# Varina, IA



Varina, IA

2018 Urban Forest Management Plan
Prepared by Emma Hanigan
Iowa Department of Natural Resources

# Table of Contents

# Executive Summary

## Overview

This plan was developed to assist the City of Varina with managing its urban forest, including budgeting and future planning. Trees can provide a multitude of benefits to the community, and sound management allows a community to best take advantage of these benefits. Management is especially important considering the serious threats posed by forest pests such as the emerald ash borer (EAB). EAB is an invasive insect imported from Eastern Asia on wood shipping crates that kills all species of ash trees (this does not include mountain ash). There is a strong possibility that 38% of Varina's city owned trees (ash) will die once EAB becomes established in the community, unless preventative treatment is used. With proper planning and management, the costs of removing dead and dying trees can be extended over years, mitigating public safety issues.

## Inventory and Results

In 2017, a tree inventory was conducted using Global Positioning System (GPS) data collectors. The inventory was a complete inventory of street and park trees. Below are some key findings of the 143 trees inventoried.

- Varina's trees provide $28,269 of benefits annually, an average of $198 a tree
- There are over 23 species of trees
- The top genera are:  Ash 38%, Maple 20%, Walnut 8% and Spruce 11%
- 6% of trees are in need of some type of management
- 4 trees are recommended for removal

## Recommendations

The core recommendations are detailed in the Recommendations Section. The Emerald Ash Borer Plan includes management recommendations as well. Below are some key recommendations.

- Of the 4 trees needing removal, 3 must be addressed immediately *City ownership of the trees recommended for removal should be verified prior to any removal*
- 15 of the 54 ash trees should be carefully examined, as they have one or more symptoms that could be related to an EAB infestation
- All trees should be pruned on a routine schedule- one third of the city every other year
- Plant a diverse mix of trees that do not include: ash, maple, cottonwood, poplar, box elder, Chinese elm, evergreen, willow or black walnut
- Check ash trees with a visual survey yearly
- With the current budget it could take 56 years to remove ash – Suggestion: request a budget increase to $4,000 annually and apply for grants to plant replacement trees

# Introduction

This plan was developed to assist Varina with the management, budgeting and future planning of their urban forest. Across the state, forestry budgets continue to decrease with more and more of that money spent on tree removal. With the anticipated arrival of Emerald Ash Borer (EAB), an invasive pest that kills native ash trees, it is time to prepare for the increased costs of tree removal or treatment and replacement planting. With proper planning and management of the current canopy in Varina, these costs can be extended over years and public safety issues from dead and dying ash trees mitigated.

Trees are an important component of Varina's infrastructure and one of the greatest assets to the community. The benefits of trees are immense. Trees provide the community with improved air quality, stormwater runoff interception, energy conservation, lower traffic speeds, increased property values, reduced crime, improved mental health and create a desirable place to live, to name just a few benefits. It is essential that these benefits be maintained for the people of Varina and future generations through good urban forestry management.

Good urban forestry management involves setting goals and developing management strategies to achieve these goals. An essential part of developing management strategies is a comprehensive public tree inventory. The inventory supplies information that will be used for maintenance, removal schedules, tree planting and budgeting. Basing actions on this information will help meet Varina's urban forestry goals.

# Inventory

In 2017, a tree inventory was conducted that included 100% of the city owned trees on both streets and parks. The tree data was collected using a handheld Global Positioning System (GPS) receiver. The data collector gives Geographic Information Systems (GIS) coordinates with an accuracy of 3 meters, which can be used in Arc GIS as an active GIS data layer. Because the inventory is a digital document the data can be updated with new information and become a working document.

The programming used to collect tree information on the data collectors was written to be compatible with a state-of-the-art software suite called i-Tree. i-Tree was developed by the USDA Forest Service to quantify the structure of community trees and the environmental services that trees provide. The i-Tree suite is a public domain which can be accessed for free.

To quantify the urban forest structure and benefits, specific data is collected for each tree. This data includes: location, land use, species, diameter at 4.5 ft, recommended maintenance, priority of that maintenance, leaf health, and wood condition. Additionally, signs and symptoms associated with EAB were noted for all ash trees. The signs and symptoms noted were canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

# Inventory Results

The data collected for the 143 city trees was entered into the USDA Forest service program Street Tree Resource Analysis Tool for Urban forestry Management as part of the i-Tree suite. The following are results from the i-Tree STREETS analysis.

# Annual Benefits

**Annual Energy Benefits**
Trees conserve energy by shading buildings and blocking winds. Varina's trees reduce energy related costs by approximately $6,992 annually (Appendix A, Table 1). These savings are both in Electricity (33.1MWh) and in Natural Gas (4,567.1Therms).

**Annual Stormwater Benefits**
Varina's trees intercept about 415,334 gallons of rainfall or snow melt a year (Appendix A, Table 2). This interception provides $11,256 of benefits to the city.

**Annual Air Quality Benefits**
Air quality is a persistent public health issue in Iowa. The urban forest improves air quality by removing pollutants, lowering air temperature, and reducing energy consumption, which in turn reduces emissions from power plants, and emitting volatile organic matter (ozone). In Varina, it is estimated that trees remove 331 lbs of air pollution (ozone ($O_3$), particulate matter less than 10 microns (PM10), carbon monoxide (CO), nitrogen dioxide ($NO_2$), and sulfur dioxide ($SO_2$)) per year with a net value of $1,253 (Appendix A, Table 3).

**Annual Carbon Benefits**
Carbon sequestration and storage reduce the amount of carbon in the atmosphere, mitigating climate change. In Varina, trees sequester about 89,741lbs of carbon a year with an associated value of $1,027 (Appendix A, Table 5). In addition, the trees store 1,675,852 lbs of carbon, with a yearly benefit of $12,569 (Appendix A, Table 4).

**Annual Aesthetics Benefits**
Social benefits of trees are hard to capture. The analysis does have a calculation for this area that includes: aesthetic value, property values, lowered rates of mental illness and crime, city livability and much more. Varina receives $7,742 in annual social benefits from trees (Appendix A, Table 6).

**Financial Summary of all Benefits**
According to the USDA Forest Service i-Tree STREETS analysis, Varina's trees provide $28,269 of benefits annually. Benefits of individual trees vary based on size, species, health and location, but on average each of the 143 trees in Varina provide approximately $198 annually (Appendix A, Table 7).

# Forest Structure

**Species Distribution**
Varina has over 23 different tree species along city streets and parks (Appendix A, Figure 1).
The distribution of trees by genera is as follows:

| | | |
|---|---|---|
| Ash | 54 | 38% |
| Maple | 28 | 20% |

| | | |
|---|---|---|
| Walnut | 11 | 8% |
| Spruce | 11 | 8% |
| Hackberry | 9 | 6% |
| Other | 7 | 5% |
| Cedar | 4 | 3% |
| Apple (crabapple) | 4 | 3% |
| Honeylocust | 3 | 2% |
| Ketucky Coffeetree | 3 | 2% |
| Redbud | 2 | 1% |
| Oak | 2 | 1% |
| Mulberry | 1 | 1% |
| Cottonwood | 1 | 1% |
| lilac | 1 | 1% |
| Linden | 1 | 1% |
| Elm | 1 | 1% |

## Age Class

Most of Varina's trees (43%) are between 24 and 36 inches in diameter at 4.5 ft (Appendix A, Figure 2). For age, it is preferred that the highest amounts of trees are in the smallest size category (a downward slope) to prepare for natural mortality and to maintain canopy cover. Varina's size curve is on the smaller side, indicating a younger than average stand.

## Condition: Wood and Foliage

Both wood condition and leaf condition are good indicators of the overall health of the urban forest. The foliage condition results for Varina indicate that 92% of the trees are in good health, with only 3% of the foliage in poor health, dead or dying (Appendix A, Figure 3 & Appendix B, Figure 3). Also, 32% of Varina's trees are in good health for wood condition (appendix A, Figure 4 & Appendix B, Figure 3). Wood condition that is in poor health, dead or dying is about 32% of the population. This 32% is an estimate of trees that need management follow up.

## Management Needs

The following outlines the specific management needs of the street and park trees by number of trees and percent of canopy (Appendix B, Figure 3).

| | | |
|---|---|---|
| Crown Cleaning | 4 | 3% |
| Crown Raising | 0 | 0% |
| Tree Staking | 0 | 0% |
| Tree Removal | 4 | 3% |
| Crown Reduction | 0 | 0% |

## Canopy Cover

The total canopy with both private and public trees is 14%, 24 acres. The canopy cover included in the Varina inventory includes approximately 4 acres (Appendix A, Figure 4). The City's Canopy goal is to increase canopy by 3%, in 30 years. To achieve this goal it is estimated that 13 trees need to be planted annually on public and private lands.

**Land Use and Location**

The majority of Varina's city and park trees are in planting strips in single family residential neighborhoods (Appendix A, Figure 6 & Appendix A, Figure7). The following describes the land use and locations for the street and park trees.

<u>Land Use</u>

| | |
|---|---|
| Single family residential | 66% |
| Park/vacant/other | 34% |
| Industrial/Large commercial | 0% |
| Small commercial | 0% |
| Multifamily residential | 0% |

<u>Location</u>

| | |
|---|---|
| Planting strip | 30% |
| Other maintained locations | 0% |
| Cutout (surrounded by pavement) | 0% |
| Front yard | 70% |

# Recommendations

**Risk Management**

Hazardous trees can be a significant threat to both people and property. Trees that are dead or dying, or that have large issues such as trunk cracks longer than 18 inches should be removed. Broken branches and branches that interfere with motorist's vision of pedestrians, vehicles, traffic signs and signals, etc should be removed.

<u>Hazardous trees</u>

Varina has 3 trees that need immediate removal. These trees can be seen on the Location of Trees with Recommended Maintenance map (Appendix B, Figure 4). Please refer to the six year maintenance plan at the end of this section. After all 4 removals are addressed, there should be follow up on the trees marked as needing maintenance. There are a total of 4 trees with these needs.

<u>Poor tree species</u>

After the removal of the critical concern trees, ash trees in poor health should be assessed for removal (Appendix B, Figure 3 & Appendix B, Figure 4). Of the 4 removals, 2 are ash trees. There are a total of 54 ash trees, and 15 of those have signs and symptoms that have been associated with EAB. In addition, there are 23 trees that are in poor health. *City ownership of the trees recommended for removal should be verified prior to any removal*

**Pruning Cycle**

Proper pruning can extend the life and good health of trees, as well as reduce public safety issues. In the Management Needs section of the Findings there are four main maintenance issues to be addressed: routine pruning, crown cleaning, crown raising, and crown reduction. Crown cleaning removes dead, diseased, and damaged limbs. Crown raising is the removal of lower branches that are 2

inches in diameter or larger in the case of providing clearance for pedestrians or vehicles. Crown reduction is removing individual limbs from structures or utility wires. It is recommended that all trees be pruned on a routine schedule every five to seven years. Please refer to the six year maintenance plan for further information.

**Planting**

Most of the planting over the next 5 years will replace the trees that are removed. It is recommended to plant 1.2 trees for every tree removed, since survival rates will not be 100%. Please refer to the six year maintenance plan at the end of this section. It is not essential that the new trees be planted in the same location of the trees being removed. However, maintaining the same number of trees helps ensure continuation of the benefits of the existing forest in Varina.

It is important to plant a diverse mix of species in the urban forest to maintain canopy health, since most insects and diseases target a genus (ash) or species (green ash) of trees. Current diversity recommendations advise that a genus (i.e. maple, oak) not make up more than 20% of the urban forest and a single species (i.e. silver maple, sugar maple, white oak, bur oak) not make up more than 10% of the total urban forest. Also, ash trees have not been recommended since 2002, due to the threat of EAB. Other species to avoid because they are public nuisances include: cottonwood, poplar, box elder, Chinese elm, evergreen, willow or black walnut, as outlined in the city ordinance.

**Continual Monitoring**

Due to the threat of EAB, it is important to continuously check the health of ash trees. It is recommended that ash trees be checked with a visual survey every year for tree decline and for the following signs and symptoms: canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

**Six Year Maintenance Plan with No Additional Funding**

Year 1
    Removal: 1 critical concern tree
    Planting and Replacement: 2 trees to be planted in open locations
    Young Tree Pruning & Maintenance:
    Visual Survey for signs and symptoms of EAB

Year 2
    Removal: 1 tree
    *Or saving for ash tree treatment and/or future ash removal
    Planting and Replacement: 1 trees in open locations from year one removals
    Young Tree Pruning & Maintenance
    Routine trimming: 1 tree
    Visual Survey for signs and symptoms of EAB

Year 3
    Removal: 1 tree
    *Or saving for ash tree treatment and/or future ash removal
    Planting and Replacement: 2 trees to be planted in open locations and locations from previous removals

Young Tree Pruning & Maintenance
Visual Survey for signs and symptoms of EAB

Year 4
    Removal: 1 tree
    *Or saving for ash tree treatment and/or future ash removal
    Planting and Replacement: 1 trees in open locations from year one removals
    Young Tree Pruning & Maintenance
    Routine trimming: 1 tree
    Visual Survey for signs and symptoms of EAB

Year 5
    Removal: 1 tree removal of any new critical concern trees and ash in poor health
    *Or saving for ash tree treatment and/or future ash removal
    Planting and Replacement: 2 trees to be planted in open locations and locations from previous removals
    Young Tree Pruning & Maintenance
    Visual Survey for signs and symptoms of EAB

Year 6
    Removal: 1 tree - removal of any new critical concern trees and ash in poor health
    *Or saving for ash tree treatment and/or future ash removal
    Planting and Replacement: 1 trees in open locations from year one removals
    Young Tree Pruning & Maintenance
    Routine trimming: 1 tree
    Visual Survey for signs and symptoms of EAB

*Reduction of ash over 6 years: Approximately 4 ash trees removed (approximately 7% of ash). It will take approximately 56 years to remove all ash with the current budget. EAB could potentially kill all ash within 4 to 15 years of its arrival.
**To remove all ash trees within 6 years, the budget would need to be increased to $8,400 a year. If the budget were increased to $4,000 a year all ash could be removed in 13 years.

# Emerald Ash Borer Plan

**Ash Tree Removal**
Tree removal will be prioritized with dead, dying, hazardous trees to be removed first (Appendix B, Figure 4). Next will be all ash in poor condition and displaying signs and symptoms of EAB (Appendix B, Figure 2 & Appendix B, Figure 3). *City ownership of the tree recommended for removal should be verified prior to any removal*

**Treatment of Ash Trees**
Chemical treatment can be effective tool for communities to spread removal costs out over several years while allowing trees to continue to provide benefits. However, treatment is not recommended if EAB is more than 15 miles away from the community. For more information on the cost of treatment strategies visit http://extension.entm.purdue.edu/treecomputer/

## EAB Quarantines

EAB is an extremely destructive plant pest and it is responsible for the death and decline of millions of ash trees. Ash in both forested and urban settings constitute a significant portion of the canopy cover in the United States. Current tools to detect, control, suppress and eradicate this pest are not as robust as the USDA would desire. In order to stay ahead of this hard to detect beetle, the USDA is attempting to contain the beetle before it spreads beyond its known positions by regulating articles.

A regulated article under the USDA's quarantine includes any of the following items:
- emerald ash borer
- firewood of all hardwood species (for example ash, oak, maple and hickory)
- nursery stock and green lumber of ash
- any other ash material, whether living, dead, cut or fallen, including logs, stumps, roots, branches, as well as composted and not composted chips of the genus ash (Mountain ash is not included)

In addition, any other article, product or means of conveyance not listed above may be designated as a regulated article if a USDA inspector determines that it presents a risk of spreading EAB once a quarantine is in effect for your county.

## Wood Disposal

A very important aspect of planning is determining how wood infested with EAB will be handled, keeping in mind that quarantines will restrict its movement. Consider who will cut and haul the dead and dying trees? Is there an accessible, secured site big enough to store and sort the hundreds of trees and the associated brush and chips? How will wood be disposed of or utilized? Do you have equipment capable of handling the amount and size of ash trees your tree inventory has identified? Once your county is under quarantine for EAB, contact USDA-APHIS-PPQ at 515-251-4083 or visit the website http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/regulatory.shtml. Wood waste can be disposed of as you normally would if your county is not part of a quarantine.

## Canopy Replacement

As budget permits, all removed trees will be replaced. All trees will meet the restrictions in city ordinance. The new plantings will be a diverse mix and will not include ash, maple, cottonwood, poplar, box elder, Chinese elm, evergreen, willow or black walnut.

## Postponed Work

While finances, staffing and equipment are focused on the management of ash, usual services may be delayed. Tree removal requests on genera other than ash will be prioritized by hazardous or emergency situations only.

## Monitoring

It is recommended that ash trees be checked with a visual survey every year for tree death and for the following signs and symptoms: canopy dieback, epicormic shoots, bark splitting, D-shaped borer exit holes, and wood pecker damage.

**Private Ash Trees**

It is strongly recommended that private property owners start removing ash trees on their property upon arrival of EAB if preventative treatments are not being used.

# Budget

**Current Budget**

Total $6,000 over 6 years ($1,000/year)

**FY 2018 Budget**
    Removal: $800
    *Or saving for ash tree treatment and/or future ash removal
    Planting: $200

**FY 2019 Budget**
    Removal: $800
    *Or saving for ash tree treatment and/or future ash removal
    Planting: $100
    Routine trimming: $100

**FY 2020 Budget**
    Removal: $800
    *Or saving for ash tree treatment and/or future ash removal
    Planting: $200

**FY 2021 Budget**
    Removal: $800
    *Or saving for ash tree treatment and/or future ash removal
    Planting: $100
    Routine trimming: $100

**FY 2022 Budget**
    Removal: $800
    *Or saving for ash tree treatment and/or future ash removal
    Planting: $200

**FY 2023 Budget**
    Removal: $800
    *Or saving for ash tree treatment and/or future ash removal
    Planting: $100
    Routine trimming: $100

*Reduction of ash over 6 years: Approximately 4 ash trees removed (approximately 7% of ash). It will take approximately 56 years to remove all ash with the current budget.

<u>Purposed Budget Increase</u>
EAB could potentially kill all ash trees in Varina within 4 years of its arrival. To remove all ash trees within 6 years the budget would need to be increased to $8,400 a year. If the budget were increased to $4,000 a year all ash could be removed within 13 years. Additionally, it is recommended that Varina apply for grants to fund replacement trees. Utility Company grants are usually between $500 and $10,000 for community-based, tree-planting projects that include parks, gateways, cemeteries, nature trails, libraries, nursing homes, and schools.

Another option being considered by many communities is treating a number of selected trees, either to maintain those trees in the landscape or to delay their removal – to spread out the costs and number of trees needing removed all at once. Trunk injection is administered every two years for the life of the tree. If treatment is discontinued, the tree dies. For instance, in this treatment scenario, the average ash diameter is 20 inches and at $15 per inch, about 4 trees could be treated per year (every other year treatment). This would be 8 trees selected for treatment $1,200 a year, and Varina would still need to find $36,800 for removal. Alternatively, if there are 15 treatable trees, it would cost approximately $2,250 a year for treatment and leave $31,200 for removal. These are alternatives to straight removal of ash trees. However, whether or not the treatment option is selected, there will be an increased cost of dealing with ash trees if EAB is found in Varina. It is suggested to consider increasing the budget to plan for this.

# Works Cited

Census Bureau. 2010. http://censtats.census.gov/data/IA/1601964290.pdf (April, 2013)

USDA Forest Service, et al. 2006. i-Tree Software Suite v1.0 User's Manual. Pp. 27-40.

McPherson EG, Simpson JR, Peper PJ, Gardner SL, Vargas KE, Ho J, Maco S, Xiao Q. 2005b. City of Charleston, South Carolina, municipal forest resource analysis. Internal Tech Rep. Davis, CA: U.S. Department of Agriculture, Center for Urban Forest Research. p. 57

Nowak, DJ and JF Dwyer. 2007. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J. (ed.) Urban and Community Forestry in the Northeast. New York: Springer. Pp. 25-46.

Peper, Paula J; McPherson, E Gregory; Simpson, James R; Vargas, Kelaine E; Xiao, Qingfu 2009. Lower Midwest community tree guide: benefits, costs, and strategic planting. Gen. Tech. Rep. PSW-GTR-219. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. p.115

# Appendix A: i-Tree Data

**Table 1: Annual Energy Benefits**

**Varina**

## Annual Energy Benefits of Public Trees

4/1/2018

| Species | Total Electricity (MWh) | Electricity ($) | Total Natural Gas (Therms) | Natural Gas ($) | Total ($) | Standard Error | % of Total Trees | % of Total $ | Avg. $/tree |
|---|---|---|---|---|---|---|---|---|---|
| Green ash | 17.6 | 1,336 | 2,428.2 | 2,380 | 3,716 | (N/A) | 37.8 | 53.1 | 68.81 |
| Silver maple | 6.4 | 484 | 836.6 | 820 | 1,304 | (N/A) | 14.7 | 18.7 | 62.10 |
| Black walnut | 3.3 | 250 | 456.3 | 447 | 697 | (N/A) | 7.7 | 10.0 | 63.36 |
| Northern hackberry | 2.0 | 152 | 284.4 | 279 | 431 | (N/A) | 6.3 | 6.2 | 47.88 |
| Spruce | 0.5 | 40 | 81.1 | 79 | 119 | (N/A) | 5.6 | 1.7 | 14.90 |
| Broadleaf Deciduous Small | 0.1 | 7 | 16.0 | 16 | 23 | (N/A) | 4.2 | 0.3 | 3.75 |
| Norway maple | 0.4 | 31 | 64.2 | 63 | 94 | (N/A) | 3.5 | 1.3 | 18.87 |
| Apple | 0.1 | 6 | 14.7 | 14 | 21 | (N/A) | 2.8 | 0.3 | 5.20 |
| Eastern red cedar | 0.4 | 34 | 65.8 | 64 | 98 | (N/A) | 2.8 | 1.4 | 24.57 |
| Honeylocust | 0.7 | 56 | 96.0 | 94 | 150 | (N/A) | 2.1 | 2.1 | 50.08 |
| Kentucky coffeetree | 0.0 | 1 | 1.4 | 1 | 2 | (N/A) | 2.1 | 0.0 | 0.66 |
| Black spruce | 0.0 | 1 | 2.4 | 2 | 3 | (N/A) | 1.4 | 0.0 | 1.65 |
| Eastern redbud | 0.1 | 6 | 13.5 | 13 | 19 | (N/A) | 1.4 | 0.3 | 9.53 |
| Northern red oak | 0.0 | 1 | 2.4 | 2 | 3 | (N/A) | 1.4 | 0.0 | 1.67 |
| Mulberry | 0.2 | 14 | 24.7 | 24 | 38 | (N/A) | 0.7 | 0.5 | 38.13 |
| Sugar maple | 0.4 | 28 | 50.0 | 49 | 77 | (N/A) | 0.7 | 1.1 | 77.21 |
| American basswood | 0.0 | 0 | 0.5 | 0 | 1 | (N/A) | 0.7 | 0.0 | 0.69 |
| Maple | 0.0 | 0 | 0.7 | 1 | 1 | (N/A) | 0.7 | 0.0 | 1.03 |
| Norway spruce | 0.1 | 4 | 9.5 | 9 | 14 | (N/A) | 0.7 | 0.2 | 13.58 |
| American elm | 0.1 | 6 | 11.7 | 11 | 18 | (N/A) | 0.7 | 0.3 | 17.66 |
| Eastern cottonwood | 0.4 | 33 | 59.0 | 58 | 91 | (N/A) | 0.7 | 1.3 | 91.02 |
| Broadleaf Deciduous Medium | 0.3 | 24 | 47.4 | 46 | 71 | (N/A) | 0.7 | 1.0 | 70.84 |
| Japanese tree lilac | 0.0 | 0 | 0.6 | 1 | 1 | (N/A) | 0.7 | 0.0 | 0.87 |
| Total | 33.1 | 2,516 | 4,567.1 | 4,476 | 6,992 | (N/A) | 100.0 | 100.0 | 48.89 |

**Table 2: Annual Stormwater Benefits**

Varina

## Annual Stormwater Benefits of Public Trees

4/1/2018

| Species | Total rainfall interception (Gal) | Total ($) | Standard Error | % of Total Trees | % of Total $ | Avg. $/tree |
|---|---|---|---|---|---|---|
| Green ash | 218,864 | 5,931 | (N/A) | 37.8 | 52.7 | 109.84 |
| Silver maple | 97,286 | 2,636 | (N/A) | 14.7 | 23.4 | 125.55 |
| Black walnut | 35,908 | 973 | (N/A) | 7.7 | 8.6 | 88.47 |
| Northern hackberry | 19,306 | 523 | (N/A) | 6.3 | 4.6 | 58.13 |
| Spruce | 5,707 | 155 | (N/A) | 5.6 | 1.4 | 19.33 |
| Broadleaf Deciduous Small | 302 | 8 | (N/A) | 4.2 | 0.1 | 1.36 |
| Norway maple | 3,252 | 88 | (N/A) | 3.5 | 0.8 | 17.63 |
| Apple | 287 | 8 | (N/A) | 2.8 | 0.1 | 1.94 |
| Eastern red cedar | 6,538 | 177 | (N/A) | 2.8 | 1.6 | 44.30 |
| Honeylocust | 9,389 | 254 | (N/A) | 2.1 | 2.3 | 84.81 |
| Kentucky coffeetree | 54 | 1 | (N/A) | 2.1 | 0.0 | 0.48 |
| Black spruce | 76 | 2 | (N/A) | 1.4 | 0.0 | 1.03 |
| Eastern redbud | 272 | 7 | (N/A) | 1.4 | 0.1 | 3.68 |
| Northern red oak | 38 | 1 | (N/A) | 1.4 | 0.0 | 0.51 |
| Mulberry | 667 | 18 | (N/A) | 0.7 | 0.2 | 18.06 |
| Sugar maple | 5,330 | 144 | (N/A) | 0.7 | 1.3 | 144.44 |
| American basswood | 8 | 0 | (N/A) | 0.7 | 0.0 | 0.22 |
| Maple | 12 | 0 | (N/A) | 0.7 | 0.0 | 0.32 |
| Norway spruce | 596 | 16 | (N/A) | 0.7 | 0.1 | 16.14 |
| American elm | 432 | 12 | (N/A) | 0.7 | 0.1 | 11.72 |
| Eastern cottonwood | 7,239 | 196 | (N/A) | 0.7 | 1.7 | 196.17 |
| Broadleaf Deciduous Medium | 3,764 | 102 | (N/A) | 0.7 | 0.9 | 102.01 |
| Japanese tree lilac | 7 | 0 | (N/A) | 0.7 | 0.0 | 0.20 |
| Citywide total | 415,334 | 11,256 | (N/A) | 100.0 | 100.0 | 78.71 |

## Table 3: Annual Air Quality Benefits

**Annual Air Quality Benefits of Public Trees**

4/1/2018

| Species | Deposition (lb) O₃ | NO₂ | PM₁₀ | SO₂ | Total Depos. ($) | Avoided (lb) NO₂ | PM₁₀ | VOC | SO₂ | Total Avoided ($) | BVOC Emissions (lb) | BVOC Emissions ($) | Total (lb) | Total ($) Standard Error | % of Total Trees | Avg. $/tree |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Green ash | 29.1 | 4.7 | 13.5 | 1.3 | 154 | 84.2 | 12.2 | 11.7 | 79.8 | 524 | 0.0 | 0 | 236.6 | 678 (N/A) | 37.8 | 12.56 |
| Silver maple | 17.7 | 3.0 | 8.6 | 0.8 | 95 | 30.1 | 4.4 | 4.2 | 28.9 | 188 | -9.2 | -35 | 88.3 | 248 (N/A) | 14.7 | 11.83 |
| Black walnut | 4.3 | 0.7 | 2.1 | 0.2 | 23 | 15.8 | 2.3 | 2.2 | 14.9 | 98 | 0.0 | 0 | 42.4 | 121 (N/A) | 7.7 | 11.00 |
| Northern hackberry | 3.0 | 0.5 | 1.5 | 0.1 | 16 | 9.7 | 1.4 | 1.3 | 9.1 | 60 | 0.0 | 0 | 26.7 | 76 (N/A) | 6.3 | 8.49 |
| Spruce | 0.5 | 0.1 | 0.5 | 0.1 | 4 | 2.6 | 0.4 | 0.4 | 2.4 | 16 | -1.7 | -6 | 5.2 | 13 (N/A) | 5.6 | 1.65 |
| Broadleaf Deciduous Small | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.5 | 0.1 | 0.1 | 0.4 | 3 | 0.0 | 0 | 1.1 | 3 (N/A) | 4.2 | 0.51 |
| Norway maple | 0.6 | 0.1 | 0.3 | 0.0 | 3 | 2.0 | 0.3 | 0.3 | 1.9 | 13 | -0.1 | -1 | 5.3 | 15 (N/A) | 3.5 | 3.02 |
| Apple | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.4 | 0.1 | 0.1 | 0.4 | 3 | 0.0 | 0 | 1.0 | 3 (N/A) | 2.8 | 0.72 |
| Eastern red cedar | 1.4 | 0.3 | 1.1 | 0.2 | 9 | 2.2 | 0.3 | 0.3 | 2.0 | 13 | -3.6 | -14 | 4.1 | 9 (N/A) | 2.8 | 2.19 |
| Honeylocust | 1.9 | 0.3 | 0.8 | 0.1 | 10 | 3.5 | 0.5 | 0.5 | 3.3 | 22 | -1.5 | -6 | 9.4 | 26 (N/A) | 2.1 | 8.65 |
| Kentucky coffeetree | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0 | 0.1 | 0 (N/A) | 2.1 | 0.08 |
| Black spruce | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.1 | 0.0 | 0.0 | 0.1 | 0 | 0.0 | 0 | 0.1 | 0 (N/A) | 1.4 | 0.18 |
| Eastern redbud | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.4 | 0.1 | 0.1 | 0.4 | 2 | 0.0 | 0 | 0.9 | 3 (N/A) | 1.4 | 1.33 |
| Northern red oak | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.1 | 0.0 | 0.0 | 0.1 | 0 | 0.0 | 0 | 0.1 | 0 (N/A) | 1.4 | 0.21 |
| Mulberry | 0.2 | 0.0 | 0.1 | 0.0 | 1 | 0.9 | 0.1 | 0.1 | 0.8 | 5 | 0.0 | 0 | 2.3 | 7 (N/A) | 0.7 | 6.56 |
| Sugar maple | 0.8 | 0.1 | 0.4 | 0.0 | 4 | 1.8 | 0.3 | 0.2 | 1.7 | 11 | -0.6 | -2 | 4.7 | 13 (N/A) | 0.7 | 12.96 |
| American basswood | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 (N/A) | 0.7 | 0.08 |
| Maple | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 (N/A) | 0.7 | 0.13 |
| Norway spruce | 0.1 | 0.0 | 0.1 | 0.0 | 0 | 0.3 | 0.0 | 0.0 | 0.3 | 2 | -0.2 | -1 | 0.6 | 1 (N/A) | 0.7 | 1.48 |
| American elm | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.4 | 0.1 | 0.1 | 0.4 | 2 | 0.0 | 0 | 0.9 | 3 (N/A) | 0.7 | 2.54 |
| Eastern cottonwood | 1.2 | 0.2 | 0.5 | 0.1 | 6 | 2.1 | 0.3 | 0.3 | 2.0 | 13 | 0.0 | 0 | 6.6 | 19 (N/A) | 0.7 | 19.04 |
| Broadleaf Deciduous Medium | 0.9 | 0.1 | 0.4 | 0.0 | 5 | 1.6 | 0.2 | 0.2 | 1.5 | 10 | -0.2 | -1 | 4.7 | 14 (N/A) | 0.7 | 13.58 |
| Japanese tree lilac | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 (N/A) | 0.7 | 0.11 |
| Citywide total | 61.6 | 10.2 | 30.0 | 2.9 | 331 | 158.5 | 23.1 | 22.0 | 150.2 | 986 | -17.2 | -65 | 441.2 | 1,253 (N/A) | 100.0 | 8.76 |

**Table 4: Annual Carbon Stored**

## Varina

## Stored CO2 Benefits of Public Trees

4/1/2018

| Species | Total Stored CO2 (lbs) | Total ($) | Standard Error | % of Total Trees | % of Total $ | Avg. $/tree |
|---|---|---|---|---|---|---|
| Green ash | 948,387 | 7,113 | (N/A) | 37.8 | 56.6 | 131.72 |
| Silver maple | 420,033 | 3,150 | (N/A) | 14.7 | 25.1 | 150.01 |
| Black walnut | 137,524 | 1,031 | (N/A) | 7.7 | 8.2 | 93.77 |
| Northern hackberry | 45,228 | 339 | (N/A) | 6.3 | 2.7 | 37.69 |
| Spruce | 2,967 | 22 | (N/A) | 5.6 | 0.2 | 2.78 |
| Broadleaf Deciduous | 977 | 7 | (N/A) | 4.2 | 0.1 | 1.22 |
| Norway maple | 9,298 | 70 | (N/A) | 3.5 | 0.6 | 13.95 |
| Apple | 949 | 7 | (N/A) | 2.8 | 0.1 | 1.78 |
| Eastern red cedar | 4,408 | 33 | (N/A) | 2.8 | 0.3 | 8.27 |
| Honeylocust | 24,503 | 184 | (N/A) | 2.1 | 1.5 | 61.26 |
| Kentucky coffeetree | 36 | 0 | (N/A) | 2.1 | 0.0 | 0.09 |
| Black spruce | 4 | 0 | (N/A) | 1.4 | 0.0 | 0.02 |
| Eastern redbud | 922 | 7 | (N/A) | 1.4 | 0.1 | 3.46 |
| Northern red oak | 25 | 0 | (N/A) | 1.4 | 0.0 | 0.09 |
| Mulberry | 3,037 | 23 | (N/A) | 0.7 | 0.2 | 22.78 |
| Sugar maple | 22,806 | 171 | (N/A) | 0.7 | 1.4 | 171.04 |
| American basswood | 13 | 0 | (N/A) | 0.7 | 0.0 | 0.09 |
| Maple | 17 | 0 | (N/A) | 0.7 | 0.0 | 0.13 |
| Norway spruce | 257 | 2 | (N/A) | 0.7 | 0.0 | 1.93 |
| American elm | 908 | 7 | (N/A) | 0.7 | 0.1 | 6.81 |
| Eastern cottonwood | 39,259 | 294 | (N/A) | 0.7 | 2.3 | 294.44 |
| Broadleaf Deciduous | 14,280 | 107 | (N/A) | 0.7 | 0.9 | 107.10 |
| Japanese tree lilac | 14 | 0 | (N/A) | 0.7 | 0.0 | 0.10 |
| Citywide total | 1,675,852 | 12,569 | (N/A) | 100.0 | 100.0 | 87.89 |

# Table 5: Annual Carbon Sequestered

Varina

**Annual CO  Benefits of Public Trees**

4/1/2018

| Species | Sequestered (lb) | Sequestered ($) | Decomposition Release (lb) | Maintenance Release (lb) | Total Released ($) | Avoided (lb) | Avoided ($) | Net Total (lb) | Total Standard ($) Error | % of Total Trees | % of Total $ | Avg. $/tree |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Green ash | 43,114 | 323 | -4,552 | -188 | -36 | 29,526 | 221 | 67,899 | 509 (N/A) | 37.8 | 49.6 | 9.43 |
| Silver maple | 28,892 | 217 | -2,017 | -74 | -16 | 10,702 | 80 | 37,504 | 281 (N/A) | 14.7 | 27.4 | 13.39 |
| Black walnut | 8,114 | 61 | -660 | -34 | -5 | 5,521 | 41 | 12,941 | 97 (N/A) | 7.7 | 9.5 | 8.82 |
| Northern hackberry | 2,520 | 19 | -217 | -19 | -2 | 3,363 | 25 | 5,646 | 42 (N/A) | 6.3 | 4.1 | 4.70 |
| Spruce | 484 | 4 | -14 | -10 | 0 | 877 | 7 | 1,337 | 10 (N/A) | 5.6 | 1.0 | 1.25 |
| Broadleaf Deciduous Smal | 157 | 1 | -5 | -2 | 0 | 152 | 1 | 302 | 2 (N/A) | 4.2 | 0.2 | 0.38 |
| Norway maple | 800 | 6 | -45 | -5 | 0 | 695 | 5 | 1,445 | 11 (N/A) | 3.5 | 1.1 | 2.17 |
| Apple | 140 | 1 | -5 | -2 | 0 | 141 | 1 | 274 | 2 (N/A) | 2.8 | 0.2 | 0.51 |
| Eastern red cedar | 43 | 0 | -21 | -8 | 0 | 747 | 6 | 761 | 6 (N/A) | 2.8 | 0.6 | 1.43 |
| Honeylocust | 2,982 | 22 | -118 | -6 | -1 | 1,240 | 9 | 4,099 | 31 (N/A) | 2.1 | 3.0 | 10.25 |
| Kentucky coffeetree | 8 | 0 | 0 | -1 | 0 | 13 | 0 | 20 | 0 (N/A) | 2.1 | 0.0 | 0.05 |
| Black spruce | 3 | 0 | 0 | 0 | 0 | 21 | 0 | 24 | 0 (N/A) | 1.4 | 0.0 | 0.09 |
| Eastern redbud | 123 | 1 | -4 | -1 | 0 | 130 | 1 | 246 | 2 (N/A) | 1.4 | 0.2 | 0.92 |
| Northern red oak | 10 | 0 | 0 | 0 | 0 | 22 | 0 | 31 | 0 (N/A) | 1.4 | 0.0 | 0.12 |
| Mulberry | 268 | 2 | -15 | -2 | 0 | 308 | 2 | 560 | 4 (N/A) | 0.7 | 0.4 | 4.20 |
| Sugar maple | 994 | 7 | -109 | -4 | -1 | 623 | 5 | 1,504 | 11 (N/A) | 0.7 | 1.1 | 11.28 |
| American basswood | 3 | 0 | 0 | 0 | 0 | 4 | 0 | 8 | 0 (N/A) | 0.7 | 0.0 | 0.06 |
| Maple | 3 | 0 | 0 | 0 | 0 | 7 | 0 | 9 | 0 (N/A) | 0.7 | 0.0 | 0.07 |
| Norway spruce | 53 | 0 | -1 | -1 | 0 | 94 | 1 | 145 | 1 (N/A) | 0.7 | 0.1 | 1.08 |
| American elm | 111 | 1 | -4 | -1 | 0 | 137 | 1 | 242 | 2 (N/A) | 0.7 | 0.2 | 1.82 |
| Eastern cottonwood | 912 | 7 | -188 | -5 | -1 | 734 | 6 | 1,453 | 11 (N/A) | 0.7 | 1.1 | 10.90 |
| Broadleaf Deciduous Medi | 0 | 0 | -69 | -4 | -1 | 539 | 4 | 466 | 3 (N/A) | 0.7 | 0.3 | 3.49 |
| Japanese tree lilac | 9 | 0 | 0 | 0 | 0 | 6 | 0 | 14 | 0 (N/A) | 0.7 | 0.0 | 0.10 |
| Citywide total | 89,741 | 673 | -8,047 | -368 | -63 | 55,604 | 417 | 136,930 | 1,027 (N/A) | 100.0 | 100.0 | 7.18 |

**Table 6: Annual Social and Aesthetic Benefits**

## Varina

# Annual Aesthetic/Other Benefits of Public Trees

4/1/2018

| Species | Total ($) | Standard Error | % of Total Trees | % of Total $ | Avg. $/tree |
|---|---|---|---|---|---|
| Green ash | 3,282 | (N/A) | 37.8 | 42.4 | 60.77 |
| Silver maple | 2,178 | (N/A) | 14.7 | 28.1 | 103.70 |
| Black walnut | 659 | (N/A) | 7.7 | 8.5 | 59.94 |
| Northern hackberry | 347 | (N/A) | 6.3 | 4.5 | 38.59 |
| Spruce | 140 | (N/A) | 5.6 | 1.8 | 17.53 |
| Broadleaf Deciduous Small | 7 | (N/A) | 4.2 | 0.1 | 1.10 |
| Norway maple | 88 | (N/A) | 3.5 | 1.1 | 17.53 |
| Apple | 7 | (N/A) | 2.8 | 0.1 | 1.63 |
| Eastern red cedar | 14 | (N/A) | 2.8 | 0.2 | 3.42 |
| Honeylocust | 778 | (N/A) | 2.1 | 10.1 | 259.39 |
| Kentucky coffeetree | 16 | (N/A) | 2.1 | 0.2 | 5.26 |
| Black spruce | 10 | (N/A) | 1.4 | 0.1 | 5.03 |
| Eastern redbud | 6 | (N/A) | 1.4 | 0.1 | 3.22 |
| Northern red oak | 3 | (N/A) | 1.4 | 0.0 | 1.54 |
| Mulberry | 15 | (N/A) | 0.7 | 0.2 | 15.48 |
| Sugar maple | 97 | (N/A) | 0.7 | 1.3 | 97.04 |
| American basswood | 2 | (N/A) | 0.7 | 0.0 | 1.78 |
| Maple | 0 | (N/A) | 0.7 | 0.0 | 0.04 |
| Norway spruce | 15 | (N/A) | 0.7 | 0.2 | 15.42 |
| American elm | 20 | (N/A) | 0.7 | 0.3 | 19.89 |
| Eastern cottonwood | 58 | (N/A) | 0.7 | 0.8 | 58.34 |
| Broadleaf Deciduous Medium | 0 | (N/A) | 0.7 | 0.0 | 0.00 |
| Japanese tree lilac | 0 | (N/A) | 0.7 | 0.0 | 0.03 |
| Citywide total | 7,742 | (N/A) | 100.0 | 100.0 | 54.14 |

**Table 7: Summary of Benefits in Dollars**

### Varina

## Total Annual Benefits of Public Trees by Species ($)

4/1/2018

| Species | Energy | $CO_2$ | Air Quality | Stormwater | Aesthetic/Other | Total ($) | Standard Error | % of Total $ |
|---|---|---|---|---|---|---|---|---|
| Green ash | 3,716 | 509 | 678 | 5,931 | 3,282 | 14,116 | (N/A) | 49.9 |
| Silver maple | 1,304 | 281 | 248 | 2,636 | 2,178 | 6,648 | (N/A) | 23.5 |
| Black walnut | 697 | 97 | 121 | 973 | 659 | 2,547 | (N/A) | 9.0 |
| Northern hackberry | 431 | 42 | 76 | 523 | 347 | 1,420 | (N/A) | 5.0 |
| Spruce | 119 | 10 | 13 | 155 | 140 | 437 | (N/A) | 1.5 |
| Broadleaf Deciduous Sn | 23 | 2 | 3 | 8 | 7 | 43 | (N/A) | 0.2 |
| Norway maple | 94 | 11 | 15 | 88 | 88 | 296 | (N/A) | 1.0 |
| Apple | 21 | 2 | 3 | 8 | 7 | 40 | (N/A) | 0.1 |
| Eastern red cedar | 98 | 6 | 9 | 177 | 14 | 304 | (N/A) | 1.1 |
| Honeylocust | 150 | 31 | 26 | 254 | 778 | 1,240 | (N/A) | 4.4 |
| Kentucky coffeetree | 2 | 0 | 0 | 1 | 16 | 20 | (N/A) | 0.1 |
| Black spruce | 3 | 0 | 0 | 2 | 10 | 16 | (N/A) | 0.1 |
| Eastern redbud | 19 | 2 | 3 | 7 | 6 | 37 | (N/A) | 0.1 |
| Northern red oak | 3 | 0 | 0 | 1 | 3 | 8 | (N/A) | 0.0 |
| Mulberry | 38 | 4 | 7 | 18 | 15 | 82 | (N/A) | 0.3 |
| Sugar maple | 77 | 11 | 13 | 144 | 97 | 343 | (N/A) | 1.2 |
| American basswood | 1 | 0 | 0 | 0 | 2 | 3 | (N/A) | 0.0 |
| Maple | 1 | 0 | 0 | 0 | 0 | 2 | (N/A) | 0.0 |
| Norway spruce | 14 | 1 | 1 | 16 | 15 | 48 | (N/A) | 0.2 |
| American elm | 18 | 2 | 3 | 12 | 20 | 54 | (N/A) | 0.2 |
| Eastern cottonwood | 91 | 11 | 19 | 196 | 58 | 375 | (N/A) | 1.3 |
| Broadleaf Deciduous Mᵉ | 71 | 3 | 14 | 102 | 0 | 190 | (N/A) | 0.7 |
| Japanese tree lilac | 1 | 0 | 0 | 0 | 0 | 1 | (N/A) | 0.0 |
| Citywide Total | 6,992 | 1,027 | 1,253 | 11,256 | 7,742 | 28,269 | (N/A) | 100.0 |
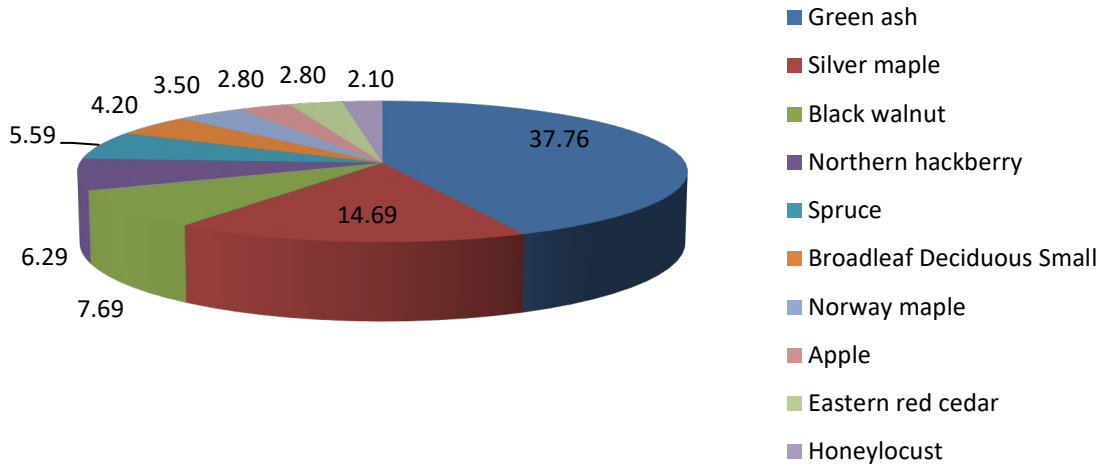
**Figure 1: Species Distribution**

## Relative Age Distribution of Top 10 Public Tree Species (%)
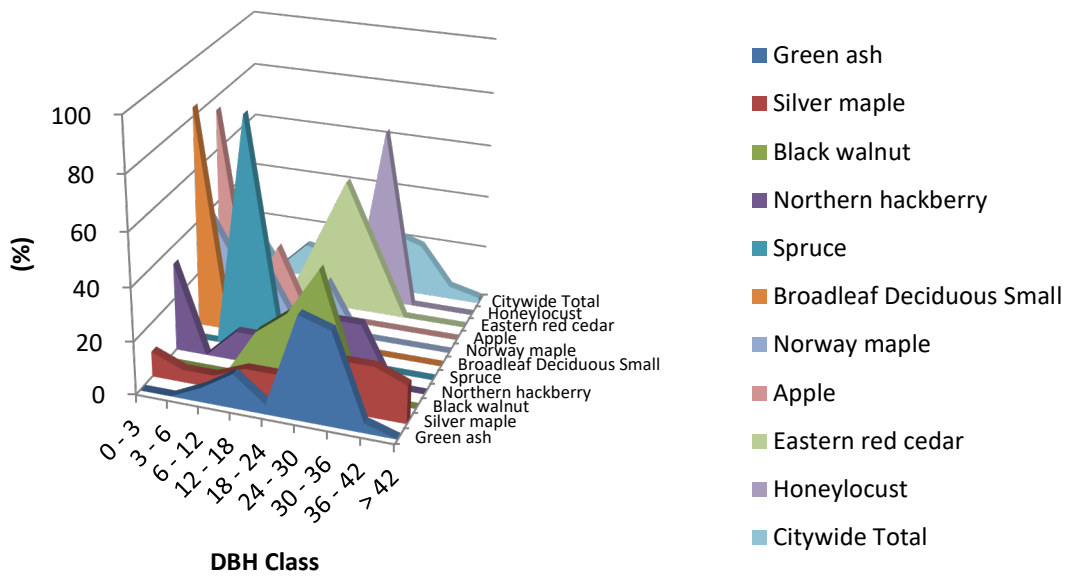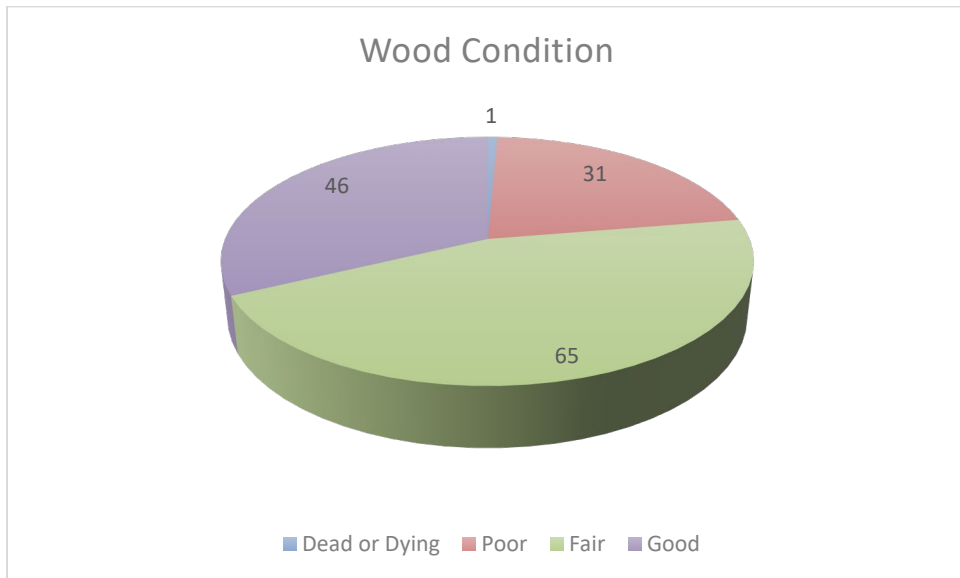


**Figure 2: Relative Age Class**

**Figure 3: Foliage Condition**



**Figure 4: Wood Condition**
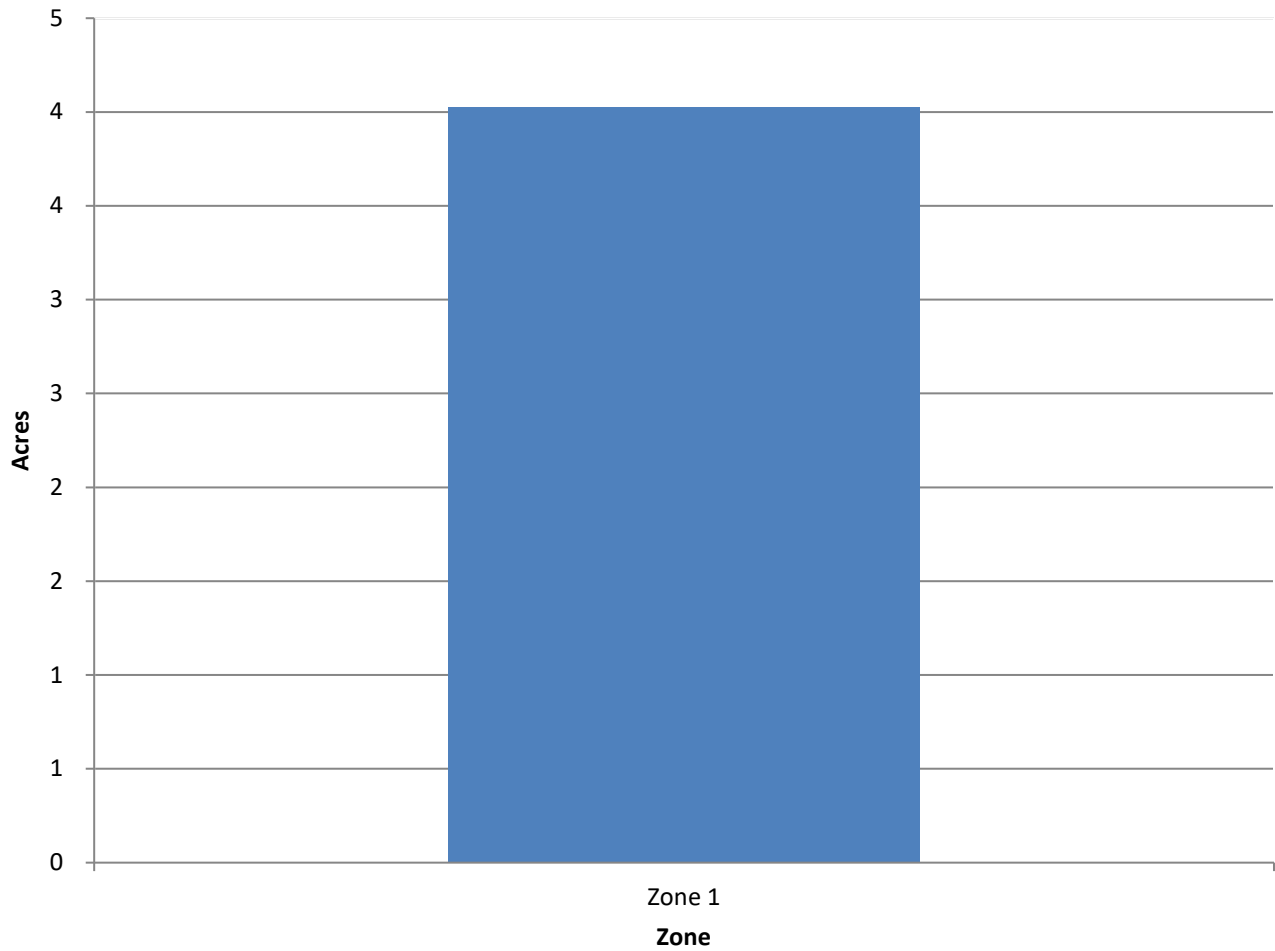
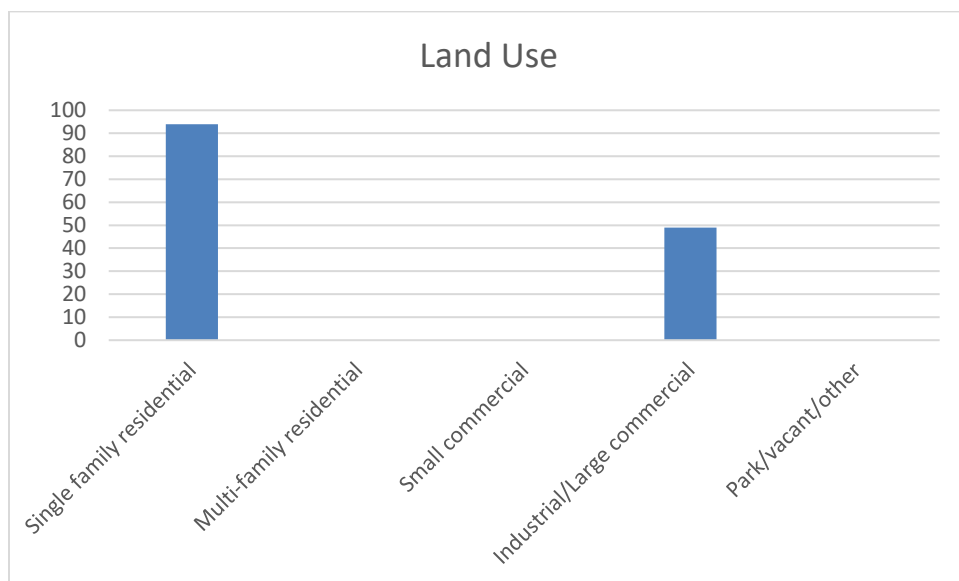## Canopy Cover of Public Trees (Acres)



**Figure 5: Canopy Cover in Acres**
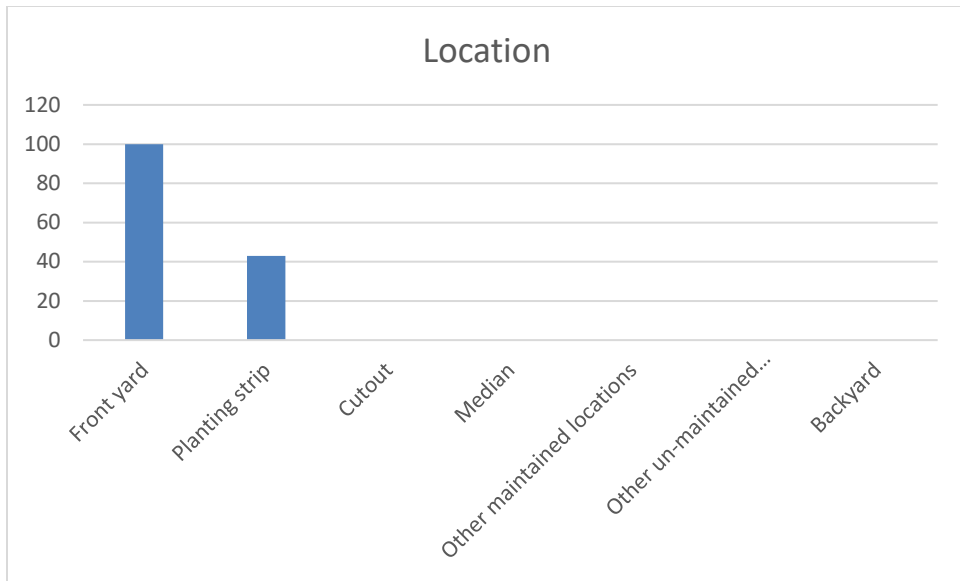


**Figure 6: Land Use of city/park trees**

**Figure 7: Location of city/park trees**

**Figure 1: Location of Ash Trees**

**Figure 2: Location of EAB symptoms**

**Figure 3: Location of Poor Condition Trees**

**Figure 4: Location of Trees with Recommended Maintenance**

**Figure 5: Maintenance Tasks** *City ownership of the trees recommended for removal should be verified prior to any removal*