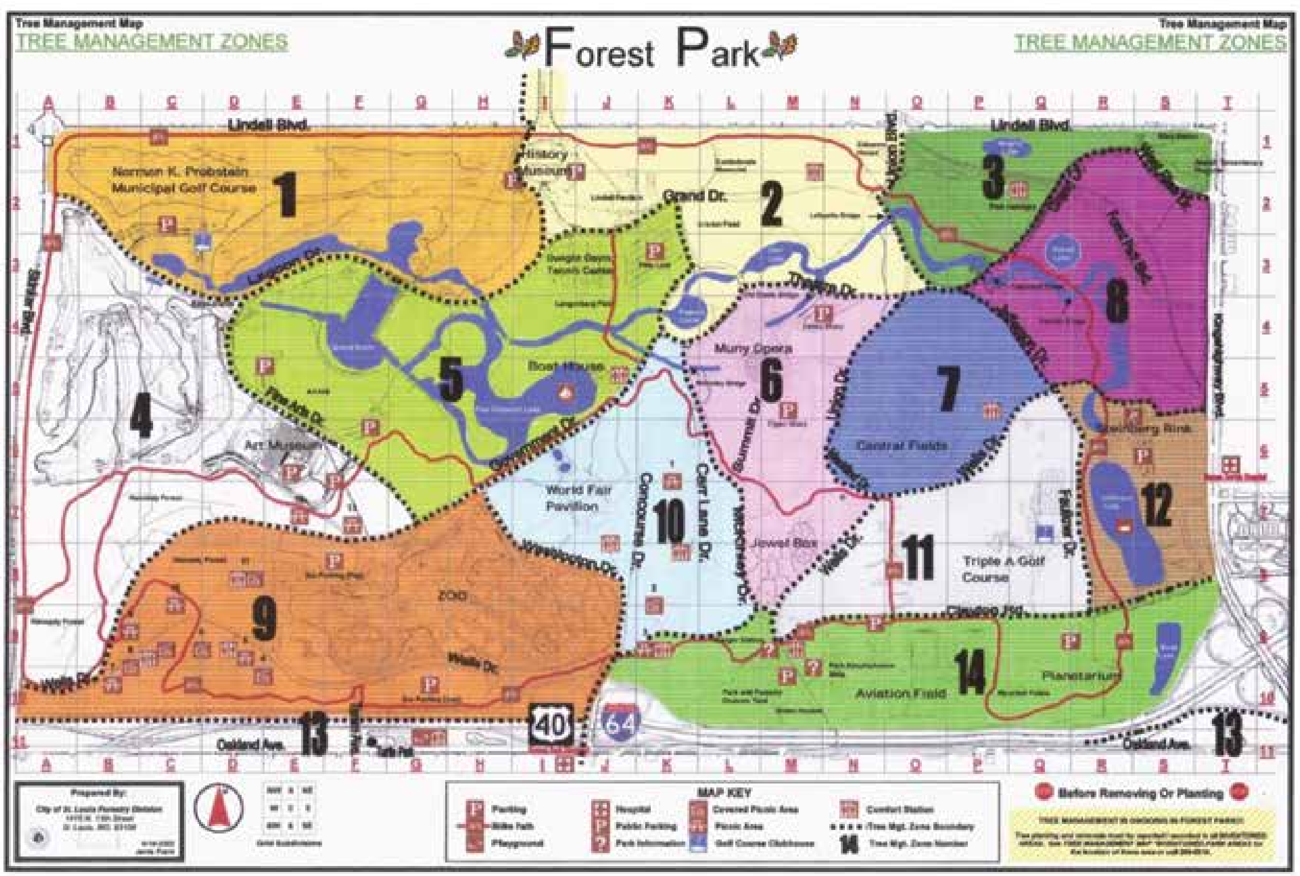
The benefits of the trees in the park correlate directly with the tree canopy cover. This is the amount and distribution of leaf surface area when viewed looking down at the tree's crown. The greater the leaf surface area exhibited by a tree, the greater its canopy cover and, as a result, the greater the benefits that particular tree is likely to provide. Trees with large leaves and spreading canopies tend to produce the most benefits.

Tree Distribution in the Park

Forest Park's tree population is dominated by broadleaf-deciduous trees, or trees that lose their leaves in autumn, encompassing 80.9% of the total population, while coniferous trees (pine, spruce, and fir trees) comprise 17.8% and broadleaf-evergreen trees, such as hollies and magnolias, consisting of 1.3% of the total. Broadleaf trees usually have larger canopies than coniferous trees, and because most of the benefits provided by trees are related to leaf surface area, large, broadleaf trees generally provide the highest level of benefit.

The Forest Park i-Tree Analysis (2011)[2], from which much of the data on the park's trees is derived, divides the park into fourteen Tree Management Zones, as illustrated

Figure 1. Forest Park Tree Management Zones



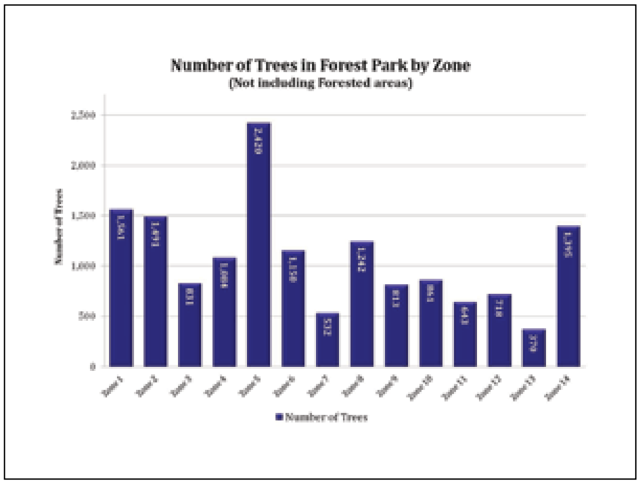


Figure 2. Number of trees in Forest Park's developed areas, by zone.

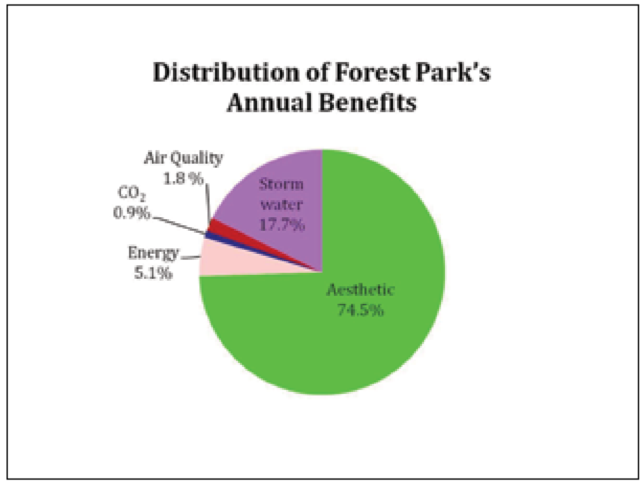


Figure 3. The annual distribution of the benefits of Forest Park's Trees.

in Figure 1. i-Tree Streets is an urban forest manager's tool developed by researchers at the United States Department of Agriculture (USDA) Forest Service, Pacific Southwest Research Station's Center for Urban Forest Research in Davis, California. The purpose of i-Tree Streets is to enable a community to assess its public tree resource by calculating its structure, function, and value. The tool was originally designed to measure the benefit and value of street trees, but it has been adapted here for use in an urban park.

Figure 2 provides information about the total number of landscape trees in each of these zones. Zone 5, where the Grand Basin and Post Dispatch Lake are located, has the most trees in its developed landscape of the Park and includes 2,420 trees, 16.0 percent of all inventoried trees. Zone 13, near the southeast corner of the park, close to the Saint Louis Science Center and the Interstate 64 / Kingshighway Boulevard interchange, is the least populated, with only 370 trees, or 2.4 percent of the total population. Zone 7, site of the Central Fields, also has relatively few trees, 532, only 3.5 percent of the total.

The Benefits of Forest Park's Trees

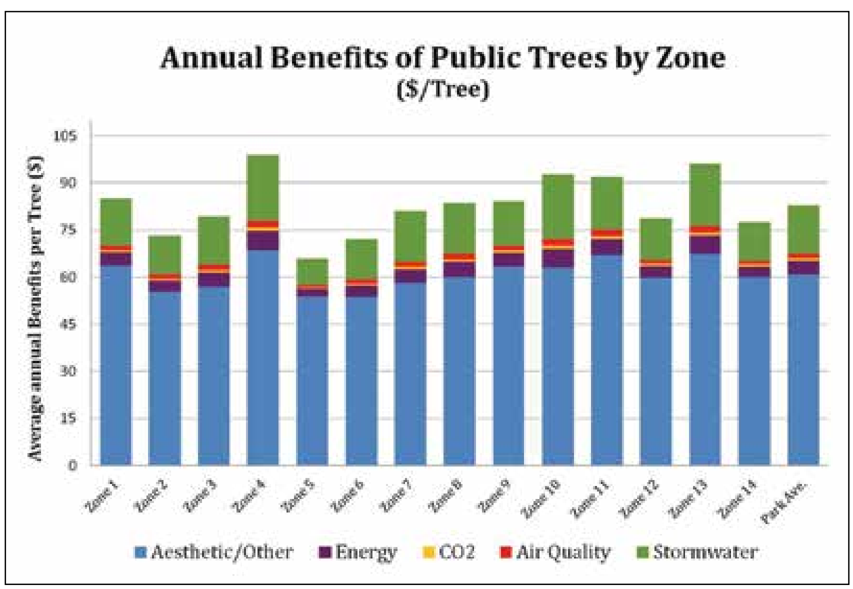
Figure 3 shows the distribution of the benefits of Forest Park's landscape trees. The aesthetic nature of trees provides the largest portion of the annual benefits, 74.5 percent of the total. Environmental services contribute the remaining 25.5 percent. Environmental benefits include stormwater mitigation, accounting for 17.7 percent of the total annual benefits, energy savings which account for 5.1 percent; air quality improvements accounting for 1.8 percent; and carbon dioxide (CO_2) reduction, contributing 0.9 percent of total annual benefits. Leaf surface area, population, and canopy cover determine a tree population's ability to produce benefits. The more canopy cover Forest Park has, the more benefits it will generate.

Figure 4 illustrates the average annual benefit per tree, in dollars, by zone. Note the more even distribution of benefits than the actual number of trees across the same area shown in Figure 2, likely due to the difference in the age and species of the trees in these areas.

Aesthetic Benefits

It is difficult to place a dollar value on the benefit Forest Park's landscape trees provide to the overall well-being of the park. Trees provide beauty in the urban landscape, improved human health, a sense of comfort and place, and habitat for urban wildlife. Part of the aesthetic benefit

Figure 4. Average annual benefit per tree, in dollars, by zone.



reported in the 2011 i-Tree analysis for Forest Park includes property values of the land on which trees stand. This quality is difficult to substantiate, particularly for public park land. Nonetheless, I'm going to stand by the report's 74.5% annual benefits attributed to aesthetics for two reasons.

First, the property value component is not completely unjustified, as the homes along Lindell Avenue, running east-west, just north of the park demonstrate. The argument could be made that these affluent homes, not to mention the upscale Central West End neighborhood, among others, would not exist in their current state if not for Forest Park. Indeed, this effect was envisioned by the park's designers. St. Louis real estate agent Andrew McKinley, citing examples of Central Park in New York City, noted at the time, "In the course of fifteen years the increased value of the surrounding property would return the cost of the park three times over in taxation."[3]

Secondly, many scholars, specifically John Dwyer, Herbert Schroeder, and Paul Gobster,[4] point out people have a strong attachment to trees in the urban landscape. Be it a sensory or a symbolic meaning, people are attracted to trees. I would argue that this attachment and association with the park's trees is also included in the 74.5 percent of the annual benefits. In short, Forest Park would not be the park it is today if it were not for its trees.

In that context, the aesthetic, social, and economic benefits, among other non-tangible related benefits, provide an estimated $902,313 annually to Forest Park, for an average of $59.71 per tree.

Energy Savings Benefits

Trees conserve energy in three principal ways:

1. Shading reduces the amount of radiant energy absorbed and stored by built surfaces, commonly referred to as the "heat island effect."
2. Transpiration of water from the leaves' surface converts moisture to water vapor and cools the air by using solar energy that would otherwise result in heating of the air. This, in addition to lack of a heat island effect, is one of the reasons parks are generally a few degrees cooler than the surrounding areas.
3. Trees deflect and slow the wind that would otherwise directly strike buildings, resulting in less conductive heat loss where outside air normally enters the building, e.g., glass windows. Windows that are "drafty" may seem less so if a tree were planted right outside the window.

Shading and climate effects from Forest Park's landscape trees are estimated to provide annual electric and natural gas savings equal to 681.7 Megawatt-hours ($53,175) and 15,216.4 therms ($8,059), respectively. Forest Park saves a total of $61,234 per year over the whole inventoried tree population (15,111 trees), resulting in an estimated average annual savings of $4.05 per tree in the developed portions of the park.

Atmospheric Carbon Dioxide (CO_2) Reduction Benefits

Trees reduce atmospheric carbon dioxide (CO_2) in two ways:

1. Directly, through sequestration of CO_2 as woody and foliar biomass as they grow.
2. Indirectly, by lowering and, thus avoiding, the demand for additional heating and air conditioning (see Energy Savings Benefits), thereby reducing emissions associated with electric power production and consumption of natural gas.

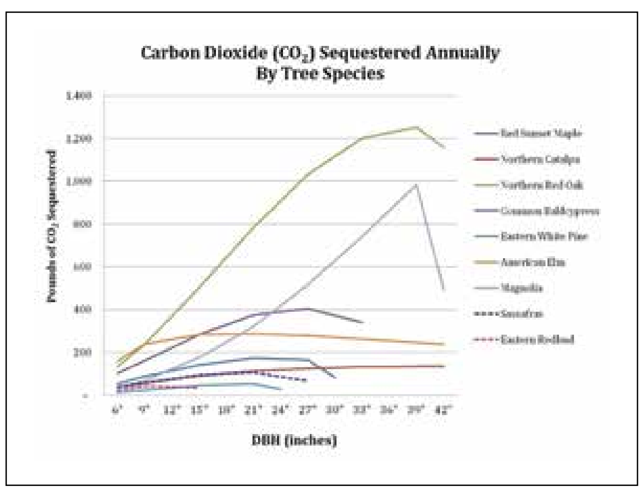
Trees sequester ("lock up") CO_2 in their roots, trunks, stems and leaves as they grow, and in wood products after they are harvested. The benefits of reduced CO_2 correlate directly with woody biomass and leaf surface area.

By tree type, pin oak provides the most CO_2 benefit ($1,802), accounting for 15.9 percent of the total annual CO_2 benefit in the park, followed by northern red oak ($837), shingle oak ($777), and American sycamore ($567). White oak is shown to provide the greatest benefits per tree ($2.49) followed by shingle oak ($2.48), pin oak ($2.33), and northern red oak ($1.74). As expected, smaller-sized trees, such as apple and eastern redbud provide CO_2 reductions at a lower rate than larger trees; their annual benefits equal $0.19 and $0.10, respectively.

Figure 5 shows the pounds of CO_2 sequestered per tree annually as it matures.[5] "DBH" – the "diameter at breast height" – is an indicator of the age of a tree. For example, a 6-inch DBH tree is a much younger tree than a 27-inch DBH tree. The graphic shows a wide-ranging ability of individual species to sequester CO_2 as they mature. Not surprisingly, the northern red oak ranked far ahead of the other species listed. The American elm actually started out by sequestering more CO_2 than the northern red oak at 6-inch DBH, but it quickly levels out and does not sequester much more CO_2 in its mature stage.

If sequestering CO_2 was all park managers were interested in accomplishing with a tree planting campaign, we would see many more oak trees planted throughout the

Figure 5. Pounds of CO_2 sequestered per tree annually by species.



park. However, as will be noted throughout this article, managers need to consider a number of issues when deciding what tree to plant in a particular location. While these numbers can be useful in knowing how much CO_2 is being sequestered, other issues need to be considered as well. As an example, the Eastern white pine, while ranking low in CO_2 sequestration (one of the lowest of the nine shown in Figure 5) due to the fact that it has needles instead of broad leaves, is an excellent tree for providing a wind break, particularly in the winter when its pine needles are still on the tree.

Air Quality Benefits

Trees improve air quality in five fundamental ways:

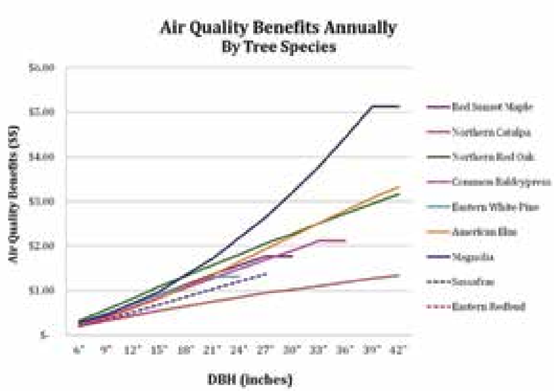
1. Absorbing gaseous pollutants, such as ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), through leaf surfaces.
2. Intercepting particulate matter (PM_{10})[6], such as dust, ash, dirt, pollen, and smoke.
3. Reducing emissions from power generation by reducing energy consumption. If planted in the right location, trees provide an indirect benefit of reduced air pollutant emissions that result from energy production.
4. Releasing oxygen through photosynthesis.
5. Transpiring water and providing shade, resulting in lower local air temperatures, thereby reducing ozone (O_3) levels.

The Forest Park i-Tree Analysis (2011) determined that each year Forest Park's landscape trees provide a savings of $8,538 by intercepting 9,262 pounds of gaseous air pollutants in the form of ozone (O_3), nitrogen dioxide (NO_2), small particulate matter (PM_{10}), and sulfur dioxide (SO_2). These pollutants are largely the result of energy consumption through the burning of fossil fuels.

By tree type, pin oak (1,049 pounds, $487), American sycamore (657 pounds, $604), Austrian pine (519 pounds, $487), and northern red oak (483 pounds, $445) intercept the greatest amounts of air pollutants per year due to their size and prevalence in the landscape tree population, accounting for 23.7 percent ($2,023) of the total annual benefits. Small-growing trees such as apple (103 pounds, $95) and eastern redbud (86 pounds, $79) contribute the least relative to the population and their mature size, which is considerably less than the larger trees.

Figure 6, using the same model that generated Figure 5, shows the air quality benefits, in dollars per tree, annually by selected species. Similar to CO_2 sequestration, the magnolia and northern red oak species show higher abilities to intercept air pollutants. The American elm, while not efficient at sequestering CO_2, is fairly proficient at intercepting air pollutants. The northern catalpa, a tree with very large leaves relative to its overall size, performs surprisingly low.

Figure 6. Air quality benefits ($$) per tree annually by species.



Additional Forested Benefits

Utilizing NLCD (National Land Cover Database) imagery,[7] i-Tree Vue estimated the amount of carbon sequestered and air pollution removed by Forest Park's forested areas, which generally comprise the Kennedy Forest in Zone 4 and the Successional Forest in Zone 10. As with the developed portion of the park, the estimate of air pollution removed includes PM_{10}, SO_2, O_3, and NO_2. Forest Park's 93.9 acres of forested area with 73.1 acres of tree canopy cover provides a total air quality improvement value of $21,508 by sequestering 97.9 tons of CO_2 and 2.5 tons of air pollution.

Table 1 compares the annual air quality benefits provided by the tree canopy in the developed portions of Forest Park with the tree canopy in the forested areas. These forested areas, covering approximately half (45.3 percent) the area of the tree canopy in the developed portions of the park, provide approximately 50 percent more benefits, or, in essence, a 1:1 ratio between the tree canopy coverage and the benefit. The trees in the forested areas did not provide greater benefits just because they were in a forest.

Table 1. Comparison of annual air quality benefits provided by the tree canopy in the developed portions of Forest Park and the forested areas.

	Developed Tree Canopy (161.2 acres)		Forest Tree Canopy (73.1 acres)	
Benefit	Quantity Removed (Tons)	Benefit Value	Quantity Removed (Tons)	Benefit Value
PM_{10}	1.8	$11,086	0.8	$5,028
SO_2	0.5	$1,038	0.2	$471
O_3	2.7	$23,972	1.2	$10,875
NO_2	0.8	$6,854	0.3	$3,110
CO_2 Sequestered	215.8	$4,463	97.9	$2,025
Total	221.6	$47,413	100.4	$21,508

Stormwater Mitigation Benefits

Trees are mini-reservoirs, controlling runoff at the

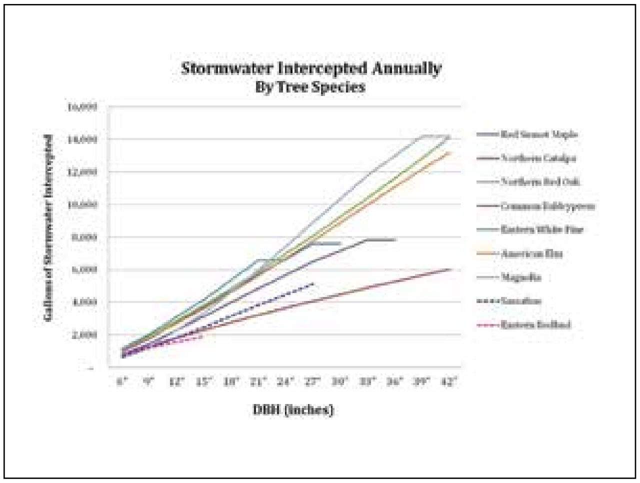


Figure 7. Gallons of stormwater intercepted per tree annually, by species.

source of the stormwater. They can reduce the amount of runoff and pollutants in stormwater in three primary ways:

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

Forest Park's landscape trees intercept 34,691,887 gallons of stormwater annually, or 2,296 gallons per tree, on average. The total value of this benefit to the park is $215,105, with an average value of $14.23 per tree. Mature, large-growing trees intercept larger volumes of water and produce greater benefits compared to mature, small-growing trees.

Figure 7 shows the number of gallons of stormwater intercepted per tree annually by selected species. The magnolia and northern red oak species again perform well, exhibiting a remarkable ability to intercept stormwater. The Eastern white pine, while demonstrating a lower capacity to sequester CO_2 and cleanse the air of pollutants, is able to intercept a high volume of stormwater.

Net Benefit and Benefit-Cost Ratio

The sum of environmental and economic benefits provided to Forest Park by its landscaped trees is $1,211,496 annually, at an average of $80 per tree. When Forest Park's annual tree-related expenditures of $287,504 are considered, the net annual benefit (benefits minus costs) returned by landscape trees is $923,992.

Applying a cost-benefit ratio (CBR) is an effective way to evaluate the park's investment in trees. A CBR is an indicator used to summarize the overall value compared to the costs. Specifically in this analysis, CBR is the ratio of the cumulative benefits provided by the park's landscape trees, expressed in monetary terms, compared to the costs associated with their management, also expressed in monetary terms. Based on the inventory count of 15,111 landscape trees (in 2006), Forest Park receives $4.21 in benefits for every $1 that is spent on its municipal forestry program. Table 2 provides a complete breakdown of the numbers.

Table 2. Forest Park's Net Benefit and Benefit-Cost Ratio.

	Total ($)	$/Tree	$/Visitor
Total Annual Benefits	$1,211,496	$80.17	$0.10
Total Annual Costs	$287,504	$19.03	$0.02
Net Annual Benefits	$923,992	$61.15	$0.08
Benefit-Cost Ratio		$4.21	

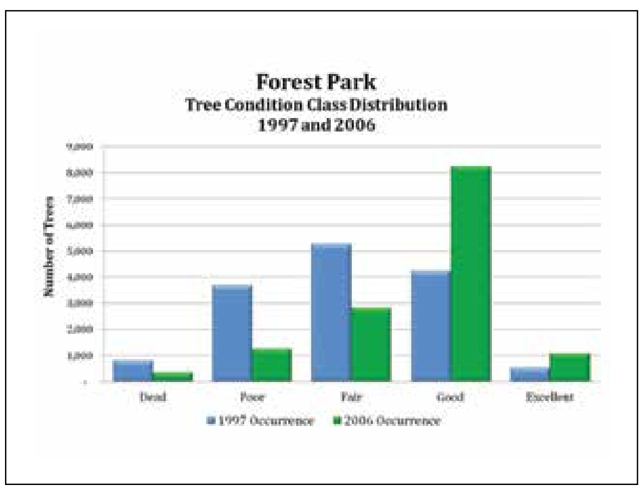
Tree Condition

Keeping the trees in Forest Park in excellent or good condition is crucial for maintaining the environmental and economic benefits they provide. Table 3 and Figure 8 show the evolution of the condition of the trees from 1997 to 2006.[8] The overall condition of the trees in Forest Park improved dramatically between these years. Due to increased – and better – management of the park's trees, a significant decrease occurred in the "dead," "poor," and "fair" categories (a 57 percent decrease, a 66 percent

Table 3. The condition of Forest Park's trees in 1997 and 2006.

Condition Class	1997 Occurrence	1997 % of Population	2006 Occurrence	2006 % of Population	Change	% Change
Dead	796	6%	342	2%	-454	-57%
Poor	3,664	25%	1,245	9%	-2,419	-66%
Fair	5,263	36%	2,818	21%	-2,445	-46%
Good	4,223	29%	8,246	60%	4023	95%
Excellent	522	4%	1,080	8%	558	107%

Figure 8. Condition of Forest Park's trees in 1997 and 2006.



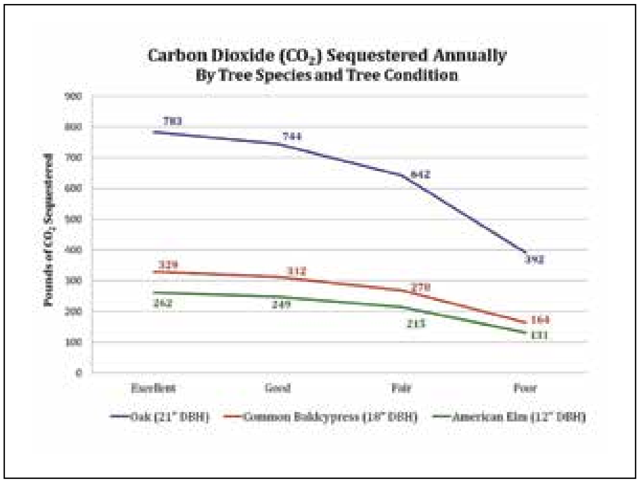


Figure 9. Carbon dioxide (CO_2) sequestration by selected tree species annually by condition.

Figure 10. Air Quality benefits in dollars by selected tree species annually by condition

decrease and a 46 percent decrease, respectively); while an increase occurred in the "good" and "excellent" categories (a 95 percent increase and a 107 percent increase, respectively). This shift occurred as dead trees were removed and those in poor and fair condition improved. This change also accounts for the increased number of young trees that are generally considered to be in good or excellent condition.

According to SKA Forestry Consultants in 2006, the number of trees fell by 737 (a 5 percent decrease) as many of the poor quality (and potentially hazardous) trees were removed.

Pruning efforts have increased the overall health and condition ratings of remaining trees. As a result, the overall maintenance needs of trees in Forest Park fell 42 percent between 1997 and 2006, most significantly in the maintenance needs typically associated with larger trees, such as hazard tree removal, hazard limb pruning, and crown cleaning.

Figures 9, 10, and 11 demonstrate the importance of maintaining a healthy tree population in order to maximize the environmental and economic benefits associated with those trees. Figure 9 shows the amount (in pounds) of CO_2 that can be sequestered by three tree species: oak (any species), common bald cypress, and American elm, at different levels of maturity. A 21" DBH oak tree in excellent condition is able to sequester 783 pounds of CO_2 annually. This is a significant number as Figure 5 shows that oak is one of the most efficient tree species in sequestering CO_2. For the same tree in good condition the sequestration level drops only 5% to 744 pounds. If the condition slips to fair, the sequestration potential drops to 642 pounds, an 18% decrease. The same tree, in poor condition, however, can sequester only 392 pounds of CO_2 annually, a 50% decrease from the original 783 pounds expected from a tree in excellent condition.

The 18-inch DBH common bald cypress and 12-inch DBH American elm show similar rates of decline in the ability to sequester CO_2 as the tree's condition deteriorates,

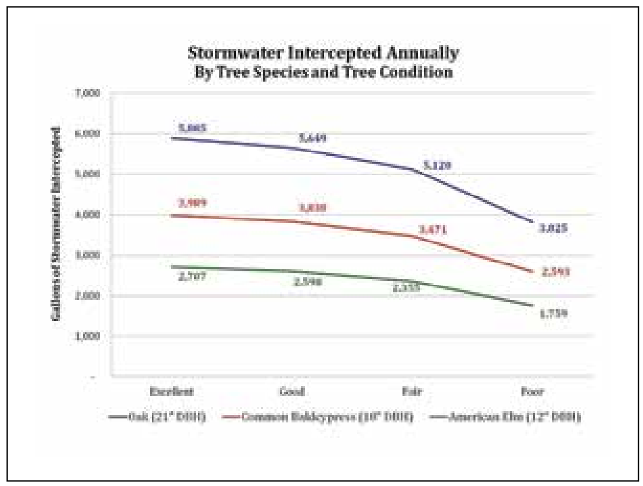


Figure 11. Gallons of stormwater intercepted by selected tree species annually by condition

although the regression is not as pronounced, perhaps due to the efficiency of the trees in sequestering CO_2, (i.e., less than that of the oak) and the smaller diameter of the trees, again, less than the larger 21-inch DBH oak. In both cases, though, a tree in poor condition is able to sequester only half the CO_2 as the same tree in excellent condition.

Figure 10 shows a similar scenario for maintaining the benefits from increased air quality. For the same three trees (21-inch DBH oak, 18-inch DBH common baldcypress and 12-inch DBH American elm), the benefits associated with air quality – the absorption of ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) through the leaf surfaces and the interception of particulate matter (PM_{10}) – decrease by approximately 50 percent when the same tree goes from excellent to poor condition. Comparable decreases in benefits are also evident for trees in good and fair condition.

Lastly, Figure 11 shows how stormwater interception is affected by the health of the tree. In this graphic, the same three trees as used in Figures 9 and 10 are used to demonstrate how much less stormwater is intercepted as the tree's condition deteriorates.

The decline, while still pronounced, is not as severe as declines shown in the two previous graphs.

For all three trees (21-inch DBH oak, 18-inch DBH common bald cypress, and 12-inch DBH American elm) there is only a decline of approximately 5 percent in the ability to intercept stormwater when the tree goes from excellent to good condition and a decrease of 13 percent when the tree slips to fair condition (19 percent for the 21-inch DBH oak). When the condition goes from excellent to poor, the ability of all three trees to intercept stormwater decreases by 35 percent. While still a significant decrease, the decline is not as severe as the 50 percent reduction found for the same trees when considering CO_2 sequestration and air quality benefits.

Figures 9, 10, and 11 stress the importance of maintaining a healthy tree population in Forest Park. These three graphs show a strong correlation between the condition of the trees and the environmental and economic benefits they provide. In addition to the loss of aesthetic benefits, if the condition of the trees declines, there will be an associated decline in benefits.

Tree Size/Age Distribution

Maintaining a healthy population of trees in Forest Park includes maintaining an appropriate size, or age, distribution. The distribution of ages within a tree population influences present and future costs as well as the flow of benefits. An ideal tree population has a higher percentage of young trees (40 percent) than established (30 percent), maturing (20 percent), and mature trees (10 percent) in order to minimize fluctuations in benefits. The age structure of Forest Park's landscape trees is considered ideal at a distribution of 51:12:24:13 (percentages of young: established: maturing: mature trees). However, the age distributions among individual tree management zones are not ideal.

As shown in Table 3 and Figure 12, while the total trees numbers fell from 14,468 to 13,731 (a reduction of 737 trees, or 5 percent), trees within the 0- to 6-inch diameter class (DBH) increased 67 percent, due to aggressive planting efforts. Trees within the 7- to 12-inch diameter

Table 4. A comparison of the size/age distribution of trees in Forest Park, 1997 and 2006.

Diameter Class (DBH)	Number of Trees in 1997	Number of Trees in 2006	Change	% Change
0 - 6"	3,482	5,831	2,349	67%
7 - 12"	4,427	1,892	-2,535	-57%
12 - 18"	2,981	2,150	-831	-28%
19 - 24"	1,963	1,757	-206	-10%
> 24"	1,615	2,101	486	30%
Total	14,468	13,731	-737	-5%

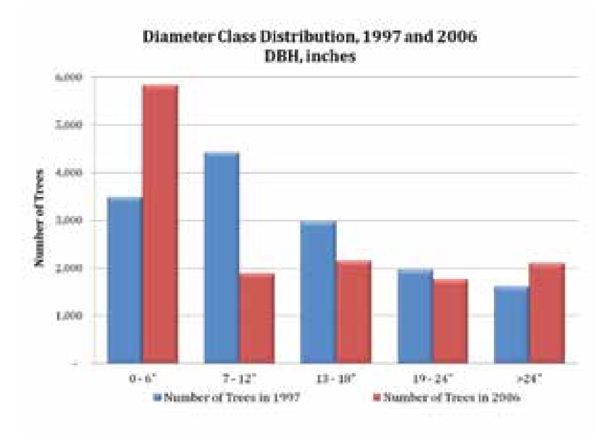


Figure 12. A comparison of the size/age distribution of trees in Forest Park, 1997 and 2006

class, though, fell by 57 percent. Many newly planted trees do not survive to reach the 7- to 12-inch diameter class, possibly due to drought or mower and weed trimmer damage. The number of trees in the larger diameter classes (13- to 18-inch and 19- to 24-inch) fell as well, except for the >24-inch class which increased by 30 percent. I could not find a reason for the decline in the 13- to 18-inch DBH and the 19- to 24-inch DBH categories, other than possibly because of the removal of some of these trees that were dead or dying. Some tree species reach their maturity at these sizes and need to be removed when necessary. It is expected that higher survival rates of smaller trees, as part of a healthier tree population, will eventually increase the number of larger trees and will create a more sustainable population, while contributing more environmental and economic benefits.

Figure 13 illustrates the relative age distribution among Forest Park's 14 tree management zones. Zones 1 through 3, 5 through 9, 12, and 14 are approaching the ideal age distribution. These ten zones have larger amounts of young trees compared to established, immature, and maturing trees in their populations. Zones 4 and 10 have relatively even-aged populations that are not ideal. Zone 4's population is 28.3 percent young, 16.5 percent established, 31.0 percent maturing, and 24.2 percent mature. Zone 10's population is 31.1 percent young, 15.8 percent established, 29.0 percent maturing, and 24.0 percent mature. Zones 11 and 13 have large amounts of mature trees (37.5 percent and 37.3 percent, respectively) compared to young trees (21.9 percent and 22.7 percent, respectively). The latter two zones are likely to see large fluctuations in costs and benefits due to the high presence of mature trees and lower presence of young trees.

Among species populations, American sycamore (63.9 percent), pin oak (67.6 percent), and Austrian pine (63.9 percent) dominate their immature (maturing) and mature size classes and have a lower representation in their young size class (12.9 percent, 21.8 percent, and 13.8 percent, respectively). The lack of younger trees for these three

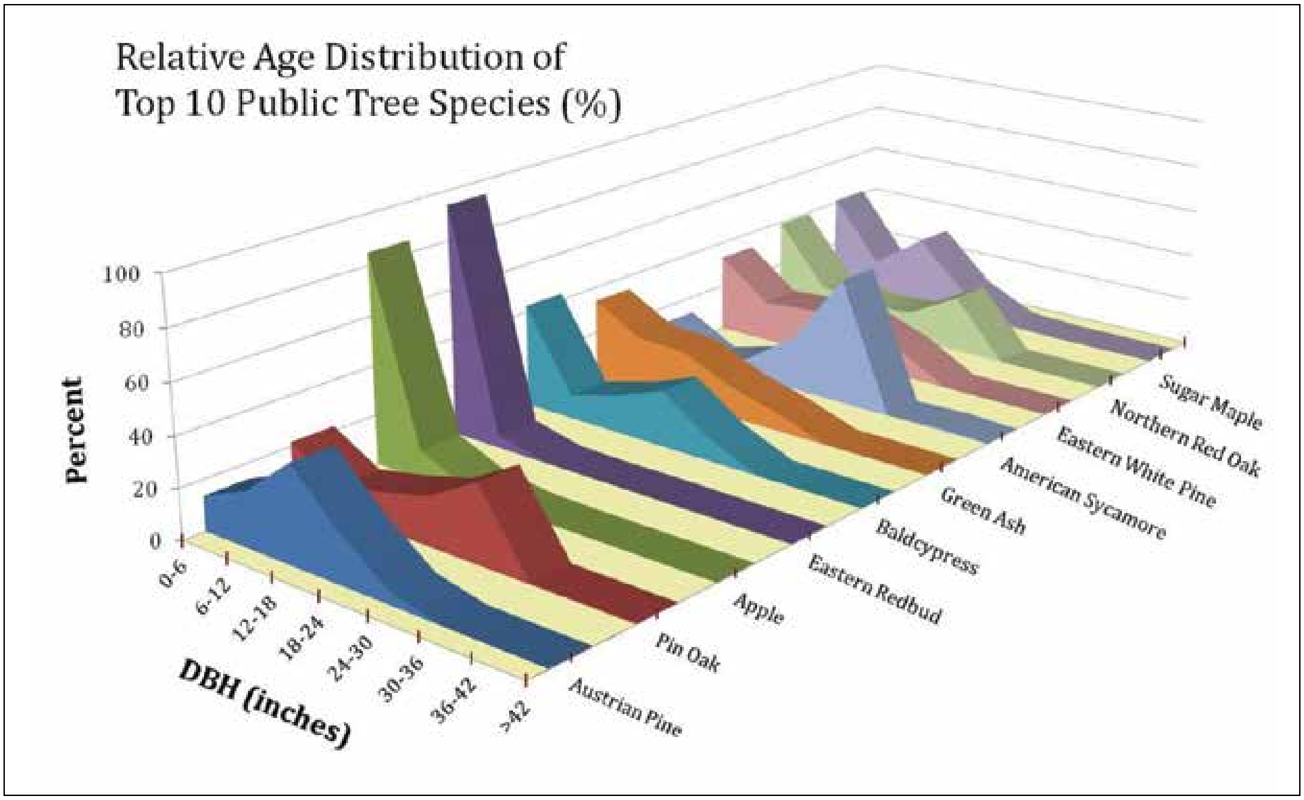
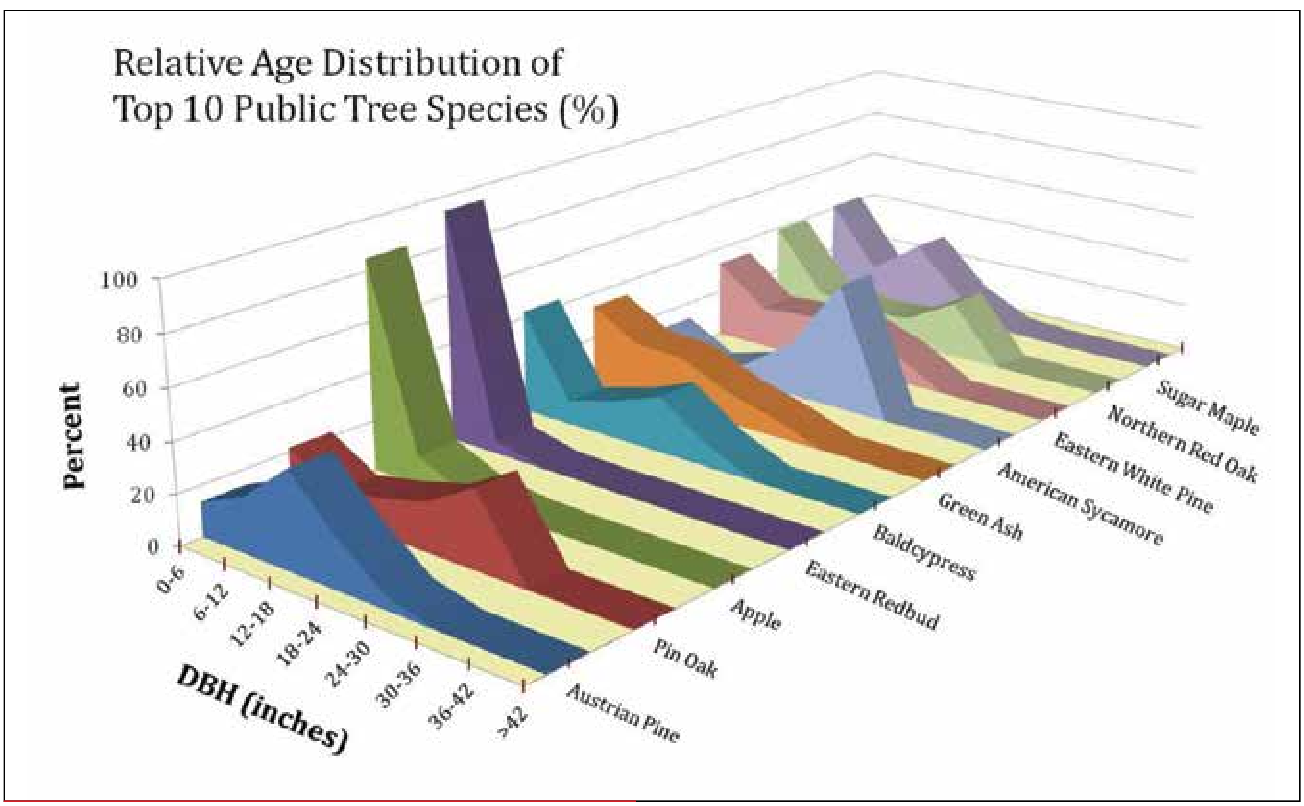


Figure 13. The relative age distribution of Forest Park trees by zone.

Figure 14. Relative age distribution of the top ten public tree species.


Relative Age Distribution of
Top 10 Public Tree Species (%)
Percent
100
80
60
40
20
0
0-6
6-12
12-18
18-24
24-30
30-36
36-42
>42
DBH (inches)
Austrian Pine
Pin Oak
Apple
Eastern Redbud
Baldcypress
Green Ash
American Sycamore
Eastern White Pine
Northern Red Oak
Sugar Maple

species stands out in Figure 14, showing the relative age distribution for the top ten public tree species in the park. While widely used in the past, the City and Forest Park Forever are actively working to minimize these individual populations as these three are now recognized as inferior species. The American sycamore compartmentalizes decay poorly, is prone to fungus infestation, and is a "messy" tree, due to its large leaf and heavy fruit production. The Pin oak has a poor survival rate in higher soil pH levels, and the Austrian pine has a poor survival rate due to issues caused by diplodia tip blight, zimmerman pine moth, and pitch mass borer.

These trees are being restricted to specific areas of the park better suited to the needs of each species. However, as noted earlier, these three species alone provide 23.7 percent ($2,023) of the total annual air quality benefits in the park and are currently the three tree species with the highest Importance Value. Without sufficient replacement species, the current functional capacity of these large-growing, high-benefit producing trees will diminish. This is an instance where the information provided in by the i-Tree Design program and graphically illustrated in Figures 5, 6, 7, 8, 9, 10, and 11 would be useful in determining appropriate replacement species.

As also illustrated in Figure 14, baldcypress (42.6 percent), sugar maple (41.1 percent), northern red oak (39.2 percent), eastern white pine (33.1 percent), and green ash (34.1 percent) have dominate amounts of trees in their young size classes and lower representations of trees in their immature and mature size classes. These large-growing species are beginning to approach an ideal distribution and will provide increasing benefits as they mature.

It is also important to consider small-growing trees in the species matrix. As shown in Figure 14, apple and eastern redbud have uneven-age distributions heavily skewed towards young trees. Of the 691 apple trees in the park, 85.0 percent are young trees, 11.6 percent are established trees, and 3.4 percent are maturing to mature trees. It is important to realize that small-growing trees mature much earlier than large-growing ones, and for this reason need a strong and more populated base of young trees to continue the canopy cover associated with these species.

Based on these results, Forest Park only lacks appropriate age distributions for three of the ten most populated species, American sycamore, pin oak, and Austrian pine.

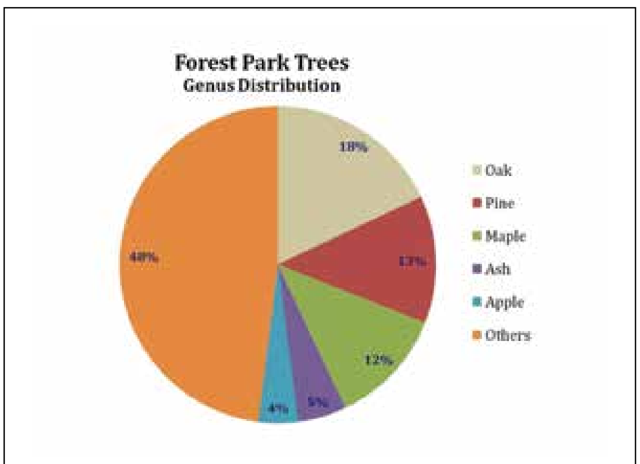
Tree Biodiversity

Ideally, no single species should make up more than 10 percent of a park's tree population. This distribution ensures a diverse population; maximizes the environmental, economic, and aesthetic benefits; and minimizes the chance of catastrophic losses from insects or diseases. There are no species in the park that exceed this 10 percent level. SKA Forestry Consultants suggest that no genus exceed 25 percent of a park's tree population, although the consultants at Davey Resource Group who wrote the Forest Park i-Tree Analysis recommend no more than 20 percent for one genus. As indicated in Figure 15 showing the top five genera represented in the park, there are none that exceed either one of these levels. The oak genus (*Quercus*) comprises 18 percent of the park's trees while the pine genus (*Pinus*) encompasses 15 percent. The maple genus (*Acer*) makes up 12 percent of the population, ash (*Fraxinus*) 5 percent, and the apple genus (*Malus*) a mere 4 percent. Forest Park has a diverse tree population, with 48 percent of the trees coming from genera other than these top five. Forest Park's tree population includes a mix of 222 species from 77 genera.

The biodiversity of the park's trees has increased dramatically since 1997. In 1997 there were 120 species found in the park's landscaped trees. By 2006, increased plantings pushed that number to 189 species. In 2010, there were 222 tree species found in the park, an increase of 46 percent between 1997 and 2010. This nearly two-fold increase, together with the appropriate age distribution of the trees noted above, is expected to provide greater environmental, economic and aesthetic benefits in the future.

Figure 16 emphasizes the importance of tree species biodiversity and its relation to providing habitat for and attracting wildlife. This graph, derived from Douglas Tallamy and Kimberley Shropshire's research,[9] shows the number of species in the listed genera that are host trees for species of Lepidoptera – butterfly and moth larvae – which are in turn important pollinators and food for birds and other animals. Dr. Tallamy, from the University of Delaware, has written extensively on the role of native plants in the ecosystem. Kimberley Shropshire is one of Dr. Tallamy's students who, with his help, took on the enormous task of compiling this list of Lepidoptera species. As an advocate of native plants in Missouri, Ann Wakeman[10] points out that lepidopteran larvae (caterpillars) are extremely valuable sources of food for many terrestrial birds, particularly warblers and neotropical migrants. Tallamy and Shropshire's work categorizes native and alien plant genera in terms of their

Figure 15. Genus distribution of the trees in Forest Park.



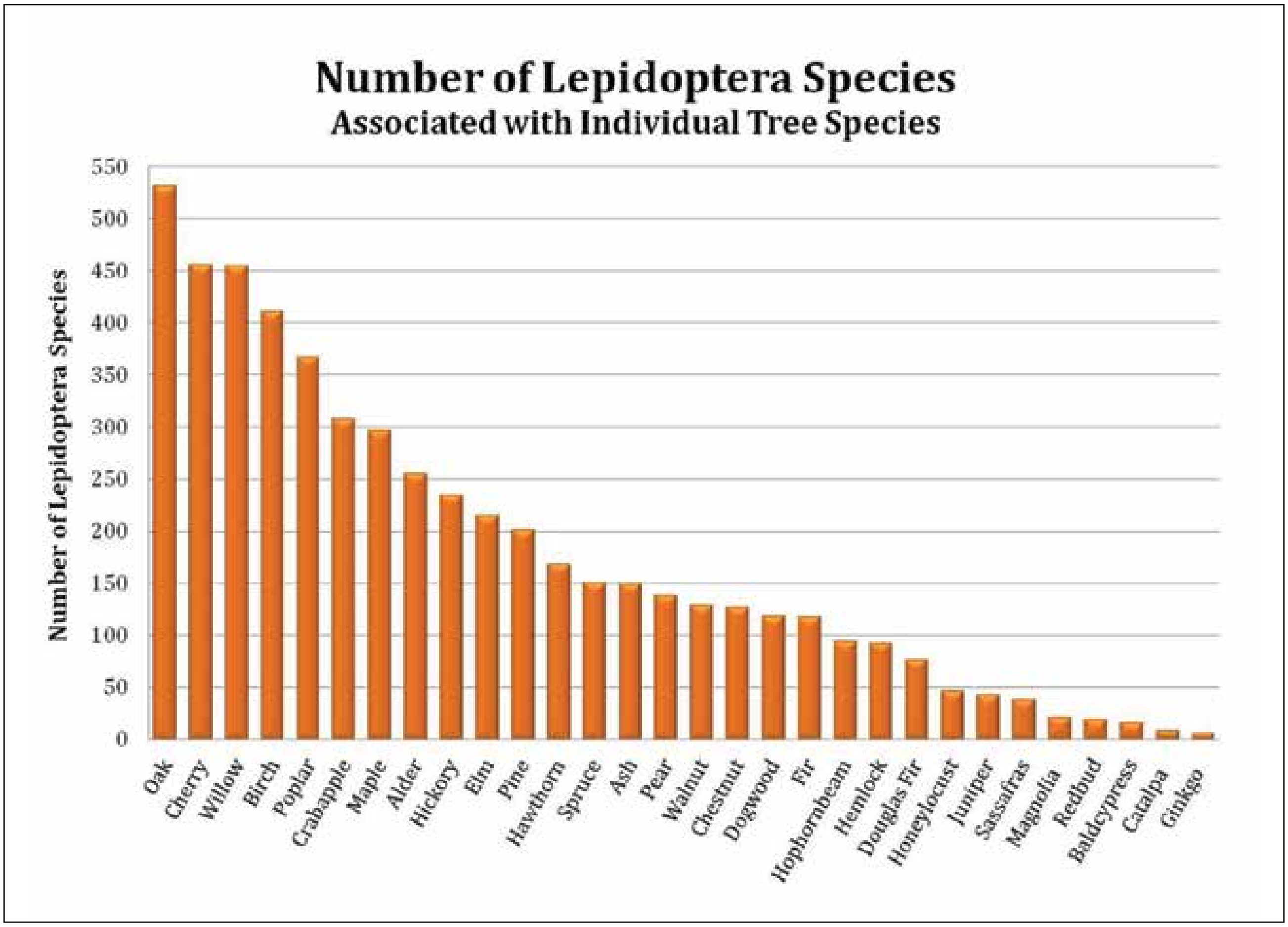


Figure 16. Tree species by genera that are host to Lepidoptera species.

ability to support insect herbivores and, by inference, overall biodiversity. They ranked all native plant genera by the number of Lepidoptera species (butterflies and moths) recorded using them as host plants. While their study focused on the Mid-Atlantic region of the United States, I believe the theory behind their analysis is valid for Forest Park. All but two of these genera, willow and poplar, are on the Suggested Planting list provided by Davey Resource Group as part of their Forest Park i-Tree Analysis, and species in all of these genera are currently found in Forest Park. Ensuring that tree species in these genera and others are kept healthy would support and attract an increasing diversity of wildlife to the park.

The ecological performance of the park has increased since the Forest Park Master Plan was approved in 1995, and subsequently implemented. The Forest Park i-Tree Report from 2011and the online i-Tree Design tools document how much we are benefitting from the trees in Forest Park. When comparing this to the health and diversity of the trees in 1997, my research shows that the trees prior to restoration of the park could not have provided the same level of benefits in 1997. As the City and Forest Park Forever have continued their care of the tree stock within the park, and as trees have continued to mature, the environmental and economic benefits today are likely greater than they were in 2006 and are substantially greater than 1997.

The trees in Forest Park also are providing ecosystem services that, on a more global scale, reduce the air pollution associated with the formation of greenhouse gases that are attributable to climate change, such as carbon dioxide (CO_2) and ozone (O_3), in addition to other pollutants like sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and small particulate matter in the air (PM_{10}).

The primary concern from a tree management perspective is that the three tree species in the park with the highest importance value – pin oak, American Sycamore, and Austrian pine – are now recognized as inferior tree species. Even though they were widely used in the past, the City and Forest Park Forever, with an emphasis on maximizing the benefits derived from the park's trees, are actively working to minimize these individual populations. American sycamore compartmentalizes decay poorly, is prone to fungus infestation, and is a "messy" tree, due to its large leaf and heavy fruit production. Pin oak has a poor survival rate in higher soil pH levels, and the Austrian pine has a poor survival rate due to issues caused by diplodia tip blight, zimmerman pine moth, and pitch mass borer These trees are being restricted to specific areas of the park better suited to the needs of each species. Skillful planning will be needed to make sure the functional capacity of these trees is suitably replaced without diminishing the benefits they provide.

ENDNOTES

[1] Annual benefits for Forest Park's landscape trees were estimated for the fiscal year 2010 using i-Tree's Streets (v4.0) and utilizing data from park's 2006 tree inventory.

[2] Data used for this analysis were obtained from the Forest Park Year 2006 tree inventory, containing 15,111 landscape trees

[3] Caroline Loughlin, *Forest Park* (St. Louis: The Junior League of St. Louis and University of Missouri Press, 1986).

[4] J. Dwyer, H.W. Schroeder, and P.H. Gobster, "The Ecological City: The Deep Significance of Urban Trees," in *In The Ecological City: Preserving and Restoring Urban Biodiversity*, edited by R.H. Platt, R.A. Rowntree, and P.C. Muick (Amherst: The University of Massachusetts Press, 1994), 137-50.

[5] This data was obtained using the i-Tree design program, found at http://www.itreetools.org/design.php.

[6] In 1987, EPA replaced the earlier Total Suspended Particulate (TSP) air quality standard with a PM-10 standard. The new standard focuses on smaller particles that are likely responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract. The PM-10 standard includes particles with a diameter of 10 micrometers or less (0.0004 inches or one-seventh the width of a human hair).

[7] NLCD is an abbreviation for National Land Cover Database. The model uses satellite-based imagery to assess land cover , including tree canopy. This is a different model than was used to assess the developed portion of the park. It should be noted that NLCD tends to underestimate tree canopy cover by 10% due to the quality of resolution in Landsat satellite images.

[8] The number of trees in the 2006 inventory used by SKA Forestry Consultants, 13,731, is 1,380 trees less than the 15,111 landscape trees used for the i-Tree analysis.

[9] D.W. Tallamy and K.J. Shropshire, "Ranking Lepidopteran Use of Native Versus Introduced Plants," *Conservation Biology* 23 (2008): 941–47.

[10] A. Wakeman, "Prairie gardening with Propagated Plants," *Missouri Prairie Journal* 30 (2009): 6-13.