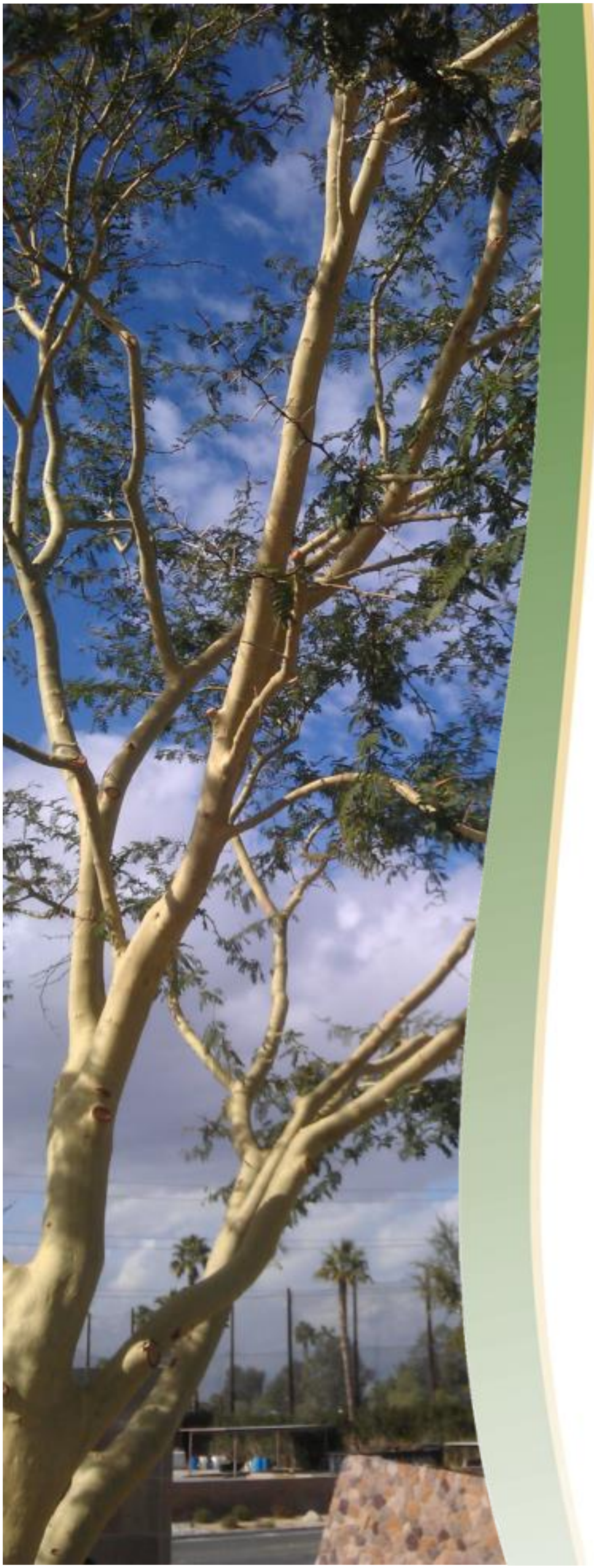

Phoenix, Arizona Project Area

Community Forest Assessment

October 2014

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This report is adapted from the standard i-tree Ecosystem Analysis report that is generated upon submission of i-Tree Eco data. Tree Eco (formerly Urban Forest Effects model) was cooperatively developed by USDA Forest Service Northern Research Station (NRS), the USDA State and Private Forestry's Urban and Community Forestry Program and Northeastern Area, the Davey Tree Expert Company, and SUNY College of Environmental Science and Forestry.

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Tables and Figures

Definitions for **bold** words are available in the Glossary.

Monetary values are reported in US dollars throughout the report.

Executive Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. Different tree species contribute different benefits at varying levels, so a community that wants to manage the urban forest with specific benefits in mind may carefully select species to plant. Tree age and stature also greatly impact benefits, and this report provides an overview of the current relative age distribution and urban forest structure. Finally, managers can use this data to understand pests and diseases present, and not yet found in the area.

In 2013, the New Mexico Energy, Minerals and Natural Resources Department (EMNRD) contracted with Davey Resource Group (DRG) to collect field data and perform an analysis of the ecosystem services and benefits of trees on a landscape level. Data was collected in 204 designated plots which were randomly distributed across the Phoenix Project Area. The data was analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

Based on this sample, it is estimated that 3,166,000 trees exist across the sample area, which covers 384.5 square miles. Tree canopy is estimated to cover 9.0% of the land area. The most common species found were velvet mesquite, California palm, and sweet acacia. The tree population is mostly young or small statured, with 44.8% of the population under 6” in **Diameter at Breast Height** (DBH).

The tree population provides valuable benefits to the communities in the Phoenix Project Area. The trees are important for air **pollution removal**, intercepting 1,770 tons of air pollution annually, valued at $5.76 million dollars. They store 305,000 tons of carbon valued at $21.7 million and sequester 35,400 tons each year, valued at $2.52 million dollars. **Carbon storage** and **carbon sequestration** values are based on a current market value of $71.21 per ton. Avoided carbon emissions are valued at $2.96 million annually. The tree population reduces stormwater runoff by 91.7 million cubic feet per year, valued at $6.1 million. Annually, this resource produces about 89,200 tons of oxygen. The largest monetary value related to the urban forest is the structural values of the trees, which are based on the replacement value of the tree at its present size and condition. These equate to $3.82 billion dollars.

The tree species found in the sample have very low susceptibility to common pests found nationwide. Predicting emergency pest infestations is more accurately done by local experts, but the i-Tree Eco model provides valuable data about what pests may become a concern. The pests most likely to influence the urban forest in the project area are Gypsy Moth and Asian Longhorned Beetle.

Phoenix urban forest managers can use this data to further understand the composition, species and age distribution, benefits and values, and possible risks in the urban forest. Air Quality and Utility managers can use the data to support planting and maintaining appropriate tree species to maximize air quality benefits. This data, unique to the project area can help managers understand the unique attributes of their communities’ urban forests.

Introduction

The 2010 Phoenix Tree and Shade Master Plan recognizes that the urban forest contributes to a healthier, more livable, and prosperous Phoenix. The city has articulated goals to preserve, protect and increase the urban forest. Trees have been assessed in three ways:

The urban forest contributes to a healthier, more livable, and prosperous Phoenix.

- **Public Tree Inventory:** An inventory of publicly-owned trees along streets, in parks, and at city facilities
- **Canopy Analysis:** Quantification of ground cover based on point-interpretation of ariel photos
- **Community Forest Assessment:** A plot-based, ground-truthed sample of all public and private trees in the city

This Community Forest Assessment can provide benchmarks for the current amount of canopy, leaf surface area, and structure of the urban forest including both public and private trees. It also provides an overview of the ecosystem services of those trees, providing an important perspective for the city's understanding of their urban forest.

The City of Phoenix, Arizona's state capitol, is located in the Salt River Valley, or "Valley of the Sun" in Central Arizona. It is the most populous city in the state, and sixth most populous city in the nation, with an estimated 1,464,405 residents. Phoenix has a subtropical desert climate with extremely hot summers and warm winters. The average annual rainfall is 8 inches (measured at Phoenix Sky Harbor International Airport). In this kind of environment, urban trees must be adapted to the weather conditions, or receive regular irrigation. The climate significantly limits the range of potential species and plant establishment. Without irrigation, plant growth rates are typically slow, and small-stature trees are common.

The project area included communities within the city limits of Phoenix, Arizona. In order to provide a more accurate representation of the trees in the urban forest, the project area did not include some of the large natural areas that were not specifically managed for vegetation. As a result, the total included acreage was 246,064 acres, or 384.5 square miles out of the city's 516.7 square miles of land.

Methods

Project Area

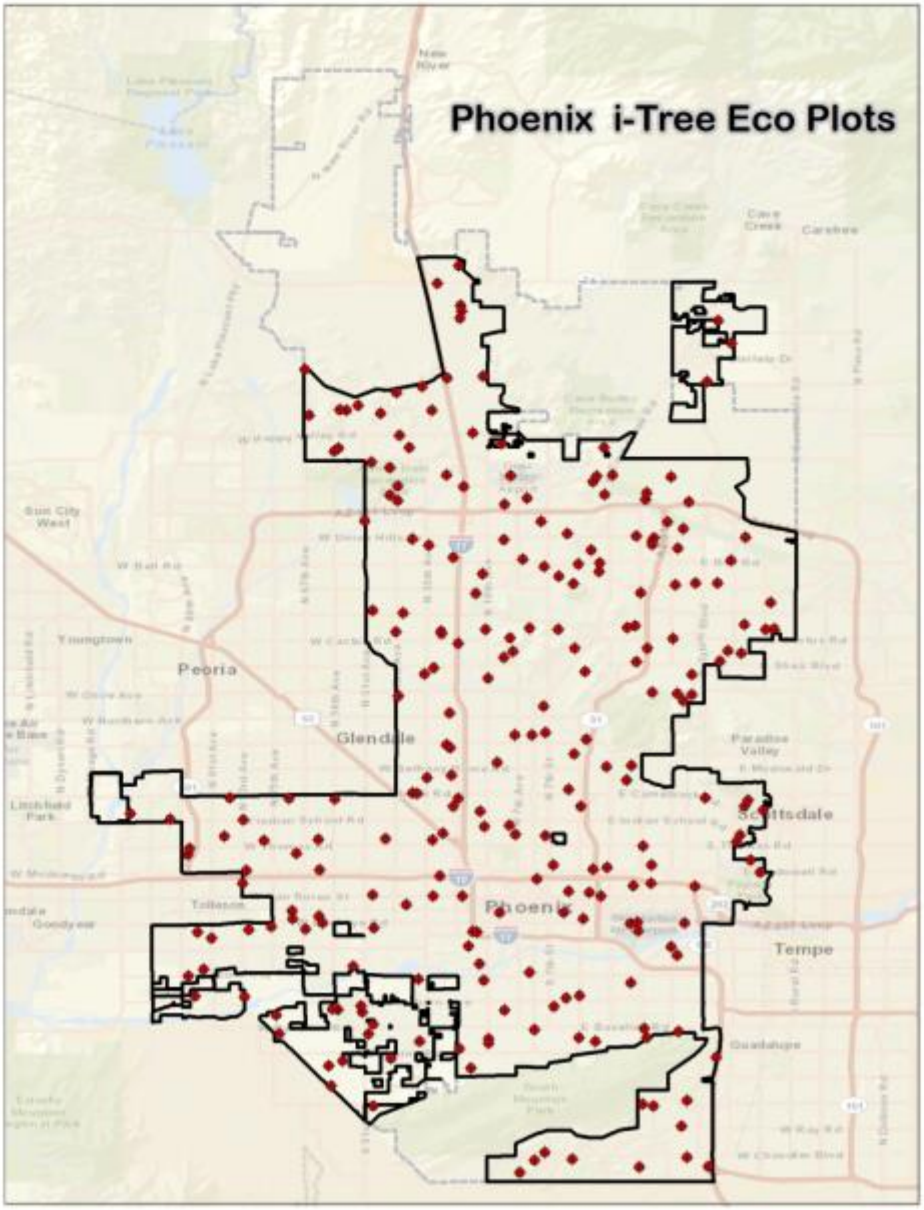


Figure 1. Project Area Boundaries, Plot Locations and City Limits

The study area includes the 384.5 square miles within the black boundary in Figure 1. The red dots show the distribution of the 204 measured plots. This area was selected because these are primarily urban areas in the city, and likely most consistent with the i-tree Eco model. It is expected that the vegetation in the included areas most profoundly influences the urban ecosystem, providing the benefits calculated by the i-Tree Eco model. That is not to say that the trees and shrubs in the excluded areas are not important in providing air quality, stormwater, carbon, and energy benefits, but their influence in the i-Tree Eco model is not likely consistent with the more urban land areas.

The excluded areas provide benefits to the community and if they become more developed should be included in future studies of Phoenix's urban forest resources. One factor that is not calculated in the study is the urban heat island effect. Vegetation on land outside the study area may mitigate heat associated with buildings and paved surfaces within the study area, and those benefits are not reflected in this model, which is geared toward understanding tree benefits in urbanized areas (Weng et al., 2003).

For example, a tree in an undeveloped area may provide the same carbon storage benefits as its urban counterpart, but because it is not in close proximity to infrastructure, the stormwater benefits are negligible. The pollutant absorption capacity depends on many factors including levels of pollutants, wind and dispersal, and proximity to the source of pollution; thus, the capacity of a tree in an undeveloped area to absorb pollution is difficult to calculate with this model which presumes urban infrastructure and activities are nearby. A tree in an undeveloped area is also unlikely to provide substantial property value benefits or have a replacement value, since wildland trees that fail are not typically replaced. Finally, since a tree in an undeveloped area is not near buildings, it cannot mitigate the energy use of air-conditioned space. So, while it is fair to say these trees still have value and provide benefits, those benefits do not fit with the attributes in the i-Tree Eco model, and it is reasonable to exclude them from the study.

i-Tree Eco Model and Field Measurements

Model Components

The model selected to calculate urban forest benefits is the i-Tree Eco model. The i-Tree Eco model is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify the urban forest structure and its numerous effects [Nowak &Crane, 2000], including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns and <10 microns).
- Total annual carbon stored and annual net carbon 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 in terms of replacement cost
- Potential impact of infestations by pests or pathogens, such as Asian longhorned beetle, gypsy moth, and others.

Field Components

In the project area, 0.10-acre plots were distributed randomly across the study site. The 204 plots were generated in Arc Map with a tolerance of 100' so they would not overlap. All field data were collected during the leaf-on season to properly assess tree canopies. Within each plot, data collection included 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 and Nowak et al., 2008].

The land uses were determined based on the primary use of the land at the sample site. Residential was assigned to sites where the primary use was housing for 1-4 families per building, and Multi-Family Residential was assigned to areas with over four families per building, such as apartments and condominiums. Commercial was assigned to buildings and associated landscaped areas and parking lots where the primary use was the sale of goods or services. Industrial was assigned to sites where the primary use was manufacturing, including parking, landscaping, and storage associated with manufacturing products. Parks and Open space included publically-owned land where the primary activities were recreational or the land was protected for conservation purposes. Vacant was assigned to land with no apparent use. Transportation was assigned to roads, sidewalks, and rail corridors.

Invasive tree species are identified using an invasive species list [AWIPWG, 2005] for Arizona. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data to determine which species are on the state invasive species list, but are native to the study area.

Urban Tree Benefit and Pathogen and pest Risk Calculations

To calculate current carbon storage, biomass for each tree was calculated by incorporating measured tree data into equations from referenced literature. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations [Nowak, 1994]. To adjust for this difference, i-tree Eco multiplies biomass results for open-grown urban trees 0.8. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera, diameter class and tree condition were 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 local carbon values.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. 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. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition [Nowak, Hoehn, & Crane, 2007].

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 and Baldocchi, Hicks, & Camara, 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 & Fraser, 1972 and Lovett, 1994] that 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, Kroll, & Nowak, 2011, Hirabayashi, Kroll, & Nowak, 2012, and 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 <2.5 (PM2.5) 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 and particulate matter less than 10 microns and greater than 2.5 microns [Murray, Marsh, &Bradford, 1994]. PM10 denotes particulate matter less than 10 microns and greater than 2.5 microns throughout the report. As PM2.5 is also estimated, the sum of PM10 and PM2.5 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. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series [USFS].

Seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature [McPherson & 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., 2002].

Potential pathogen and pest risk is based on their range maps and the known pathogen and pest and pathogen host species that are likely to experience mortality. Range maps from the Forest Health Technology Enterprise Team (FHTET) [2010] were used to determine the proximity of each pest or pathogen to Maricopa County. For the county, it was established whether the pest occurs within Maricopa County; is within 750 miles of Maricopa County; or is greater than 750 miles away from the Maricopa County border. FHTET did not have disease range maps for Dutch elm disease or chestnut blight. The range of these pathogens was based on known occurrence and the host range, respectively [FHTET, 2009].

Findings

Tree Population Characteristics

This section provides an overview of the species, condition, density, geographic origin, and age (size class) of the tree population. These values help provide context for the following sections on canopy cover and leaf area, as well as the ecological and economic benefits of Phoenix's public and private trees.

Species Distribution

The sample identified 60 unique tree species, but the urban forest likely has far greater diversity. Table 1 and Figure 2 show the ten most prevalent species found in the sample. Based on this sample, it is estimated that the urban forest of Phoenix has 3,166,000 trees with a tree canopy cover of 9.0%. Because of the sampling method used, the species distribution has very high error rates, and species proportions should not be relied on for management decisions. The i-tree Streets model is more appropriate for determining species composition in the community if desired.

Table 1. Common Tree Species Composition

Species	# of Trees	Standard Error (+/-)	Error %
Velvet mesquite	261,048	83,551	32%
California palm	237,968	78,718	33%
Sweet acacia	211,693	140,883	67%
Chinese elm	180,665	74,339	41%
Mexican fan palm	161,349	69,816	43%
Yellow paloverde	130,680	99,117	76%
Honey mesquite	130,631	80,913	62%
Citrus spp	126,990	77,720	61%
Bottle tree	108,750	46,982	43%
Tesota	95,645	59,262	62%

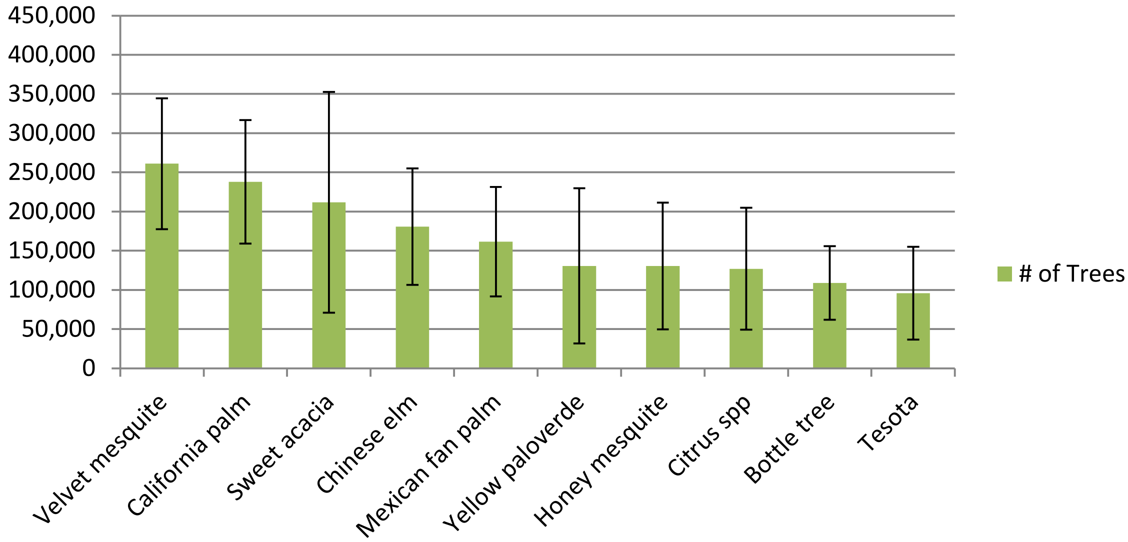


Figure 2. Common Species

Species Richness

Table 2 shows the number of species found in this sample in each Land Use type. This information is provided to show the diversity of trees in the sample, but is not likely a reflection of the full species diversity across the landscape due to the sample size of just 204 plots. The purpose of this plot-based sampling method is to provide a landscape view of the region's public and private trees. A complete tree inventory would provide a better understanding of species diversity in the project area, but would be prohibitively time consuming and difficult to access all private property

The i-tree Eco model uses established calculations to for species diversity indexes, which allow quantitative comparisons of species richness. The Shannon-Wiener Diversity Index assumes that all the species in an area have been sampled, and has a moderate sensitivity to sample size. The Menhinick Index is an indicator of species dominance and has a low sensitivity to sample size and therefore may be more appropriate for comparisons among cities. The Simpson's Diversity Index is an indicator of species dominance and has a low sensitivity to sample size and is appropriate for comparisons between land-use types.

Table 2. Species Richness

Land Use	Species	Species/Acre	Shannon-Wiener Diversity Index	Menhinick Index	Simpson's Index
Commercial	17	4.9	2.6	2.3	14.5
Industrial	3	2.5	1.0	1.2	3.8
Multi-Family Residential	14	9.6	2.4	2.6	12.2
Parks/Open Space	12	3.0	2.2	1.8	8.2
Residential	45	6.2	3.5	4.2	29.1
Transportation	2	2.9	0.6	1.2	3.0
Vacant	2	4.0	0.6	0.8	1.9
CITY TOTAL	60	3.0	3.6	3.7	27.3

Trees by Land Use Distribution

Based on the 204 sampled plots, about 3.1 million trees are present in the study area on public and private property in Phoenix. Trees in residential and multi-family areas make up 66.7% (about 2.1 million) of the trees sampled in this assessment. Ten percent (10%) of the trees were found in commercial areas, followed by 6% along roads (transportation), vacant and parks and 5% in industrial land uses (Figure 3).

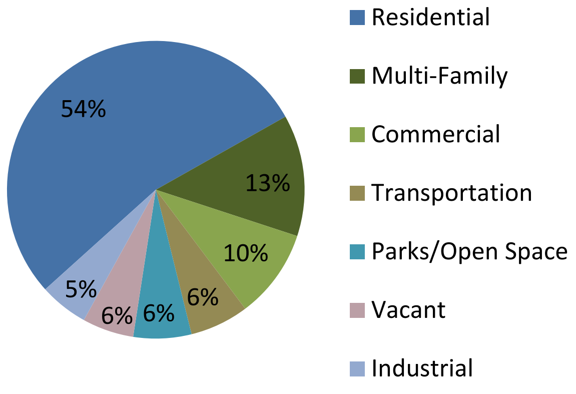


Figure 3. Number of Trees by Land Use

Tree Density

Another way to consider tree distribution is to analyze the number of trees per acre in each land use type (Figure 4). The multi-family residential areas had 19 trees per acre, followed by vacant with 18 trees per acre, and commercial with about 17 trees per acre. Over all, the city tree density in the studied area is 12.9 trees per acre. Appendix II shows comparable values from other cities, including other Southwestern cities, as reported by i-Tree Eco.

Commercial areas have about 17 trees per acre.

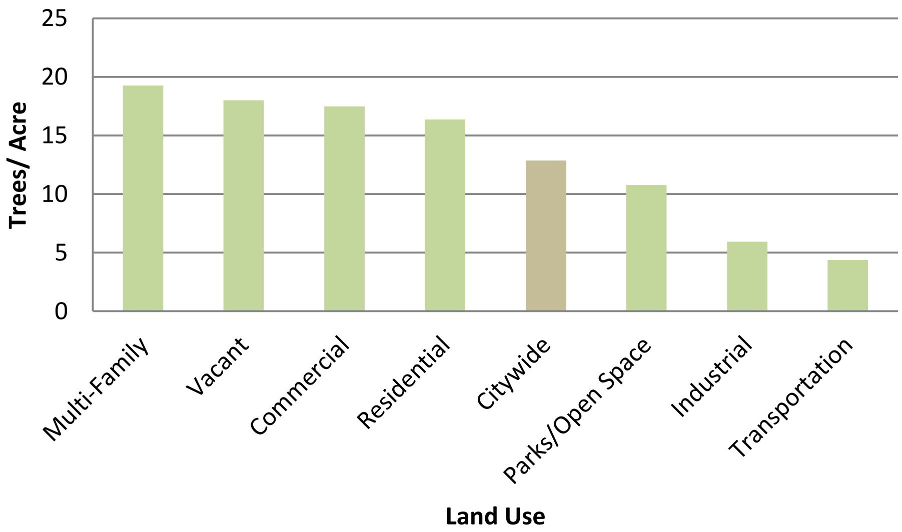


Figure 4. Trees per Acre by Land Use

Relative Age Distribution

For woody plants, the DBH typically increases incrementally annually, so it may be used to estimate the age of the population. Based on the relationship between age and diameter, the distribution of the sampled trees indicates a young or small-statured population with 44.8% of the population under 6" DBH (Figure 5).

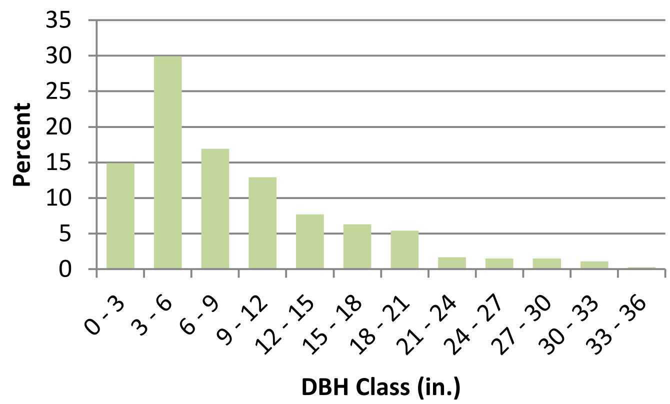


Figure 5. Citywide Relative Age Distribution

Considering the land uses, Figure 6 shows that vacant and transportation land uses have the most young or small-stature trees with 29% of the industrial population under 3" DBH and 33% of the vacant population under 3". In both land uses, all trees found in the sample were under 12" DBH. Multi-family residential areas have the largest portion of established trees over 18" DBH at 17.9%.

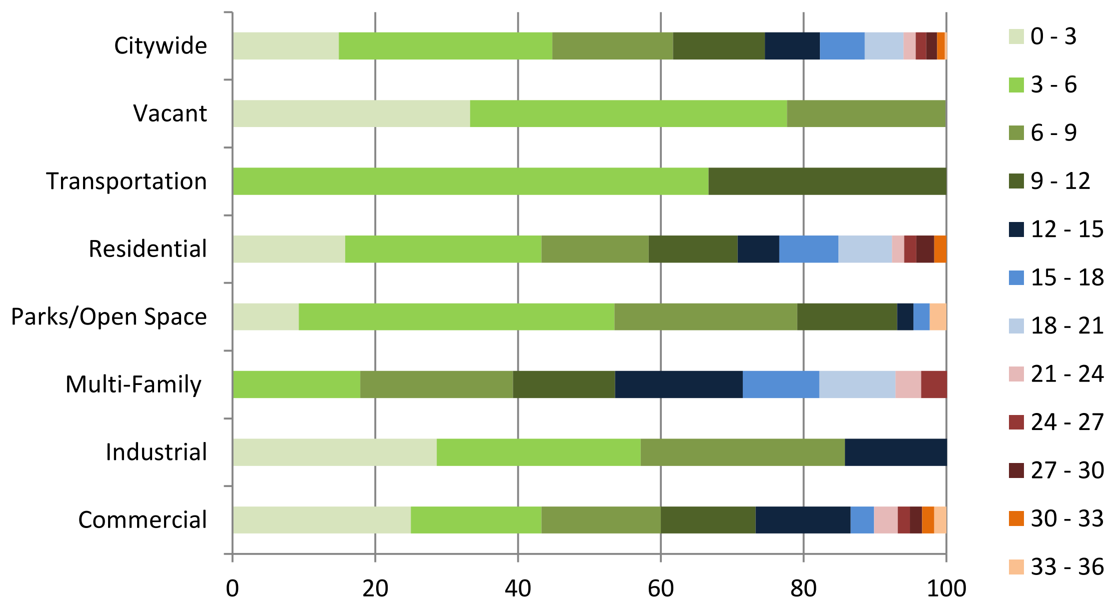
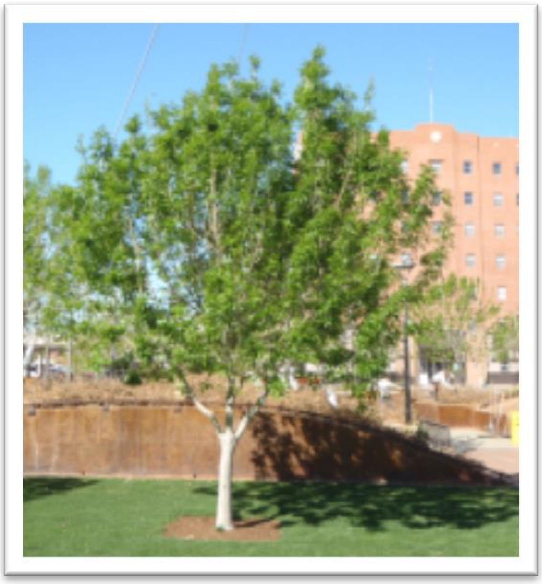


Figure 6. Age Distribution by Land Use



The majority of trees sampled are in good to excellent condition.

Tree Condition

Tree condition can be related to species fitness, tree age, environmental stressors, and maintenance, and these typically vary with land use. Almost 80% of trees in the sample are in good to excellent condition (photo, left). About 2/3 of the trees in both residential land uses and transportation areas are in excellent condition. The commercial land use had the largest percent of poor to dead trees, with 44.4% (Figure 7 and Table 3). Table 3 provides the percent of trees in each condition class by land use. The calculated standard error (SE) is provided in grey text.

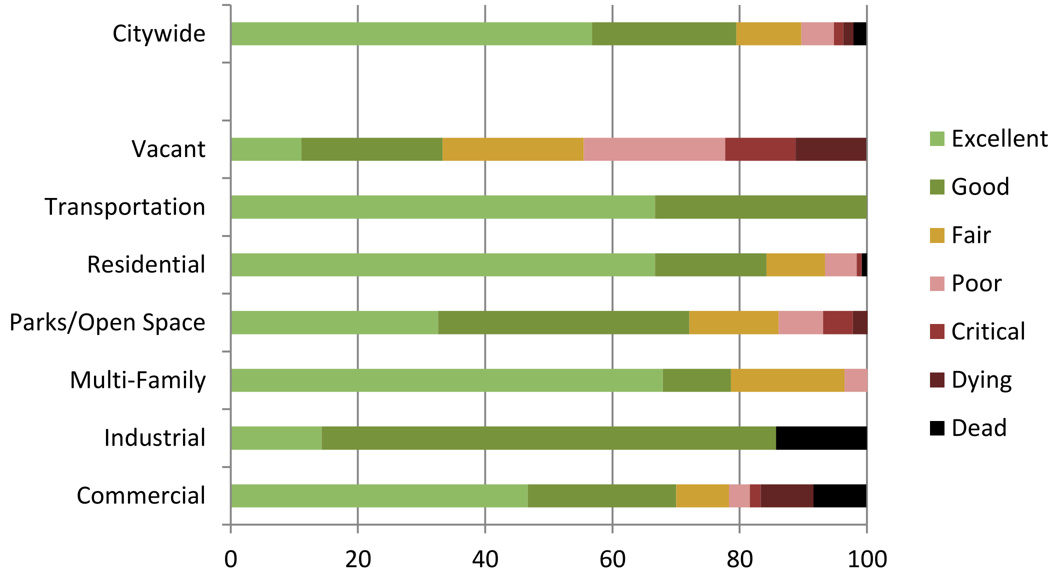


Figure 7. Condition (%) by Land Use

Table 3. Condition (%) by Land Use

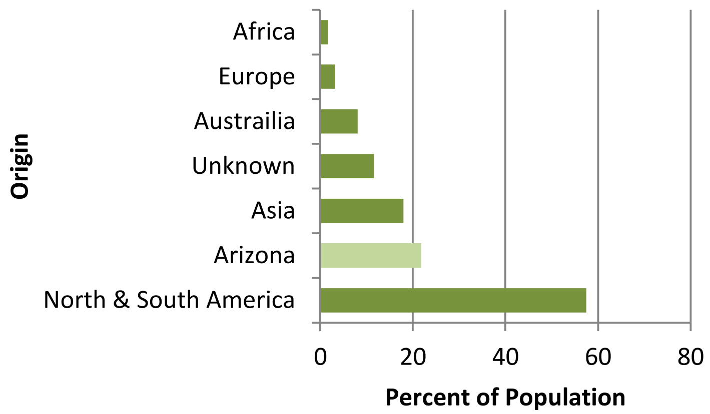
	Excellent		Good		Fair		Poor		Critical		Dying		Dead	
Land Use	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Commercial	46.7	11.3	23.3	7.56	8.3	3.51	3.3	3.2	1.7	1.6	8.3	6.24	8.3	3.83
Industrial	14.3	10.87	71.4	16.8									14	15.7
Multi-Family Residential	67.9	11.17	10.7	6.23	17.9	8.25	3.6	3.66						
Parks/Open Space	32.6	12.54	39.5	7.07	14	4.77	7	5.08	4.7	4.67	2.3	1.69		
Residential	66.7	6	17.5	4.84	9.2	2.86	5	1.74	0.8	0.85			0.8	0.81
Transportation	66.7	16.97	33.3	17										
Vacant	11.1	13.66	22.2	9.76	22.2	7.81	22.2	7.81	11	3.9	11.1	3.9		
CITY TOTAL	56.8	4.05	22.7	3.22	10.2	1.98	5.1	1.22	1.5	0.6	1.6	0.65	2	1.01

Tree Species Origin Distribution

Urban forests are composed of a mixture of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction of the urban forest resource by a species-specific pest or pathogen, but it can also pose a risk to native plants if some of the exotic species spread beyond planting sites and aggressively suppress the establishment of native species in both the urban and wildland areas. Those 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, 2011]. There is only one tree species found in the sample, African sumac, which is considered invasive in Arizona. It comprises 0.6% of the population and may only cause a minimal level of impact. The model does not calculate the level of impact these trees have on local ecosystems, an assessment best left to the determination of local forest managers.

Figure 8 shows the origin distribution of species found in the sample. In Phoenix, about 58% of the trees are species native to North or South America, while 22% are native to the state. Species exotic to North America make up 31% of the population. Eighteen percent (18%) of the sampled trees are native to Asia. Totals do not sum to 100% due to rounding, and because Arizona natives are a subset of North American natives.

Figure 8. Percent of Live Trees by Species Origin



Cover and Leaf Area

Importance Value and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. In the project area, the most impactful species, in terms of leaf area and population, are velvet mesquite, Afghan pine, and California palm. The 20 most important species are listed in Table 4. Importance values (IV) are calculated as the sum of relative leaf area and relative composition. Importance values can be used to understand the benefits trees provide based on populations of species, and can help managers identify species that are providing most of the benefits.

Table 4. Top 20 Species by Importance Value

Common Name	Percent Population	Percent Leaf Area	Importance Value
Velvet mesquite	8.25	8.70	16.95
Afghan pine	2.75	10.63	13.39
California palm	7.52	5.56	13.07
Bottle tree	3.44	8.76	12.19
Sweet acacia	6.69	5.41	12.10
Chinese elm	5.71	5.30	11.00
Honey mesquite	4.13	6.84	10.97
Mexican fan palm	5.10	2.71	7.81
Blue paloverde	2.43	3.74	6.17
Olive	2.73	3.20	5.93
Yellow paloverde	4.13	1.71	5.83
Citrus	4.01	1.64	5.65
Rosewood	1.85	1.27	3.12
Queen palm	1.81	0.93	2.74
Ironwood	1.78	0.83	2.61
Feather bush	2.13	0.42	2.55
Juniper	2.34	0.13	2.47
Orchid tree	1.78	0.38	2.16
White mulberry	1.78	0.20	1.98
Saguaro	1.48	0.10	1.58
Other species	28.38	32.23	59.73

Groundcover and Canopy

Groundcover types impact stormwater runoff, availability of planting sites, and indicate the degree of urban density. The most dominant ground cover types were bare soil (21%), rock (25%), and tar (asphalt) (19%). The sampled areas were 66.3% impervious (building, cement, rock, and tar), The study also calculated “plantable area” as an aggregate of bare soil, herbs, lawn & wild grass, representing 41.4% of the land area. As an added layer, above ground cover, tree canopy was calculated to cover 9.0%, and shrub cover was calculated as 5.3%. (Figure 9 and Table 5)

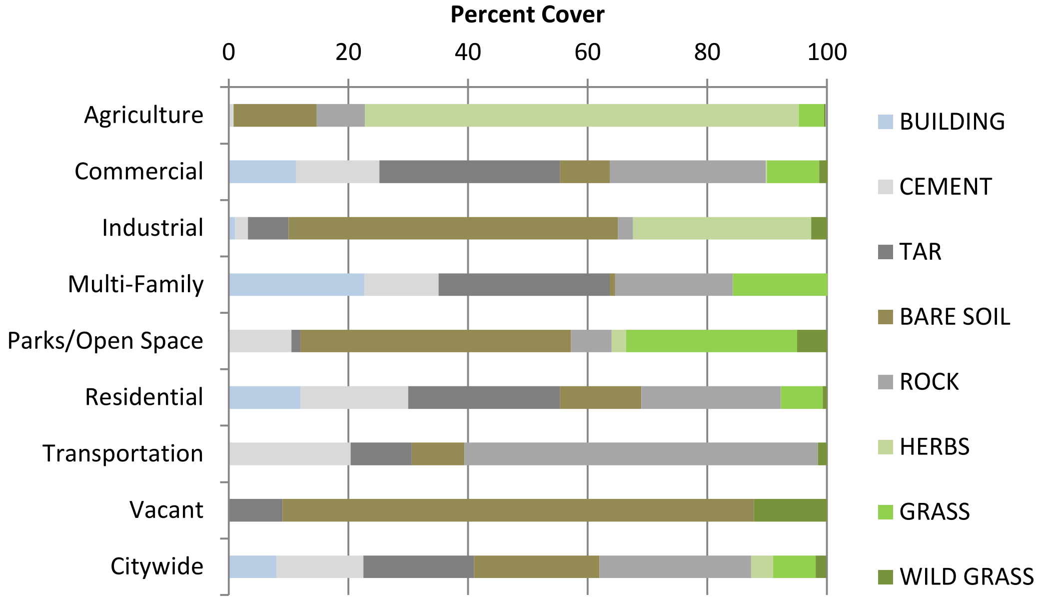


Figure 9. Ground Cover Type Distribution

Table 5. Percent Ground Cover by Land Use

Ground Cover	BUILDING		CEMENT		TAR		BARE SOIL		ROCK	
Land Use	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)	%	SE (+/-)
Agriculture			0.8	0.8			13.9	5.99	8.1	7.71
Commercial	11.3	3.27	13.9	3.62	30.2	5.12	8.3	3.89	26.1	4.59
Industrial	1.1	1.12	2.1	1.3	6.8	4.61	55.1	12.14	2.5	2.62
Multi-Family	22.7	4.45	12.4	2.49	28.6	6.26	0.9	0.47	19.7	5.17
Parks/Open Space			10.5	2.94	1.5	0.89	45.2	6.23	6.8	3.2
Residential	12	1.7	18	1.15	25.4	2.68	13.6	2.64	23.3	2.59
Transportation			20.4	13.03	10.2	9.34	8.8	8.01	59.1	17.66
Vacant					9	8.05	78.8	9.94		
CITY TOTAL	8	0.86	14.5	2.53	18.5	2.28	21	2.43	25.3	3.56

Ground Cover	HERBS		GRASS		WILD GRASS		WATER		SHRUB	
Land Use	%	SE	%	SE	%	SE	%	SE	%	SE
Agriculture	72.5	10.84	4.2	3.98	0.3	0.24	0.3	0.24		
Commercial	0.2	0.14	8.7	3.62	1.4	1.04			4.3	1.00
Industrial	29.8	12.28			2.6	1.73			11.1	6.48
Multi-Family			15.8	6.35					3.4	0.77
Parks/Open Space	2.4	1.05	28.6	6.51	5.0	2.71	0.1	0.05	8.8	1.83
Residential	0	0.03	7	1.45	0.7	0.44	0.1	0.06	3.9	0.59
Transportation					1.5	1.33			1.9	1.01
Vacant					12.2	8.62			19.2	10.52
CITY TOTAL	3.7	1.42	7.1	1	1.8	0.55	0	0.03	5.3	0.93

Economic and Ecological Benefits

Structural and Functional Values

Urban forests have structural values based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree), and functional values based on the functions the trees perform (e.g., remove pollution, reduce energy use).

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees [Nowak, Crane, & Dwyer, 2002]. Annual functional values also tend to increase with increased number and size of healthy trees, and are usually on the order of several million dollars per year. Through proper management, urban forest values can be increased; however, the values and benefits can decrease if the amount of healthy tree cover declines.

The urban forest can remove pollutants from the air.

Structural values:

- Structural value: $3.82 billion
- Carbon storage: $21.7 million

Annual functional values:

- Carbon sequestration: $2.52 million
- Pollution removal: $5.76 million
- Lower energy costs and carbon emission reductions: $25.8 million
- Avoided Stormwater Runoff: $6.11 million

Relative Tree Effects

The urban forest in Phoenix provides benefits that include carbon storage and sequestration, and air pollutant removal. To help understand the relative value of these benefits, tree benefits were compared to estimates of average **municipal carbon emissions** [EIA, 2003, and Census.gov, 2003], average **passenger automobile emissions** [EPA, 2002, BTS 2004, and Graham, Wright & Turhollow, 1992], and average **household emissions** [EIA, 2001].

<u>Carbon storage is equivalent to:</u>
• Amount of carbon emitted in Phoenix in 13 days
• Annual carbon (C) emissions from 183,000 automobiles
• Annual C emissions from 91,800 single-family houses

<u>Carbon monoxide removal is equivalent to:</u>
• Annual carbon monoxide emissions from 272 automobiles
• Annual carbon monoxide emissions from 1,130 single-family houses

Nitrogen dioxide removal is equivalent to:
• Annual nitrogen dioxide emissions from 14,400 automobiles
• Annual nitrogen dioxide emissions from 9,610 single-family houses

Sulfur dioxide removal is equivalent to:
• Annual sulfur dioxide emissions from 67,800 automobiles
• Annual sulfur dioxide emissions from 1,140 single-family houses

Particulate matter less than 10 micron (PM10) removal is equivalent to:
• Annual PM10 emissions from 2,412,000 automobiles
• Annual PM10 emissions from 233,000 single-family houses

Annual carbon sequestration is equivalent to:
• Amount of carbon emitted in Phoenix in 1.5 days
• Annual C emissions from 21,200 automobiles
• Annual C emissions from 10,700 single-family houses

For definitions and calculations, see Appendix I.

Air Quality

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to trees and shrubs 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 pollution from power plant emissions. 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 & Dwyer, 2007].

Pollution removal by trees and shrubs in Phoenix was estimated using field data, hourly air quality data and weather data. Maricopa County is a non-attainment area for PM10, O3, and CO, meaning it does not meet the National Ambient Air Quality Standards for those pollutants. As a result, development can be limited, and the county must actively search for programs to reduce these pollutants. It is estimated that trees and shrubs remove a total of 1,765 tons of air pollution per year, with an associated value of $5.8 million. Pollution removal was greatest for PM10 (905 tons), with an estimated value of $4.8 million. Figure 10 shows the tons of pollutants removed and their associated values. This estimate is based on estimated local incidence of adverse health effects of the BenMAP model and national median externality costs associated with pollutants [Abdollahi, Ning, & Appeaning, 2000].

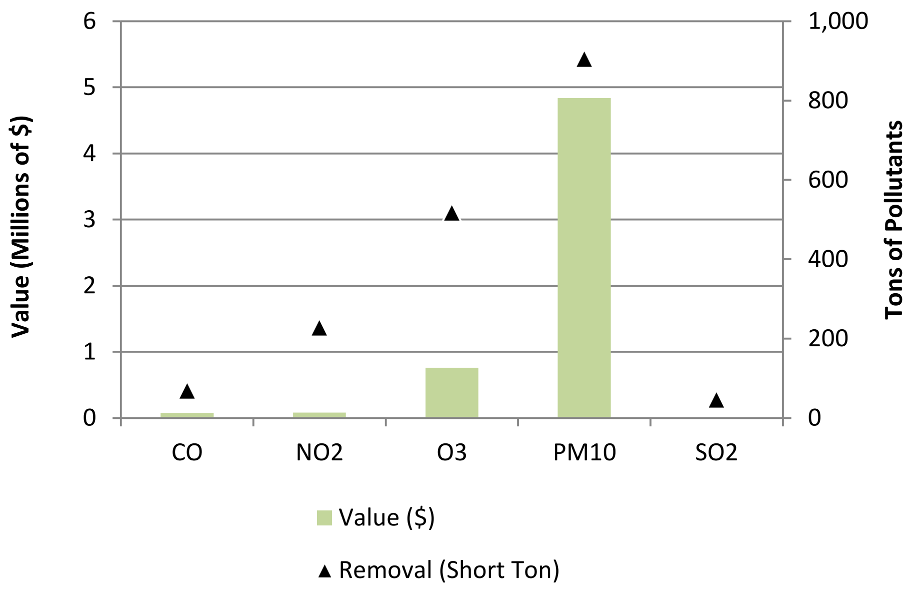


Figure 10. Annual Pollution Removal (bars) and Associated Value (points)

Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue, altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power plants [Nowak & Dwyer, 2007].

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The annual sequestration of the project area trees is about 35,400 tons of carbon per year with an associated value of $2.52 million. The populations of bottle tree and velvet mesquite sequester the greatest amounts of carbon annually, while smaller-stature species such as blue paloverde and citrus have less sequestration capacity. Figure 11 shows the species that store the largest amounts of carbon each year. **Carbon storage** and **carbon sequestration** values are calculated based on $71.21 per ton.

As trees grow, they store carbon as wood. As trees die and decay, they release much of the stored carbon back into the atmosphere. Thus carbon storage is an indication of the amount of carbon that can be released if trees die and decompose. At their current age and size, the trees in the project area are estimated to store 305,000 tons of carbon, valued at $21.7 million.

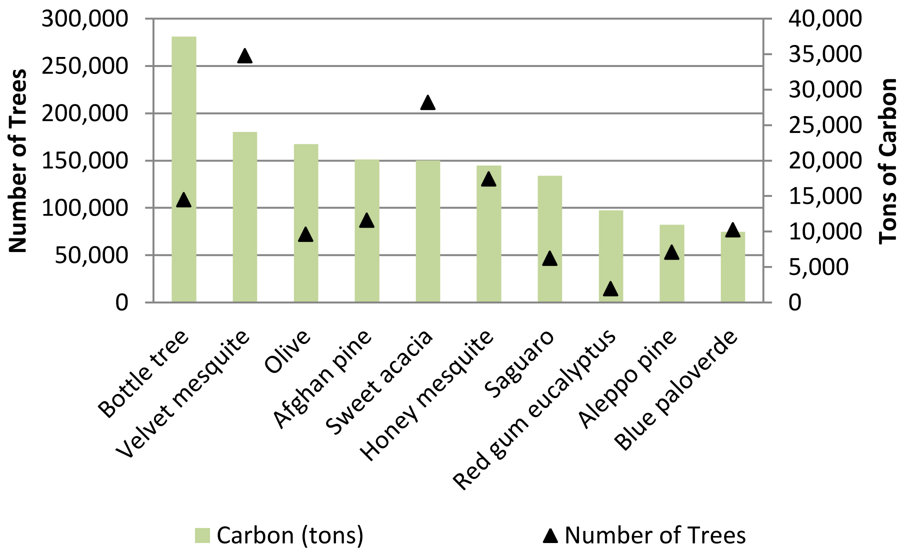


Figure 11. Top Ten Annual Carbon Sequestering Species

Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The net annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in the project area are estimated to produce 89,200 tons of oxygen per year. Table 6 shows the varying oxygen production of different tree species. This tree benefit is monetarily insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen [Broecker, 1970]. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent, so the monetary value of this contribution is considered negligible.

Table 6. Top 20 Oxygen Producing Species

Species	Oxygen (tons)	Net Carbon Sequestration (tons/yr)	Number of trees	Leaf Area (square miles)
Bottle tree	8,970	3,364	108,750	9.83
Sweet acacia	8,629	3,236	211,693	6.07
Velvet mesquite	7,489	2,808	261,048	9.76
Honey mesquite	6,347	2,380	130,631	7.67
Olive	5,326	1,997	72,201	3.28
Saguaro	4,199	1,574	46,997	0.11
Chinese elm	3,883	1,456	180,665	5.94
Afghan pine	3,620	1,358	87,137	11.93
Blue paloverde	3,330	1,249	77,047	4.20
Citrus spp	3,287	1,233	126,990	1.84
Desert Ironwood	2,247	843	95,645	1.03
Texas ebony	2,105	789	28,220	2.66
Jerusalem thorn	1,914	718	42,330	2.01
Willow acacia	1,904	714	29,406	3.76
Leadtree spp	1,724	646	28,220	1.21
Coolabah	1,697	636	14,936	2.50
Indian rosewood	1,623	609	77,118	2.38
Silk oak	1,583	593	14,936	1.94
Feather bush	1,343	504	67,433	0.47
Aleppo pine	1,292	484	53,225	4.54

Avoided Stormwater Runoff

Surface runoff can be a cause for concern in urban areas, as it can cause flooding and contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of precipitation is intercepted by vegetation (trees, grasses, forbs, and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff. In urban areas, the large extent of impervious surfaces increases the amount of surface runoff, and the cost of infrastructure a community must invest in managing stormwater for the safety of residents and property.

One limitation of the i-Tree Eco model is that grasses and forbs are not specifically accounted for in reporting benefits. In areas such as the desert southwest, these land cover types play a very important role in managing stormwater runoff. Grasses and forbs in the desert southwest may have a proportionately greater role than in other climate types where trees and shrubs are more plentiful. While no specific benefit data is available based on the model, the overall percentage of these land cover types found in this study is substantial (Table 7). Thus, realized stormwater benefits are likely even higher if herbs, grasses, and forbs are considered.

Table 7. Vegetation NOT Accounted for in Model

Ground Cover	HERBS		GRASS		WILD GRASS		Total
Land Use	%	SE	%	SE	%	SE	%
Agriculture	72.5	10.84	4.2	3.98	0.3	0.24	77.0
Commercial	0.2	0.14	8.7	3.62	1.4	1.04	10.3
Industrial	29.8	12.28			2.6	1.73	32.4
Multi-Family			15.8	6.35			15.8
Parks/Open Space	2.4	1.05	28.6	6.51	5	2.71	36.0
Residential	0	0.03	7	1.45	0.7	0.44	7.7
Transportation					1.5	1.33	1.5
Vacant					12.2	8.62	12.2
CITY TOTAL	3.7	1.42	7.1	1	1.8	0.55	12.6

Urban trees are beneficial in reducing surface runoff. Trees intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees throughout the project area help to reduce runoff by an estimated 91.7 million cubic feet a year with an associated value of $6.1 million dollars. Figure 12 shows the species that provide the highest rainfall interception values. This figure demonstrates that population numbers alone do not dictate the interception value, rather, interception is related to leaf surface area which is influenced by tree age, health, species, and stature.

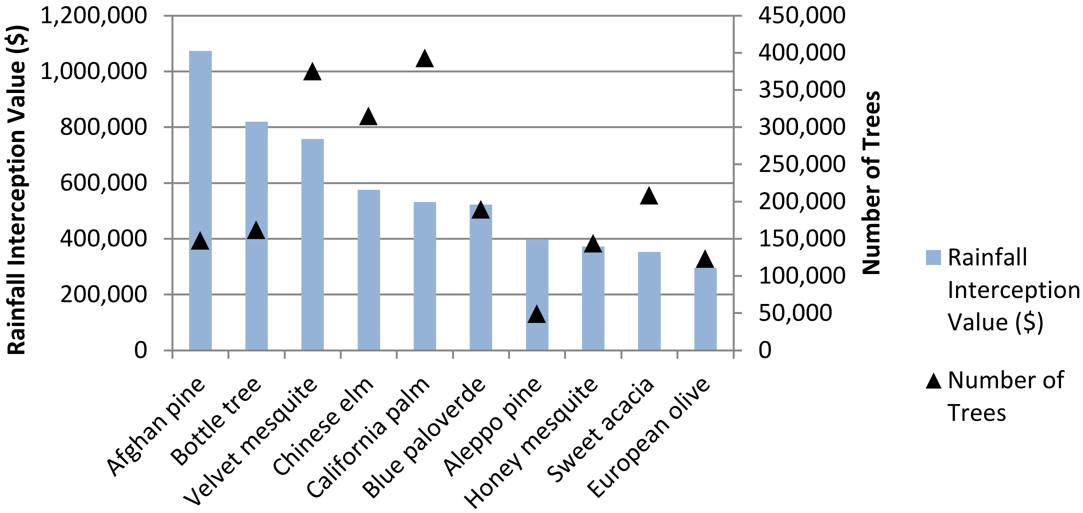


Figure 12. Rainfall Interception Value (bars) and Number of Trees (points)

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. Table 8 shows the amount of energy savings trees provide to residential buildings. The values for Table 9 were calculated considering savings during heating and cooling seasons. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to air-conditioned residential buildings [McPherson & Simpson, 1999].

Trees in Phoenix are estimated to reduce energy-related costs from residential buildings by $22.9 million annually (Table 9). Trees also provide an additional $2.9 million dollars in value by reducing the amount of carbon released by fossil-fuel based power plants, a reduction of 41,565 tons of carbon emissions (Table 8). Negative numbers indicate a cost due to increased energy use or carbon emission.

Table 8. Annual Energy Savings Due to Trees Near Residential Buildings

	Heating	Cooling	Total
MBTU[1]	-116,415	n/a	-116,415
MWH[2]	-9,217	224,687	215,470
Carbon avoided (t[3])	-2,877	44,442	41,565

[1]One million British Thermal Units
[2]Megawatt-hour
[3]Short ton

Table 9. Annual Savings[1] ($) in Residential Energy Expenditure

	Heating	Cooling	Total
MBTU	-1,955,773	n/a	-1,955,773
MWH	-1,062,720	25,906,411	24,843,691
Carbon Avoided	-204,885	3,164,885	2,960,000

[1]Based on the prices of $115.3 per MWH and $16.8 per MBTU
[2]One million British Thermal Units
[3]Megawatt-hour

Potential Urban Forest Health Impacts

Pathogen and Pest Proximity and Risk

Pathogens and pests can infest urban forests, potentially killing trees and reducing the health, value and sustainability of the urban forest. As pathogens and pests tend to have differing tree hosts, the potential damage or risk of each pest or pathogen will differ among cities. Thirty-one pests and pathogens were analyzed for their potential impact and compared with their range maps [FHTET] for the contiguous United States. In Figure 13, the bars associated with a particular pest or pathogen are color coded according to Maricopa County's proximity to the pest or pathogen occurrence in the United States. None of the pests evaluated in this model occur in Maricopa County. Yellow bars indicate that the pest or pathogen is within 750 miles of the Maricopa County, and green bars indicate that it is beyond 750 miles of the county boundary.

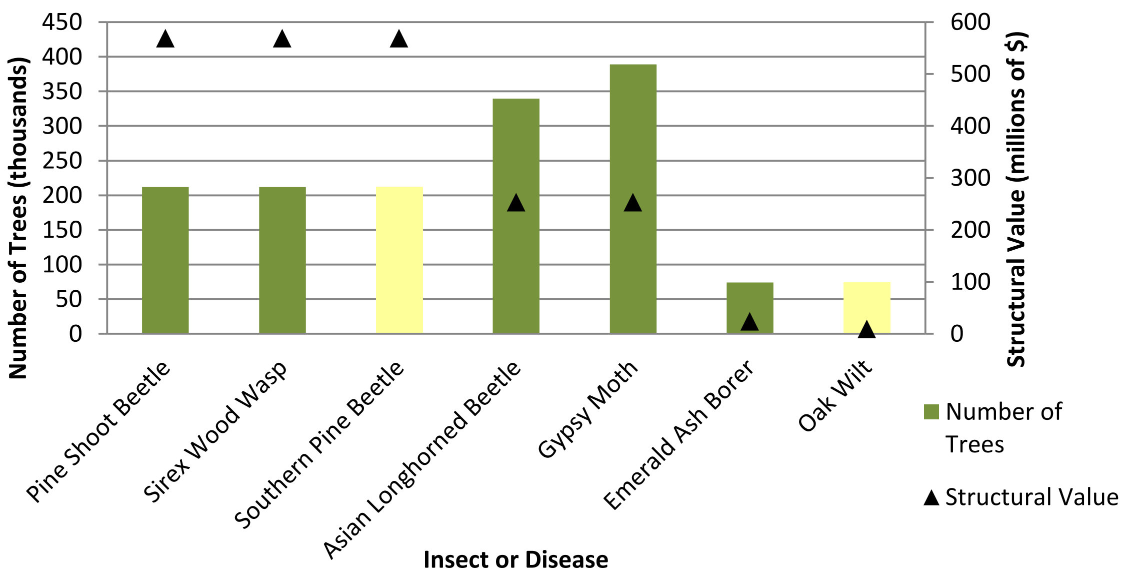


Figure 13. Number of Susceptible Trees (bars) and Structural Value by Pest or Pathogen (points)

Though 31 pathogens and pests were assessed for their impact on Phoenix's urban forests, only 7 species have been identified as having potential impacts, and are described below. The two pests with the greatest likely potential for impact are Gypsy Moth [NASPF, 2005c], and Asian Longhorned Beetle [NASPF, 2005a], which could impact 6.8% and 6.2% of tree populations, respectively. It should be noted that i-Tree Eco uses the inventory data to calculate the damage potential of a given pathogen to the area of interest. The model does not calculate whether there is a reasonable risk that this pathogen will move there in the foreseeable future. The model calculates the damage potential, assuming the pathogen will reach the study area and attack the associated tree species.

The Gypsy Moth (GM) [NASPF, 2005c] is a defoliator that feeds on many species causing widespread defoliation and tree death in the eastern US if outbreak conditions last several years. This insect threatens 6.8% of the population, which represents a potential loss of $176 million in structural value.

Asian Longhorned Beetle (ALB) [NASPF, 2005] is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 6.2% of the Phoenix urban forest, which represents a potential loss of $177 million in structural value.

The Pine Shoot Beetle (PSB) [Ciesla, 2001] is a wood borer that attacks various pine species, though Scotch pine is the preferred host in North America. PSB has the potential to affect 4.4% of the population ($666 million in structural value).

Southern Pine Beetle is found in counties adjacent to Maricopa, but not within the county itself. Although the Southern Pine Beetle (SPB) [Clarke & Nowak, 2009] will attack most pine species, its potential hosts in the Phoenix area are Afghan, Aleppo, Canary Island, Chir and Japanese black pines. This insect threatens 4.4% of the population, which represents a potential loss of $666 million in structural value.

The Sirex Wood Wasp (SW) [Haugen & Hoebeke, 2005] is a wood borer that primarily attacks pine species. SW poses a threat to 4.4% of the Phoenix urban forest, which represents a potential loss of $666 million in structural value.

Emerald Ash Borer (EAB) [NASPF, 2005b] has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 1.3% of the population ($27.5 million in structural value).

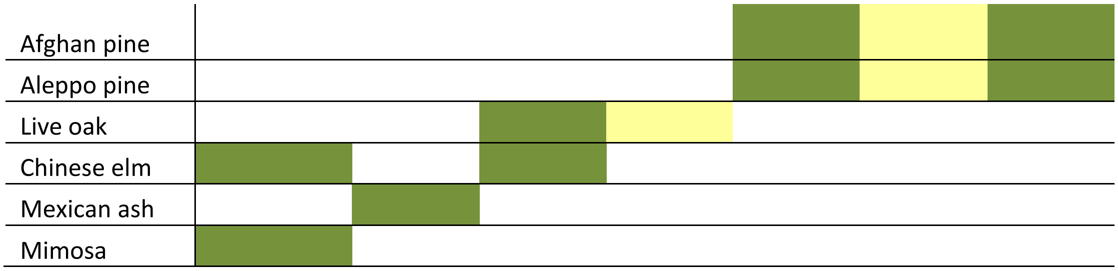
Oak Wilt (OW) [Rexrode & Brown, 1983], which is caused by a fungus, is a prominent disease among oak trees. OW poses a threat to 1.1% of the Phoenix urban forest, which represents a potential loss of $10.2 million in structural value.

Pathogen and Pest Risk by Tree Species

Based on the host tree species for each pest and the current range of the pest [FHTET, 2009], it is possible to determine what the risk is that each tree species sampled in the urban forest could be attacked by an pest or pathogen.

Table 10. Pathogen or Pest Risk by Tree Species

	Pest or Pathogen						
Tree Species	Asian Longhorned Beetle	Emerald Ash Borer	Gypsy Moth	Oak Wilt	Pine Shoot Beetle	Southern Pine Beetle	Sirex Wood Wasp


Afghan pine
Aleppo pine
Live oak
Chinese elm
Mexican ash
Mimosa

Appendix I. Glossary and Calculations

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, Wright, & Turhollow, 1992)

Carbon emissions Total city carbon emissions were based on 2003 US per capita carbon emissions – calculated as total US emissions (EIA, 2003) divided by the 2003 US total population (Census.gov). This value was multiplied by the population of Phoenix (1.49 million) to estimate total city carbon emissions.

Carbon storage The amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. Carbon storage and carbon sequestration values are calculated based on $71.21 per ton.

Carbon sequestration The removal of carbon dioxide from the air by plants. Carbon storage and carbon sequestration values are calculated based on $71 per ton.

Diameter at Breast Height (DBH) Is the diameter of the tree measured 4'6" above grade.

Energy saving Value is calculated based on the prices of $116.9 per MWH and $11.79 per MBTU.

Household emissions (average) based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household (EIA, 2001)
- CO_2, SO_2, and NOx power plant emission per KWh (EPA)
- CO emission per kWh assumes 1/3 of one percent of C emissions is CO (EIA, 1994)
- PM10 emission per kWh (Layton, 2004, 2005)
- CO_2, NOx, SO_2, PM10, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) (Abraxas Energy Consulting)
- CO_2 and fine particle emissions per Btu of wood (Houck et al., 1998)
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) (www.env.bc.ca, 2005)
- Emissions per dry ton of wood converted to emissions per Btu based on average dry weight per cord of wood and average Btu per cord (ianrpubs.unl.edu).

Monetary values ($) are reported in US Dollars throughout the report.

PM 2.5 consists of particulate matter less than 2.5 microns.

PM10 consists of particulate matter less than 10 microns and greater than 2.5 microns. As PM2.5 is also estimated, the sum of PM10 and PM2.5 provides the total pollution removal and value for particulate matter less than 10 microns.

P**assenger automobile emissions** per mile (average) were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (EPA, 2004). Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics, 2004).

Pollution removal Value is calculated based on the prices of $1,136 per ton (carbon monoxide), $1260 per ton (ozone),$226 per ton (nitrogen dioxide), $110 per ton (sulfur dioxide), $5840 per ton (particulate matter less than 10 microns and greater than 2.5 microns), $17993 per ton (particulate matter less than 2.5 microns).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces. This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to interesting results depending on various atmospheric factors. Generally, pollution removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

Structural value Value based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree).

Ton Short ton (U.S.) (2,000 lbs).

Appendix II. Comparison of Urban Forests

Sometimes it is useful to determine how a city compares to other areas. Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model. This comparison information is provided by the i-Tree Eco model and reporting.

Table 11. Total Tree Benefits in Other Areas

Area	Number of trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)	Pollution Removal (tons/year)
Calgary, Canada	11,889,000	445,000	21,422	326
Atlanta, GA	9,415,000	1,345,000	46,433	1,662
Toronto, Canada	7,542,000	992,000	40,345	1,212
New York, NY	5,212,000	1,351,000	42,283	1,677
Phoenix, AZ	3,166,000	305,000	35,400	1,770
Baltimore, MD	2,627,000	596,000	16,127	430
Philadelphia, PA	2,113,000	530,000	16,115	576
Washington, DC	1,928,000	523,000	16,148	418
Albuquerque, NM	1,504,000	226,000	9,710	366
El Paso, TX	1,281,000	92,800	7,430	318
Boston, MA	1,183,000	319,000	10,509	284
Woodbridge, NJ	986,000	160,000	5,561	210
Minneapolis, MN	979,000	250,000	8,895	305
Syracuse, NY	876,000	173,000	5,425	109
Morgantown, WV	661,000	94,000	2,940	66
Moorestown, NJ	583,000	117,000	3,758	118
Las Cruces, NM	257,000	17,800	1,580	92
Eastern Colorado	251,000	71,900	2,200	77
Jersey City, NJ	136,000	21,000	890	41
Freehold, NJ	48,000	20,000	545	21

Table 12. Per-Acre Values of Tree Effects in Other Areas

Area	Number of Trees	Carbon Storage (tons)	Carbon Sequestration (tons/year)
Morgantown, WV	119.7	17.0	0.53
Atlanta, GA	111.6	15.9	0.55
Calgary, Canada	66.7	2.5	0.12
Woodbridge, NJ	66.5	10.8	0.38
Moorestown, NJ	62.0	12.5	0.4
Syracuse, NY	54.5	10.8	0.34
Baltimore, MD	50.8	11.5	0.31
Washington, DC	49.0	13.3	0.41
Toronto, Canada	48.3	6.4	0.26
Freehold, NJ	38.5	16.0	0.44
Boston, MA	33.5	9.0	0.3
New York, NY	26.4	6.8	0.21
Minneapolis, MN	26.2	6.7	0.24
Philadelphia, PA	25.0	6.3	0.19
Albuquerque, NM	17.8	2.7	0.11
Jersey City, NJ	14.3	2.2	0.09
Phoenix, AZ	12.9	1.2	0.14
El Paso, TX	12.7	0.9	0.07
Eastern Colorado	12.1	3.5	0.11
Las Cruces, NM	9.1	0.6	0.06

Appendix III. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are [Nowak, 1995]:

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities [Nowak, 2000]. Local urban management decisions also can help improve air quality.

Table 13. Urban Forest Management Strategies to Improve Air Quality

Strategy	Result
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix IV. Species Distribution and Botanical Names

Common Name	Species	Percent Population	Percent Leaf Area	Importance Value
Velvet mesquite	*Prosopis velutina*	8.25	8.71	16.95
Afghan pine	*Pinus eldarica*	2.75	10.64	13.39
California palm	*Washingtonia filifera*	7.52	5.56	13.08
Bottle tree	*Brachychiton populneus*	3.44	8.76	12.20
Sweet acacia	*Acacia farnesiana*	6.69	5.42	12.10
Chinese elm	*Ulmus parvifolia*	5.71	5.30	11.01
Honey mesquite	*Prosopis glandulosa*	4.13	6.84	10.97
Mexican fan palm	*Washingtonia robusta*	5.10	2.71	7.81
Blue paloverde	*Parkinsonia florida*	2.43	3.74	6.18
Yellow paloverde	*Parkinsonia microphylla*	4.13	1.71	5.83
Aleppo pine	*Pinus halepensis*	1.68	4.05	5.73
Citrus	*Citrus* spp.	4.01	1.64	5.65
Olive	*Olea europaea*	2.28	2.93	5.21
Indian rosewood	*Dalbergia sissoo*	2.44	2.12	4.56
Willow acacia	*Acacia salicina*	0.93	3.35	4.28
Desert Ironwood	*Olneya tesota*	3.02	0.92	3.94
Texas ebony	*Ebenopsis ebano*	0.89	2.37	3.26
Jerusalem thorn	*Parkinsonia aculeata*	1.34	1.79	3.13
Queen palm	*Syagrus romanzoffiana*	1.81	0.93	2.74
Coolabah	*Eucalyptus coolabah*	0.47	2.23	2.70
Feather bush	*Lysiloma watsonii*	2.13	0.42	2.55
Juniper	*Juniperus* spp.	2.34	0.13	2.47
Mexican ash	*Fraxinus berlandieriana*	1.34	1.06	2.40
Carob	*Ceratonia* spp.	0.45	1.83	2.27
Silk oak	*Grevillea robusta*	0.47	1.73	2.20
Orchid tree	*Bauhinia purpurea*	1.78	0.38	2.16
Desert museum paloverde	*Parkinsonia hybrid Desert Museum*	1.21	0.91	2.13
Tipu tree	*Tipuana tipu*	0.94	1.15	2.09
White mulberry	*Morus alba*	1.78	0.20	1.98
Algarrobo	*Prosopis chilensis*	0.77	1.20	1.97
Leadtree	*Leucaena* spp.	0.89	1.08	1.97
Red gum eucalyptus	*Eucalyptus camaldulensis*	0.47	1.32	1.79

Common Name	Species	Percent Population	Percent Leaf Area	Importance Value
Pygmy date palm	*Phoenix roebelenii*	1.34	0.42	1.75
Mexican Bird of paradise tree	*Caesalpinia mexicana*	1.05	0.41	1.46
Saguaro	*Carnegia gigantea*	1.48	0.10	1.58
Mediterranean fan palm	*Chamaerops humilis*	0.89	0.47	1.36
Oriental arborvitae	*Platycladus orientalis*	0.89	0.47	1.36
Date palm	*Phoenix dactylifera*	0.45	0.87	1.31
African sumac	*Rhus lancea*	0.61	0.69	1.30
Live oak	*Quercus virginiana*	1.05	0.14	1.20
Oleander	*Nerium oleander*	0.89	0.19	1.08
Shoestring acacia	*Acacia stenophylla*	0.45	0.49	0.94
Ocotillo	*Fouquieria splendens*	0.45	0.41	0.86
Acacia	*Acacia* spp.	0.76	0.02	0.79
King palm	*Archontophoenix cunninghamiana*	0.45	0.32	0.77
Olive	*Olea* spp.	0.45	0.28	0.72
Mimosa	*Albizia julibrissin*	0.45	0.19	0.64
Moreton Bay Fig	*Ficus macrocarpa*	0.45	0.11	0.56
Indian laurel fig	*Ficus retusa ssp nitida*	0.45	0.10	0.55
Argentine mesquite	*Prosopis alba*	0.45	0.10	0.55
Mescalbean	*Dermatophyllum secundiflorum*	0.45	0.09	0.54
Glossy privet	*Ligustrum lucidum*	0.45	0.07	0.52
Luckynut	*Thevetia peruviana*	0.45	0.05	0.50
Aloe yucca	*Yucca aloifolia*	0.45	0.05	0.49
Purpleleaf plum	*Prunus cerasifera*	0.45	0.03	0.48
Saltbush	*Atriplex* spp.	0.29	0.15	0.44
Lotebush	*Ziziphus obtusifolia*	0.29	0.06	0.35
Laurel-leafed snailseed	*Cocculus laurifolius*	0.16	0.12	0.28
Paloverde	*Parkinsonia* spp.	0.16	0.12	0.28
Desert broombush	*Templetonia egena*	0.16	0.09	0.25
Hackberry	*Celtis* spp.	0.15	0.05	0.20

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