



# State of the Urban Forest Report

## City of Syracuse, New York

June 2016

Prepared for:  
City of Syracuse  
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## Acknowledgements

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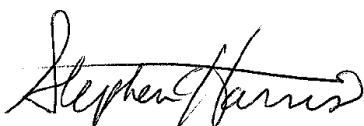
Urban forests are a multi-tasking green infrastructure. They function as an outdoor air conditioner and filter, water control system, wind barrier, anger and mood management program, beautification initiative, and even sunblock. These ecosystem services, public health benefits, and aesthetic enhancements translate into cleaner air, lower energy costs, healthier people, more valuable properties, and increased economic activity for Syracuse residents. Syracuse's public trees provide an estimated \$2 in benefits for every \$1 spent on management costs. Like an investment portfolio, these benefits will accrue value over time provided that the city commits to careful stewardship.

Urban forests are also our first line of defense in a hotter, more unpredictable climate. And while urban forests are an important part of the city's identity and history, Syracuse has seen a decrease in public trees (street and park) since 1978. Since 1994, there has been little change in canopy cover but a significant change in species composition; invasive species have proliferated and compromised the ability of segments of the urban forest to provide ecosystem benefits.

In light of these changes to the landscape and their significance to the quality of life in Syracuse, the Syracuse Parks Department commissioned a State of the Urban Forest Report that can serve as the foundation for future planning by the city and its residents. This report draws on a public tree inventory completed by Davey Resource Group in 2014 and long-term monitoring data provided by the USDA Forest Service Northeastern Research Station in Syracuse.

By analyzing change, measuring canopy, and quantifying the benefits of our urban forest, this report provides a comprehensive assessment of our urban forest and a foreshadowing of the future. This report will help our community determine what we want from our urban forest and how to get there.

*Note: This report analyzed trees at two levels. "Urban forests" refers to all the trees inside city limits on all lands. "Municipal forests" refers to publicly-owned street and park trees managed by the Syracuse Parks Department.*



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## Project Team

The City of Syracuse provided information regarding the public tree inventory and urban forestry program budget.

Davey Resource Group completed the public tree inventory and prepared this State of the Urban Forest Report in collaboration with USDA Forest Service and the City of Syracuse.

USDA Forest Service Northeastern Research Station completed the i-Tree ecosystem analysis, urban tree canopy assessment, and Syracuse *Urban Forest Master Plan: Guiding the City's Forest Resource Into the 21<sup>st</sup> Century*.

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## Executive Summary

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Understanding an urban forest's structure, function, and value can promote management decisions that will improve environmental quality. Many assessments of Syracuse, New York's urban and municipal forest structure, function, and value have been conducted between 2009 and 2014. Syracuse's State of the Urban Forest Report documents the results of these assessments and recommends further actions to assist Syracuse in creating a sustainable urban forest and management program.

The state of the urban forest can be summarized as follows:

- Number of trees: 1,583,000
- Tree canopy cover: 27%; statistically the same since 1994
- Most common species: European buckthorn, sugar maple, tree-of-heaven
- Invasive species composition: 36%
- Pests that pose greatest risk to tree populations: winter moth and Asian longhorned beetle
- Most functionally beneficial species: European buckthorn, sugar maple, Norway maple
- Size class diameter distribution (DBH): 0–9 inches (80%); 9–18 inches (13%); 18–24 inches (4%); and greater than 24 inches (3%)
- Carbon storage: 247,000 tons (\$32.8 million)
- Carbon sequestration: 6,856 tons/year (\$912,000/year)
- Pollution removal: 177 tons/year (\$6.5 million/year)
- Avoided stormwater runoff: 13,275,000 cubic feet/year (\$884,000/year)
- Building energy savings: 22,500 MBTUs and 2,600 megawatts (MWH) (\$818,000/year)
- Avoided carbon emissions: 753 tons (\$100,000)
- Total functional value: \$9.2 million/year
- Structural value: \$735 million

The state of the municipal forest can be summarized as follows:

- Number of trees: 42,622
- Street right-of-way tree canopy cover: 4% of total land cover within city limits and 15% of total tree canopy cover
- Park tree canopy cover: 3% of total land cover within city limits and 8% of canopy cover
- Most common street tree species: Norway maple, thornless honeylocust, crabapple
- Most common park tree species: Norway maple, sugar maple, northern white cedar
- Pests that pose greatest risk to tree populations: winter moth and Asian longhorned beetle
- Most functionally beneficial street tree species: Norway maple, thornless honeylocust, silver maple
- Most functionally beneficial park tree species: Norway maple, sugar maple, black locust
- Size class diameter street tree distribution (DBH): 0–9 inches (44%); 9–18 inches (30%); 18–24 inches (14%); and greater than 24 inches (11%)
- Size class diameter park tree distribution: 37% (0–9 inches); 33% (9–18 inches); 14% (18–24 inches); and 16% (greater than 24 inches)
- Carbon storage: 17,500 tons (\$2.3 million)
- Carbon sequestration: 500 tons/year (\$69,000/year)
- Pollution removal: 10 tons/year (\$230,000/year)
- Avoided stormwater runoff: 648,000 cubic feet/year (\$44,000/year)
- Building energy savings: up to an estimated \$138,000/year
- Aesthetic property value improvement: \$1.5 million/year
- Total functional value: \$1.9 million/year
- Structural value: \$62 million



Syracuse’s vision for its urban forest is to create a sustainable resource that is proactively managed to provide its citizens maximum benefit. The state of the urban forest findings are used to help develop recommendations for maximizing tree canopy and enhancing management programs to improve environmental value based on the natural functions of trees.



**Photograph 1.** Syracuse has extensive data on the state of its urban forest resource, most recent of which includes the 2014 public tree inventory data. This State of the Urban Forest Report summarizes the results of all available data across the entire urban forest and the municipal urban forest, which serves as a baseline for management recommendations and the future development of an urban forest master plan.

## Introduction

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Syracuse's urban forest—including all trees on public and private lands within the city boundaries—softens the urban landscape and safeguards the city's livability. Syracuse's street and park trees, along with all trees on private lands, play a prominent role in providing benefits to the community. A series of partnerships, community groups, and city departments are required to maintain and care for this resource.

## Purpose

The State of the Urban Forest Report was developed for the City of Syracuse and all persons who manage, protect, and plant trees in Syracuse. The City of Syracuse, United States Department of Agriculture Forest Service, and Davey Resource Group partnered to complete this report. The purpose of the report is to provide structural and functional information about the urban forest (including the municipal forest) and recommend strategies for its proactive management, protection, and growth.

## Background

Several studies have been commissioned in order to gain a clearer understanding of the complex interplay between Syracuse's urban forest and the rest of the city, including its citizens, businesses, buildings, streets, and other infrastructure. Some of those studies compiled a baseline data set, some quantified the benefits that trees provide, and some established benchmarks and provided recommendations for managing this complex resource. This State of the Urban Forest Report summarizes the results of 2014 data and uses historical findings as a framework for many of the recommendations. Data used in this report include:

- Urban Forest Assessment: data was collected from 199 field plots located throughout Syracuse; data on the urban forest structure were analyzed in 2014 using the i-Tree Eco model developed by USDA Forest Service.
- Municipal Forest Assessment: a public tree inventory was conducted by Davey Resource Group in 2014; data were analyzed using the i-Tree Eco model.
- Urban Tree Canopy Assessment: data were analyzed in 2009 by USDA Forest Service Northern Research Station.
- Syracuse Urban Forest Master Plan: a comprehensive urban forest assessment developed by USDA Forest Service Northern Research Station that combined results from: a 1999 urban tree canopy assessment; a 2000 street tree inventory; a 1978 street tree inventory; a survey on desirable and undesirable tree characteristics and functions (per city residents); and a survey on the best trees for various city conditions (per local tree experts).

# *The Importance of Syracuse's Urban Forest*

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An urban forest is defined as all woody and herbaceous vegetation found within an urban area, including: street trees; public property and park trees; and trees on private property. Trees add significant value to the landscape and are an integral component to any community's environment.

## *Air Quality*

Trees can directly and indirectly affect local air quality. Trees lower air temperatures that tend to reduce pollutant emissions, directly remove air pollutants, emit volatile organic compounds that contribute to pollution formation, and alter building energy use that affects pollutant emissions from power plants.

## *Carbon Storage and Sequestration*

Trees absorb carbon during photosynthesis and store carbon as biomass. As trees grow, they accumulate more biomass and, therefore, more carbon. When trees die, the carbon can go back to the atmosphere through decomposition.

## *Stormwater Management*

Trees and forests can reduce stormwater runoff and improve water quality through intercepting rainfall, absorbing soil moisture and chemicals, transpiring water, and increasing soil infiltration. These hydrologic effects can reduce risk of flooding and improve public health by minimizing sediments, chemicals, and pathogens found within waterways.

## *Energy Savings*

Trees near buildings alter building energy use by cooling air temperatures, blocking winds, and shading building surfaces. Energy use is decreased during the summer season, but depending on location and species, energy use can increase or decrease in the winter due to variable wind speeds and solar access around buildings. The conservation of energy use from trees near air-conditioned and heated buildings will consequently alter pollutant and greenhouse gas emissions from power plants, thereby improving air quality and public health.

## *Aesthetic and Other Benefits*

While there are multiple ways to calculate aesthetic value, there is no tangible benchmark to capture the aesthetic benefits the urban forest provides to the overall well-being of those who work, play, and live in the city. Trees provide beauty in the urban landscape, privacy to homeowners, improved public health, a sense of comfort and place, and refuge for urban wildlife. Trees promote better business by stimulating frequent shopping, longer shopping trips, and a willingness on the part of residents to pay more for goods and parking in the urban environment (Wolf 1999). However, a value of some of these benefits may be reflected by the property values of the land on which trees stand.

Syracuse's urban forest provides numerous benefits to the community. However, to achieve sustainability, maintaining this resource requires constant attention and commitment. The need for proactive management programs is compounded by issues of urban stress such as vandalism, compacted soils, pollution, limited growing space, insufficient nutrients, and environmental impacts from pests, diseases, and physical events such as strong storms, wind, ice, flooding, and drought.



## State of the Urban Forest

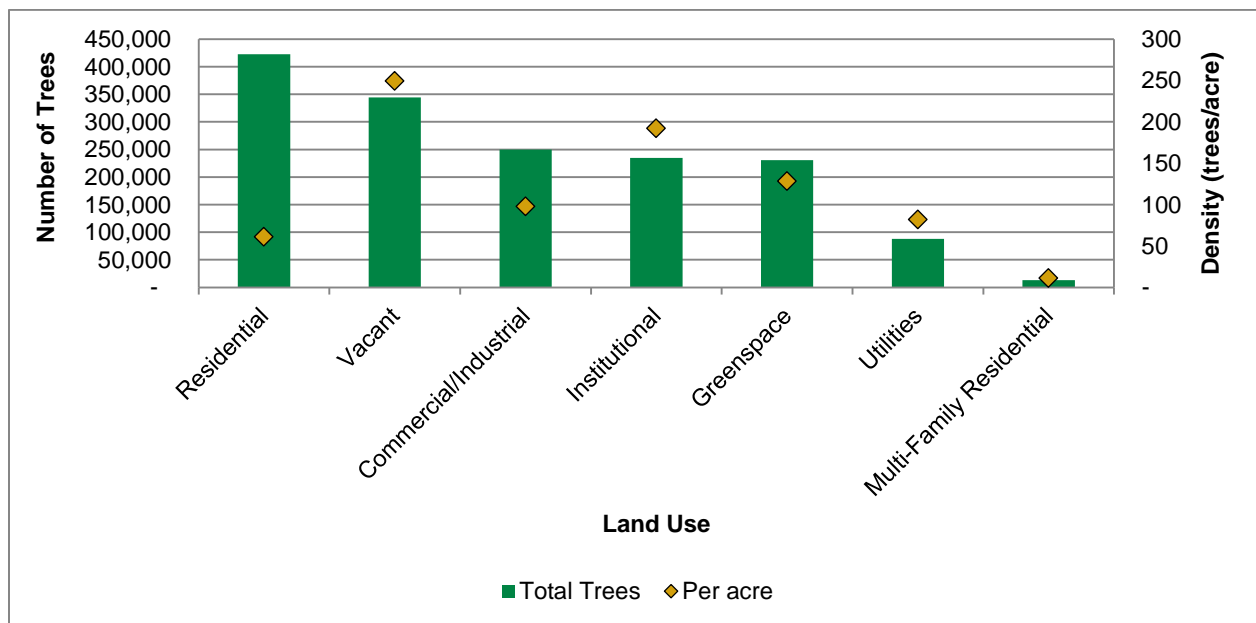
Data analysis, national and state averages, and best management practices are used to provide an overview of the state of Syracuse's urban forest. To establish a framework for evaluating the state of the urban forest, the following indicators were assessed:

- **Extent**—The number of existing private and public trees and the distribution throughout different land uses and neighborhoods.
- **Canopy Cover**—The distribution of tree canopy throughout the city, changes in canopy over time, and the effects tree canopy has on surface temperatures.
- **Species Diversity**—The distribution of tree species, ability to withstand threats from invasive pests and diseases, and species population importance relative to functional benefits.
- **Size Class Distribution**—The distribution of citywide and species-specific tree populations' trunk-size classes.
- **Structural and Functional Benefits**—Explanation of trees as assets that appreciate in value over time.

Data sources analyzed in this section of the report include the 2014 i-Tree Eco urban forest model estimate and the 2009 urban tree canopy assessment.

### Extent of the Urban Forest

The urban forest of Syracuse has an estimated 1,583,000 trees, with an overall tree density of 99 trees per acre. Figure 1 illustrates that residential land use comprises the greatest number of trees (422,000 trees) in Syracuse; however, vacant land has the highest tree density (249 per acre). Land use results reflects determinations made in the field during plot sampling and not city parcel land use designations.



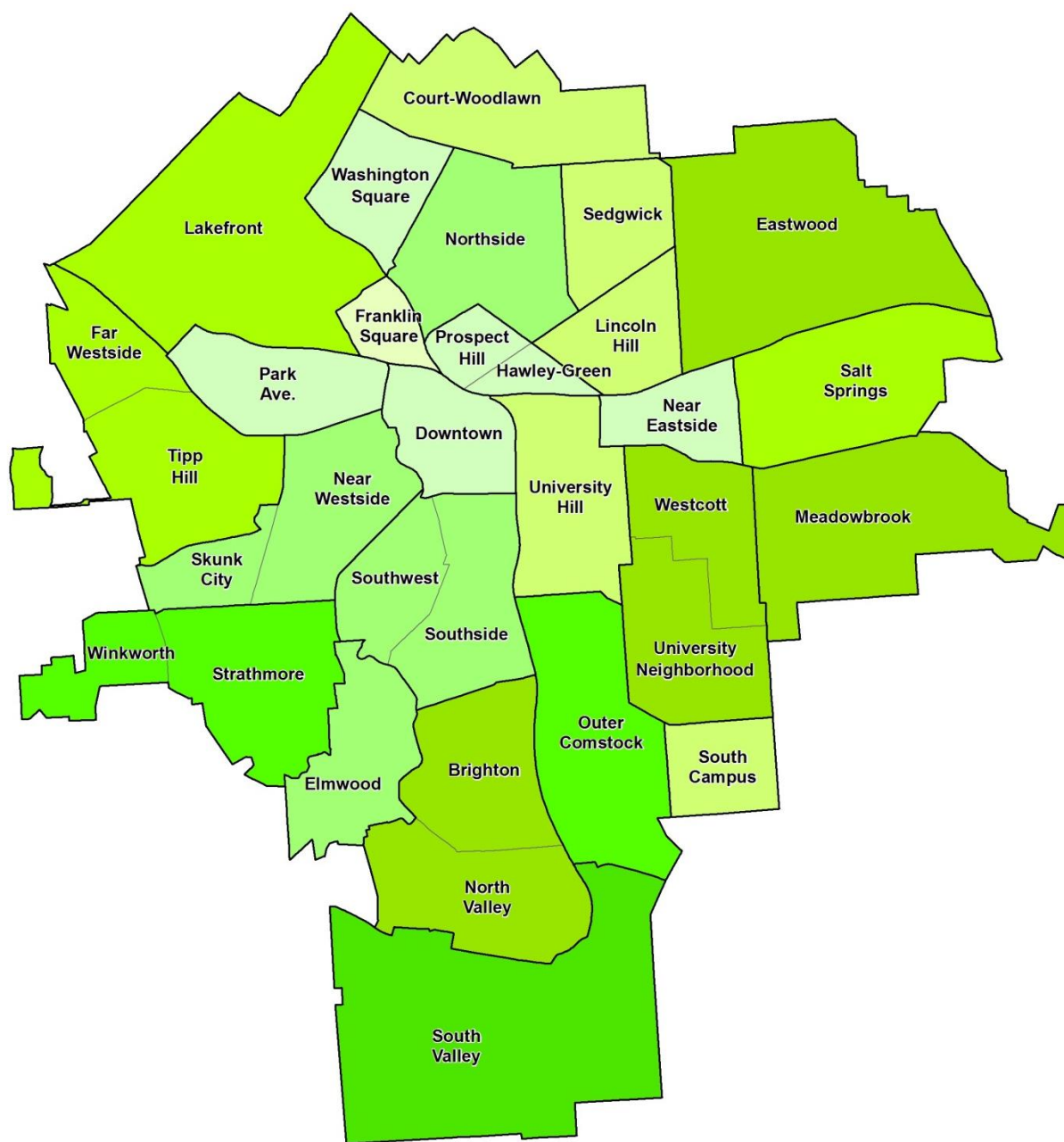
**Figure 1. Number and density of trees by land use.**

The structural value of Syracuse's urban forest is estimated at \$735 million. This asset represents the cost to replace all of the trees in Syracuse and can be understood as the total structural value of the urban forest. With proper care and maintenance, trees can appreciate in value over time. Such a valuable asset deserves careful planning, maintenance, and protection.

Syracuse has 31 distinct neighborhoods. For the purpose of this report, some of the city's neighborhoods have been combined. These 25 combined neighborhood units (referred to as neighborhoods) more closely reflect how the city manages its urban forest. Figure 2 illustrates Syracuse's estimated tree distribution by neighborhood.



**Photograph 2.** The urban forest of Syracuse has an estimated 1,583,000 trees, with an overall tree density of 99 trees per acre.



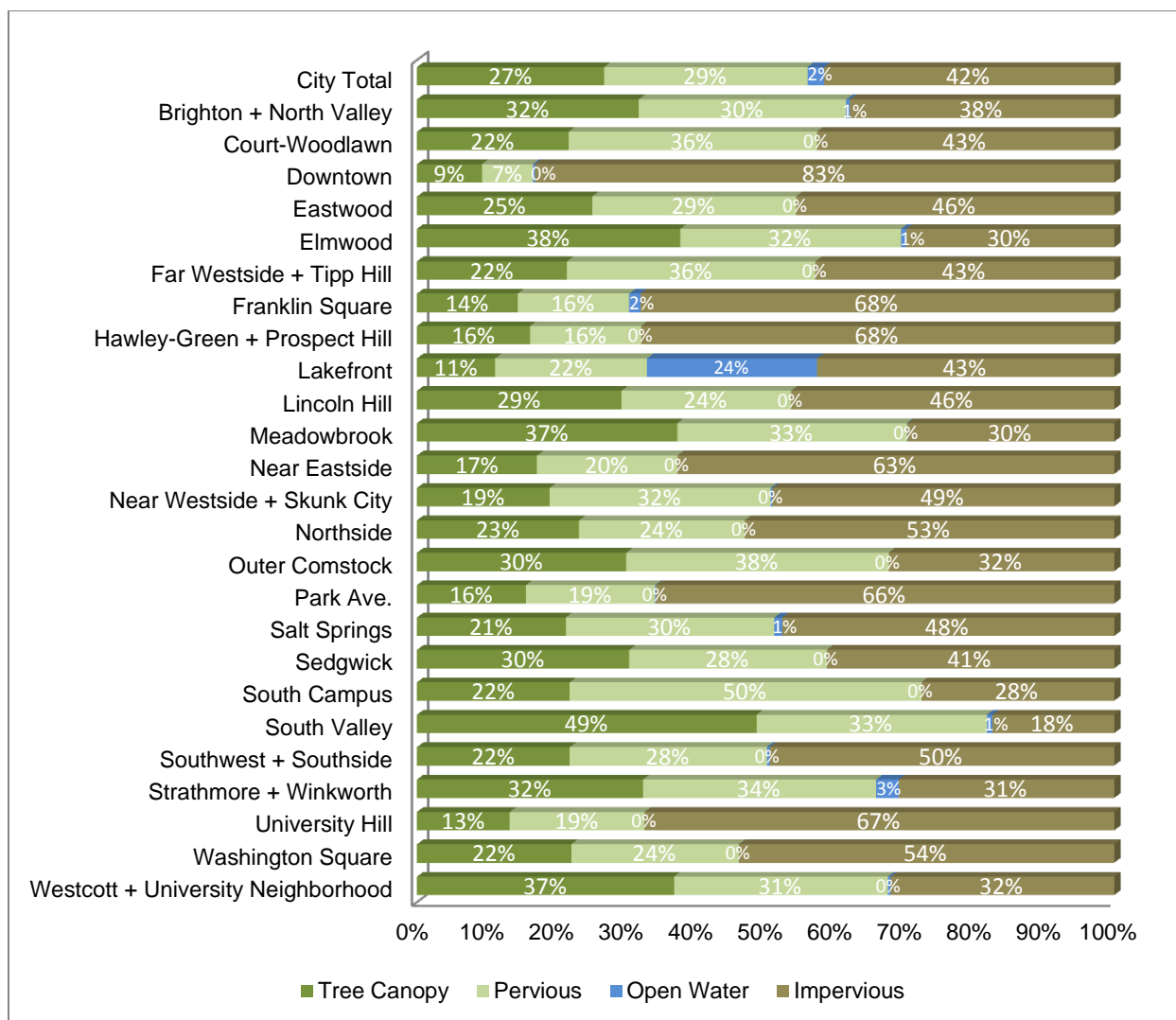
### Estimated Trees



**Figure 2. Estimated number of trees in each Syracuse, New York neighborhood.**

## Urban Tree Canopy Cover

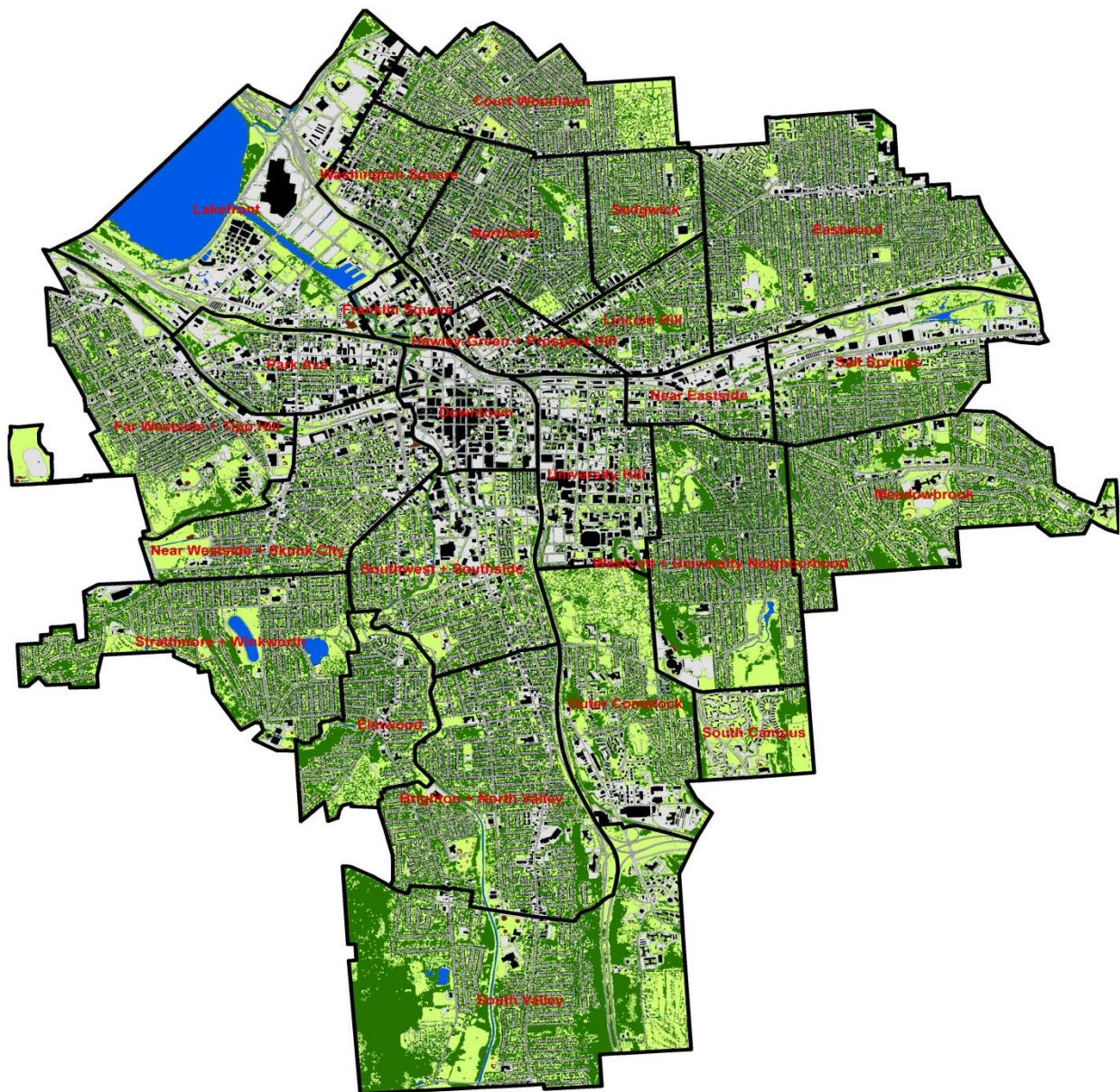
Tree canopy can be meaningfully understood from an aerial perspective and is comprised of the leaves, stems, and branches of all trees within a specific area. Syracuse's urban tree canopy was assessed in 2009 using USDA Forest Service assessment protocols (O'Neil-Dunne et al. 2009). Tree canopy in the City of Syracuse comprises 27% of all land cover (approximately 16,408 acres). Possible tree canopy (pervious) comprises 29% of all land cover, impervious makes up 42%, and open water comprises 2% of all land cover (Figure 3). Syracuse has 4,400 acres of tree canopy and approximately 4,700 more acres of possible tree canopy. Figure 4 illustrates the results of the 2009 land cover analysis, shown with neighborhood boundaries.



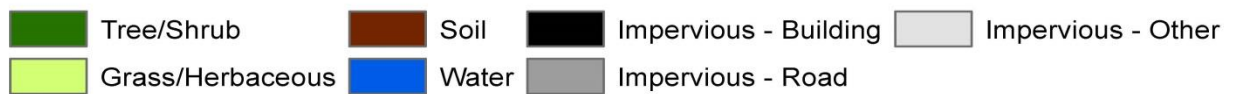
**Figure 3. Percent land cover by Syracuse, New York neighborhood.**

Figure 3 also illustrates the distribution of tree canopy and possible tree canopy across all 25 neighborhoods. Tree cover is highest in the South Valley (49%) and lowest in Downtown (9%). Impervious cover is highest in Downtown (83%) and lowest in South Valley (18%). The five neighborhoods with the greatest possibility for tree canopy (tree canopy combined with pervious area) are South Valley, South Campus, Meadowbrook, Elmwood, and Outer Comstock.





## Land Cover



**Figure 4. Land cover map for Syracuse, New York.**



## Tree Cover Change

Tree cover change in Syracuse was analyzed by interpreting change at 1,000 random points throughout the city between 1994–1998 (mixed date images) and 2012 based on established methods (Nowak and Greenfield 2002, Nowak et al. 2013). The years analyzed were 1994–1998, 1999, 2003, 2006, 2009, and 2012. Statistically, tree cover has not changed over the 18-year period (Table 1).

Table 1. Change in Percent Tree Cover

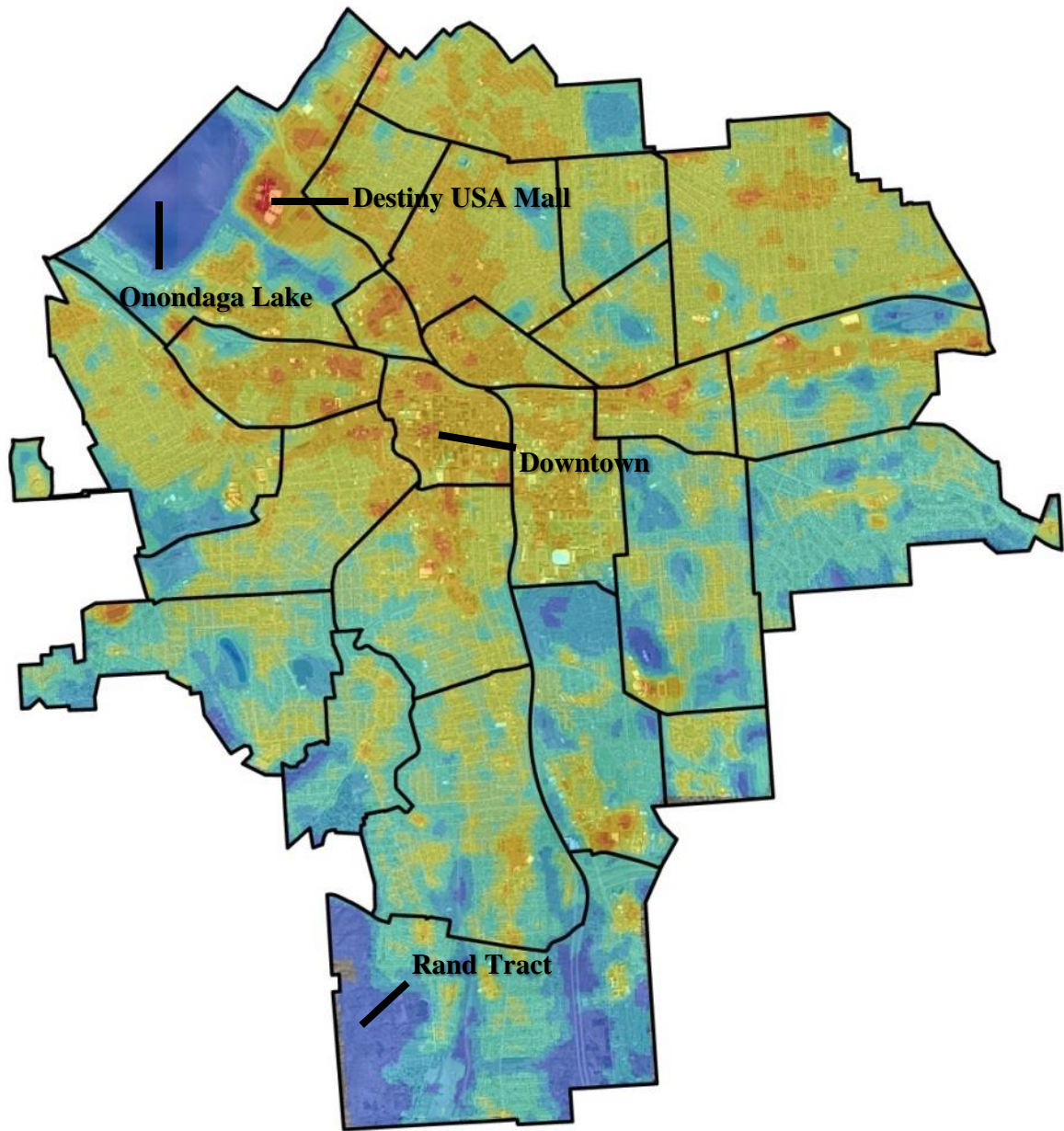
| Year      | Tree Cover |
|-----------|------------|
| 1994–1998 | 28%        |
| 1999      | 27%        |
| 2003      | 26%        |
| 2006      | 27%        |
| 2009      | 27%        |
| 2012      | 28%        |

## Surface Temperatures

Variation in Syracuse’s surface temperatures was mapped using the thermal band from Landsat 8 (July 16, 2015) (see Appendix A). Average surface temperature was calculated for Syracuse, and the difference from the mean (79° F) was mapped for each 30-meter pixel to illustrate the relatively warm and cool areas of the city. The map depicts surface temperatures, not air temperatures, but both temperatures are related (Unger et al. 2009, Kawashima et al 2009). Cooler surface temperatures tend to be associated with water and high tree cover; warmer temperatures tend to be associated with high impervious cover (Figure 5). On average, the warmest neighborhood is Downtown; whereas, the coolest is South Valley (Table 2).

Table 2. Top 5 Coolest and Warmest Neighborhoods

|                                    | Temperature Difference from Average Citywide |    |
|------------------------------------|--|----|
|                                    | °F   | °C |
| <b>Top 5 Coolest Neighborhoods</b> |  |    |
| South Valley                       | -6   | -4 |
| Elmwood                            | -2   | -1 |
| Meadowbrook                        | -2   | -1 |
| Outer Comstock                     | -2   | -1 |
| Westcott + University Neighborhood | -2   | -1 |
| <b>Top 5 Warmest Neighborhoods</b> |  |    |
| Northside                          | 4  | 2  |
| Park Avenue                        | 5  | 3  |
| Hawley-Green + Prospect Hill       | 5  | 3  |
| Franklin Square                    | 6  | 3  |
| Downtown                           | 6  | 4  |



## Degrees Celsius



*Figure 5. Estimated difference in average surface temperatures in Syracuse.*

## Urban Forest Species Diversity and Resiliency

A diversity index describes the number of tree species and their abundance in the landscape. Table 3 shows the results of the Simpson diversity index, which suggests that residential land use represents the highest overall tree species diversity, while institutional land use represents the lowest.

Table 3. Urban Forest Species Diversity

| Land Use                  | Simpson |
|---------------------------|---------|
| Commercial and Industrial | 4       |
| Greenspace                | 9       |
| Institutional             | 3       |
| Multi-Family Residential  | 14      |
| Residential               | 20      |
| Utilities                 | 10      |
| Vacant                    | 6       |
| Citywide                  | 13      |

Urban forests are comprised of a mix of native and non-native tree species. Thus, urban forests often have higher tree diversity than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction caused by a species-specific insect or disease. The two most common species sampled in Syracuse were *Rhamnus cathartica* (European buckthorn) and *Acer saccharum* (sugar maple), comprising 21% and 10% of the urban forest population. Table 4 presents the ten most common tree species in Syracuse. About 55% of the urban forest population is comprised of species native to North America, while 43% is represented by species native to New York.

Table 4. Urban Forest Species Distribution

| Botanical Name             | Common Name          | Percent of Population |
|----------------------------|----------------------|-----------------------|
| <i>Rhamnus cathartica</i>  | European buckthorn   | 21%                   |
| <i>Acer saccharum</i>      | sugar maple          | 10%                   |
| <i>Ailanthus altissima</i> | tree-of-heaven       | 7%                    |
| <i>Rhus typhina</i>        | staghorn sumac       | 7%                    |
| <i>Acer negundo</i>        | boxelder             | 6%                    |
| <i>Acer platanoides</i>    | Norway maple         | 5%                    |
| <i>Prunus serotina</i>     | black cherry         | 4%                    |
| <i>Ostrya virginiana</i>   | eastern hophornbeam  | 3%                    |
| <i>Picea abies</i>         | Norway spruce        | 3%                    |
| <i>Thuja occidentalis</i>  | northern white cedar | 3%                    |

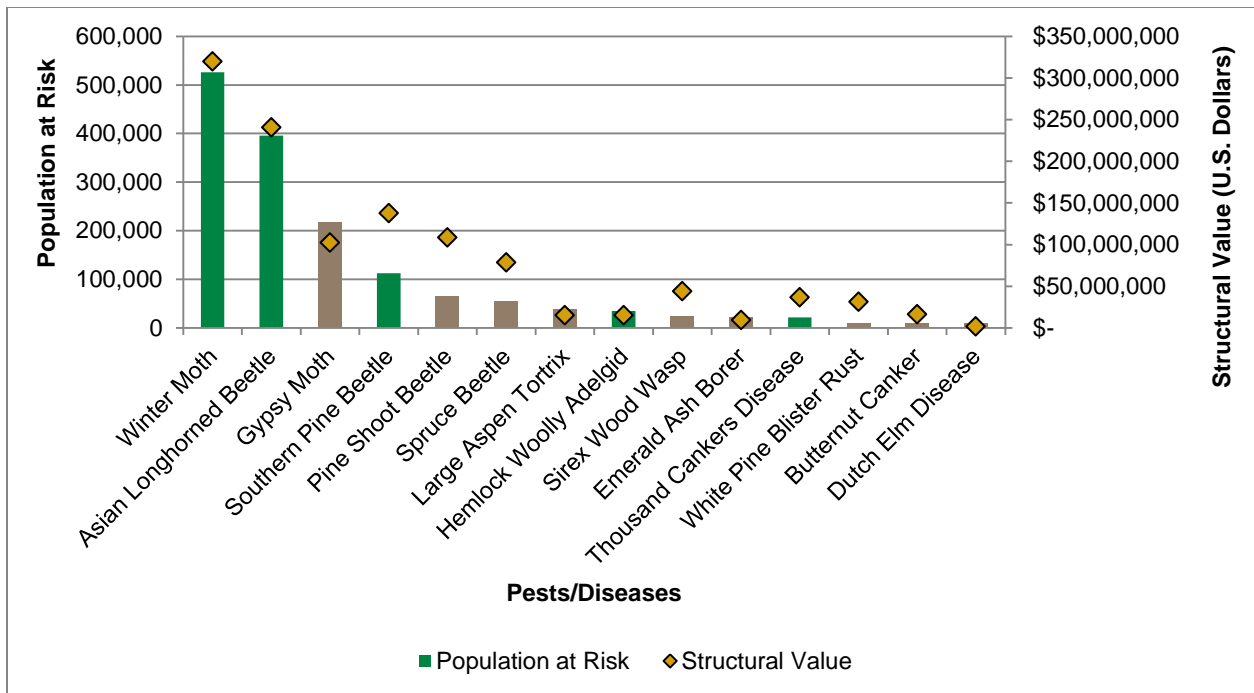
While non-natives have their benefits, they can also pose a risk to native plants if some of the non-native species are invasive plants that can potentially outcompete native species. Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas (USDA National Invasive Species Information Center 2011). Five of the 102 tree species sampled in Syracuse are identified as invasive on the state invasive species list (NYDEC 2011). These invasive species comprise 36% of the tree population. Table 5 lists the five invasive trees species present in the sample of Syracuse.

Table 5. Urban Forest Invasive Species

| Botanical Name             | Common Name        | Number of Invasive Species | % of Total Urban Forest Population |
|----------------------------|--------------------|----------------------------|------------------------------------|
| <i>Rhamnus cathartica</i>  | European buckthorn | 334,261                    | 21%                                |
| <i>Ailanthus altissima</i> | tree-of-heaven     | 111,285                    | 7%                                 |
| <i>Acer platanoides</i>    | Norway maple       | 82,508                     | 5%                                 |
| <i>Robina pseudoacacia</i> | black locust       | 38,690                     | 2%                                 |
| <i>Lonicera × bella</i>    | Belle honeysuckle  | 1,790                      | <1%                                |
| Total                      |                    | 568,534                    | 36%                                |

### Resiliency Against Forest Pests and Diseases

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, value, and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will vary among cities. Thirty-one pests were analyzed for their potential impact and were compared with pest range maps for the conterminous United States. Fourteen pests present a potential threat to kill a tree in the urban forest. These pests are all located within 250 miles of Syracuse. In Figure 6, the green bars represent pests and diseases within 250 miles of Onondaga County; the brown bars represent pests and diseases in Onondaga County. The pests with the greatest and most immediate potential impact in Onondaga County are gypsy moth and the pine shoot beetle.



**Figure 6. Number of trees and value of trees susceptible to various pests and diseases.**

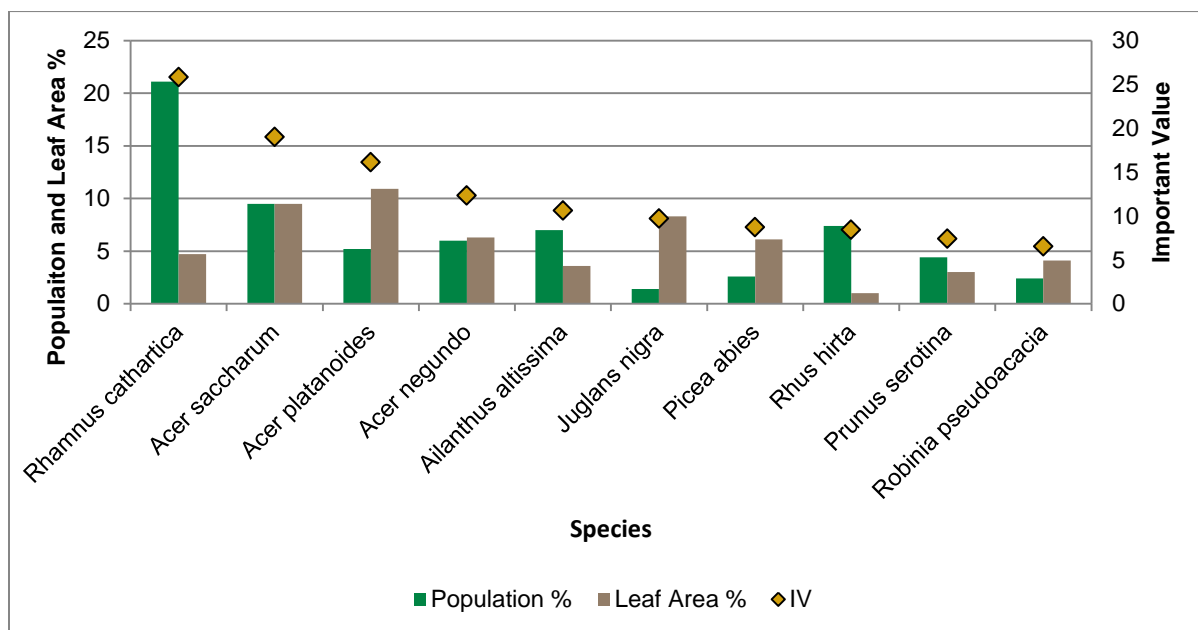
- Winter Moth (*Operophtera brumat*, WM) (Childs 2011) is a pest with a wide range of host species. Syracuse could lose up to 39% of its trees to this pest, which represents \$320 million in structural value.
- Asian Longhorned Beetle (*Anoplophora glabripennis*, ALB) (U.S. Forest Service 2005a) is an insect that bores into and kills a wide range of hardwood species, including maple. ALB poses a threat to 30% of the urban forest population, which represents a potential loss of \$241 million in structural value.
- Gypsy Moth (*Lymantria dispar*, GM) (U.S. Forest Service 2005c) is a defoliator that feeds on many species, causing widespread defoliation and tree death if outbreak conditions last several years. GM threatens 16% of the urban forest population, which represents a potential loss of \$102 million in structural value.
- Southern Pine Beetle (*Dendroctonus frontalis* Zimmermann, SPB) (Clarke and Nowak 2009) will attack all pine species and some spruce and hemlock. SPB threatens 8% of the urban forest population, which represents a potential loss of \$138 million in structural value.
- Pine Shoot Beetle (*Tomicus piniperda*, PSB) (Ciesla 2001) is a wood borer that attacks various pine species; however, *Pinus sylvestris* (Scotch pine) is the preferred host in North America. PSB has the potential to affect 5% of the urban forest population, which represents a potential loss of \$109 million in structural value.



## Urban Forest Species Importance

Understanding the importance of a tree species to the urban forest is based not only on its presence but also on its ability to provide environmental benefits to Syracuse. An Importance Value (IV) is calculated by a species' percent of the population and a species population's percent of leaf area. The IV can range from 0 to 100, with an IV of 100 suggesting total reliance on one species for benefits.

If IV values are greater or less than the percentage of a species, it indicates that the loss of that species may be more important or less important than its population percentage implies. The ten most important species in Syracuse are shown in Figure 7. *Rhamnus cathartica* (European buckthorn), an invasive species, is the most important species due to its population size, which is twice the size of the next most popular species. The most dominant species in terms of leaf area are *Acer platanoides* (Norway maple), *A. saccharum* (sugar maple), and *Juglans nigra* (black walnut). There are four invasive species on which Syracuse heavily relies for benefits.

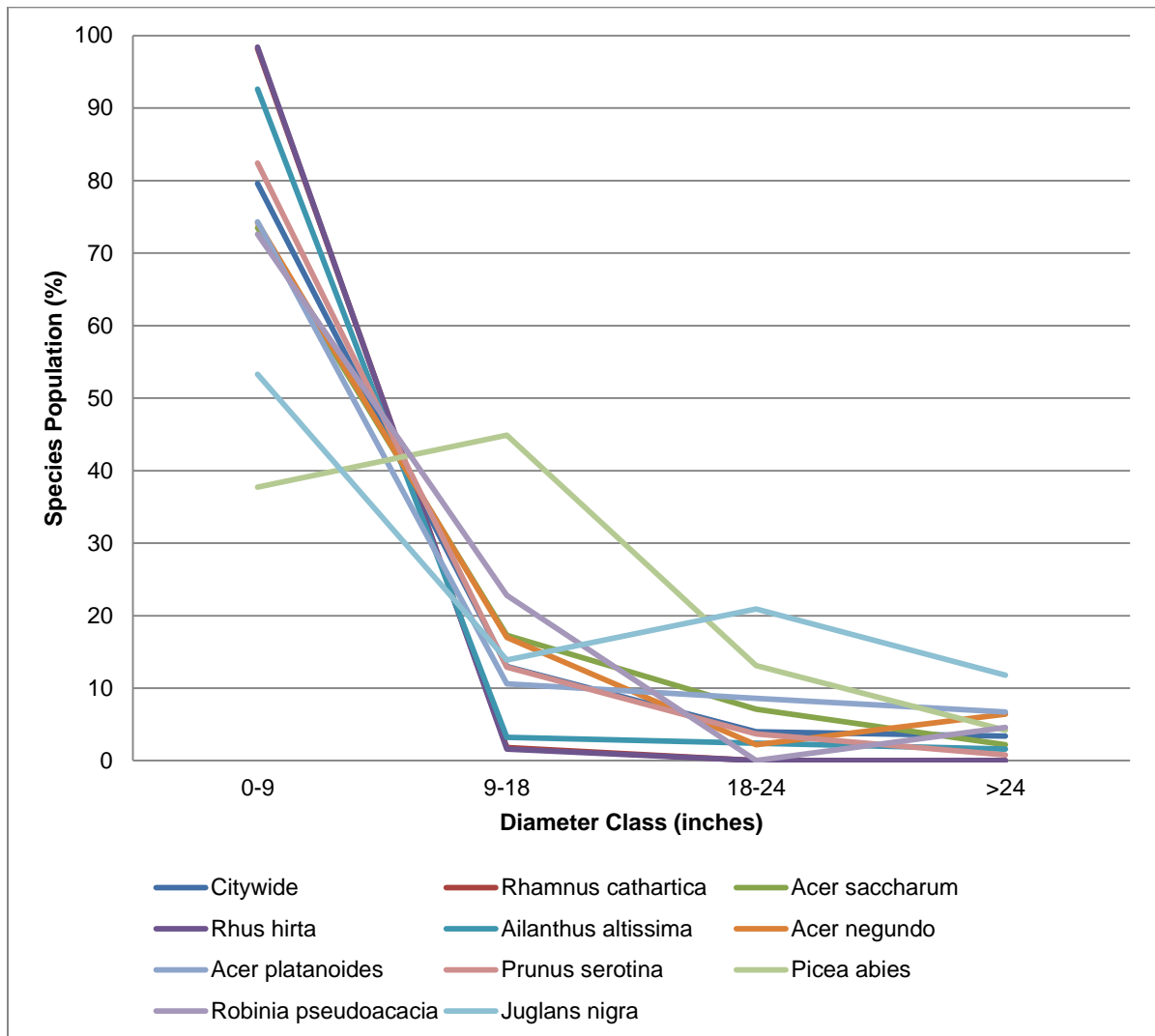


**Figure 7. Top ten most important species and their total population and leaf area.**

## Urban Forest Size Class Distribution

The distribution of trees among size classes within a tree population influences the sustainability of the population, along with present and future environmental and economic benefits. An uneven-size class distribution and a high proportion of trees with trunk diameters less than 8 inches can offset establishment- and age-related mortality. Also, the percentage of older trees declines with age. Trunk diameter is measured at 4.5 feet above the ground. An “ideal,” uneven distribution suggests that the largest fraction of trees (40% of the total) should be less than 8 inches, while only 10% should be greater than 24 inches (Richards 1982/83).

The majority of Syracuse’s trees are less than 9 inches diameter at breast height (DBH), indicating that most of the population consists of small and potentially new trees. Trees with diameters less than 9 inches represent 80% of the population; trees with diameters 9 to 18 inches make up 13% of the population; trees with diameters 18–24 inches comprise 4% of the population; and trees with diameters greater than 24 inches comprise 3% of the population (Figure 8).

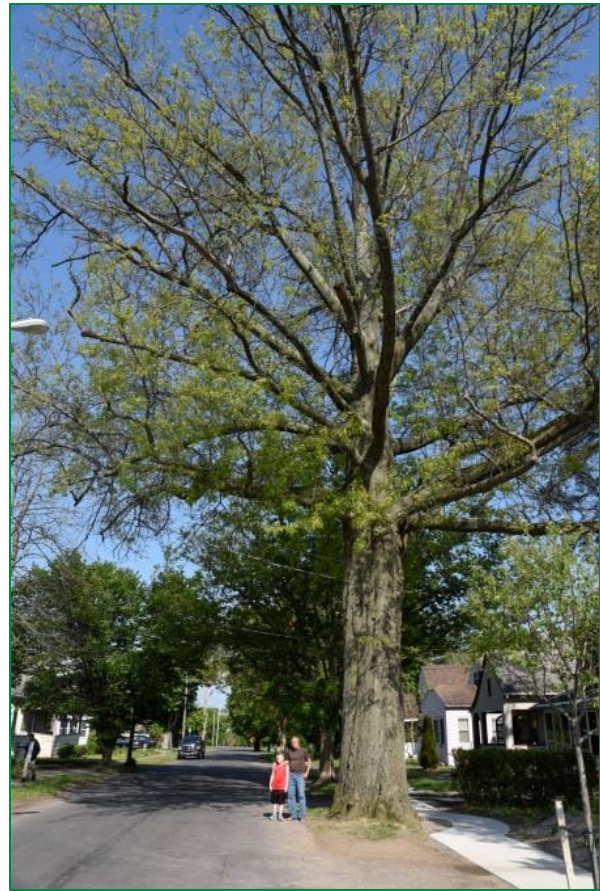


**Figure 8. Percent of urban tree population and ten most important species populations by diameter class.**

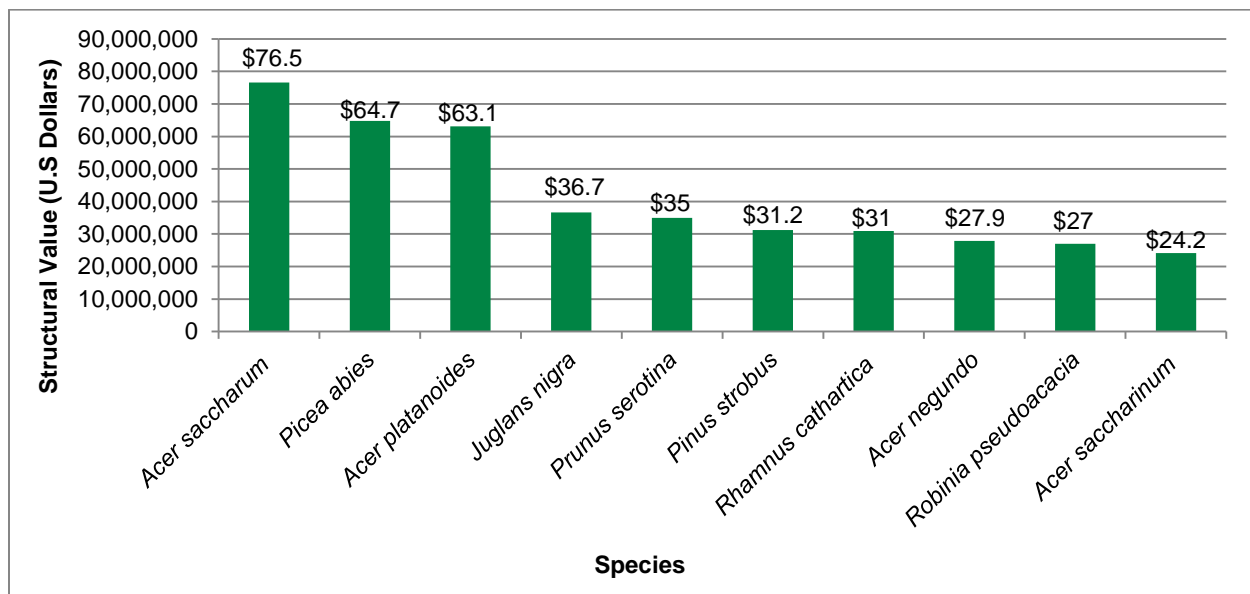
Figure 8 also shows the size class distribution of the ten most important species in Syracuse. Many of these species have stable populations, with the largest presence of the population being less than 9 inches DBH. *Picea abies* (Norway spruce) does not have a stable population; the biggest size class distribution for this species is greater than 9 inches DBH. *Juglans nigra* (black walnut) has a stable population, despite many black walnuts being greater than 18 inches.

### Urban Forest Structural Values

Structural value accounts for the historical investment in trees over their lifetime and serves as a way to quantify the monetary value of trees at a given time, based on their current number, stature, placement, and condition. The structural value of Syracuse's urban forest is estimated at \$735 million. Figure 9 illustrates the structural values of Syracuse's urban forest by species. The species with the highest structural values are *Acer saccharum* (sugar maple), *Picea abies* (Norway spruce), and *A. platanoides* (Norway maple).



**Photograph 3.** Canopy cover drives overall benefits and large trees provide the most benefits per tree. Mature, large-growing trees account for 3% of the urban forest population.



**Figure 9. Top 10 species with greatest structural value in Syracuse.**

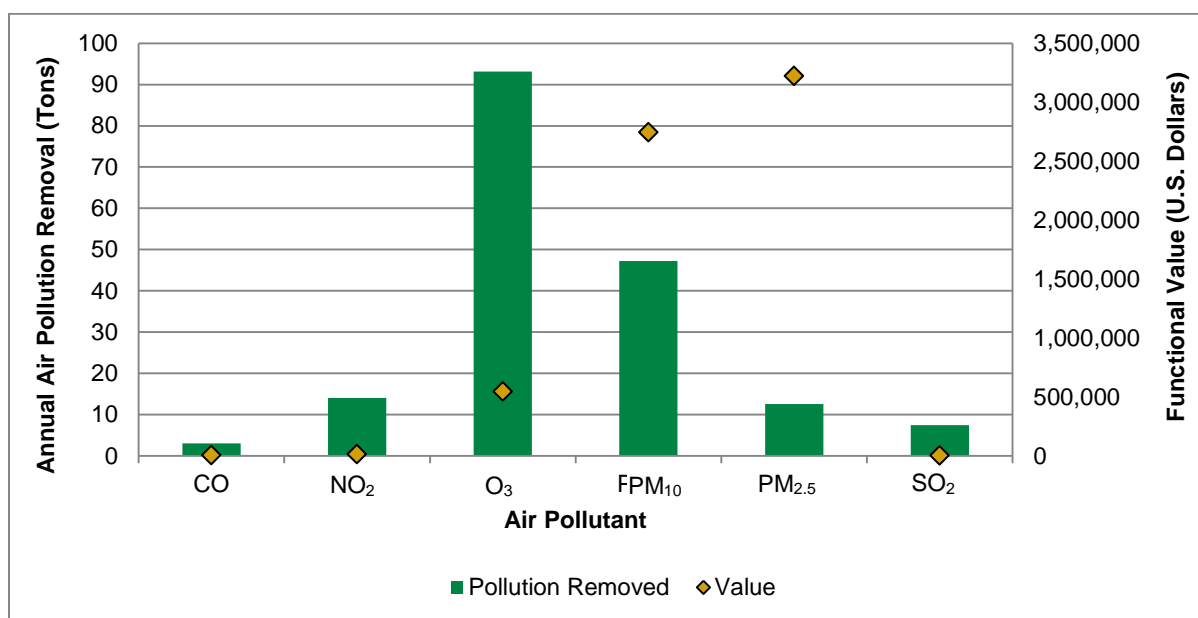
## Urban Forest Functional Benefit Values

The structural value of an urban forest is predicated on the cost of having to replace trees with other comparable trees. An urban forest also has a functional value (either positive or negative) based on the quantifiable benefits the trees provide.

### Air Pollution Removal

Poor air quality is a common problem in many urban areas. It can lead to public health decline, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from power plants. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2007).

Pollution removal by trees in Syracuse was estimated using a combination of field data and pollution and weather data (2005). On an annual basis, trees remove an estimated 177 tons of air pollutants, including: ozone ( $O_3$ ); carbon monoxide (CO); nitrogen dioxide ( $NO_2$ ); particulate matter less than 10 microns and greater than 2.5 microns ( $PM_{10}$ ); particulate matter less than 2.5 microns ( $PM_{2.5}$ ); and sulfur dioxide ( $SO_2$ ). The associated value of annual pollution removal is \$6.5 million (see Appendix A). An average acre of tree canopy in Syracuse contributes \$1,500 in annual air quality improvements. Pollution removal was highest for ozone (Figure 10).



**Figure 10. Pollution removal and associated value for trees.**

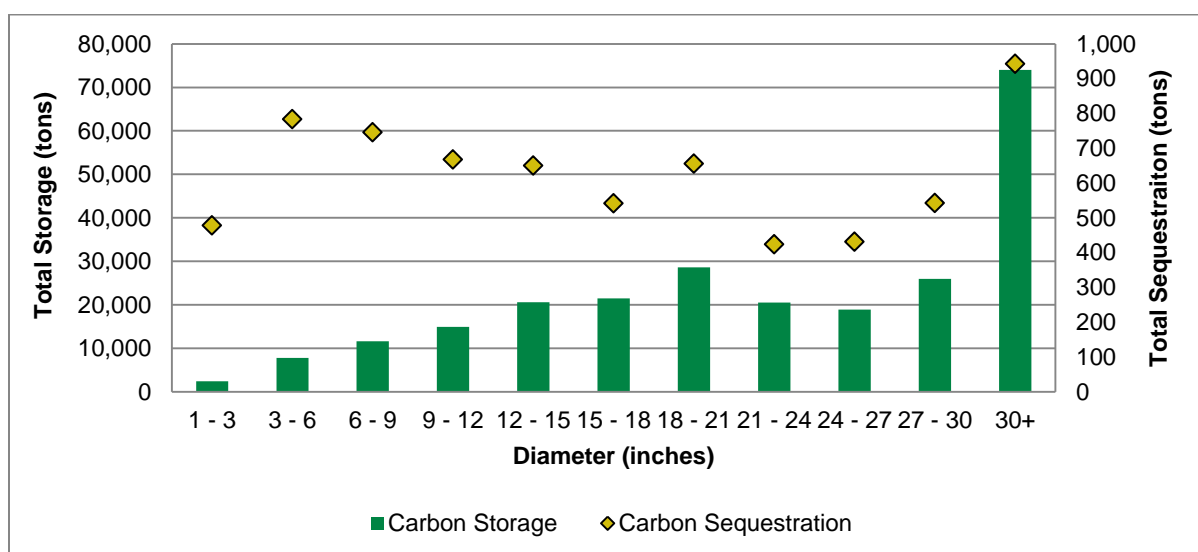
The best species for removing air pollution are the species with the most leaf area. The species that remove the most pollution are: *Acer platanoides* (Norway maple); *A. saccharum* (sugar maple); *Juglans nigra* (black walnut); *A. negundo* (boxelder); and *Picea abies* (Norway spruce). These top five species provide about 41% of all the pollution removal benefits.

## Carbon Storage and Sequestration

Climate change is a global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, consequently altering carbon dioxide emissions from fossil-fuel based power plants (Abdollahi et al. 2000).

As trees grow, they store more carbon as wood. As trees die and decay, they release much of the stored carbon back to the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be lost if trees are allowed to die and decompose. Trees in Syracuse are estimated to store 247,000 tons of carbon (\$32.8 million). An average acre of tree canopy in Syracuse stores a value of \$7,400 in atmospheric carbon.

As a healthy tree grows, so too does the annual amount of carbon sequestered. Syracuse's trees sequester 6,856 gross tons of carbon per year, with an associated value of \$912,000 (see Appendix A). An average acre of tree canopy in Syracuse sequesters an annual value of \$200 in atmospheric carbon. Within Syracuse's urban forest, sequestration is highest in the smaller diameter classes (Figure 11) due to their relative extent.



**Figure 11. Carbon total storage and annual sequestration by diameter class.**

Species of large-growing trees that are healthy and grow relatively quickly tend to sequester the most carbon annually and store the most carbon. Thus, to enhance carbon storage in the urban forest, planting large, long-lived species is the best strategy (Nowak et al. 2002b). The Syracuse tree species that sequester the most carbon on an annual basis are: *Acer saccharum* (sugar maple); *A. negundo* (boxelder); *Salix* spp. (willow species); *Populus deltoides* (eastern cottonwood); and *A. platanoides* (Norway maple). The species that store the most carbon are: *A. saccharum* (sugar maple); *A. platanoides* (Norway maple); *A. negundo* (boxelder); *Robinia pseudoacacia* (black locust); and *Ailanthus altissima* (tree-of-heaven). *A. platanoides* (Norway maple), *Robinia pseudoacacia* (black locust), and *Ailanthus altissima* (tree-of-heaven) are invasive species.



## Avoided Stormwater Runoff

Surface runoff can be a cause for concern in many urban areas, as it can contribute flooding and pollution in streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by trees, while the other portion reaches the ground. The portion of precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Trees intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees in Syracuse help reduce runoff by an estimated 13,275,000 cubic feet per year, with an associated value of \$884,000 (see Appendix A). An average acre of tree canopy in Syracuse mitigates an annual value of \$200 in stormwater management.

The species that have the greatest impact on reducing runoff through rainfall interception are *Acer platanoides* (Norway maple); *A. saccharum* (sugar maple); *Juglans nigra* (black walnut); *A. negundo* (boxelder); and *Picea abies* (Norway spruce).

## Building Energy Use

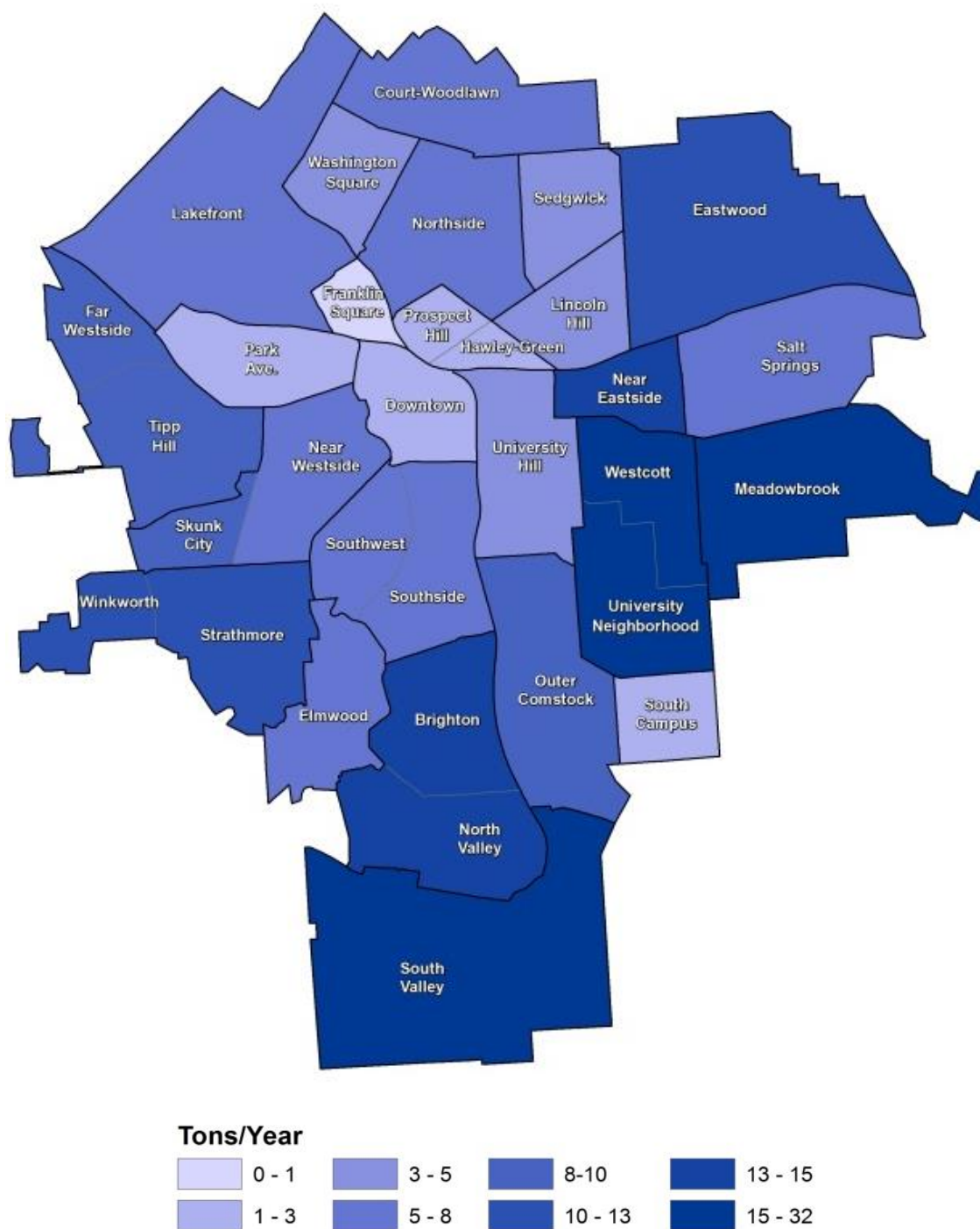
Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Trees in Syracuse are estimated to reduce energy use by 22,500 MBTUs and 2,600 megawatts (MWH). Reduced energy-related costs from residential buildings are estimated to be \$818,000 per year. Trees also provide an additional \$100,000 in value by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of 753 tons of carbon emissions). Among air-conditioned and heated buildings, an average acre of tree canopy in Syracuse saves an annual value of \$200 in energy conservation.

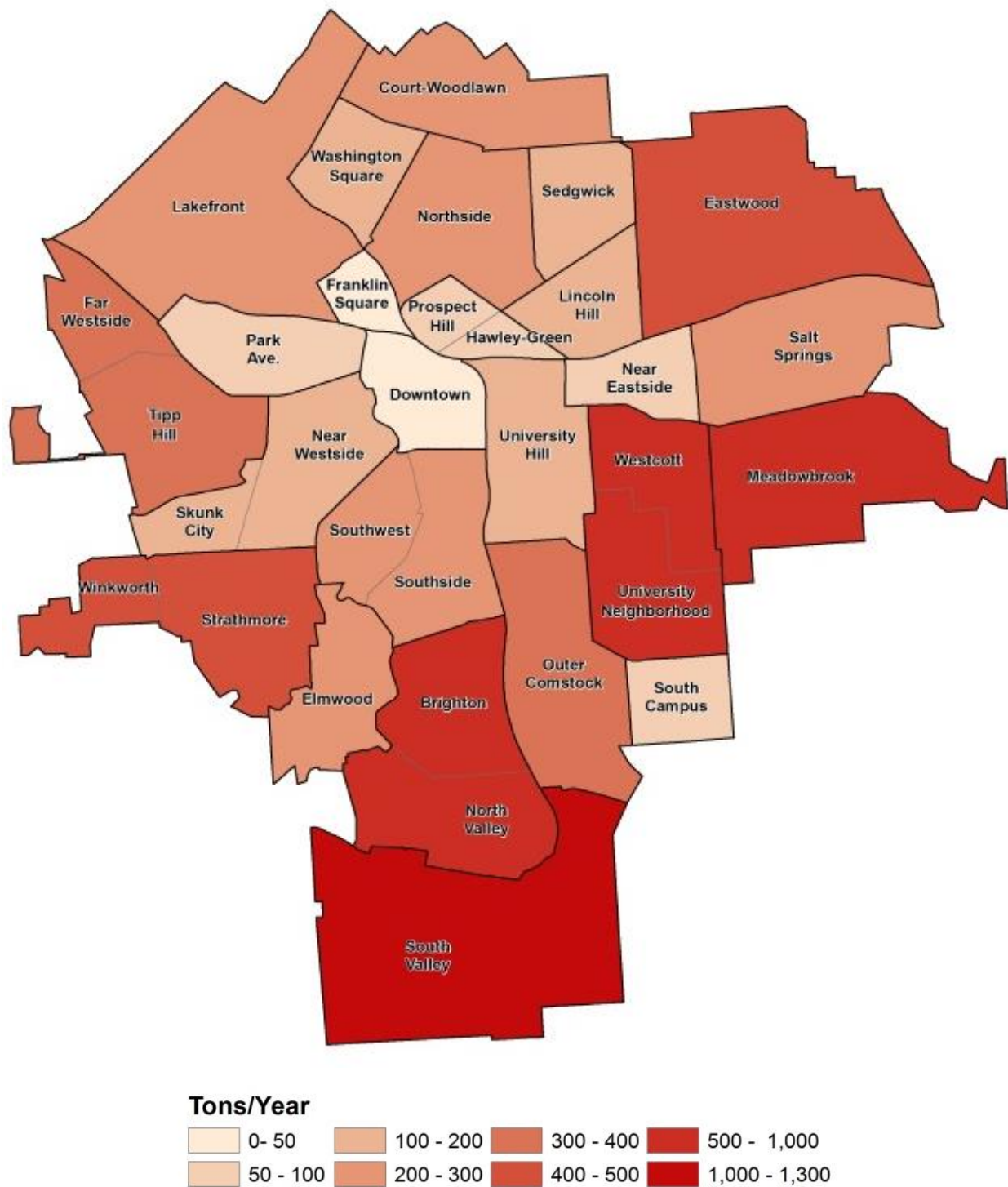
Modeling of energy effects is not quantified by tree species but rather by tree type. Effects of trees on building energy use depends on tree size, type, and distance and direction from a building. The best locations tend to be towards the north, northeast, and northwest, followed by the west and the east of an air-conditioned or heated building. Trees to the south of buildings can increase energy costs due to tree shade.

## Functional Benefit Values by Neighborhood

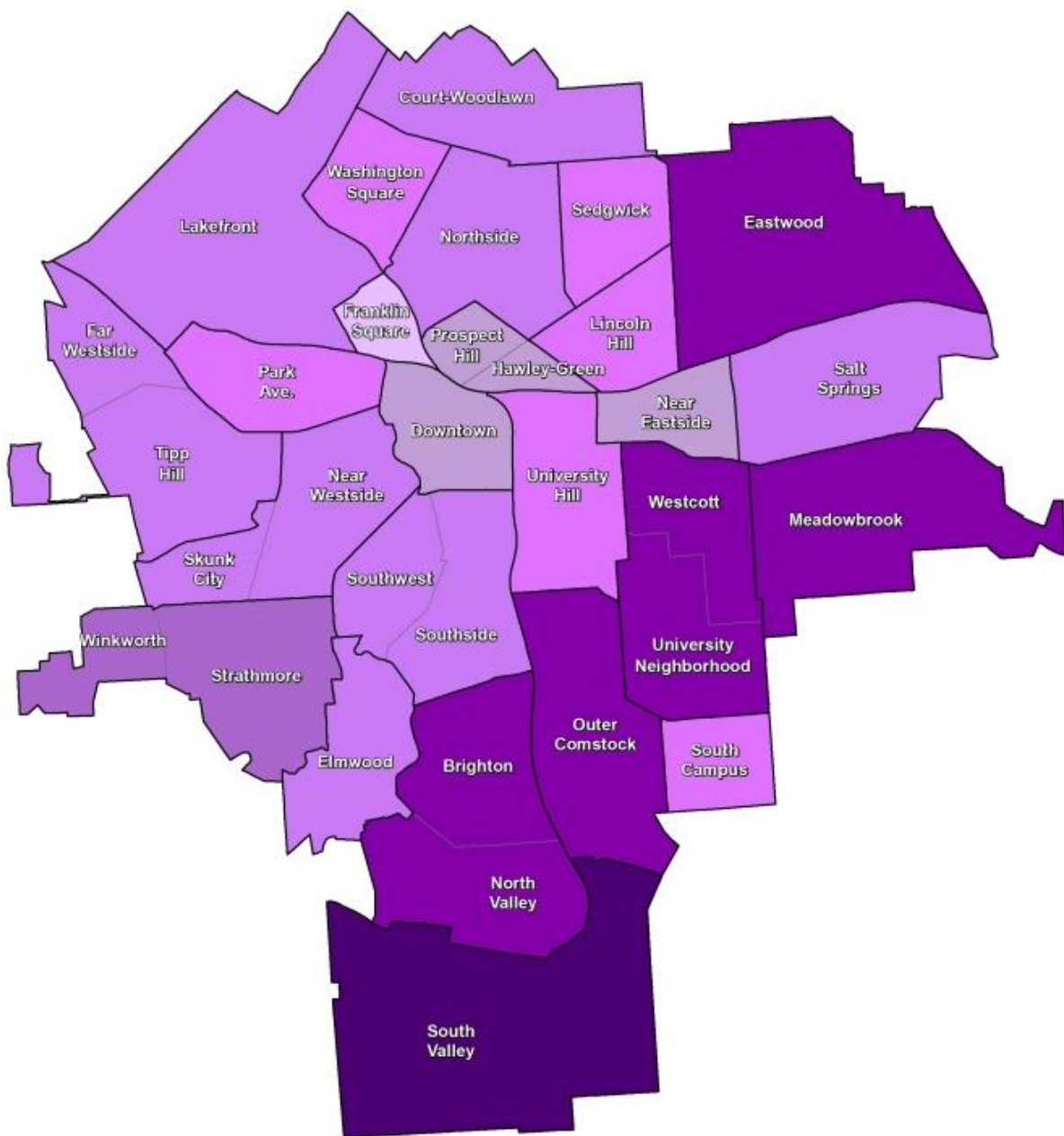
Functional values for each neighborhood were estimated by determining the functional values per square meter of tree cover (based on the field data and tree cover map) and then extrapolating those standardized values to the square meters of tree cover in each neighborhood (Figures 12, 13, and 14). Thus, the neighborhood values are proportionate to the amount of tree cover in the neighborhood. Energy conservation cannot be extrapolated to the neighborhoods due to the dependency of the value on specific orientation around buildings.



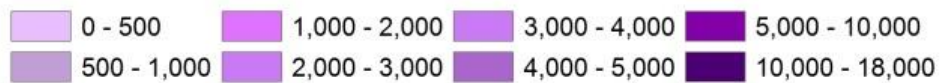
**Figure 12. Estimated annual carbon sequestration by trees per Syracuse neighborhood.**



**Figure 13. Estimated annual pollution removal by trees per Syracuse neighborhood.**



#### Thousand Gallons/Year



**Figure 14. Estimated annual stormwater by trees per Syracuse neighborhood.**

## *State of the Municipal Forest*

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Data analysis, national and state averages, and best management practices are used to provide an overview of the state of Syracuse's municipal forest. The municipal forest is comprised of city-managed street and park tree populations. To establish a framework for evaluating the state of the municipal forest, the following indicators were assessed:

- **Extent and Stocking Level**—The number of existing street and park trees and the estimation of potential street trees.
- **Species Diversity**—The distribution of tree species along streets and within parks, the ability of the street tree population to withstand threats from invasive pests and diseases, and species population importance relative to functional benefits.
- **Size Class Distribution**—The distribution of street and park trees size by trunk diameter.
- **Land Use**—The distribution of street trees citywide.
- **Functional Benefits and Return on Investment**—Explanation of public tree-related benefits and the ratio of returned benefit from the cost of public tree maintenance.

Data sources analyzed in this section of the report include the 2014 street and park tree inventory data and i-Tree Eco urban forest model benefit estimates. Comparisons to the 2014 street tree population are made in reference to street tree data from the 2001 Syracuse Urban Forest Master Plan that assesses the 2000 and 1978 street tree inventories. These comparisons provide further context for data analysis.

### *Extent of the Municipal Forest*

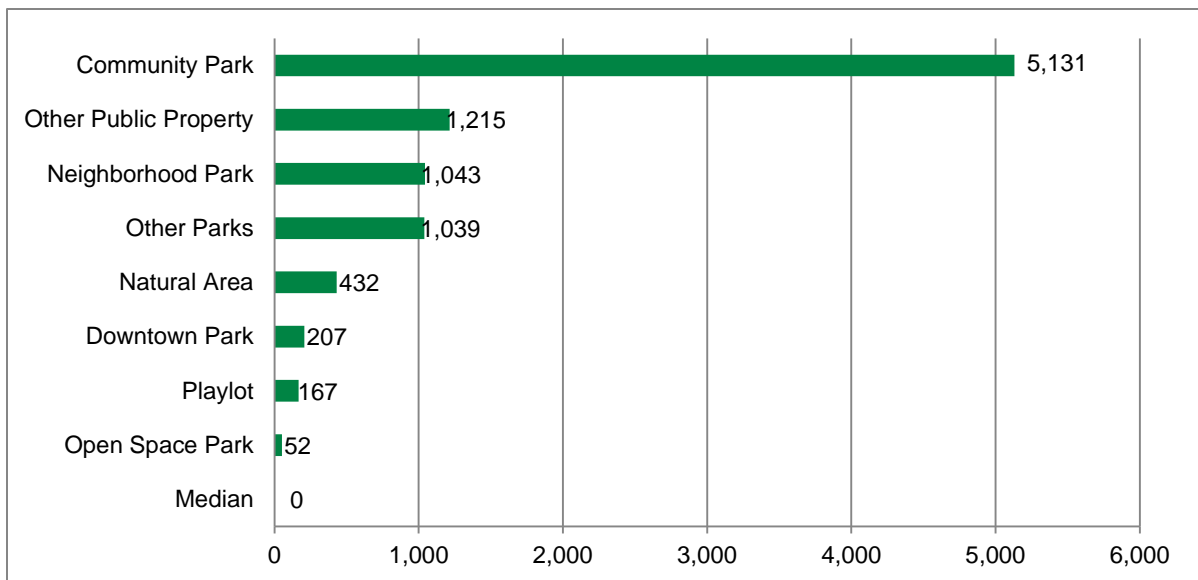
The street and park tree resources that comprise the municipal forest serve as the basis of green infrastructure and create a sense of unity and character throughout the City of Syracuse. Accurate street and park tree inventory data are integral to understanding the municipal forest resource.

### *Park Tree Resource*

Syracuse's park system is approximately 960 acres. The park tree resource includes neighborhood parks, community parks, downtown parks, playlots, natural area parks, median parks, open space parks, other parks, and other public properties.

In 2014, Davey Resource Group inventoried the park tree resource in Syracuse. Data were collected for 8,933 publicly-managed trees, including all landscape trees and only trees along wooded areas with associated heightened risk that carry potential for entire tree or limb failure. The 2000 park tree inventory reported 9,132 park trees. Figure 15 illustrates the number of trees per park type.





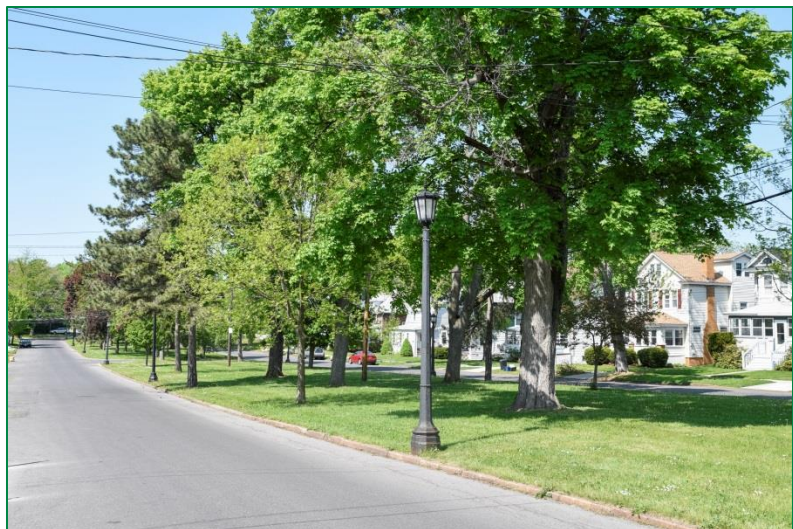
**Figure 15. Extent of the park tree resource by park type (2014).**

The structural value of Syracuse's inventoried park trees is estimated at \$16.3 million. This value represents the cost to replace all of the trees and can be viewed as the value of the park tree resource as a structural asset. Trees are assets that appreciate in value over time. With proper care and maintenance, trees can provide greater value and for a longer period of time. With such immense value, this resource merits careful planning, maintenance, and protection.

### Street Tree Resource

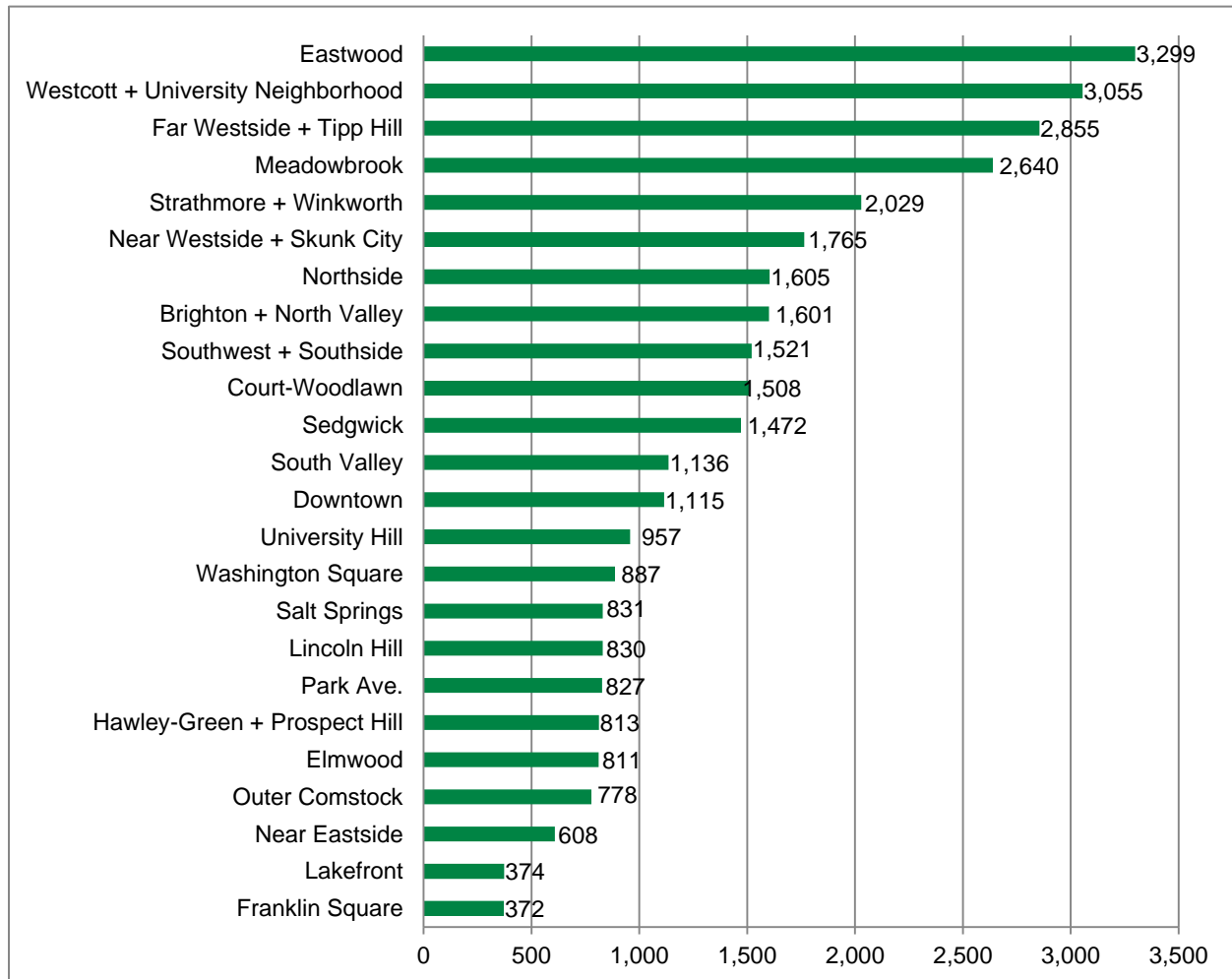
There are 345 centerline miles and 690 street side miles in Syracuse. Street tree inventories were completed in the years 2014, 2000, and 1978. The 2014 street tree inventory reported 33,689 trees, the 2000 street tree inventory reported 34,165 trees, and the 1978 street tree inventory reported 39,030 trees. Between the years 2000 and 2014, there has been a decrease, or loss, of 476 street trees. Between years 1978 and 2014, Syracuse's street tree population has lost an average of 148 trees per year.

The structural value of Syracuse's street trees is estimated at \$45.9 million. This value represents the cost to replace all of the street trees and can be viewed as the value of the street tree resource as a structural asset.



**Photograph 4.** Syracuse street trees total 33,689 and constitute an estimated structural value of \$45.9 million.

Figure 16 illustrates the number of trees per neighborhood. The five neighborhoods with the greatest amount of street trees include: Eastwood; Westcott + University; Far Westside + Tipp Hill; Meadowbrook; and Strathmore + Winkworth. The five neighborhoods with the least amount of street trees include: Franklin Square; Lakefront; Near Eastside; Outer Comstock; and Elmwood. South Campus is not in neighborhood results for street trees because there are no street trees inventoried in that neighborhood.



**Figure 16. Extent of the street tree resource by neighborhood (2014).**

### Stocking Level

Stocking level helps determine tree planting needs and budgets. A street tree stocking level may be projected using information about the community, tree inventory data, and common street tree planting practices. The most accurate way to assess a street tree stocking level is to use inventory data and divide the number of existing street trees by the number of potential street trees (existing trees and planting sites). However, Syracuse's inventory does not include planting sites. A theoretical way to assess a street tree stocking level is to use the inventory data and divide the number of existing trees by an estimated number of potential street trees in Syracuse.

The theoretical stocking level for Syracuse is 40%. There are 33,689 inventoried street trees and 395 city-managed street miles; this estimate assumes the possibility of 1 tree every 50 feet, along both sides of the street, to achieve full stocking. The 2001 Syracuse Urban Forest Master Plan reported a stocking level of 47% in the year 2000. The national average stocking level is 60% (Cornell University 2015). When the estimated stocking level is determined using theoretical assumptions, the actual number of vacant planting sites may be significantly less than estimated due to unknown space constraints such as inadequate growing space, proximity of private trees, utility conflicts, and other site conditions.

Syracuse's estimated street trees per street mile is 85—which is slightly above the mean of 80 reported in New York statewide (Cowett and Bassuk 2011). Table 6 provides a list of the 24 neighborhoods with inventoried street trees and each of their estimated street trees per mile. Of the 24 neighborhoods, 13 meet or exceed the reported average number of trees per mile in the state of New York (80 trees per mile).

Table 6. Street Trees (2014) per Mile of Neighborhoods

| Neighborhoods                      | Trees per Mile |
|------------------------------------|----------------|
| Brighton + North Valley            | 52             |
| Court-Woodlawn                     | 72             |
| Downtown                           | 101            |
| Eastwood                           | 94             |
| Elmwood                            | 81             |
| Far Westside + Tipp Hill           | 114            |
| Franklin Square                    | 124            |
| Hawley-Green + Prospect Hill       | 90             |
| Lakefront                          | 75             |
| Lincoln Hill                       | 83             |
| Meadowbrook                        | 106            |
| Near Eastside                      | 68             |
| Near Westside + Skunk City         | 74             |
| Northside                          | 73             |
| Outer Comstock                     | 78             |
| Park Avenue                        | 75             |
| Salt Springs                       | 55             |
| Sedgwick                           | 113            |
| South Valley                       | 67             |
| Southwest + Southside              | 72             |
| Strathmore + Winkworth             | 92             |
| University Hill                    | 80             |
| Washington Square                  | 89             |
| Westcott + University Neighborhood | 127            |

Stocking level can also be determined by calculating the number of trees per street mile and by the number of trees per capita. Stocking level per capita is a useful metric that addresses the relationship between population density and street tree density. The more streets and residents there are in a city, the greater the need for trees to provide benefits. Syracuse's ratio of street trees per capita is 0.23—which is below the average of 0.37 reported for 22 U.S. cities (McPherson and Rowntree 1989). Currently, there is 1 tree for every 4 Syracuse residents.



**Photograph 5.** Syracuse has an estimated 85 street trees per street mile and 0.23 tree per capita.

## Land Use Distribution

Syracuse has seven groupings of 93 official land use categories. Table 7 shows tree distributions for each land use group. The majority of public trees (74%) is found within the residential land use.

Table 7. Street Tree Distribution Among Land Use (2014)

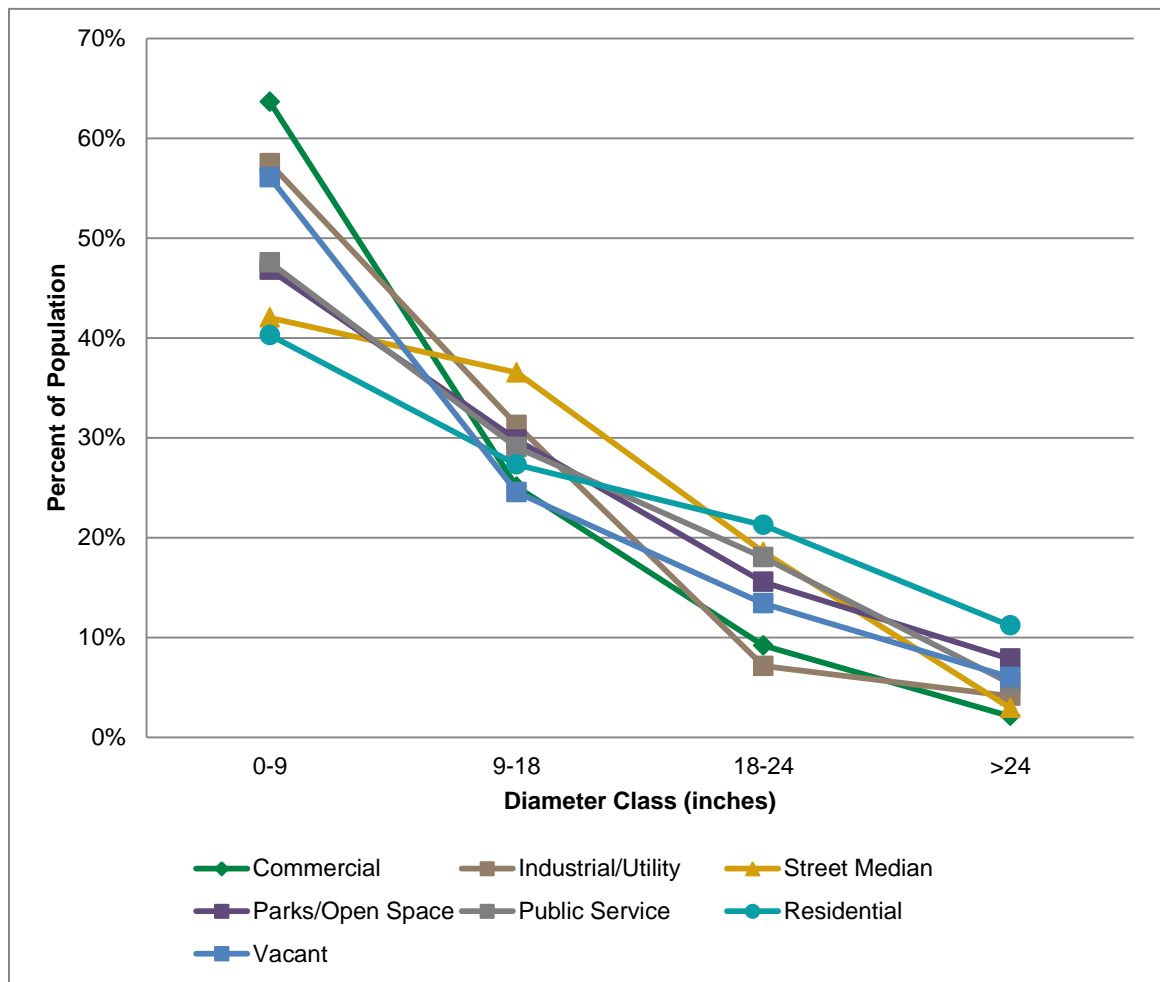
| Land Use Group     | Percent of Population |
|--------------------|-----------------------|
| Commercial         | 10%                   |
| Industrial/Utility | 1%                    |
| Street Median      | 2%                    |
| Parks/Open Space   | 2%                    |
| Public Service     | 5%                    |
| Residential        | 74%                   |
| Vacant             | 6%                    |

Most of the trees (71%) in the residential land use are of the large-growing type, 9% are medium-growing type, and 20% are small-growing type (Table 8). The trend of greater large-growing trees than small-growing trees, along with greater small-growing trees than medium-growing trees, is present throughout all land uses. Parks/Open Space and Public Service land uses have the greatest distribution of large-growing trees. Street Median land use has the greatest distribution of small-growing trees.

Table 8. Street Tree Distribution Among Land Use by Tree Type (2014)

| Land Use           | Tree Type |        |       |
|--------------------|-----------|--------|-------|
|                    | Large     | Medium | Small |
| Commercial         | 70%       | 15%    | 15%   |
| Industrial/Utility | 65%       | 12%    | 23%   |
| Street Median      | 63%       | 13%    | 24%   |
| Parks/Open Space   | 79%       | 8%     | 13%   |
| Public Service     | 79%       | 8%     | 13%   |
| Residential        | 71%       | 9%     | 20%   |
| Vacant             | 72%       | 11%    | 17%   |

Figure 17 illustrates size class distribution of trees within each land use. All land uses trend toward the ideal distribution. As trees mature and begin to decline, a tree population skewed towards the 0–9 inch DBH size class will ensure that tree canopy and flow of benefits continue to exist.



**Figure 17. Street tree distribution among land use by size class (2014).**



## Municipal Forest Diversity and Resiliency

Syracuse's inventoried public tree population includes a mix of over 200 species. The distribution of a variety of species types can decrease the impact of species-specific pests and diseases by limiting the number of trees that are susceptible. This, in turn, reduces the time and money spent on mitigating problems resulting from an infestation. Additionally, a wide variety of tree species may help minimize the impacts from pests and diseases and physical events such as storms, wind, ice, flooding, or drought.

Identifying species distribution is integral to properly managing a tree population. A general rule for species diversity within a tree population is that no single species should represent more than 10% of the population; however, some urban forest researchers are calling for more stringent standards such as 5% representation of a single species in a population.

### Park Tree Resource

The predominant species in parks are *Acer platanoides* (Norway maple) and *A. saccharum* (sugar maple), comprising 11% and 8% of the park tree population. All other species represent less than 5% of the population. This distribution is very favorable in comparison to conventional species distribution standards. Table 9 presents the park population's species distribution.

Table 9. Species Distribution of Park Trees (2014)

| Botanical Name                       | Common Name           | Percent of Population |
|--------------------------------------|-----------------------|-----------------------|
| <i>Acer platanoides</i>              | Norway maple          | 11%                   |
| <i>Acer saccharum</i>                | sugar maple           | 8%                    |
| <i>Thuja occidentalis</i>            | northern white cedar  | 4%                    |
| <i>Pinus nigra</i>                   | Austrian pine         | 4%                    |
| <i>Robinia pseudoacacia</i>          | black locust          | 3%                    |
| <i>Gleditsia triacanthos inermis</i> | thornless honeylocust | 3%                    |
| <i>Acer negundo</i>                  | boxelder              | 3%                    |
| <i>Quercus rubra</i>                 | red oak               | 3%                    |
| <i>Fraxinus pennsylvanica</i>        | green ash             | 3%                    |
| <i>Picea abies</i>                   | Norway spruce         | 2%                    |

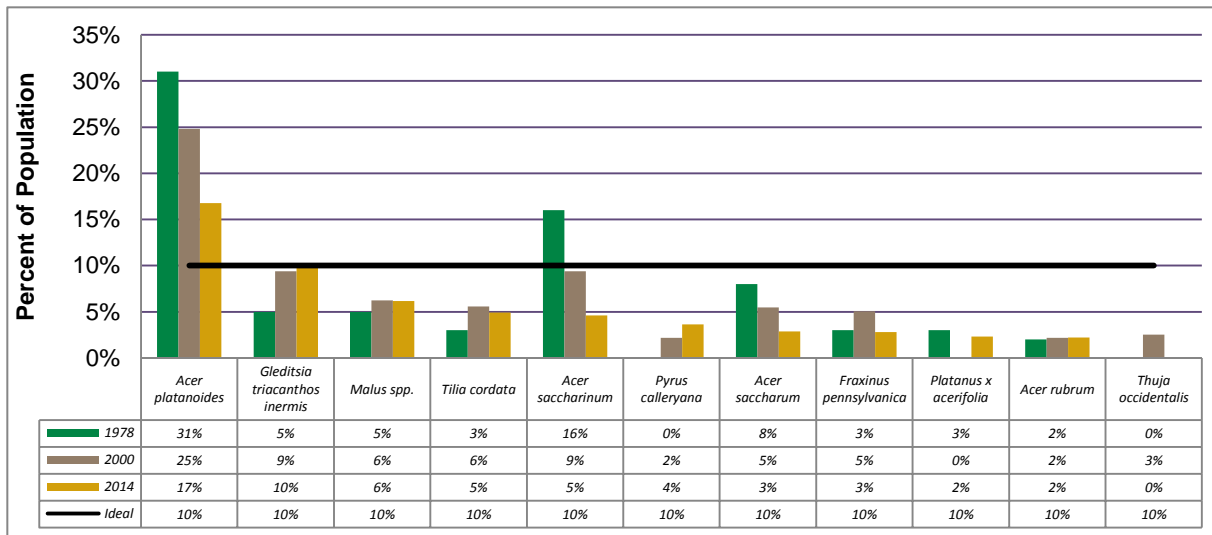
### Street Tree Resource

In 2014, the most predominant species along streets were *Acer platanoides* (Norway maple) and *Gleditsia triacanthos inermis* (thornless honeylocust). These species were also the two most common species in 2000. From 2000 to 2014, Norway maple decreased by 2,312 trees (percentage of population decreased by 8%), while thornless honeylocust increased by 285 trees (percentage of population increased by 1%). Figure 18 illustrates the distribution of species during the years 1978, 2000, and 2014.

The Norway maple population comprised 17% of the street tree inventory in 2014, 25% of the population in 2000, and 31% of the population in 1978. With continued management of Norway maple's distribution, the City of Syracuse may achieve the goal of reducing this invasive species to 10% of the population by the year 2029 (or earlier).

Other large reductions in species population from 2000 to 2014 include: *Acer saccharinum* (silver maple), which decreased by 1,459 trees (4%); *A. saccharum* (sugar maple), which decreased by 791 trees (2%); and *Fraxinus pennsylvanica* (green ash), which decreased by 677 trees (2%). Green ash is being heavily managed due to the presence of emerald ash borer.

Due to quality management and greater species distribution, the population has gradually become more resilient to pests and diseases and other impacts.



**Figure 18. Comparison of species distribution for street trees in the years 1978, 2000, and 2014 to the ideal distribution.**

The majority of Syracuse’s neighborhoods exceeds the industry guideline that no single species in a population represents greater than 10% of the total population. Table 10 shows one neighborhood that meets the rule, five neighborhoods that nearly meet the rule, and the remaining 18 neighborhoods that exceed the rule. Appendix B contains a list of all 24 neighborhoods along with their respective top five species distributions.

**Table 10. List of Neighborhoods with Good and Bad Species Distributions (2014)**

| Good – Meets 10% Species Rule | Fair – Near 10% Species Rule  | Poor – Exceeds 10% Species Rule  |
|-------------------------------|---|--|
| Near Westside + Skunk City    | Lincoln Hill<br>Near Eastside<br>Outer Comstock<br>Park Ave.<br>Southwest + Southside | Brighton + North Valley<br>Court-Woodlawn<br>Downtown<br>Eastwood<br>Elmwood<br>Far Westside + Tipp Hill<br>Franklin Square<br>Hawley-Green + Prospect Hill<br>Lakefront<br>Meadowbrook<br>Northside<br>Salt Springs<br>Sedgwick<br>South Valley<br>Strathmore + Winkworth<br>University Hill<br>Washington Square<br>Westcott + University Neighborhood |

## Large- vs. Small-Growing Trees

Many factors drive species choice, including planting site conditions, potential infrastructure conflicts, tree maintenance concerns, and street design considerations. In some cases, small- or medium-growing trees are the best (or only) option. Nonetheless, environmental and economic research shows that large-growing trees should be planted wherever possible to increase tree canopy and tree-related benefits.

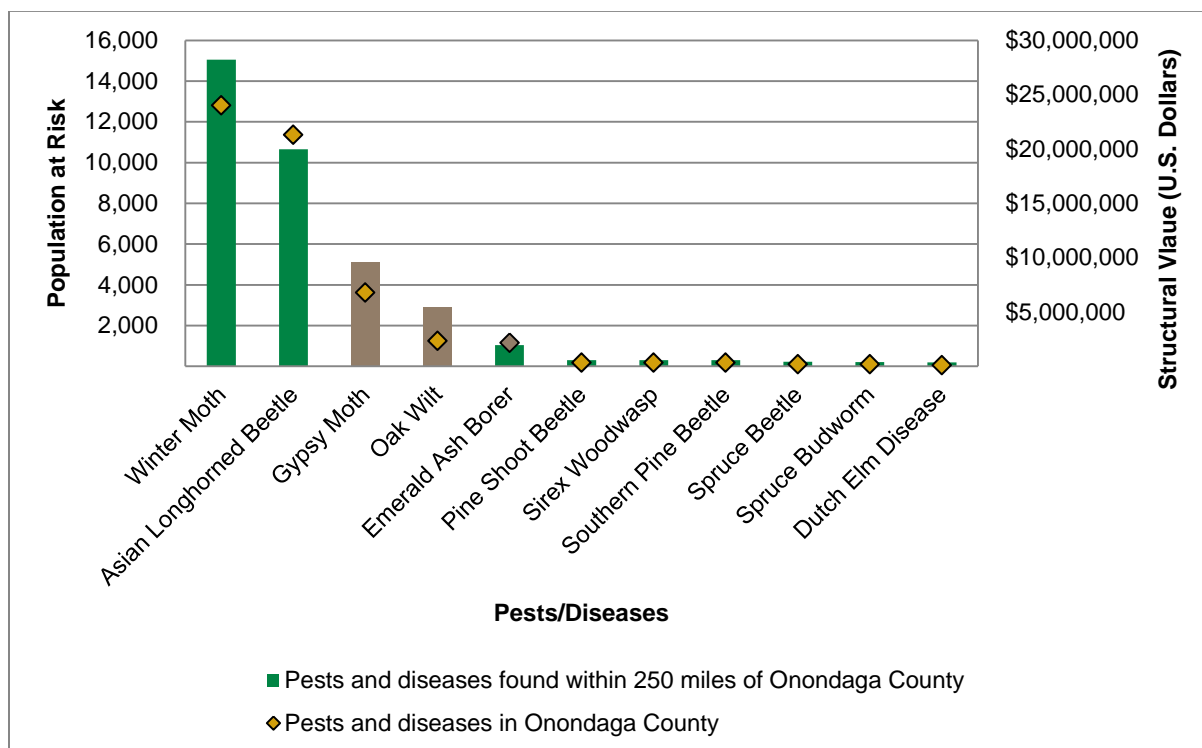
Table 11 shows that most of Syracuse's inventoried street trees are large-growing (71%), followed by small-growing trees (19%), and medium-growing trees (10%). There are five neighborhoods with small-growing trees that comprise more than 20% of their respective population and large-growing trees that comprise less than 70% of their respective population. Those neighborhoods include: Eastwood; Near Westside + Skunk City; Northside; Salt Springs; and Southwest + Southside.

Table 11. Citywide Size Distributions of Street Trees by Tree Type in Neighborhoods (2014)

| Neighborhoods                      | Large | Medium | Small |
|------------------------------------|-------|--------|-------|
| Brighton + North Valley            | 74%   | 8%     | 18%   |
| Court-Woodlawn                     | 70%   | 9%     | 21%   |
| Downtown                           | 87%   | 9%     | 4%    |
| Eastwood                           | 67%   | 12%    | 21%   |
| Elmwood                            | 80%   | 9%     | 12%   |
| Far Westside + Tipp Hill           | 70%   | 8%     | 21%   |
| Franklin Square                    | 57%   | 25%    | 18%   |
| Hawley-Green + Prospect Hill       | 67%   | 14%    | 18%   |
| Lakefront                          | 61%   | 25%    | 14%   |
| Lincoln Hill                       | 73%   | 10%    | 17%   |
| Meadowbrook                        | 71%   | 7%     | 22%   |
| Near Eastside                      | 71%   | 7%     | 21%   |
| Near Westside + Skunk City         | 64%   | 11%    | 25%   |
| Northside                          | 64%   | 12%    | 25%   |
| Outer Comstock                     | 75%   | 10%    | 14%   |
| Park Avenue                        | 67%   | 14%    | 19%   |
| Salt Springs                       | 65%   | 13%    | 22%   |
| Sedgwick                           | 72%   | 11%    | 17%   |
| South Valley                       | 80%   | 5%     | 15%   |
| Southwest + Southside              | 65%   | 11%    | 24%   |
| Strathmore + Winkworth             | 72%   | 10%    | 18%   |
| University Hill                    | 72%   | 12%    | 15%   |
| Washington Square                  | 78%   | 9%     | 13%   |
| Westcott + University Neighborhood | 76%   | 8%     | 15%   |
| Citywide                           | 71%   | 10%    | 19%   |

## Resiliency Against Forest Pests and Diseases

Pests and diseases pose serious threats to tree health and longevity. Many pests target a single species or an entire genus. The inventory data were analyzed to provide a general estimate of the percentage of trees that are susceptible to some known pests and diseases. In Figure 19, there are 11 pests and diseases within 250 miles of Syracuse that have the potential to kill a tree in Syracuse. The green bars reflect pests and diseases within 250 miles of Onondaga County; the brown bars are pests and diseases in Onondaga County. Awareness and early diagnosis are essential to ensuring the long-term health and durability of street trees. Figure 19 illustrates the number and value of at-risk street trees that are most susceptible to known pests and diseases.



**Figure 19. Number and value of street trees susceptible to known pests and diseases in New York State (2014).**

Pests and diseases that pose a significant threat to Syracuse's street tree population include:

- Winter Moth (WM) is a pest with a wide range of host species. Syracuse could potentially lose 45% of its street tree population to this pest. This potential loss equates to \$23.9 million in structural value.
- Asian Longhorned Beetle (ALB) is an insect that bores into and kills a wide range of hardwood species, including maple. ALB poses a threat to 32% of the street tree population. This potential loss equates to \$21.3 million in structural value.
- Gypsy Moth (GM) feeds on many species and causes widespread defoliation and tree death if outbreak conditions last several years. GM poses a threat to 15% of the street tree population, including oak. This potential loss equates to \$6.8 million in structural value.

- Oak Wilt (caused by *Ceratocystis fagacearum*, OW) (Rexrode and Brown 1983) is a fungal disease that shrivels the foliage of oaks and some other species and quickly kills trees when infested. OW poses a threat to 9% of the street tree population. This potential loss equates to \$2.3 million in structural value.
- Emerald Ash Borer (*Agrilus planipennis*, EAB) (USDA FS 2005b) are invasive insects that have killed millions of ash trees throughout the U.S. since 2002. EAB poses a threat to 3% of the street tree population. This potential loss equates to \$2.2 million in structural value.

Syracuse should be aware of signs and symptoms of infestations and should be prepared to act if a significant threat is observed in its tree population or a nearby community. An integrated pest management plan should be established for pests or diseases that could have the greatest impact on the population. The plan should focus on identifying and monitoring threats, understanding the economic threshold, selecting the correct treatment, properly timing management strategies, recordkeeping, and evaluating results.

### Municipal Forest Species Importance

Importance Value (IV) of a tree species to the municipal forest forecasts what species could provide the most environmental and economic benefits to Syracuse. The higher the IV suggests more reliance on one species. The 10 most important species for street ROW and parks are shown in Table 12.

Table 12. Top 10 Most Important Species (2014)

| Street ROW Tree Resource      |                      |                  |
|-------------------------------|----------------------|------------------|
| Botanical Name                | Common Name          | Importance Value |
| <i>Acer platanoides</i>       | Norway maple         | 23.09            |
| <i>Gleditsia triacanthos</i>  | honeylocust          | 7.55             |
| <i>Acer saccharinum</i>       | silver maple         | 6.92             |
| <i>Platanus × acerifolia</i>  | London planetree     | 4.14             |
| <i>Acer saccharum</i>         | sugar maple          | 4.01             |
| <i>Tilia cordata</i>          | littleleaf linden    | 3.82             |
| <i>Malus species</i>          | apple species        | 3.78             |
| <i>Fraxinus pennsylvanica</i> | green ash            | 3.74             |
| <i>Acer rubrum</i>            | red maple            | 2.76             |
| <i>Pyrus calleryana</i>       | Callery pear         | 2.26             |
| Park Tree Resource            |                      |                  |
| <i>Acer platanoides</i>       | Norway maple         | 13.45            |
| <i>Acer saccharum</i>         | sugar maple          | 9.56             |
| <i>Robinia pseudoacacia</i>   | black locust         | 3.92             |
| <i>Quercus rubra</i>          | red oak              | 3.62             |
| <i>Acer negundo</i>           | boxelder             | 3.26             |
| <i>Fraxinus pennsylvanica</i> | green ash            | 2.85             |
| <i>Tilia americana</i>        | American linden      | 2.81             |
| <i>Acer saccharinum</i>       | silver maple         | 2.73             |
| <i>Pinus nigra</i>            | Austrian pine        | 2.64             |
| <i>Thuja occidentalis</i>     | northern white cedar | 2.64             |

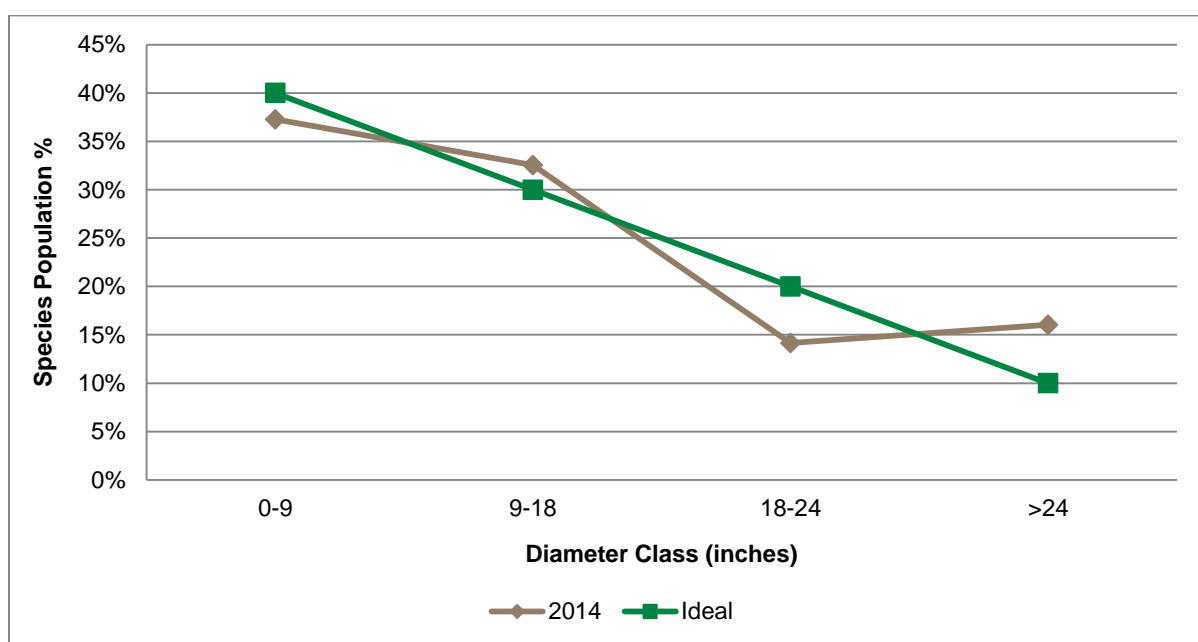


## Municipal Forest Size Class Distribution

Trunk-size class distribution affects the benefits trees provide to the community and the sustainability of the tree population. An ideal size class distribution has a greater percentage of smaller trees than larger trees. This provides for an even flow of benefits and more predictable tree maintenance expenditures over time.

### Park Tree Resource

The size distribution of Syracuse's park trees is ideal, with more small trees than large trees (Richards 1982/83). Figure 20 compares the park population to the ideal. Of Syracuse's inventoried trees, 37% are less than 9 inches DBH, 33% are 9–18 inches DBH, 14% are 18–24 inches DBH, and 16% are greater than 24 inches DBH. The distribution is close, but maintaining park tree canopy and the flow of benefits provided by the park trees will require even greater commitment to tree planting.

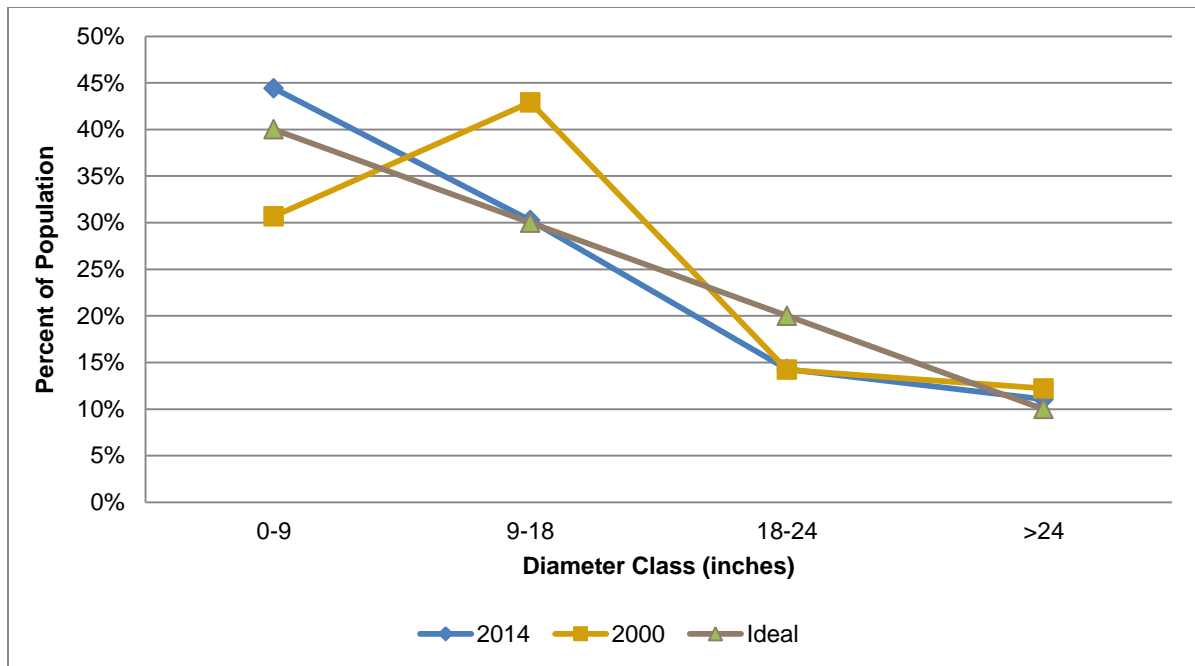


**Figure 20. Size class distribution within the park tree population compared to the ideal (2014).**

### Street Tree Resource

The size class distribution of Syracuse's street trees in 2014 is ideal, with more small trees than large trees. Of Syracuse's street trees inventoried in the year 2014, 44% are less than 9 inches DBH, 30% are 9–18 inches DBH, 14% are 18–24 inches DBH, and 11% are greater than 24 inches DBH.

Figure 21 compares the 2014 street tree population and 2000 street tree population to the ideal. Based on the street tree population in 2000, many of the 9–18 inches DBH trees and less than 9 inches DBH trees have since matured. Over the last 14 years, young trees have not successfully sustained the street tree population. However, since 2000, Syracuse has planted enough trees to replenish the young tree population. Maintaining street tree canopy and the flow of benefits provided by street trees will require continued commitment to planting trees.



**Figure 21. Size class distribution within the street tree populations in 2014 and 2000 compared to the ideal.**

Size class distribution can also be assessed within neighborhoods. This provides insight into where to focus planting and management needs. Table 13 illustrates the street tree size class distribution of all 24 neighborhoods. Of the neighborhood populations, 20 follow a theoretical ideal distribution of 40:30:20:10, and four are lacking sufficient young trees to replace established trees. Implementing a stronger planting initiative in these four neighborhoods and continuing street tree planting efforts in the other 20 neighborhoods will create a more stable age structure. Additionally, implementing a well-planned young tree care and training pruning program throughout the city, particularly in neighborhoods with a high percentage of trees less than 9 inches DBH (greater than 50%), will ensure a higher volume of larger trees in the future.

Table 13. Size Class Distribution Within the Street Tree Population Among Neighborhoods (2014)

| Neighborhoods                      | 0–9 | 9–18 | 18–24 | >24 |                         |
|------------------------------------|-----|------|-------|-----|-------------------------|
| Lakefront                          | 79% | 15%  | 3%    | 3%  | Follow the Ideal        |
| Downtown                           | 69% | 27%  | 3%    | 1%  |                         |
| Near Westside + Skunk City         | 61% | 22%  | 9%    | 8%  |                         |
| Park Avenue                        | 58% | 24%  | 12%   | 7%  |                         |
| University Hill                    | 56% | 33%  | 8%    | 3%  |                         |
| Far Westside + Tipp Hill           | 55% | 27%  | 9%    | 8%  |                         |
| Near Eastside                      | 53% | 33%  | 10%   | 4%  |                         |
| Southwest + Southside              | 48% | 27%  | 14%   | 11% |                         |
| Hawley-Green + Prospect Hill       | 48% | 32%  | 15%   | 5%  |                         |
| Franklin Square                    | 46% | 51%  | 3%    | 1%  |                         |
| Northside                          | 46% | 26%  | 14%   | 14% |                         |
| Elmwood                            | 45% | 31%  | 13%   | 11% |                         |
| Salt Springs                       | 43% | 28%  | 14%   | 15% |                         |
| Court-Woodlawn                     | 42% | 31%  | 13%   | 14% |                         |
| Strathmore + Winkworth             | 41% | 34%  | 15%   | 9%  |                         |
| Outer Comstock                     | 41% | 36%  | 16%   | 7%  |                         |
| Brighton + North Valley            | 39% | 28%  | 17%   | 17% |                         |
| Westcott + University Neighborhood | 39% | 28%  | 19%   | 14% |                         |
| Eastwood                           | 36% | 32%  | 17%   | 15% |                         |
| Sedgwick                           | 35% | 33%  | 20%   | 11% |                         |
| Meadowbrook                        | 37% | 34%  | 18%   | 11% |                         |
| Lincoln Hill                       | 36% | 38%  | 16%   | 10% | Do Not Follow The Ideal |
| Washington Square                  | 28% | 34%  | 17%   | 20% |                         |
| South Valley                       | 27% | 37%  | 19%   | 16% |                         |

### *Municipal Forest in Relation to the Urban Forest*

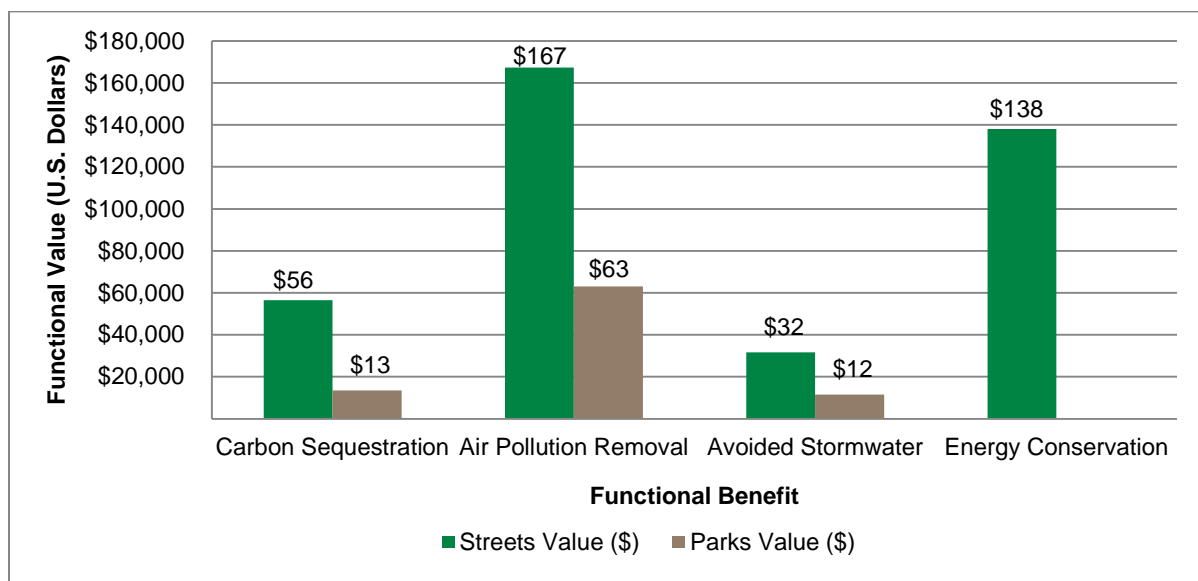
To sustain and grow this valuable municipal resource, new trees and a variety of species must continually be planted. There are an estimated 1,583,000 trees in Syracuse; the combined populations of street ROW trees and park trees represent 3% of the urban forest. The structural value of the municipal forest (\$62.2 million) represents 8% of the urban forest's structural value. Syracuse's urban forest is comprised of 4,400 acres of tree canopy. Of the total canopy cover, 15% represents canopy within the street ROW and 8% represents canopy within parks. Percent canopy cover in street ROW is illustrated by neighborhood in Appendix C. The urban forest has a greater issue with presence of invasive species than the municipal forest. All populations are relatively stable in size distribution. Over time and with planned management, the municipal forest has become more stable.

## Municipal Forest Functional Benefit Values

The i-Tree Eco model estimated that the inventoried street tree and park tree populations provide a value of \$343,000 in annual benefits. Figure 22 summarizes the annual benefits for the street and park tree populations. Street trees provide Syracuse an annual benefit of \$255,000, which includes avoided stormwater runoff (\$32,000), air pollution removal (\$167,000), and carbon sequestration (\$56,000). Park trees provide Syracuse an annual benefit of \$88,000, which includes avoided stormwater runoff (\$12,000), air quality (\$63,000), and carbon sequestration (\$13,000).

There was not sufficient data to estimate energy conservation values using i-Tree Eco. However, estimates can be made with the information presented in this report and with the use of i-Tree Streets. Since the street tree canopy represents 15% of the total urban tree canopy, municipal energy conservation values can be extrapolated to be at least 15% of the \$918,000 of the total urban forest energy conservation. Syracuse's street trees can provide up to an estimated \$138,000 per year in energy conservation. This method is likely an underestimate of energy conservation provided. Based on a separate i-Tree model (i-Tree Streets), the street tree population is estimated to provide up to \$1.8 million per year in energy conservation.

According to i-Tree Streets, the aesthetic value of the street tree population is estimated to improve property value by up to \$1.5 million per year.



**Figure 22. Breakdown of the municipal forest's total annual benefits provided to Syracuse.**

## Municipal Forest Costs and Benefits

Using the i-Tree Eco value estimates for street and park trees (\$343,000) and approximate energy and aesthetic values (\$138,000 and \$1.5 million, respectively), Syracuse's street and park tree populations provide an estimated total of \$1,981,000 in annual benefits. On average, one of Syracuse's municipal trees provides a benefit equal to \$46 per year.

The city urban forestry budget for fiscal year 2015–2016 was \$916,600. The benefit-cost ratio for these public trees versus city expenditures is 2.16 to 1. Essentially, the community receives \$2.16 of returned benefits for every \$1 spent on tree maintenance.

## Recommendations

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The urban forest improves the environment and makes the city a more desirable place to live, work, and play. To maintain a sustainable urban forest in light of the challenges identified in this report, the city will need to continue to plant more trees than it removes from a diverse selection of quality stock. Pruning trees for structure earlier in their life and on a consistent cycle will reduce storm damage and increased tree life. Management Plan updates, operational improvements, new and creative funding sources, and public outreach will also need to be part of this ongoing effort. Even if the public tree resource is sustainably managed, it accounts for only 15% of the urban forest canopy and 4% of the total land cover. Therefore, Syracuse should prioritize the need to update the Municipal Tree Ordinance and Urban Forest Master Plan (last updated in 1981 and 1999, respectively). Because land-use change and development will have the greatest impact on the future of the urban forest, there should be close coordination with the Planning Department's historic process to update Syracuse's zoning code. Summarized below are the major recommendations, defined in two categories: Canopy Goal Setting and Master Plan Development.

### Canopy Goal Setting

Setting a tree canopy goal is an important step in the planning process, as goals provide metrics by which performance can be measured throughout future years. The process of setting a goal also helps establish realistic standards.

There are a number of ways canopy goals can be set:

- *Comparisons to an Industry Standard.* American Forests, a recognized leader in conservation and community forestry, has established standards and goals for canopy cover in metropolitan areas. American Forests recommends that cities have an overall canopy of 40%, with 15% canopy in the central business district, 25% in urban neighborhoods, and 50% in suburban neighborhoods. Syracuse falls below most of those standards, as illustrated in Table 14.
- *Comparison of Existing Canopy to Possible Canopy.* Relative canopy is a measure of how much canopy has been achieved compared to how much canopy is possible. This metric is useful with respect to setting realistic goals for very different areas. Syracuse has a potential canopy cover of 56%. The 2009 tree canopy assessment revealed Syracuse's tree canopy to be 27%, which makes its relative canopy 48% (27% tree canopy cover divided by 56% potential canopy cover equals 48% of what is possible). Relative tree canopy is a recommended metric to use until an actual canopy goal is set.

Another way of examining "possible canopy" is calculating the quantity of new trees a particular canopy goal would require, then determining whether that number is realistic. For example, to reach 40% canopy, 2,107 additional acres, or approximately 209,000 trees, would need to be planted (Table 15) using the current average of 99 trees per acre. These numbers do not take into account canopy lost in Syracuse each year. Installation of this many trees is unlikely in the next five to ten years, meaning a 40% canopy goal may be unrealistic.



- *Comparisons to Other Cities.* Comparing Syracuse’s tree canopy cover to other cities can be a helpful exercise with the caveat that every city is unique. Some cities assess their canopy cover on a countywide basis. Charlotte and Louisville have high canopy cover but span large counties that include more rural areas. Other cities have geography or climates that affect canopy levels. Cincinnati and Pittsburgh have high canopy cover, but both have many undevelopable hillsides that require trees for stabilization. A list of city tree canopy cover and goals can be found in Table 16.
- *Outcome-Based Goals.* Choosing a canopy goal based on the desired benefits outcome, (e.g., reduction in heat stress, stormwater intercepted) is also a possibility using i-Tree analysis projections. For example, if 30% canopy is reached, an additional 19 tons of air pollutants would be removed from the atmosphere on an annual basis. This removal of pollutants would return a value of roughly \$712,000 (Table 17).
- *Neighborhood Goals.* Canopy goals can also be set beyond broad citywide numbers. In the coming years, neighborhoods in need of more canopy (and associated benefits) can focus their efforts on preservation and planting activities. These local goals can help equally distribute canopy benefits among all residents, no matter where they live.

It is not uncommon to use a combination of the above methods. A phased goal approach is also common (e.g., achieving no-net-loss within five years, followed by an increase of 5% canopy by 2025). Some cities establish target dates; others have ongoing goals. Some establish target percentages; others aim for an increase of any kind.

Once established, the goal should be adopted by the city council and referenced into city policy to inform planting strategy, but also to use in outreach and education campaigns. To ensure that tree canopy goals survive transitions in leadership, these goals must be institutionalized in other processes (including legislation and regulation) and included in the next version of the city’s comprehensive plan.

In order to track progress, the urban tree canopy assessment should be updated every five years. When multiple years of data are available, trends of which neighborhoods are losing the most canopy, or losing canopy at the fastest rates, can be determined. Data trends can help achieve future canopy goals.

Table 14. American Forest UTC Standards Compared to Syracuse 2009 Tree Canopy

|                              | American Forest<br>Recommendations* | Syracuse 2009 |
|------------------------------|-------------------------------------|---------------|
| Average of All Zones         | 40%                                 | 27%           |
| Central Business Districts** | 15%                                 | 9%            |
| Urban Residential***         | 25%                                 | 25%           |
| Suburban Residential         | 50%                                 | n/a           |

\* American Forests recommendations for metropolitan areas east of the Mississippi.

\*\* Considered Syracuse Downtown neighborhood.

\*\*\* Considered all Syracuse neighborhoods excluding Downtown.

Table 15. Initial Calculations to Reach Canopy Goals

|  | Today | Change in Tree Canopy |         |
|--|-------|-----------------------|---------|
| Tree Canopy %  | 27%   | 30%                   | 40%     |
| Tree Canopy Acres  | 4,400 | 4,880                 | 6,507   |
| Acres of Tree Canopy Needed to Reach Change of Tree Canopy % | 0     | 480                   | 2,107   |
| Total Trees Needed   | 0     | 47,520                | 208,593 |

Table 16. City Comparisons of Tree Canopy and Tree Canopy Goals

| Location            | UTC        | Year        | UTC Goal      | Goal Target Date    |
|---------------------|------------|-------------|---------------|---------------------|
| Atlanta, GA         | 48%        | 2008        | Increase      | Ongoing             |
| Annapolis, MD       | 42%        | 2006        | 50%           | 30-year plan (2036) |
| Pittsburgh, PA      | 40%        | 2011        | 60%           | 20-year plan (2031) |
| Cincinnati, OH      | 38%        | 2011        | Increase      | Ongoing             |
| New Haven, CT       | 38%        | 2009        | Add 10K trees | 5-year plan (2014)  |
| Louisville, KY      | 37%        | 2013        | 40%           | Ongoing             |
| Washington, DC      | 35%        | 2009        | 40%           | 20-year plan (2029) |
| Boston, MA          | 29%        | 2006        | 49%           | 10-year plan (2016) |
| <b>Syracuse, NY</b> | <b>27%</b> | <b>2009</b> | <b>-</b>      | <b>-</b>            |
| Lexington, KY       | 25%        | 2013        | 30%           | ongoing             |
| New York, NY        | 24%        | 2006        | 30%           | 2036                |
| New Orleans, LA     | 23%        | 2009        | Increase      | Ongoing             |
| Providence, RI      | 23%        | 2007        | 30%           | 10-year plan (2020) |
| Cleveland, OH       | 19%        | 2013        | -             | -                   |
| Chicago, IL         | 17%        | 2007        | 25%           | Ongoing             |
| Indianapolis, IN    | 14%        | 2008        | 19%           | 10-year plan (2018) |

Table 17. Initial Calculations to Reach Change in Benefit Goal Related to Change in Canopy

|  |                      | Today | Change in Tree Canopy |              |
|--|----------------------|-------|-----------------------|--------------|
| Tree Canopy %  |                      | 27%   | 30%                   | 40%          |
| Tree Canopy Acres  |                      | 4,400 | 4,880                 | 6,507        |
| Acres of Tree Canopy Needed to Reach Change of Tree Canopy % |                      | 0     | 480                   | 2,107        |
| Change in Annual Air Quality                                 | Function (tons)      | 0     | 19                    | 85           |
|  | Value                | 0     | \$712,105             | \$3,124,476  |
| Change in Annual Sequestered/Avoided                         | Function (tons)      | 0     | 830                   | 3,643        |
|  | Value                | 0     | \$104,984             | \$460,634    |
| Change in Carbon Storage                                     | Function (tons)      | 0     | 26,934                | 118,175      |
|  | Value                | 0     | \$3,405,312           | \$14,941,361 |
| Change in Annual Stormwater Management                       | Function (cu. feet ) | 0     | 1,448,749             | 6,356,625    |
|  | Value                | 0     | \$96,453              | \$423,203    |
| Change in Annual Energy Conservation                         | Value                | 0     | \$100,153             | \$439,440    |

## Master Plan Development

The analyses in this report substantiate the need for additional attention, support, and funding with respect to urban forestry planning, design, management, and maintenance in Syracuse. The information gained from analysis results can be used to inform the city's municipal tree management strategy and to promote an invaluable asset through the development of an urban forest master plan. The information can also help Syracuse develop the relationships and resources it needs to achieve its urban forestry goals. To ensure sustainability and maximize the benefits of Syracuse's urban forest resource, the following management practices should be explored and prioritized during the development of a comprehensive urban forest master plan:

### Tree Care

**Reduce invasive species.** Syracuse's urban forest has a large concentration of invasive species (36% of the population). In the municipal forest, *Acer platanoides* (Norway maple) and *Robinia pseudoacacia* (black locust) are the most common invasive species. The following measures are encouraged:

- Develop a strategy to reduce invasive species from public streets, parks, and other public properties and reduce reliance of invasive trees for benefits.
- Educate private landowners about invasive species and the importance of their removal from the landscape.

**Monitor for pest and diseases that threaten forest resource values.** Winter moth, Asian longhorned beetle, gypsy moth, southern pine beetle, and pine shoot beetle present the greatest threat to the value of the urban forest. Winter moth, Asian longhorned beetle, gypsy moth, oak wilt, and emerald ash borer present the greatest threat to the street tree population. The following measures are encouraged:

- Develop municipal action plans for high-concern pest/disease issues in order to proactively manage potential outbreaks.
- Develop educational material that informs residents about specific pests and diseases (how to identify the problem and what to do about it).
- Form a neighborhood watch program that involves working groups who are vigilant of neighborhood trees during peak times of the year in which pests and diseases are present.

**Improve size class distribution.** The urban forest and municipal forest populations have a high volume of trees in the 0 to 9 inches DBH size class, and smaller amounts of trees in the 9 to 18 inches DBH, 18 to 24 inches DBH, and greater than 24 inches DBH size classes. In the municipal forest, Lincoln Hill, Washington Square, and South Valley are the only neighborhoods where trees in the 0 to 9 size class have a smaller presence than trees in the larger size classes (9 to 18 inches DBH, 18 to 24 inches DBH, and greater than 24 inches DBH). The following measures are encouraged:

- Develop and implement tree care strategies to meet a 90% or better success rate of newly planted trees.
- Perform all public tree care activities to ANSI Standards.
- Produce a basic tree care brochure for public education that includes how to prune, mulch, water, and contact a certified arborist.

**Increase tree benefits.** Syracuse's urban forest provides approximately \$9.2 million in annual benefits, which equates to about \$6 per tree, or \$2,000 per acre. The municipal forest provides an annual benefit of \$1.9 million, or about \$46 per tree. *Rhamnus cathartica* (European buckthorn) is the most beneficial species in the urban forest, followed by *Acer saccharum* (sugar maple), *A. platanoides* (Norway maple), and *A. negundo* (boxelder). Of the street tree species in the municipal forest, *A. platanoides* (Norway maple) is the most beneficial species, followed by *Gleditsia triacantios* (honeylocust), *A. saccharinum* (silver maple), and *Platanus × acerifolia* (London planetree). Of the park tree population in the municipal forest, *A. saccharum* (sugar maple), *Robinia pseudoacacia* (black locust), and *Quercus rubra* (red oak) are the most beneficial species. The following measures are encouraged:

- Strengthen and enforce tree protection policies, particularly for the more desired tree species since Syracuse currently relies heavily on invasive trees for benefits.
- Strengthen and implement tree maintenance policies to increase tree health and decrease tree risk to ensure a stronger presence of mature, large trees.
- Acquire funds, grants, and donations to help implement tree maintenance policy.
- Encourage tree preservation on private property.

## Tree Planting

**Increase extent of the population.** The urban forest is comprised of an estimated 1.6 million trees at a density of 99 trees per acre. The municipal forest is comprised of 42,622 publicly-managed trees. Since 2001, the municipal forest size has decreased by 675 publicly-managed trees. The street tree stocking level exceeds the reported state average; however, 11 neighborhoods fall behind the state average of 80 trees per mile. The neighborhoods with the five lowest level of trees per mile include: Brighton + North Valley (52); Salt Springs (55); South Valley (67); Near Eastside (68); and Court-Woodlawn (72). The following measures are encouraged:

- Initiate tree stewardship efforts that emphasize privately-owned land should focus on improving the density of trees within the land uses with the lowest reported densities, including Multi-Family Residential and Residential.
- Foster neighborhood group partnerships to educate residents about the importance of trees in the neighborhood and encourage tree plantings on private and public lands.
- Replant municipal trees when they are removed in order to maintain steady replacement of the tree population; approximately 600 trees would need to be planted every year to keep pace with typical removal rates.
- Street tree planting efforts should be prioritized by the neighborhoods with the lowest densities. Either simply filling existing planting spaces or creating more planting spaces may be needed.

**Increase tree canopy.** Relative tree canopy is 48%. The citywide tree canopy represents 27% of all land area, and possible tree canopy represents 29% of all land area. Tree canopy has stayed the same for the last 18 years. Downtown, Lakefront, University Hill, Franklin Square, and Park Avenue have the least amount of canopy. South Valley, South Campus, Meadowbrook, Elmwood, and Outer Comstock have the greatest potential for tree canopy. The following measures are encouraged:

- Establish a reasonable tree canopy goal.
- Acquire funds, grants, and donations to help increase the municipal tree maintenance and planting ability.
- Educate the public about the importance of planting and caring for trees.
- Develop and implement a tree planting plan for street and park trees that includes prioritized areas (i.e., neighborhoods, streets, or parks) and focuses on quantifiable benefits (i.e., stormwater management, air quality improvement, or equity).
- Identify the success rate of tree plantings three years after installation and develop strategies for minimizing loss.



**Cool neighborhoods with more canopy cover.** The average surface temperature citywide is 79° F. Elevated surface temperatures lead to greater heat island effect, which negatively influences air quality. The warmest neighborhoods are Downtown, Franklin Square, Hayley-Green + Prospect Hill, Park Avenue, and Northside. The following measures are encouraged:

- Implement requirements for new developments and re-developments to meet a specific amount of trees per impervious surface square foot.
- Employ planting strategies that promote the healthy growth of trees within an urban setting, such as floating sidewalks, alternative soil mixtures, expanded tree wells, and systems to direct and manage root growth.

**Improve species diversity.** There is a good mix of species in the urban forest landscape; however, the distribution among the urban forest and municipal forest is limited, as there is a large percentage of single species. Of the urban forest, *Rhamnus cathartica* (European buckthorn) represents 21% of the population. Of the municipal forest, *Acer platanoides* (Norway maple) represents 17% of the street tree population and 11% of the park tree population. Both species are relied heavily upon for benefits, but are also invasive. On the street tree neighborhood level, 23 of the 24 neighborhoods have species distributions that exceed the 10% rule. The following measures are encouraged:

- Maintain a species recommendation list for public use that represents a variety of proven high-performing species.
- Maintain a species recommendation list for municipal use that represents a variety of proven high-performing yet uncommon species (species representing less than 5% of the population).
- Continue to increase species diversity in Syracuse's street and park tree resources so that no single species is greater than 10% of the population at most, maybe even 5%.
- Design street and park tree plantings that complement diversity needs on a neighborhood basis.
- Experiment with species that are not present in the municipal forest and are suitable for the plant hardiness zones 5 and 6.

**Maximize tree benefits.** In the urban forest and municipal forest, the distribution of large-growing versus small- and medium-growing trees is good. Less than 50% of each population is a small distribution (urban forest 35% and municipal forest 19%) or medium-growing distribution (urban forest 10% and municipal forest 10%). Of the municipal forest, the Franklin Square, Lakefront, Near Westside + Skunk City, Northside, and Southwest + Southside neighborhoods have the greatest distribution of small- and medium-growing trees. These five neighborhoods also have below average tree canopy cover. The following measures are encouraged:

- Plant large-growing species wherever growing-space allows within street ROW, parks, and other public properties.
- Develop and implement public outreach and educational programs that encourage the planting of large-growing trees on private property.
- Improve the equitable distribution of benefits by utilizing tree canopy data combined with environmental and/or socioeconomic data to determine the areas in highest need of additional canopy cover.

## *Plan and Inventory Updates*

The best approach to maintaining an urban forest is to establish a proactive tree management program that incorporates a public tree inventory, urban forest sample inventory, urban tree canopy assessment, municipal tree management plan, state of the urban forest report, and an urban forest master plan.

**Update public tree inventory.** A street tree inventory has been kept current since 1978. The following measures are encouraged:

- Update the tree inventory database via tree management software as maintenance work is performed, track work history, and evaluate productivity to plan work and project budgets.
- Every year, re-inventory 20% of the street and park tree population by conducting a Level 2 assessment, along with a Level 1 assessment on the remaining 80% of the street and park tree populations.
- Re-inventory all street and park trees in five years.

**Update urban forest tree sample inventory.** There have been two completed assessments (2000 and 2014) of the urban forest's tree population. The following step is encouraged:

- Update the urban forest tree sampling estimate in 20 years.

**Update the tree canopy assessment.** There have been two completed urban tree canopy assessments (1999 and 2009).

- Update the urban tree canopy assessment in 10 years.

**Update the municipal tree management plan.** The management plan has been kept current since 1978.

- Maintain and implement a Public Tree Management Plan to systematically provide appropriate care to public trees.

**Update the state of the urban forest report.** There are two state of the urban forest reports (2001 and 2016). The 2001 Master Plan has components of a state of the urban forest report and a master plan. The following measures are encouraged:

- Update this report every 10 years after a re-inventory of streets and parks and urban tree canopy assessment.
- Include information from a re-inventory of urban forest trees every 20 years.

**Update the master plan.** There is one master plan that was completed in 2001. The following measures are encouraged:

- Develop a master plan that incorporates a vision for the urban forest and includes collaboration and cooperation of many stakeholders from the federal, state, city, nonprofit, and public levels.
- Update the master plan every 20 years.

## Summary and Conclusions

Periodically assessing the composition, extent, and vitality of Syracuse's urban forest will be integral to measuring the success of the city's urban forestry programs. Investing in green infrastructure has proven to be a worthwhile venture. To deliver on the recommendations in this report, the City of Syracuse must attain a shared vision for its urban forest by collaborating with various partners and stakeholders. The urban forest benchmark values can be used to set goals, inform partners and key stakeholders of the state of the urban forest, and measure future progress during the development of an urban forest master plan.

### Syracuse, New York Benchmark Values

#### Urban Tree Canopy Cover (2009)

- UTC, all areas 27% (of land area)
- UTC, street ROW 15% (of tree canopy)
- UTC, parks 8% (of tree canopy)

#### Tree Count

- Complete Urban Forest (2014) - 1,583,000
- Street Trees (2014) - 33,689
- Park Trees (2014) - 8,933
- Street Trees Per Mile (2014) - 85
- Total Street Trees Per Capita (2014) – 0.23

#### Species Diversity: Number of Species Exceeding 10% of Population

- Street Trees (2014) - 2
- Park Trees (2014) - 1
- Complete Urban Forest (2014) - 2

#### Invasive Species Composition

- Complete Urban Forest (2014) – 36%
- Street Trees (2014) – 18%
- Park Trees (2014) – 14%

#### Urban Forest Pest Susceptibility (2014)

- Winter Moth - 526,000 Trees (39%)
- Asian Longhorned Beetle - 396,000 Trees (30%)
- Gypsy Moth - 218,000 Trees (16%)
- Southern Pine Beetle - 113,000 Trees (8%)
- Pine Shoot Beetle - 66,000 Trees (5%)

#### Urban Forest Benefit Values (2014)

- Total Annual Benefit, \$9.2 million
- Annual Per Tree Benefit, \$6
- Annual Per Acre Benefit, \$2,000

#### Municipal Tree Benefit Values (2014)

- Total Annual Benefit, \$1.9 million
- Annual Return Benefit, \$2.16
- Annual Per Tree Benefit, \$46
- Annual Per Capita Benefit, \$14

#### Structural Values (2014)

- Urban Forest, \$735.3 million
- Municipal Forest \$62.2 million

## Appendix A

### *i-Tree Eco Model and Field Measurements*

i-Tree Eco is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area).
- Amount of pollution removed hourly by the urban forest and its associated percent air quality improvements throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and particulate matter (less than 2.5 microns and less than 10 microns).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

In the field, 0.10-acre plots were randomly distributed. All field data are typically collected during the leaf-on season to properly assess tree canopies. Within each plot, typical data collection (actual data collection may vary depending upon the user) includes: land use; ground and tree cover; individual tree attributes of species; stem diameter; height; crown width; crown canopy missing and dieback; and distance and direction to residential buildings (Nowak et al. 2005, 2008).

Invasive species are identified using an invasive species list [NYDEC 2011) for the state in which the urban forest is located. These lists are not exhaustive and cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list but are native to the study area.

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross annual carbon sequestered, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1. Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. Estimates of value are based on the carbon value for the United States Interagency Working Group (2015) updated to current dollar values. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988, Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972, Lovett 1994) and were adjusted depending on leaf phenology and leaf area. Removal estimates of particulate matter less than 10 microns incorporated a 50% resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al., 2011, 2015; Hirabayashi 2011).

Air pollution removal value was calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP). The model uses a damage-function approach that is based on the local change in pollution concentration and population (Davidson et al. 2007).

National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al. 1996) and particulate matter less than 10 microns and greater than 2.5 microns (Van Essen et al. 2011).  $PM_{10}$  denotes particulate matter less than 10 microns and greater than 2.5 microns throughout the report. As  $PM_{2.5}$  is also estimated, the sum of  $PM_{10}$  and  $PM_{2.5}$  provides the total pollution removal and value for particulate matter less than 10 microns.

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al. 2007).

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height, and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al. 2002a). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.



Potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps from the Forest Health Technology Enterprise Team (FHTET) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, the following options were established: whether the insect/disease occurs within the county; is within 250 miles of the county edge; is between 250 and 750 miles away; or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and host range, respectively.

## *Estimating Land Surface Temperature using Landsat 8*

The estimation of land surface temperature was conducted using the Landsat 8 Thermal Band (bands 10 and/or 11) and NDVI (USGS 2015, Weng et al. 2004). For Syracuse, this process was conducted using band 11, as there was less noise in the image; however, using both bands and assembling an average is possible.

All calculations were conducted using the ArcGIS10.1 Raster Calculator based on the following calculations:

Conversion from digital numbers to radians.

$$L_{\lambda} = M_L Q_{cal} + A_L$$

where:

$L_{\lambda}$  = TOA spectral radiance (Watts/( m<sup>2</sup> \* srad \* μm))

$M_L$  = Band-specific multiplicative rescaling factor from the metadata

(RADIANCE\_MULT\_BAND\_x, where x is the band number)

$A_L$  = Band-specific additive rescaling factor from the metadata

(RADIANCE\_ADD\_BAND\_x, where x is the band number)

$Q_{cal}$  = Quantized and calibrated standard product pixel values (DN)

Conversion from spectral radiance to satellite brightness temperature.

where:

$$T_t = \frac{K_2}{\ln\left(\frac{K_1}{L_{\lambda}} + 1\right)}$$

$T$  = At-satellite brightness temperature (K)

$L_{\lambda}$  = TOA spectral radiance (Watts/( m<sup>2</sup> \* srad \* μm))

$K_1$  = Band-specific thermal conversion constant from the metadata

(K1\_CONSTANT\_BAND\_x, where x is the thermal band number)

$K_2$  = Band-specific thermal conversion constant from the metadata

(K2\_CONSTANT\_BAND\_x, where x is the thermal band number)

Conversion from at satellite brightness temperature to land surface temperature

Calculate emissivity

Generate NDVI dataset.

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

where:

*NIR* = The near infrared band (Landsat 8 – Band 5)

*Red* = The red band (Landsat 8 – Band 4)

NDVI is an index describing vegetation by showing the difference between near-infrared (which is strongly reflected by vegetation) and red light (which is absorbed by vegetation).

Generate the proportion of vegetation layer from the NDVI data

$$P_v = (NDVI - NDVI_{min} / NDVI_{max} - NDVI_{min})^2$$

where:

$P_v$  = The proportion of vegetation

*NDVI* = The NDVI dataset generated above

*NDVI<sub>min</sub>* = The minimum value in the NDVI dataset

*NDVI<sub>max</sub>* = The maximum value in the NDVI dataset

Generate land surface emissivity layer

$$e = 0.004P_v + 0.986$$

where:

$P_v$  = The proportion of vegetation

*e* = Land surface emissivity

Calculate the Land Surface Temperature

$$LST_k = T / 1 + w * (T / p) * \ln(e)$$

where:

*LST<sub>k</sub>* = Land surface temperature in degrees kelvin

*T* = At satellite brightness temperature

*w* = wavelength of emitted radiance (11.5 μm)

*p* =  $h * c / s$  ( $1.438 * 10^{-2}$  m K)

where:

*h* = Planck's constant ( $6.626 * 10^{-34}$  Js)

*s* = Boltzmann constant ( $1.38 * 10^{-23}$  J/K)

*c* = velocity of light ( $2.998 * 10^8$  m/s)

Convert temperature from degrees kelvin to degrees celsius.

$$LST_c = LST_k - 273.15$$

## Appendix B

### Species Distribution by Neighborhood

| Neighborhood                       | Number of Trees | Species 1                            | Percent of Population | Species 2                            | Percent of Population | Species 3                            | Percent of Population |
|------------------------------------|-----------------|--------------------------------------|-----------------------|--------------------------------------|-----------------------|--------------------------------------|-----------------------|
| Brighton + North Valley            | 1,601           | <i>Acer platanoides</i>              | 20%                   | <i>Gleditsia triacanthos inermis</i> | 7%                    | <i>Malus</i> spp.                    | 7%                    |
| Court-Woodlawn                     | 1,508           | <i>Acer platanoides</i>              | 24%                   | <i>Malus</i> spp.                    | 7%                    | <i>Acer saccharinum</i>              | 7%                    |
| Downtown                           | 1,115           | <i>Gleditsia triacanthos inermis</i> | 54%                   | <i>Pyrus calleryana</i>              | 9%                    | <i>Tilia cordata</i>                 | 7%                    |
| Eastwood                           | 3,299           | <i>Acer platanoides</i>              | 20%                   | <i>Acer saccharinum</i>              | 9%                    | <i>Malus</i> spp.                    | 6%                    |
| Elmwood                            | 811             | <i>Acer platanoides</i>              | 28%                   | <i>Acer negundo</i>                  | 7%                    | <i>Acer saccharum</i>                | 5%                    |
| Far Westside + Tipp Hill           | 2,855           | <i>Acer platanoides</i>              | 19%                   | <i>Acer negundo</i>                  | 5%                    | <i>Acer saccharum</i>                | 5%                    |
| Franklin Square                    | 372             | <i>Pyrus calleryana</i>              | 23%                   | <i>Tilia cordata</i>                 | 19%                   | <i>Gleditsia triacanthos inermis</i> | 11%                   |
| Hawley-Green + Prospect Hill       | 813             | <i>Gleditsia triacanthos inermis</i> | 19%                   | <i>Malus</i> spp.                    | 9%                    | <i>Pyrus calleryana</i>              | 9%                    |
| Lakefront                          | 374             | <i>Gleditsia triacanthos inermis</i> | 42%                   | <i>Pyrus calleryana</i>              | 22%                   | <i>Acer platanoides</i>              | 5%                    |
| Lincoln Hill                       | 830             | <i>Acer platanoides</i>              | 15%                   | <i>Gleditsia triacanthos inermis</i> | 11%                   | <i>Tilia cordata</i>                 | 7%                    |
| Meadowbrook                        | 2,640           | <i>Acer platanoides</i>              | 19%                   | <i>Malus</i> spp.                    | 10%                   | <i>Gleditsia triacanthos inermis</i> | 8%                    |
| Near Eastside                      | 608             | <i>Gleditsia triacanthos inermis</i> | 12%                   | <i>Acer platanoides</i>              | 11%                   | <i>Fraxinus pennsylvanica</i>        | 5%                    |
| Near Westside + Skunk City         | 1,765           | <i>Acer platanoides</i>              | 10%                   | <i>Gleditsia triacanthos inermis</i> | 9%                    | <i>Syringa reticulata</i>            | 5%                    |
| Northside                          | 1,605           | <i>Acer platanoides</i>              | 16%                   | <i>Malus</i> spp.                    | 11%                   | <i>Acer saccharinum</i>              | 7%                    |
| Outer Comstock                     | 778             | <i>Acer platanoides</i>              | 13%                   | <i>Gleditsia triacanthos inermis</i> | 9%                    | <i>Acer saccharinum</i>              | 5%                    |
| Park Ave.                          | 827             | <i>Gleditsia triacanthos inermis</i> | 11%                   | <i>Malus</i> spp.                    | 8%                    | <i>Acer platanoides</i>              | 8%                    |
| Salt Springs                       | 831             | <i>Acer platanoides</i>              | 17%                   | <i>Gleditsia triacanthos inermis</i> | 9%                    | <i>Malus</i> spp.                    | 9%                    |
| Sedgwick                           | 1,472           | <i>Acer platanoides</i>              | 21%                   | <i>Gleditsia triacanthos inermis</i> | 7%                    | <i>Tilia cordata</i>                 | 7%                    |
| South Valley                       | 1,136           | <i>Acer platanoides</i>              | 20%                   | <i>Gleditsia triacanthos inermis</i> | 13%                   | <i>Malus</i> spp.                    | 7%                    |
| Southwest + Southside              | 1,521           | <i>Gleditsia triacanthos inermis</i> | 13%                   | <i>Malus</i> spp.                    | 11%                   | <i>Acer platanoides</i>              | 9%                    |
| Strathmore + Winkworth             | 2,029           | <i>Acer platanoides</i>              | 23%                   | <i>Gleditsia triacanthos inermis</i> | 7%                    | <i>Malus</i> spp.                    | 6%                    |
| University Hill                    | 957             | <i>Gleditsia triacanthos inermis</i> | 24%                   | <i>Tilia cordata</i>                 | 8%                    | <i>Platanus × acerifolia</i>         | 8%                    |
| Washington Square                  | 887             | <i>Acer platanoides</i>              | 18%                   | <i>Acer saccharinum</i>              | 12%                   | <i>Acer saccharum</i>                | 8%                    |
| Westcott + University Neighborhood | 3,055           | <i>Acer platanoides</i>              | 20%                   | <i>Gleditsia triacanthos inermis</i> | 5%                    | <i>Tilia cordata</i>                 | 5%                    |

### Percent Canopy Cover in Rights-of-Way by Neighborhood



## Appendices D

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