Tree Inventory Summary Report

City of Bloomington, Indiana

September 2019

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Acknowledgments

Bloomington's vision to promote and preserve the urban forest and improve the management of public trees was a fundamental inspiration for this project. This vision will ensure canopy continuity, which will reduce stormwater runoff and energy use and improve aesthetic value, air quality, and public health.

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Executive Summary

The City of Bloomington commissioned an inventory to assess trees, stumps, and planting sites located within public street rights-of-way (ROW) and parks. Understanding an urban forest's structure, function, and value can promote management decisions that will improve public health and environmental quality. DRG collected and analyzed the inventory data to understand species composition and tree condition, and to generate maintenance recommendations. This report will discuss the health and benefits of the inventoried street ROW and park tree population throughout the City of Bloomington.

Key Findings

- A total of 24,371 sites were assessed, including 19,013 trees, 741 stumps, and 4,617 planting sites.
- The most common species are: *Acer rubrum* (red maple), 13%; *Pyrus calleryana* (callery pear), 7%; *Quercus rubra* (northern red oak), 6%; *A. saccharum* (sugar maple), 6%; and *Q. palustris* (pin oak), 6%.
- Most (48%) inventoried street and park trees are young, 0–8 inches diameter at breast height (DBH).
- The overall condition of the tree population is healthy (Fair to Good).
- Risk Ratings include: 18,023 Low Risk trees; 910 Moderate Risk trees; and 80 High Risk trees.
- Primary Maintenance recommendations include: 8,833 Discretionary Prunes; 5,997 Training Prunes; 2,881 Prunes; 1,302 Removals; 1,428 Large-growing Tree Plantings; 454 Medium-growing Tree Plantings; and 2,735 Small-growing Tree Plantings.
- Bloomington's tree population provides approximately $968,823 in the following annual benefits:
  - *Aesthetic and Other Tangible Benefits*: valued at $643,202 per year.
  - *Air Quality*: 16,230 pounds of pollutants removed valued at $23,884 per year.
  - *Net Total Carbon Sequestered and Avoided*: 3,679,323 pounds valued at $10,870 per year.
  - *Energy*: 853,140 kilowatt-hours (kWh) and 19,190 therms valued at $76,686 per year.
  - *Stormwater:* 34,545,160 gallons valued at $214,180 per year.

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Section 1: Tree Inventory Assessment

Project Area

From February to August 2019, a team of DRG staff assessed and inventoried trees, stumps, and planting sites along the public street ROW and select parks in Bloomington, Indiana. Parks included Bryan Park, Building Trades, Butler Park, Lower Cascades, Miller Showers Park, Olcott Park, Peoples Park, Rose Hill Cemetery, Seminary Park, Twin Lakes Recreation Center and Sports Complex, and White Oak Cemetery. See Appendix A for an overview of the site location methodology used during the inventory.

Species Diversity

Throughout the city's streets and parks, 24,371 sites were inventoried, including 19,013 trees (17,541 street and 1,472 park), 741 stumps, and 4,617 planting sites. Figure 1 shows the composition of the most populous species compared to all inventoried species. The composition of a tree population should follow the 10-20-30 Rule for species diversity: a single species should represent no more than 10% of the urban forest, a single genus should represent no more than 20%, and a single family should represent no more than 30%.

Of all the species inventoried in Bloomington, *Acer rubrum* (red maple) at 13% is the only species that exceeds the 10% threshold.

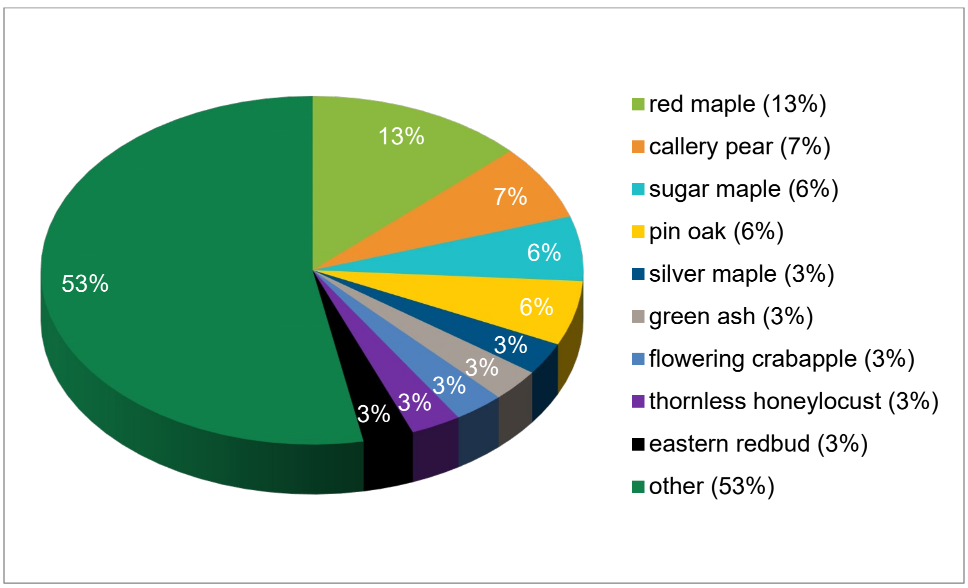
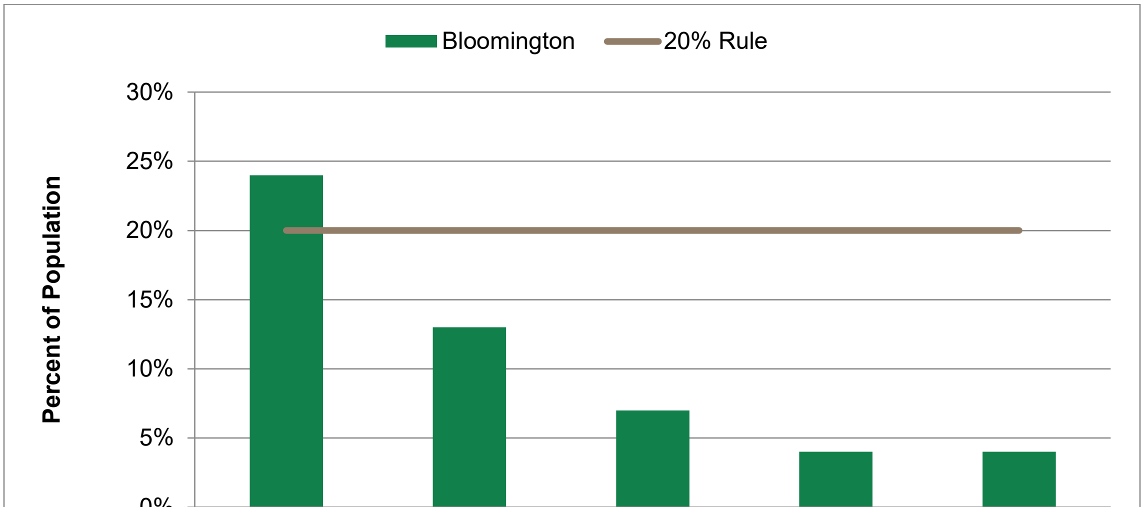


Figure 1. Tree species composition in the City of Bloomington.

Figure 2 compares the percentages of the five most common genera identified during the inventory to the 20% Rule. *Acer* (maple) exceeds the recommended 20% threshold for a single genus in a population at 24%.



	maple	oak	pear	ash	elm
Bloomington	24%	13%	7%	4%	4%
20% Rule	20%	20%	20%	20%	20%

Figure 2. Top five genera in the City of Bloomington in relation to the 20% Rule.

Diameter Size Class Distribution

Analyzing the diameter size class distribution (measured as diameter at breast height [DBH]) provides an estimate of the relative age of a tree population and lends insight into maintenance practices and needs.

The inventoried trees were categorized into the following diameter size classes: young trees (0–8 inches DBH); established trees (9–17 inches DBH); maturing trees (18–24 inches DBH); and mature trees (greater than 24 inches DBH). These categories were chosen so that the population could be analyzed following Richards' ideal distribution (1983). Richards proposed an ideal diameter size class distribution for street trees based on observations of well-adapted trees in Syracuse, New York. Richards' ideal distribution suggests that the largest fraction of trees (approximately 40% of the population) should be young (less than 8 inches DBH), while a smaller fraction (approximately 10%) should fall in the large-diameter size class (greater than 24 inches DBH). A tree population with an ideal distribution would have an abundance of newly planted and young trees, and lower numbers of established, maturing, and mature trees.

Figure 3 compares the inventoried tree diameter size class distribution to the ideal proposed by Richards (1983). The distribution trends toward the ideal. With proper management, this ideal will balance out as the urban forest in the city ages. Continued tree planting, care, and maintenance of the young and established tree population will help contribute to a sustainable size distribution of street and park trees in Bloomington.

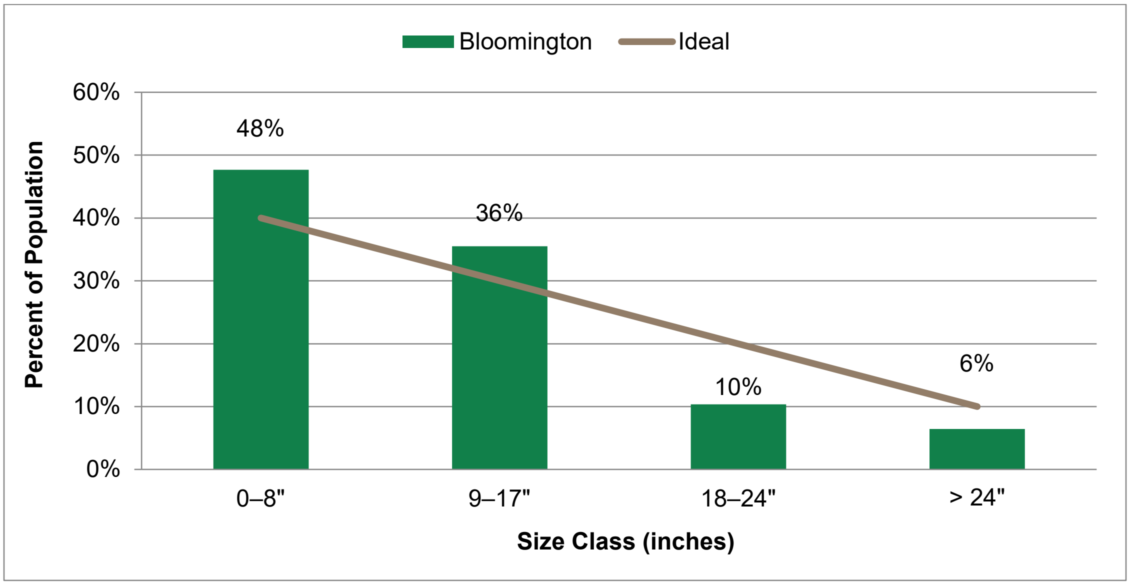


Figure 3. Age class distribution compared to Richards' (1983) ideal.

Condition

Several factors were considered for the condition of each tree. Root characteristics, branch structure, trunk, canopy, and foliage condition, and the presence of pests were all assessed. The condition of each inventoried tree was rated as either Good, Fair, Poor, or Dead.

The majority of inventoried street and park/public spaces trees (50%) was recorded to be in Fair condition (Figure 4). Based on these data, the general health of the inventoried tree population is Fair to Good or healthy.

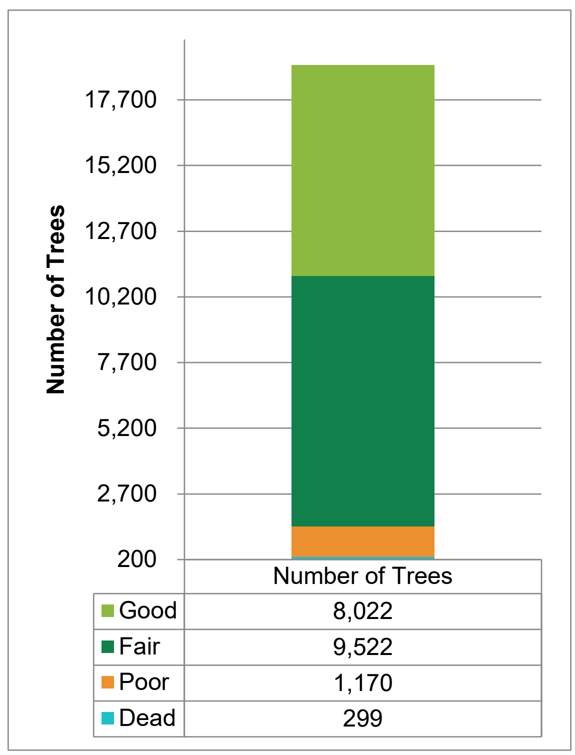


Figure 4. Overall condition of the inventoried population.

Figure 5 illustrates the general condition of the urban forest in relation to relative age classes. Most of the young, established, and maturing trees were rated to be in Fair condition. With proactive care and an established maintenance schedule, the city can improve the long-term health of its urban forest.

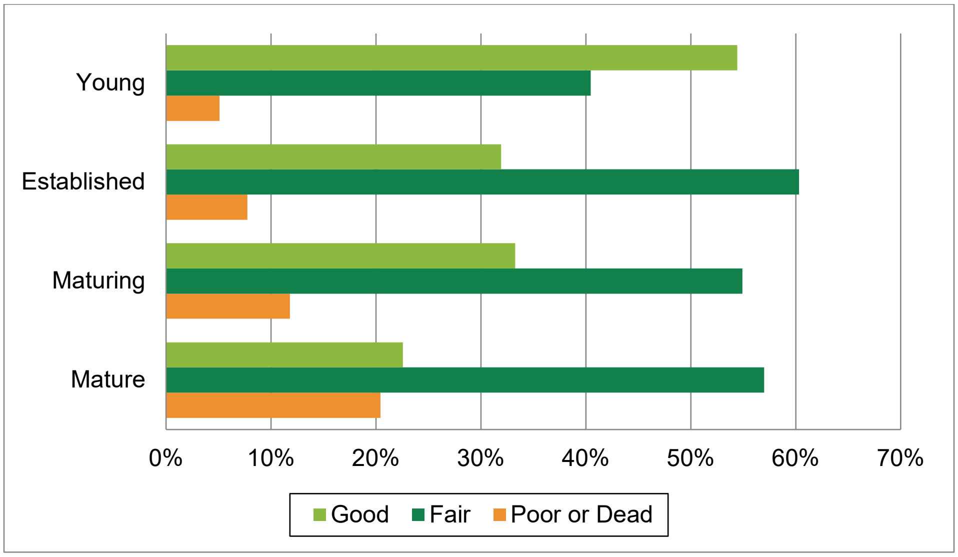


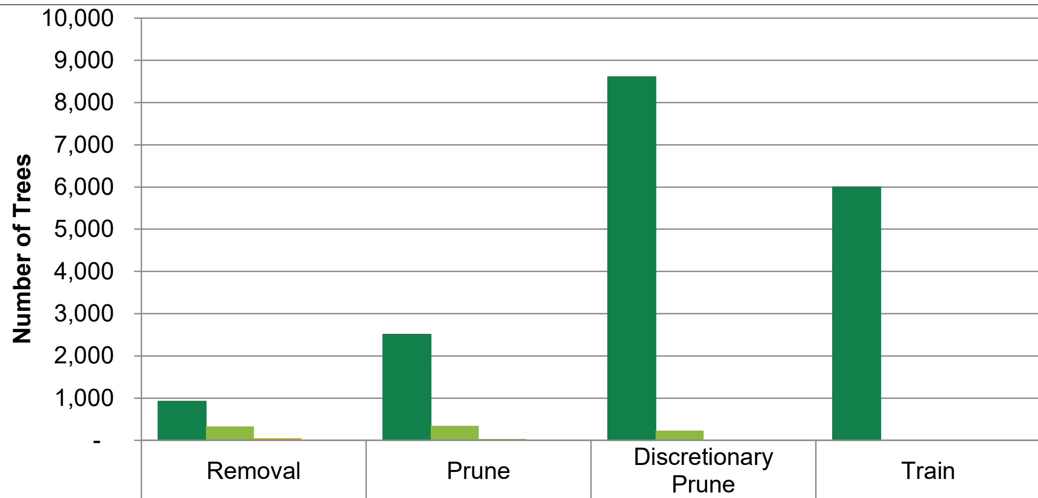
Figure 5. Tree condition by age class.

Primary Maintenance and Risk

Primary maintenance refers to the task identified for a tree or site: Removal, Prune, Discretionary Prune, Training Prune, Plant Tree, or Stump Removal. Risk is a graduated scale that measures potential tree-related hazardous conditions. A tree is considered hazardous when its potential risks exceed an acceptable level of risk.

DRG based the maintenance recommendations and risk values (Figure 6) on the evaluation of species, diameter class, condition, impact of hazard, and defects found in each individual tree. Identifying and ranking the maintenance needs of a tree population enables tree work to be assigned priority based on observed defects. Once prioritized, tree work can be systematically addressed to eliminate the greatest risk and liability first (Stamen 2011).

Based on the inventoried population in the city, the following maintenance recommendations should be implemented: 1,302 Removals, 2,881 Prunes, 8,833 Discretionary Prunes, and 5,997 Training Prunes. Figure 6 illustrates the risk values associated with each maintenance need.



	Removal	Prune	Discretionary Prune	Train
Low	919	2,504	8,605	5,995
Moderate	333	347	228	2
High	50	30	-	-
Severe	-	-	-	-

Figure 6. Maintenance needs by risk rating.

Street Tree Planting

Prior to conducting tree inventories, most municipalities determine available planting sites primarily through resident requests. With the inventory data, Bloomington now knows the exact location of every available planting site along the street ROW.

The tree inventory found a total of 4,617 vacant planting sites distributed throughout Bloomington (Table 1). Of the inventoried sites, 1,428 were potential planting sites for large-size trees (8-foot-wide and greater growing space size); 454 were potential sites for medium-size trees (6- to 7-foot-wide growing space sizes); and 2,735 were potential sites for small-size trees (4- to 5-foot-wide growing space sizes).

Table 1. Vacant Planting Sites

Tree Type	Number of Trees	Percentage of Trees
Large	1,428	31%
Medium	454	10%
Small	2,735	59%
Total	4,617	100%

Section 2: Benefits of the Urban Forest

The urban forest plays an important role in supporting and improving the quality of life in urban areas. A tree's shade and beauty contribute to a community's quality of life and soften the often hard appearance of urban landscapes and streetscapes. When properly maintained, trees provide communities abundant environmental, economic, and social benefits that far exceed the time and money invested in planting, pruning, protection, and removal.

Environmental Benefits

- Trees decrease energy consumption and moderate local climates by providing shade and acting as windbreaks.
- Trees act as mini-reservoirs, helping to slow and reduce the amount of stormwater runoff that reaches storm drains, rivers, and lakes. One hundred mature tree crowns intercept roughly 100,000 gallons of rainfall per year (U.S. Forest Service 2003a).
- Trees help reduce noise levels, cleanse atmospheric pollutants, produce oxygen, and absorb carbon dioxide.
- Trees can reduce street-level air pollution by up to 60% (Coder 1996). Lovasi (2008) suggested that children who live on tree-lined streets have lower rates of asthma.
- Trees stabilize soil and provide a habitat for wildlife.

Economic Benefits

- Trees in a yard or neighborhood increase residential property values by an average of 7%.
- Commercial property rental rates are 7% higher when trees are on the property (Wolf 2007).
- Trees moderate temperatures in the summer and winter, saving on heating and cooling expenses (North Carolina State University 2012, Heisler 1986).
- On average, consumers will pay about 11% more for goods in landscaped areas, with this figure being as high as 50% for convenience goods (Wolf 1998b, Wolf 1999, and Wolf 2003).
- Consumers also feel that the quality of products is better in business districts surrounded by trees than those considered barren (Wolf 1998b).
- The quality of landscaping along the routes leading to business districts had a positive influence on consumers' perceptions of the area (Wolf 2000).

Social Benefits

- Tree-lined streets are safer; traffic speeds and the amount of stress drivers feel are reduced, which likely reduces road rage/aggressive driving (Wolf 1998a, Kuo and Sullivan 2001a).
- Chicago apartment buildings with medium amounts of greenery had 42% fewer crimes than those without any trees (Kuo and Sullivan 2001b).
- Chicago apartment buildings with high levels of greenery had 52% fewer crimes than those without any trees (Kuo and Sullivan 2001a).
- Employees who see trees from their desks experience 23% less sick time and report greater job satisfaction than those who do not (Wolf 1998a).
- Hospital patients recovering from surgery who had a view of a grove of trees through their windows required fewer pain relievers, experienced fewer complications, and left the hospital sooner than similar patients who had a view of a brick wall (Ulrich 1984, 1986).
- When surrounded by trees, physical signs of personal stress, such as muscle tension and pulse rate, were measurably reduced within three to four minutes (Ulrich 1991).

The trees growing along the public streets constitute a valuable community resource. They provide numerous tangible and intangible benefits, such as pollution control, energy reduction, stormwater management, property value increases, wildlife habitat, education, and aesthetics.

The services and benefits of trees in the urban and suburban setting were once considered to be unquantifiable. However, by using extensive scientific studies and practical research, these benefits can now be confidently calculated using tree inventory information. The results of applying a proven, defensible model and method that determines tree benefit values for the City of Bloomington's tree inventory data are summarized in this report using DRG's TreeKeeper® inventory management software. The results of Bloomington's tree inventory provide insight into the overall health of the city's public trees and the management activities needed to maintain and increase the benefits of trees into the future.

Tree Benefit Analysis

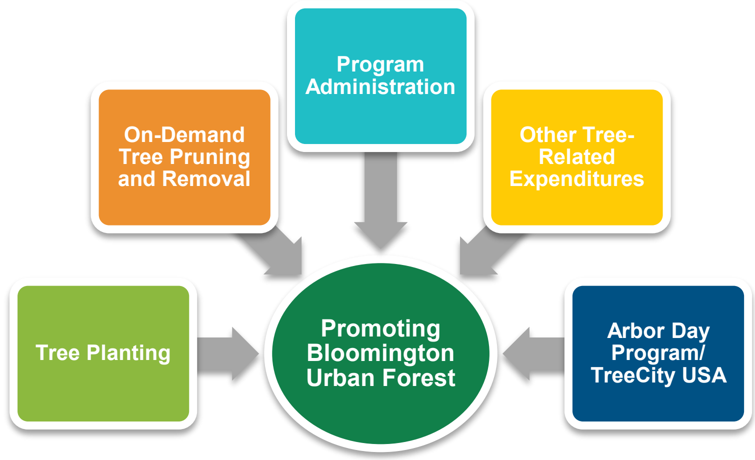
TreeKeeper® calculates the ecosystem benefits of individual trees, groups of trees, or an entire urban forest using inventory data. TreeKeeper® ecosystem benefits value is based on the science of i-Tree. i-Tree is a suite of Tools which analyzes an inventoried tree population's structure to estimate the benefits of that tree population. These quantified benefits are described below.

- **Aesthetic/Other Benefits:** Shows the tangible and intangible benefits of trees reflected by increases in property values (in dollars).
- **Stormwater:** Presents reductions in annual stormwater runoff due to rainfall interception by trees measured in gallons.
- **Energy:** Presents the contribution of the urban forest towards conserving energy in terms of reduced natural gas use in the winter (measured in therms [thm]) and reduced electricity use for air conditioning in the summer (measured in Megawatt-hours ([MWh]).
- **Carbon Sequestered and Avoided:** Presents annual reductions in atmospheric CO_2 due to sequestration by trees and reduced emissions from power plants due to reductions in energy use measured pounds. The model accounts for CO_2 released as trees die and decompose and CO_2 released during the care and maintenance of trees.
- **Air Quality:** Quantifies the air pollutants (ozone [O_3], nitrogen dioxide [NO_2], sulfur dioxide [SO_2], particulate matter less than 10 micrometers in diameter [PM_{10}]) deposited on tree surfaces, and reduced emissions from power plants (NO_2, PM_{10}, volatile organic compounds [VOCs], SO_2) due to reduced electricity use in pounds. The potential negative effects of trees on air quality due to biogenic volatile organic compounds (BVOC) emissions is also calculated.

i-Tree Tools

i-Tree Tools software was developed by the U.S. Department of Agriculture, Forest Service (USDA FS) with the help of several industry partners, including The Davey Tree Expert Company. Learn more at www.itreetools.org.

In addition to tree inventory data, TreeKeeper® requires regional data, including energy prices, property values, stormwater, and air quality costs, to generate the environmental and economic benefits trees provide. If community program local economic data are not available, TreeKeeper® uses default economic inputs from a reference city selected by USDA FS for the climate zone in which the community is located. Any default value can be adjusted for local conditions by contacting the TreeKeeper® support team.



Bloomington's Inputs

Local data were available at the time of this plan and were used to the greatest extent possible with TreeKeeper® to calculate the benefits Bloomington's street and park trees provide its citizens. i-Tree methods DRG used for Bloomington are further described in Appendix B.

Bloomington's Annual Benefits

TreeKeeper® estimated that the street ROW and park trees provide a total annual benefit of $968,823. Essentially, $968,823 annually is saved to cool buildings, manage stormwater, and clean the air. In addition, community aesthetics were improved and property values increased because of the presence of trees. On average, one of Bloomington's trees provides an annual benefit of $51 per tree or $11 per capita (85,071 estimate 2017).

The assessment found that aesthetics and other tangible and intangible benefits trees provide were the greatest value to the community (approximately $643,202, 66% of total benefit). In addition to increasing property values, trees also play a major role in stormwater management. The city's trees managed 34.5 million gallons of stormwater, which equates to a savings of approximately $214,180 in stormwater management costs. Stormwater management comprises 22% of the annual benefits street and park trees provide. Energy conservation, reductions in CO_2, and removal of other air pollutants are important benefits as well. Energy conservation accounted for 8% of the annual benefits, while CO_2 and air pollutant reductions accounted for nearly 4% of the annual benefits. Figure 7 summarizes the categories of annual benefits for the tree population.

Table 2 presents results for individual tree species from the benefit analysis. The population of red maple is the most beneficial ($145,596 annually). If this species was lost to Asian longhorned beetle or other threats, its loss would be felt more than the community may realize.

The average benefit per tree is $51. Of 40 species with population representing 1% or more of the population, 21 species are performing above the average. Top 5 performers are *Celtis occidentalis* (common hackberry) at $91.12 per tree, *Ulmus pumila* (Siberian elm) at $90.15 per tree, *Quercus palustris* (pin oak) at $88.52 per tree, *Ulmus* x (hybrid elm) at $79.95 per tree, and *Morus alba* (white mulberry) at $78.05 per tree.

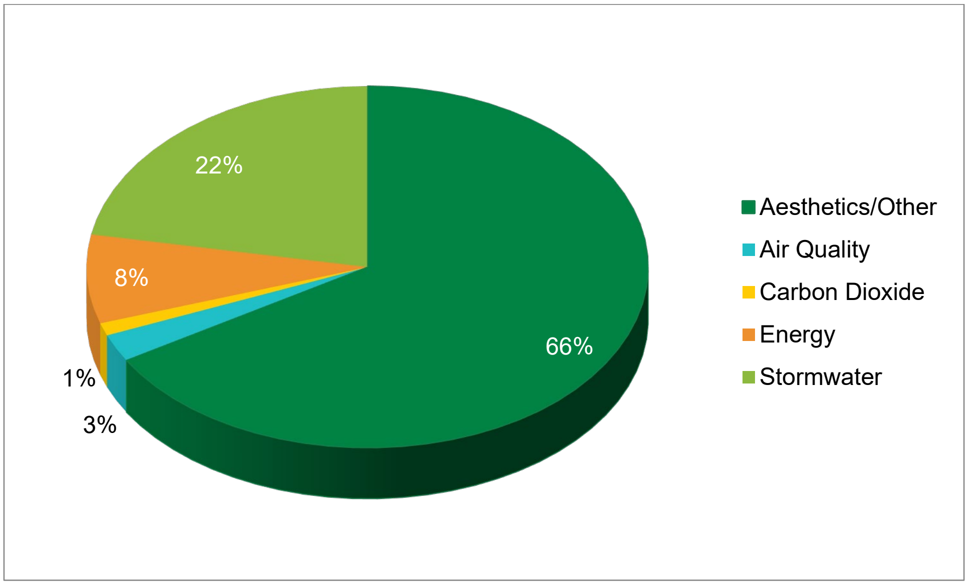


Figure 7. Breakdown of total annual benefits provided to Bloomington.

Table 2. Benefit Data for Common Trees by Species

Most Common Trees Collected During Inventory		Number Trees	Percent of Total Trees	Total Benefit	Benefit per Tree	Performing Above Average (YES/NO/AVG)
Common Name	Botanical Name		(%)	($)	($)	
red maple	*Acer rubrum*	2,520	13%	145,596	57.78	Yes
callery pear	*pyrus calleryana*	1,270	7%	20,804	16.38	No
northern red oak	*Quercus rubra*	1,116	6%	86,343	77.37	Yes
sugar maple	*Acer saccharum*	1,072	6%	68,264	63.68	Yes
pin oak	*Quercus palustris*	589	3%	52,139	88.52	Yes
silver maple	*Acer saccharinum*	585	3%	44,137	75.45	Yes
green ash	*Fraxinus pennsylvanica*	570	3%	39,216	68.80	Yes
flowering crabapple	*Malus* spp.	541	3%	13,296	24.58	No
thornless honeylocust	*Gleditsia tracanthos inermis*	537	3%	30,174	56.19	Yes
eastern redbud	*Cercis canadensis*	516	3%	10,780	20.89	No
hybrid elm	*Ulmus x*	494	3%	39,495	79.95	Yes
eastern white pine	*Pinus strobus*	459	2%	23,424	51.03	Yes
American sweetgum	*Liquidambar styraciflua*	421	2%	28,575	67.87	Yes
Japanese tree lilac	*Syringa reticulata*	420	2%	9,795	23.32	No
tuliptree	*Liriodendron tulipifera*	418	2%	20,430	48.88	No
littleleaf linden	*Tilia cordata*	404	2%	15,540	38.47	No
ginko	*Ginko biloba*	392	2%	18,321	46.74	No
flowering dogwood	*cornus florida*	310	2%	6,860	22.13	No
common hackberry	*Celtis occidentalis*	295	2%	26,880	91.12	Yes
cherry/plum spp.	*Prunus* spp.	289	2%	6,422	22.22	No
swamp white oak	*Quercus bicolor*	289	2%	15,977	55.28	Yes
eastern redcedar	*Juniperus virginiana*	267	1%	7,453	27.91	No
Norway spruce	*Picea abies*	265	1%	8,365	31.57	No
black walnut	*Juglans nigra*	256	1%	15,336	59.91	Yes
arborvitae spp.	*Thuja* spp.	243	1%	6,369	26.21	No
white ash	*Fraxinus americana*	237	1%	14,049	59.28	Yes
Kentucky coffeetree	*Gymnocladus dioicus*	206	1%	5,881	28.55	No
Colorado spruce	*Picea pungens*	199	1%	5,339	26.83	No
common baldcypress	*Taxodium distichum*	169	1%	7,351	43.50	No
Norway maple	*Acer platanoides*	168	1%	8,279	49.28	No
American sycamore	*Platanus occidentalis*	158	1%	10,933	69.20	Yes
Japanese zelkova	*Zelkova serrata*	157	1%	8,026	51.12	Yes
blackgum	*Nyssa sylvatica*	156	1%	2,677	17.16	No

Most Common Trees Collected During Inventory		Number Trees	Percent of Total Trees	Total Benefit	Benefit per Tree	Performing Above Average (YES/NO/AVG)
Common Name	Botanical Name		(%)	($)	($)	
eastern hemlock	*Tsuga candensis*	154	1%	5,423	35.21	No
white mulberry	*Morus alba*	139	1%	10,849	78.05	Yes
black cherry	*Prunus serotina*	138	1%	8,702	63.06	Yes
American linden	*Tilia americana*	132	1%	5,741	43.49	No
Shumard oak	*Quercus shumardii*	103	1%	6,517	63.27	Yes
black locust	*Robinia pseudoacacia*	99	1%	6,554	66.20	Yes
Siberian elm	*Ulmus pumila*	97	1%	8,745	90.15	Yes
other trees	~128 varying species	2,163	11%	93,766	43.35	---
Total	~168 species	19,013	100%	**968,823**	**50.96**	**AVG**

Aesthetic/Other Benefits

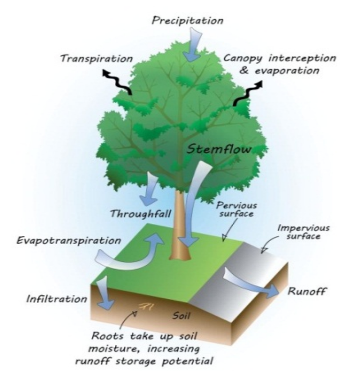
The total annual benefit associated with property value increases and other tangible and intangible benefits of trees inventoried is $643,202. The average benefit per tree equals $338 per year.

Air Quality Benefits

The inventoried tree population annually removes 16,230 pounds of air pollutants (including ozone, nitrogen dioxide, sulfur dioxide, and particulate matter) through deposition and avoidance. The air quality benefit is approximately $23,884 annually. The average benefit per tree equals $12.55 per year.

Carbon Benefits

Trees sequester carbon dioxide (CO_2) during growth (Nowak et al. 2013). This prevents CO_2 from reaching the upper atmosphere, where it can react with other compounds and form harmful gases like ozone, which adversely affects air quality. The i-Tree Streets model takes into account the carbon emissions that are not released from power stations due to the heating and cooling effect of trees (i.e., conserved energy in buildings and homes). It also calculates emissions released during tree care and maintenance, such as driving to the site and operating equipment. The net carbon benefit is approximately $10,870 per year. The average benefit per tree equals $5.71 per year.



- *Trees reduce stormwater runoff by capturing and storing rainfall in their canopy and releasing water into the atmosphere.*
- *Tree roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil.*
- *Trees help slow down and temporarily store runoff and reduce pollutants by absorbing nutrients and other pollutants from soils and water through their roots.*
- *Trees transform pollutants into less harmful substances.*

Energy Benefits

Street trees conserve energy by shading structures and surfaces, which reduces electricity use for air conditioning in the summer. Trees divert wind in the winter to reduce natural gas use. Based on the inventoried trees, the annual electric and natural gas savings are equivalent to 853,140 kWh of electricity and 19,190 therms of natural gas, which accounts for an annual savings of $76,686 in energy consumption at $40 per tree.

Stormwater Benefits

Trees intercept rainfall, which helps lower costs to manage stormwater runoff. The inventoried trees in Bloomington intercept 34,545,160 gallons of rainfall annually. On average, the estimated annual savings for the city in stormwater runoff management is $214,180 ($112.55 per tree).

Discussion/Recommendations

The TreeKeeper® benefits analysis found that trees provide environmental and economic benefits to the community by virtue of their mere presence on the streets. Currently, the aesthetic/other benefits provided trees were rated as having the greatest value to the community. The property value increase provided by trees is important to stimulate economic growth. In addition to increasing aesthetics and property values, trees provide shade and windbreaks to reduce energy usage, manage stormwater through rainfall interception, sequester CO_2, and remove air pollutants.

To increase the benefits the urban forest provides, the city should plant young, large-statured tree species that manage the most stormwater, absorb the most CO_2, and remove the most air pollutants. Leafy, large-stature trees consistently created the most environmental and economic benefits. The following list of tree species is used for improving environmental benefits (i-Tree Species 2019):

Pollutant Removal

- *Ulmus americana* (American elm)
- *Liriodendron tulipifera* (tuliptree)
- *Tsuga cannadensis* (eastern hemlock)
- *Betula alleghaniensis* (yellow birch)
- *Tilia americana* (American linden)

Carbon Storage

- *Quercus sumardii* (Shumard oak)
- *Platanus occidentalis* (American sycamore)
- *Zelkova serrata* (Japanese zelkova)
- *Ulmus americana* (American elm)
- *Betula alleghaniensis* (yellow birch)

Stormwater Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)
- *Magnolia acuminata* (cucumber magnolia)

Energy Reduction

- *Liriodendron tulipifera* (tuliptree)
- *Ulmus americana* (American elm)
- *Platanus occidentalis* (American sycamore)
- *Tilia americana* (American linden)
- *Betula alleghaniensis* (yellow birch)

Conclusion

Managing trees in urban areas can be complicated. Navigating the recommendations of experts, the needs of residents, the pressures of local economics and politics, concerns for public safety and liability, physical components of trees, forces of nature and severe weather events, and the expectation that these issues are resolved all at once is a considerable challenge.

The City of Bloomington must carefully consider these challenges to understand fully the needs of maintaining an urban forest. By completing a tree inventory, the city has shown interest in preserving the urban forest, but also maintaining it for future generations. If the city utilizes the inventory to plant and care for trees, maintained for years to come will be the health and safety of Bloomington's trees and residents.

Bloomington's urban forest has a large population of maple (particular red maple), has a stable population of four times more young trees than mature trees, and is in Fair condition. There are 80 High Risk trees, a recommended 1,302 Removals, and 2,881 Prunes. The average annual benefit per tree is $51 in Bloomington, and each year the total population returns a benefit to the community equal to $968,823. Bloomington has been a Tree City USA for more than 35 years. With continued dedication to its street and park tree resources, the city can improve the diversity, stability, and condition of its trees and increase the annual benefits they provide.

Glossary

Address/Location (data field): Identifies the location of each tree and stump by address, on street, side, and X and Y coordinates.

canopy: Branches and foliage that make up a tree's crown.

condition (data field): The general health assigned to each inventoried tree considering signs of stress, poor structure, mechanical damage, soil and root problems, disease, and pests. Condition categories include: Good (a tree shows no major problems), Fair (a tree has minor problems that may be corrected with time or corrective action), Poor (a tree has major problems that are irrecoverable), Dead (a tree shows no signs of life).

defects (data field): A indication of the most significant structural defect present limited to: dead and dying parts, broken and/or hanging branches, cracks, weakly attached branches and codominant stems, missing or decayed wood, tree architecture, and root problems.

Discretionary Prune (Primary Maintenance Need): Trees needing routinely inspected and pruned within the community's regularly pruning cycle.

diameter at breast height (DBH): See **tree size**.

diameter: See **tree size**.

Extreme Risk tree: The Extreme Risk category applies in situations where tree failure is imminent and there is a high likelihood of impacting the target, and the consequences of the failure are "severe." In some cases, this may mean immediate restriction of access to the target zone area to avoid injury to people.

further inspection (data field): Tree that require additional and/or future inspections due to a variety of issue beyond the scope of the inventory, including: recent construction damage, advanced risk assessment, or insect/disease monitoring.

genus: A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature, the genus name is either used as a standalone term or is followed by a Latin adjective or epithet to form the name of a species.

High Risk tree: The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely," or consequences are "severe" and likelihood is "likely." In a population of trees, the priority of High Risk trees is second only to Extreme Risk trees.

inventory: See **tree inventory**.

i-Tree Tools: State-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools software helps communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.

Low Risk tree: The Low Risk category applies when consequences are "negligible" and likelihood is "unlikely," or consequences are "minor" and likelihood is "somewhat likely." Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required.

Moderate Risk tree: The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely," or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk trees.

multi-stems (data field): Identifies the number of stems or trunks splitting less than 1 foot above ground level.

Overhead utilities (data field): Indication of the presence of overhead utilities.

Plant Tree (Primary Maintenance Need): During the inventory, planting sites were identified by street, address, and site number. The size of the site is designated as small, medium, or large (indicating the ultimate size the tree will attain), depending on available growing space and the presence of overhead wires. Lacking local code definitions, planting sites are determined based on standard specifications throughout the arboriculture industry and accepted technical journals.

Primary Maintenance (data field): The type of tree work needed to reduce immediate risk, including: remove, prune, train, discretionary, stump removal, and plant tree.

Prune (Primary Maintenance Need): These trees require selective removal of dead, diseased, dying, and/or broken wood, to minimize potential risk. Priority of work should be dependent upon the risk associated with the individual trees.

pruning: The selective removal of plant parts to meet specific goals and objectives.

Removal (Primary Maintenance Need): Trees designated for removal have defects that cannot be cost-effectively or practically treated. Most of the trees in this category have a large percentage of dead crown. All trees with safety risks that could be potential threats to persons or property and seen as potential liabilities to the client would be in this category. This category includes large dead and dying trees that are high-liability risks as well as those that pose minimal liability to persons or property (such as trees in poor locations or undesirable species).

right-of-way (ROW): See **street right-of-way**.

risk: Combination of the probability of an event occurring, along with its consequence.

risk assessment (data field): Level 2 qualitative risk assessment based on the ANSI A300 (Part 9) and the companion publication *Best Management Practices: Tree Risk Assessment*, published by the International Society of Arboriculture (2011).

risk rating (data field): The overall risk rating of the tree determined by combining the likelihood of tree failure impacting a target and the consequence of failure. The specified period for the risk assessment is one year. Trees can have multiple failure modes with various risk ratings. One risk rating per tree was assigned during the inventory. The failure mode having the greatest risk will serve as the overall tree risk rating. Risk ratings are Low, Moderate, High, and Extreme. A Low-Risk tree poses a low overall level of risk. A Moderate-Risk tree may pose some risk, particularly during storm events or abnormal weather. A High-Risk tree presents a high likelihood of tree or tree part failure, even during normal weather conditions. An Extreme-Risk tree poses a significant risk and probability of failure at all times. Risk rating is meant to serve as a prioritization mechanism for our clients, but the client is ultimately responsible for determining the level of acceptable risk.

species (data field): Fundamental category of taxonomic classification, ranking below a genus or subgenus, and consisting of related organisms capable of interbreeding.

stem: A woody structure bearing buds and foliage and giving rise to other stems.

street name (data field): The name of a street right-of-way or road identified using posted signage or parcel information.

street right-of-way (ROW): A strip of land generally owned by a public entity over which facilities, such as highways, railroads, or power lines, are built.

street tree: A street tree is defined as a tree within the right-of-way.

Stump Removal (Primary Maintenance Need): This category indicates a stump that should be removed.

Train (Primary Maintenance Need): These are young trees that must be pruned to correct or eliminate weak, interfering, or objectionable branches to minimize future maintenance requirements. Generally, these trees are up to 20 feet in height to allow for work with a pole pruner and by a person standing on the ground. Based on Bloomington's training pruning schedule, grouped in the training pruning category are trees up to 6 inches trunk diameter.

tree: A tree is defined as a perennial woody plant that may grow more than 20 feet tall. A tree generally has one main stem, although many species may grow as multi-stemmed forms.

tree benefit: An economic, environmental, or social improvement that benefits the community and results mainly from the presence of a tree. A benefit contains real or intrinsic value.

tree inventory: Comprehensive database containing information or records about individual trees typically collected by an arborist.

tree size (data field): A tree's diameter measured to the nearest inch in 1-inch size classes at 4.5 feet above ground, also known as diameter at breast height (DBH) or diameter.

tree grate (data field): The presence of a grate around a tree in a well/pit growing space.

urban forest: All the trees within a municipality or a community. This can include the trees along streets or rights-of-way, in parks and greenspaces, in forests, and on private property.

References

American National Standards Institute. 2011. *ANSI A300 (Part 9)–2011, American National Standard for Tree Care Operations—Tree, Shrub, and Other Woody Plant Management Standard Practices (Tree Risk Assessment a. Tree Structure Assessment)*. Londonderry: Tree Care Industry Association, Inc.

Richards, N.A. 1983. "Diversity and Stability in a Street Tree Population." *Urban Ecology* 7(2):159–171.

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Appendix A
Data Collection and Site Location Methods

Data Collection Methods

DRG collected tree inventory data using a proprietary data collection program (Rover) loaded onto pen-based field computers equipped with geographic information system (GIS) and global positioning system (GPS) receivers. The knowledge and professional judgment of DRG's staff ensure the high quality of inventory data.

Data fields are defined in the glossary of the summary report. At each site, the following data fields were collected:

- Address/Location
- Condition
- Defects
- Further inspection
- Primary maintenance
- Multi-Stem
- Notes
- Overhead utilities
- Risk assessment
- Risk rating
- Species
- Tree size*
- Tree Grate

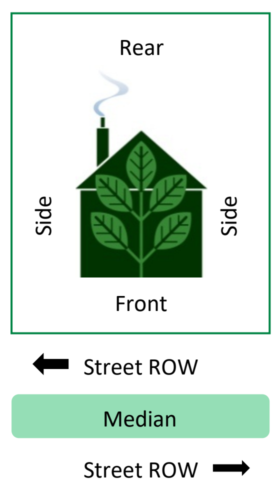
* measured in inches in diameter at 4.5 feet above ground (or diameter at breast height [DBH])

Maintenance needs are based on ANSI A300 (Part 1) (ANSI 2008). Risk assessment and risk rating are based on *Best Management Practices: Tree Risk Assessment* (International Society of Arboriculture [ISA] 2011).

The data collected were provided in Davey's TreeKeeper® inventory management software, an ESRI® shapefile andMicrosoft Excel™ spreadsheet on a thumb drive that accompanies this report.

Site Location Methods

Individual street trees were located using a methodology that identifies sites by *area*, *address number*, *street name*, *side*, and *block side*. This methodology was developed by DRG to help ensure consistent assignment of location.



Side values for sites along the street ROW.

Address Number and Street Name

The *address number* was recorded based on visual observation by the arborist at the time of the inventory (the address number was posted on a building at the inventoried site). Where there was no posted address number on a building, or where the site was located by a vacant lot with no GIS parcel addressing data available, the arborist used his/her best judgment to assign an address number based on opposite or adjacent addresses.

Sites in medians or islands were assigned an address number using the address closest to the site. Each segment was numbered with an assigned address that was interpolated from addresses facing that median/island.

The *street name* assigned to a site was determined by street ROW parcel information and posted street name signage.

Side Value

Each site was assigned a *side value*. Side values include: *front*, *side*, and *median* (includes islands), or *rear* based on the site's location in relation to the lot's street frontage (Figure 1). The *front side* is the side that faces the address street. *Side* is the name of the street the arborist walks towards or walks away from while collecting data. *Median* indicates a median or island. The *rear* is the side of the lot opposite the front.

Block Side

Block side information for a site includes the *on street*.

- The *on street* is the street on which the site is located. The *on street* may not match the address street. A site may be physically located on a street that is different from its street address (i.e., a site located on a side street).

Park Site Location

Park and/or public space site locations were collected using the same methodology as street ROW sites; however, the park name is recorded as well.

Site Location Examples

The tree trimming crew in the truck traveling westbound on E. Mac Arthur Street is trying to locate an inventoried tree with the following location information:

Address/Street Name:	226 E. Mac Arthur Street
Side:	Side To
On Street:	Davis Street

The tree site circled in red signifies the crew's target site. Because the tree is located on the side of the lot, the *on* street is Davis Street, even though it is addressed as 226 East Mac Arthur Street.

Figure 3. Location information collected for inventoried trees at Corner Lots A and B.

Corner Lot A		**Corner Lot B**	
Address/Street Name:	205 Hoover St.	Address/Street Name:	226 E Mac Arthur St.
Side:	Side	Side:	Side
On Street:	Taft St.	On Street:	Davis St.
Address/Street Name:	205 Hoover St.	Address/Street Name:	226 E Mac Arthur St.
Side:	Side	Side:	Front
On Street:	Taft St.	On Street:	E Mac Arthur St.
Address/Street Name:	205 Hoover St.	Address/Street Name:	226 E Mac Arthur St.
Side:	Side	Side:	Front
On Street:	Taft St.	On Street:	E Mac Arthur St.
Address/Street Name:	205 Hoover St.		
Side:	Front		
On Street:	Hoover St.		

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Appendix B
i-Tree Methodology

i-Tree Streets regionalizes the calculations of its output by incorporating detailed reference city project information for 16 climate zones across the United States. Bloomington falls within the Lower Midwest Climate Zone. Sample inventory data from Indianapolis represent the basis for the Lower Midwest Reference City Project for the Lower Midwest Community Tree Guidelines. The basis for the benefit modeling in this study compares the inventory data from Bloomington to the results of Lower Midwest Reference City Project to obtain an estimation of the annual benefits provided by Bloomington's resource.

Growth rate modeling information was used to perform computer-simulated growth of the existing tree population for one year and account for the associated annual benefits. This "snapshot" analysis assumed that no trees were added to or removed from the existing population. Calculations of carbon dioxide (CO_2) released due to decompositions of wood from removed trees did consider average annual mortality. This approach directly connects benefits with tree-size variables such as diameter at breast height (DBH) and leaf-surface area. Many benefits of trees are related to processes that involve interactions between leaves and the atmosphere (e.g., interception, transpiration, photosynthesis); therefore, benefits increase as tree canopy cover and leaf surface area increase.

For each of the modeled benefits, an annual resource unit was determined on a per-tree basis. Resource units are measured as megawatt-hours of electricity saved per tree; therms of natural gas conserved per tree, pounds of atmospheric CO_2 reduced per tree; pounds of nitrogen dioxide (NO_2), particulate matter (PM_{10}), and volatile organic compounds (VOCs) reduced per tree; cubic feet of stormwater runoff reduced per tree; and square feet of leaf area added per tree to increase property values.

Prices were assigned to each resource unit using economic indicators of society's willingness to pay for the environmental benefits trees provide. Estimates of benefits are initial approximations as some benefits are difficult to quantify (e.g., impacts on psychological health, crime, and violence). In addition, limited knowledge about the physical processes at work and their interactions make estimates imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Therefore, this method of quantification provides first-order approximations. It is meant to be a general accounting of the benefits produced by urban trees—an accounting with an accepted degree of uncertainty that can, nonetheless, provide science-based platform for decision-making.

A detailed description of how the default benefit prices are derived, refer to the *Indianapolis, Indiana Municipal Forest Resource Analysis* (Peper and others 2008) and the *Lower Midwest Community Tree Guide* (Peper and others 2009). i-Tree Streets' default values from the Lower Midwest Climate Zone were used for air quality and stormwater benefit prices and local values were used for energy usage and aesthetics and other benefits.

Bloomington's Benefit Prices Used in this Analysis

Benefits	Price	Unit
Electricity	$0.068	$/Kwh
Natural Gas	$0.973	$/Therm
CO_2	$0.00334	$/lb.
PM_{10}	$0.99	$/lb.
NO_2	$.82	$/lb.
SO_2	$1.50	$/lb.
VOC	$0.30	$/lb.
O_3	$0.82	$/lb.
H_2	$0.0062	$/gallon
Average Home Resale Value	$135,400	$

Using these prices, the magnitude of the benefits provided by the public tree resource was calculated based on the science of i-Tree Streets using DRG's TreeKeeper® inventory management software. For a detailed description of how the magnitudes of benefit prices are calculated, refer to the *Indianapolis, Indiana Municipal Forest Resource Analysis* (Peper and others 2008).