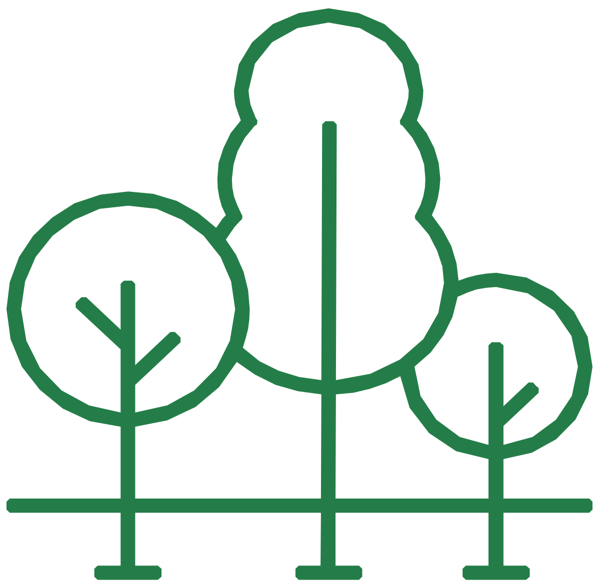
Athens Clarke County
Community Tree Study (iTree Eco)
Final Project Report

(Mayor & Commission Version)

(Prepared for the Athens-Clarke County Mayor and Commission by Athens-Clarke County (ACC), Central Services Department – Landscape Management Division, ACC Community Forestry Coordinator - Rodney Walters)



Athens-Clarke County
CommunityTree Study, 2021

Athens- Clarke County (ACC) iTree Eco Study, Final Project Report

A. ACC iTree Eco Study Project Description

The ACC iTree Eco Study, conducted in 2021 was designed to produce reliable data and information that identifies key characteristics about the trees in Athens-Clarke County on both private and public lands on a Countywide scale. This data and information includes composition, structure, and function of Athens' trees. This information is intended to inform Athens citizens about the community's trees and to provide County government decision makers and managers better information about the ACC's community trees. This will allow more informed decisions may be made in the dimensions of tree planting, maintenance, and updates to tree related policies and ordinance.

1. Purpose and Objectives of the ACC iTree Eco Study

This project met its purpose through the collection of tree and site data on 316 one tenth acre plots and by producing a wealth of reliable data about ACC's community trees within 10 separate stratification (land use) categories. The private land use areas includes single family residential, multi-family residential, industrial/commercial, and private agriculture/natural land areas. The public land use areas includes the University of Georgia undeveloped lands (agriculture and forested lands), ACC right-of-ways, ACC maintained park areas (defined by mowed and other highly maintained areas), ACC buildings/facilities properties, and ACC natural/undeveloped lands. An "Other" land use category includes both private and public holdings under the following criterion; churches, cemeteries, hospitals, schools, airport, state, and federal properties. The summary findings of the ACC iTree Ecosystem Analysis, 2021 states:

"ACC Community Tree Study Summary, 2021
Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the ACC Community Tree Study urban forest was conducted during 2021. Data from 316 field plots located throughout Athens Clarke County were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 13,460,000
- Tree Cover: 58.2 %
- Most common species of trees: Sweetgum, Loblolly pine, Water oak
- Percentage of trees less than 6" (15.2 cm) diameter: 57.3%
- Pollution Removal: 1.875 thousand tons/year ($2.8 million/year)
- Carbon Storage: 1.879 million tons ($320 million)
- Carbon Sequestration: 92.56 thousand tons ($15.8 million/year)
- Oxygen Production: 192.3 thousand tons/year
- Avoided Runoff: 150.1 million cubic feet/year ($10 million/year)
- Building energy savings: $4,780,000/year
- Carbon Avoided: 7.603 thousand tons/year ($1300000/year)
- Structural values: $7.12 billion"

The entire report may be seen in Appendix A.

In addition to the 2021 ACC iTree Ecosystem Analysis, separate sub-study reports were generated from plot data information through the iTree Eco model for ACC Right-of-ways, ACC Buildings/facilities, ACC Parks, and ACC Natural/undeveloped lands (Appendices D, E, F, G). Other reports may easily be generated when needed in other land use categorization areas, such as single family residential properties, to inform future ordinance decisions.

The 2021 ACC iTree Eco Study objectives were met as follows: The goal to engage in partnerships among ACC, the University of Georgia (UGA), and other tree-related communities to collect the random sample plot data of ACC's trees was realized. In addition to completing the primary end product, which is an iTree Eco model generated, peer reviewed analyses of ACC's private and public trees on a countywide scale (Appendix A), in-depth information has been produced regarding tree related human health & pollution removal values, tree leaf area, trees per acre, overall tree numbers, tree percentage of each land use category (stratum), tree species distribution, and storm water runoff mitigation. This information exist in the form of dozens of spreadsheets, graphs, and charts (Appendix H.1. - H.9). This new and credible information about ACC's community forest diversity, distribution, and tree related environmental and economic benefits is now available to help broaden the goal of developing a more comprehensive understanding about the functions and benefits provided by ACC's trees to Athens residents and county decision makers. This will information help facilitate community tree education and to inform and guide tree related policy and ordinance decisions. Additionally, this information may now serve as credible baseline data for the development of a 20 year strategic community forest management plan.

2. Current Benefits to the Urban and Community Forestry Program

The 2021 ACC iTree Eco Study benefits the Urban and Community Forestry Program in the areas of education, planning, management, and maintenance. The ACC Community Tree study in intended to serve as a communication tool to boost conversations and interests as part of a public information and education campaign about the community's trees. This study shows trees as assets and may encourage investments in management and maintenance and thus increase community forest health and resiliency. The initial findings from this study are already being evaluated and an executive summary white paper will be delivered during a formal presentation to the ACC Mayor and Commission in May, 2022. UGA's Dr. Gordon and ACC staff will present information from the recent community forest assessment to provide detailed information on the current condition of ACC's community's forest and the management and policy needs required to sustain it.

The ACC Mayor and Commission's formal acceptance of the ACC Community Tree Study, is intended to educate and inform decision makers and residents alike about the value of the community's trees. A narrative about the structure, function, and value of ACC's community forest is being developed to guide tree related discussions, deliberations, and actions that are informed by credible data for the improvement of Athens' community forests. For example, this data may inform conversations that explor placing more lands under conservation easements to protect soils and thus tree canopy capacity. It may help enlighten the business community about monetary benefits that are produced by trees. The new and credible information from this study sheds light on the fact that ACC, which currently spends less than 1.16 cents per tree annually on direct field maintenance and risk mitigation activities, likely has a need to increase its tree maintenance and management resource allocations. This iTree Eco study conveys the critical role of ACC's publicly owned natural land areas and informs, in understandable terms, ecosystem values of its substantive green infrastructure areas. The pollution mitigation function and human health related benefits provided by the community trees is a powerful illustration about ecological and human interconnection. And, the storm water runoff data displays a vital and functional engineering utility, with values in the millions of dollars, provided by Athens' trees. Ultimately, the baseline data from the ACC tree study will be applied to formulate the development of a 20 year urban and community strategic management plan where subsequent 5 year studies will help to advise an adaptive management process for community forestry in ACC.

The ACC iTree Eco Study was designed to benefit Georgia's Urban and Community Forest program as a pilot project that holds the potential to serve as a model for other Georgia communities who may seek to conduct an iTree Eco study. A presentation about the process involved in developing and implementing an iTree Eco tree inventory and analysis was shared with the Georgia urban and community forestry community at the Georgia Tree Council Conference on November 4, 2021 (Appendix B). The presentation conveyed the steps involved in planning and implementing an iTree Eco study. It also shared some of the results and graphical product outputs that are generated from the iTree computer model. The development of this study has created an avenue whereby other Georgia communities may request information, consultations, suggestions, and discuss insights gained from urban and community forest members, within the State of Georgia.

The increases in professional and community capabilities that were realized through the experiences of everyone who was involved will only help to strengthen the Urban and Community Forestry program. The process has increased community networking and partnership, and project implementation capacities. It has provided valuable hands on involvement and long-term networking connections and opportunities among the urban forest professionals and UGA community forestry students who were involved. As these students graduate onward to other communities, they will carry their newfound connections, knowledge and experience to other circles. This will further contribute synergies among young urban forestry professionals at the State level and beyond, which will serve to strengthen Georgia's urban and Community Forestry programs and advance urban forestry in Georgia.

3. ACC iTree Eco Study Project Deliverables

- **Agreement with UGA, Warnell School of Forestry's, Dr. Jason Gordon to produce an Athens-Clarke County Urban Tree Inventory Outreach Publication, ACC iTree Study Executive Summary white paper and presentation to the ACC Mayor and Commission**. This white paper will provide a description of data analysis results as well as interpretations and implications from a public tree management perspective and from a private property perspective (Appendix C). Outcomes may include, for example, recommendations for ordinance incentives for conserving soils, tree planting, and other measures. Presentation to convey highlights of Executive summary (about the ACC Tree Study) and to address Athens decision makers for consideration to officially accept the iTree ACC Community Tree Study.

- **The Athens-Clarke County Community Tree Study, PowerPoint was presented by Rodney Walters and Dr. Jason Gordon to the Georgia Urban and Community Forestry community at the Georgia Tree Council Conference on November 4, 2021**. The presentation conveyed the process involved in developing and implementing an iTree Eco tree inventory, along with preliminary findings from the ACC Tree Study analyses of the first 228 plots, and concluded with a set of key takeaways (Appendix B – now updated to include all the 316 plots from which data was collected).

- **iTree Eco program generated report: iTree Ecosystem Analysis, ACC Community Tree Study, Urban Forest Effects and Values, November 2021** (Appendix A). Report delivered to ACC, Central Services Director (who communicated the summary to the ACC Manager) and the ACC Landscape Management managers. This report will be presented to the ACC Community Tree Council and will become publically available through the ACC Community Forester's web page.

- iTree Eco program generated report: iTree Ecosystem Analysis, ROW - ACC Community Tree Study, Urban Forest Effects and Values, November 2021 (Appendix D). Report delivered to the ACC Central Services Director and the ACC Landscape Management managers. Components of this report will be shared with the Mayor and Commission and will be available to the public.

ACC iTree Eco Study Project Deliverables (Continued)

- iTree Eco program generated report: iTree Ecosystem Analysis, Buildings & Facilities -ACC Community Tree Study, Urban Forest Effects and Values, November 2021 (Appendix E). Report delivered to the ACC Central Services Director and the ACC Landscape Management managers. Components of this report will be shared with the Mayor and Commission and will be available to the public.

- iTree Eco program generated report: iTree Ecosystem Analysis, Maintained/Mowed Park Areas - ACC Community Tree Study, Urban Forest Effects and Values, November 2021 (Appendix F). Report delivered to the ACC Central Services Director and the ACC Landscape Management managers. Components of this report will be shared with the Mayor and Commission and will be available to the public.

- iTree Eco program generated report: iTree Ecosystem Analysis, ACC Leisure Services, Natural, & Undeveloped Lands - ACC Community Tree Study, Urban Forest Effects and Values, November 2021 (Appendix G). Report will be made available to the ACC Sustainability Office and will be available to the public.

- Dozens of the ACC iTree Study model generated spreadsheets, graphs, and charts showing the breakdown analyses from the study's plot data. A subset of these materials may be viewed in Appendix H.1. - H.9.

- Athens-Clarke County Community Tree Study professionally produced video that describes the Athens' Community historical interest in trees, tree benefits, and introduction to the 2021 ACC Community Tree Study (Community Tree Study | Athens-Clarke County, GA - Official Website (accgov.com).

- What to Expect from the Community Tree Study professionally produced video that describes to private land owners when student data collections visit their property to collect tree study plot data (Community Tree Study | Athens-Clarke County, GA - Official Website (accgov.com).

- ACC Land Use Category Maps and 2021 ACC Community Tree Study plot maps in arcmap shapefile format and on Arc GIS Online. The link to this map is available to the public on the ACC Community Tree Study webpage (Community Tree Study | Athens-Clarke County, GA - Official Website (accgov.com).

4. ACC iTree Eco Study Project, Plan Changes or Modifications

The ACC iTree Eco study went according to plan with a two notable exceptions. The first change was an addition of a publicity plan into the project. The planning and setup phase specified the procurement of permissions to allow access private properties for plot data collection. Based on Dr. Gordon's recommendation, a publicity plan was developed. A request was made to ACC's Public Information Office for assistance who provided their support in the development of a publicity plan, which contributed to the success of the study. The ACC GIS Office also contributed tonline GIS service resources as an additional public access provision that helped residents complete online forms.

The other aspect of this project that deviated from the original plan occurred as a result of some technical limitations and challenges within the iTree Eco programing. The student data collection teams were collecting plot data faster than the private property access permissions were able to be acquired. In order to keep the student data collection teams working, a decision was made to generate new public and private property plots. The public plots gave students new areas from which to immediately collect data on public properties and the newly generated private plots provided new contacts from which requests for property access permissions could be made. Soon afterward, it was discovered that these new plots could not be added to an already existing project without losing the data that had already been previously transferred from the data collection devices into the iTree Eco Program. It was believed that a viable work around would be to simply create new projects, with the same exact setup parameters, collect the data and then later merge the data. As it turned out, the data from these "individual" projects could not be merged. As a result, plot data from over a hundred and fifty plots had to be entered by hand. In order to deliver the minimum number of plots (228) required by the project for statistical reliability on time for the project deadline. At this point, since there remained available data from an extra 88 plots and because this data would make the final product more reliable if included, a request was made to the Georgia Forestry Commission for a project deadline extension. The approval of this request provided enough time for the data entry completed by the end of November.

B. ACC iTree Eco Study Project Marketing and Public Relations

Figure 1. ACC's Community Forestry Coordinator, Rodney Walters

A publicity plan was formulated to inform the public about the ACC iTree Eco Study and to help facilitate permissions for private property access requests. Monthly meetings among representatives of ACC Landscape Management, the Warnell School of Forestry, the ACC Public Information Office, and the ACC GIS Office. These meetings were conducted between December, 2020 and April 2021 in order to develop the publicity plan (Appendix I.1). The publicity plan consisted of a water bill insert, an ACC Accent newsletter article, two media releases, social media posts, a Community Tree Study webpage, online maps, door hangars, informational fact sheets, and a Letter from the ACC Community Forestry Coordinator. The Community Forester letter requested permissions for private property access from private property owners.

1. ACC ITree Eco Press Releases, Media Items, and Announcements

The water bill insert was send out with the March, 2021 Athens water bill (Appendix I.2.). The first ACC Community Tree study related press release, occurring on February 23, 2021 (Appendix I.3.). It contained a statement about the upcoming tree study within the 2021 Athens Arbor Day Celebration news article. The second media release occurred on April 20th, 2021 (Appendix I.4.). This publication was a more specific description of the Community Tree Study. Another article announcing the upcoming tree study was published in the Vol.24, Issue 4, Accent, ACCGov Employee and Retiree Newsletter (Appendix I.5), Vol.24, Issue 4. The ACC public Information office released 5 social media post about the planned Community Tree Study between 25th, 2021 and April 20, 2021 (Appendix I.6). These articles, social media posts, and features were designed to kick off the tree study by informing the public that the study would be occurring and describing the why the study was being conducted.

2. Web Site, Videos, Online Permission Form, Project Information Document, Fact Sheet, Online Interactive Map, Door Hangars, and Letter from the Forester.

The ACC Community Study Webpage (Community Tree Study | Athens-Clarke County, GA - Official Website (accgov.com)) was built to inform the public about what the Community Tree Study is and to provide information about data collection, to notify Athens residents that they could be contacted with a request for permission to access their property, and to provide a "button" link to the Property Access Permission Form. The webpage contains 2 professionally produced videos, Community Tree Study, Summer 2021 featuring the

ACC Community Forester and What to Expect from the Tree Study Team featuring Dr. Jason Gordon and student data collectors. The Community Tree Study, Summer 2021. Both of these videos may be viewed on the ACC Community Tree Study Webpage (Community Tree Study | Athens-Clarke County, GA - Official Website (accgov.com)) or on You Tube at < https://www.youtube.com/watch?v=w-5KmD7jD7c > and < https://youtu.be/PFgkteEK41g >. The webpage also contains links to documents: Information about the Community Tree Study and request for help from property owners where study plots are located (Appendix I.7) and a UGA Warnell School of Forestry Fact sheet titled Stem-up Community Tree Inventory Instructions (Appendix I.8.). The last item on the tree study webpage is link to an online (AGOL) interactive map <https://www.arcgis.com/home/webmap/viewer.html?webmap=a19568ec33de402f90a1594a7315640c&extent=-83.5152,33.9624,-83.4977,33.9715 > that shows the 1/10 acre plots to scale as you zoom in on them as well as 10 land use stratification zones. The ACC Gov, Community Tree Study webpage was designed to both inform the public about the Community Tree Study and to serve as a place where property owners could verify what was going on with the tree study and have the ability, through the online form, to provide their permission for the data collection teams to go on the property.

In addition to the ACC Community Tree Study webpage, 2 door hangars and a letter from the ACC forester were created as part of the information and permission request process. One door hangar is a permission request complete with a QR code to quickly access the online permission form and the other is a notification that the data teams had visited the property and completed their data collection (Appendix I.9.). The ACC Forester letter is a brief description of the tree study project and a property access request. The ACC forester letter contained a QR code so property owners could quickly access the online permission form and the letter also mailed out with a paper permission form and self-addressed postage paid return envelope (Appendix I.10.).

The purpose of the early 2021 publicity plan was to both inform residents about the upcoming ACC Community tree study and to ask for permissions to go on private property in order to collect data for the tree study. This activity may be considered as phase 1 of the overall public relations and marketing component of the ACC Community Tree Study. A second phase of marketing and public relations will occur in the spring and summer of 2022 with another round of media releases and ACC Community Forester engagements with Athens' communities, beginning with the Community Tree Council, the ACC Mayor and Commission, and the public to share the findings and to communicate the recommendations of the forthcoming Executive Summary White paper that will be written by Dr. Jason Gordon about the findings of the ACC iTree Eco study to both ACC decision makers and the public.

The work upon which this publication is based was funded in whole or in part through an Urban and Community Forestry grant awarded the Southern Region, State and Private Forestry, U.S. Forest Service and administered by the Georgia Forestry Commission.

Appendix

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(Mayor & Commission Version)

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Athens-Clarke County
Community Tree Study 2001

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Appendix A: (Countywide)

i-Tree

Ecosystem Analysis

ACC Community Tree Study

Urban Forest Effects and Values

November 2021

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the ACC Community Tree Study urban forest was conducted during 2021. Data from 316 field plots located throughout ACC Community Tree Study were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 13,460,000
- Tree Cover: 58.2 %
- Most common species of trees: Sweetgum, Loblolly pine, Water oak
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- Building energy savings: $4,780,000/year
- Carbon Avoided: 7.603 thousand tons/year ($1300000/year)
- Structural values: $7.12 billion

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of ACC Community Tree Study has an estimated 13,460,000 trees with a tree cover of 58.2 percent. The three most common species are Sweetgum (20.8 percent), Loblolly pine (12.9 percent), and Water oak (10.8 percent).

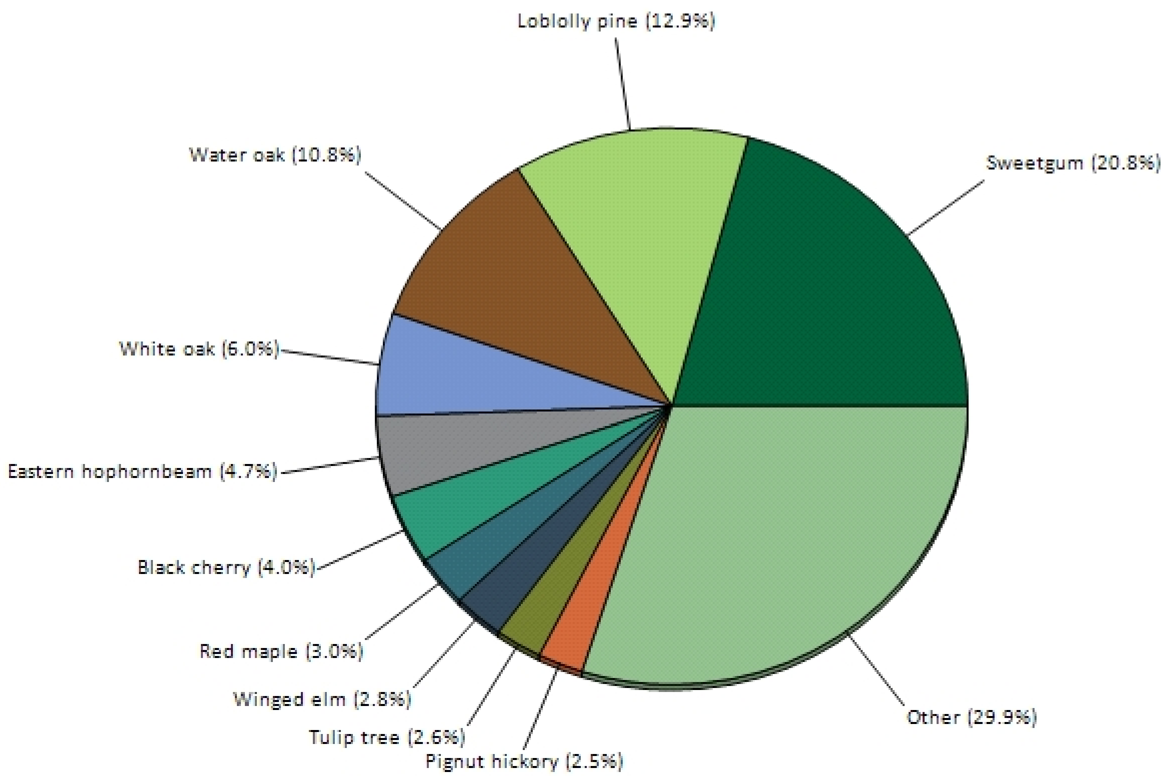


Figure 1. Tree species composition in ACC Community Tree Study

The overall tree density in ACC Community Tree Study is 175 trees/acre (see Appendix III for comparable values from other cities). For stratified projects, the highest tree densities in ACC Community Tree Study occur in Private Ag. & Natural Lands followed by ACC LS Natural & Undev Lands and Single Family Residential.

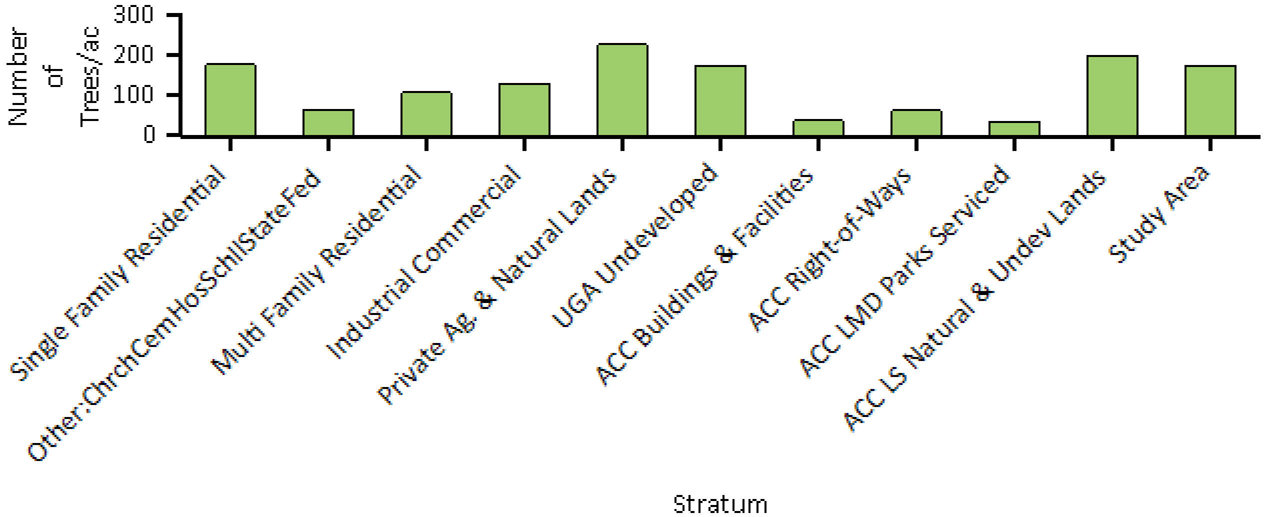


Figure 2. Number of trees/ac in ACC Community Tree Study by stratum

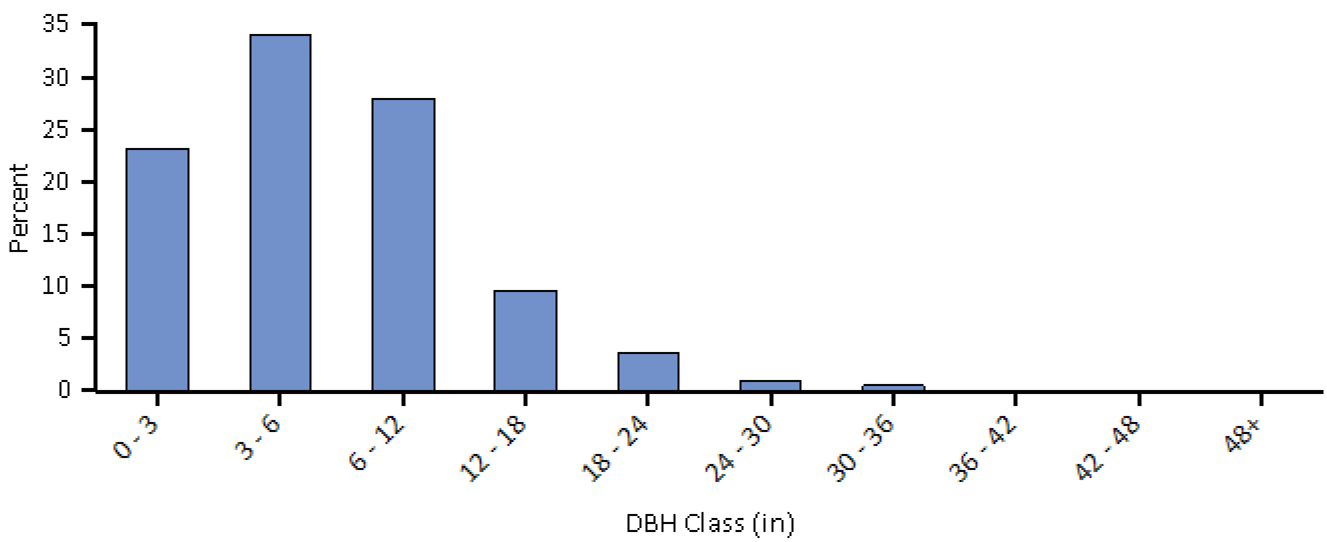


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix 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 by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In ACC Community Tree Study, about 91 percent of the trees are species native to North America, while 88 percent are native to Georgia. Species exotic to North America make up 9 percent of the population. Most exotic tree species have an origin from Asia (5 percent of the species).

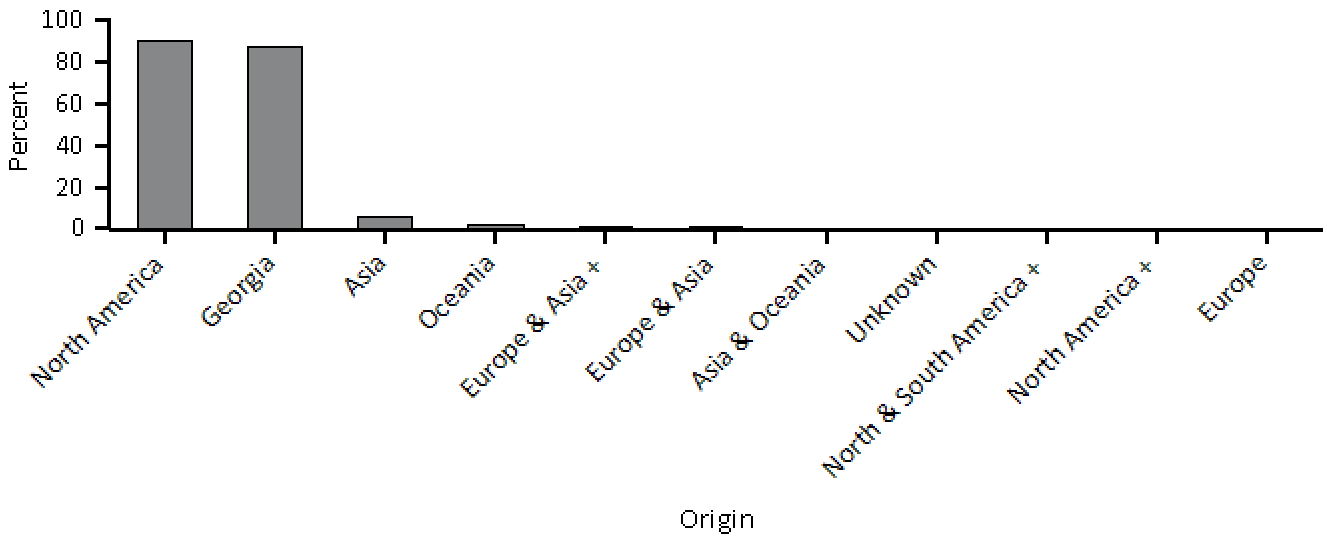


Figure 4. Percent of live tree population by area of native origin, ACC Community Tree Study

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. Twelve of the 123 tree species in ACC Community Tree Study are identified as invasive on the state invasive species list (Georgia Exotic Pest Plant Council 2006). These invasive species comprise 2.9 percent of the tree population though they may only cause a minimal level of impact. The three most common invasive species are Chinese privet (1.4 percent of population), Amur honeysuckle (0.4 percent), and Chinaberry (0.3 percent) (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 58 percent of ACC Community Tree Study and provide 969.7 square miles of leaf area. Total leaf area is greatest in Private Ag. & Natural Lands followed by Single Family Residential and ACC LS Natural & Undev Lands.

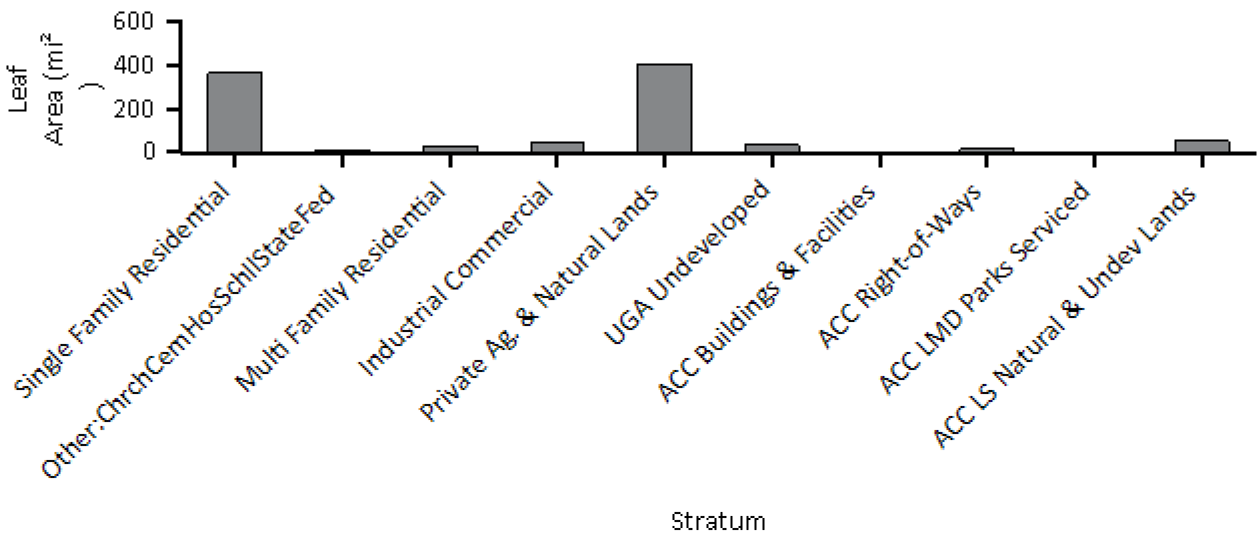


Figure 5. Leaf area by stratum, ACC Community Tree Study

In ACC Community Tree Study, the most dominant species in terms of leaf area are Sweetgum, Water oak, and White oak. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in ACC Community Tree Study

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Sweetgum	20.8	16.0	36.8
Water oak	10.8	15.8	26.6
Loblolly pine	12.9	9.2	22.1
White oak	6.0	15.0	21.0
Tulip tree	2.6	7.3	9.9
Eastern hophornbeam	4.7	2.3	7.0
Northern red oak	1.5	5.3	6.8
Black cherry	4.0	1.4	5.4
Red maple	3.0	2.4	5.4
Winged elm	2.8	1.7	4.5

Common ground cover classes (including cover types beneath trees and shrubs) in ACC Community Tree Study include duff/mulch, bare soil, unmaintained grass, buildings, water, rock, and other impervious, impervious covers such as tar, and cement, and herbaceous covers such as grass, and herbs (Figure 6). The most dominant ground cover types are Duff/Mulch (43.4 percent) and Grass (19.5 percent).

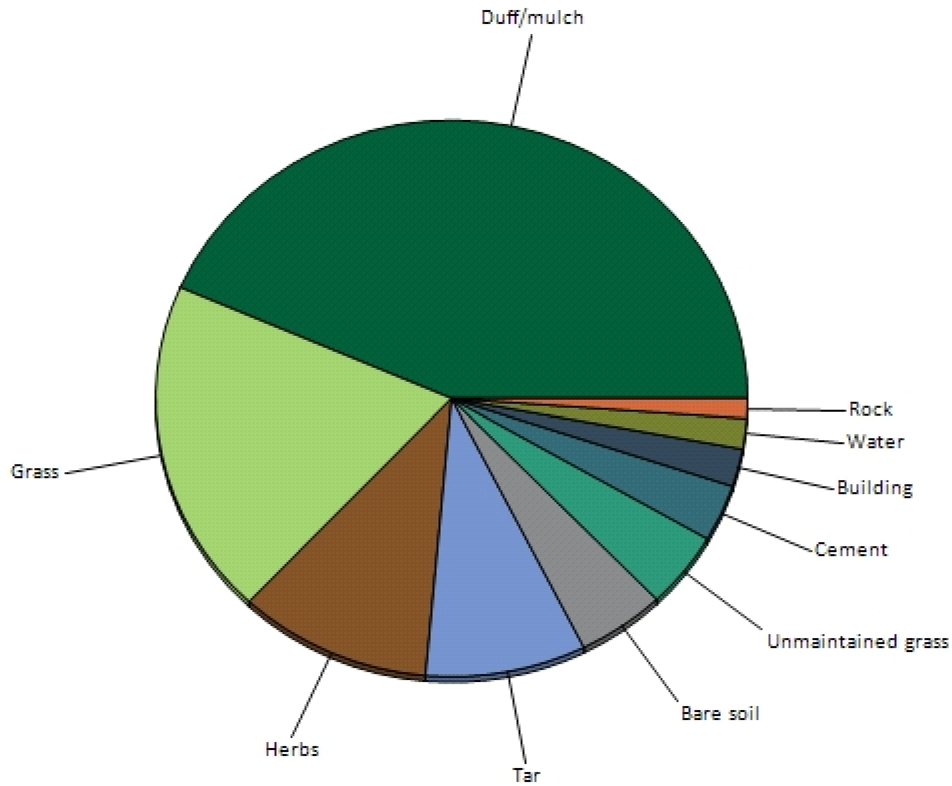


Figure 6. Percent of land by ground cover classes, ACC Community Tree Study

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in ACC Community Tree Study was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 1.875 thousand tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of $2.8 million (see Appendix I for more details).

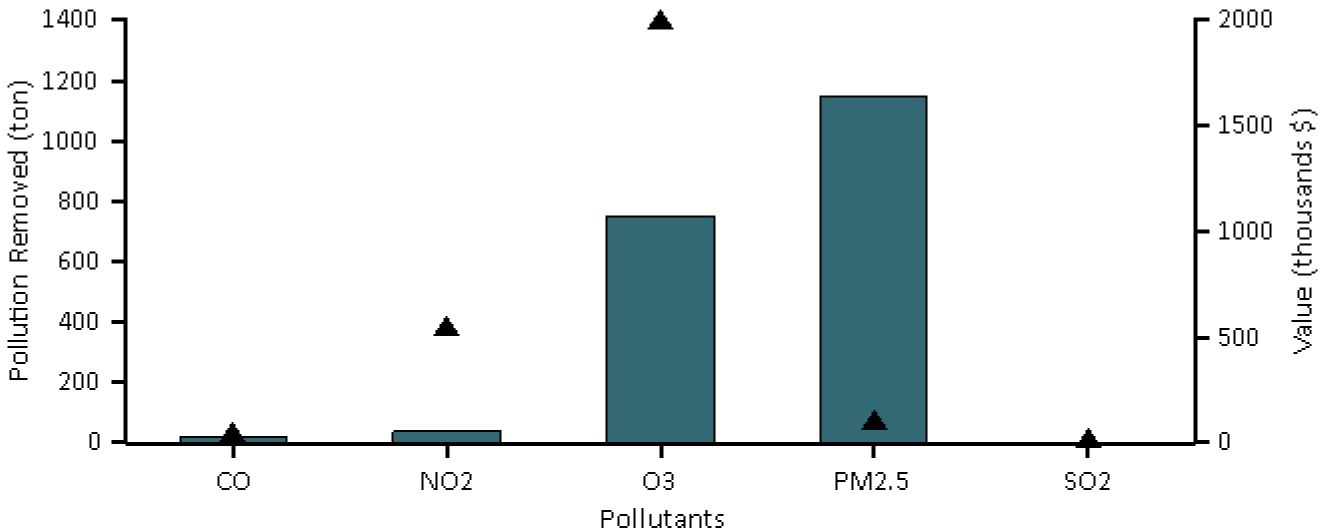


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, ACC Community Tree Study

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] 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 positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2021, trees in ACC Community Tree Study emitted an estimated 6.409 thousand tons of volatile organic compounds (VOCs) (2.196 thousand tons of isoprene and 4.213 thousand tons of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Fifty- nine percent of the urban forest's VOC emissions were from Water oak and White oak. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. 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 and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

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 gross sequestration of ACC Community Tree Study trees is about 92.56 thousand tons of carbon per year with an associated value of $15.8 million. Net carbon sequestration in the urban forest is about 72.11 thousand tons. See Appendix I for more details on methods.

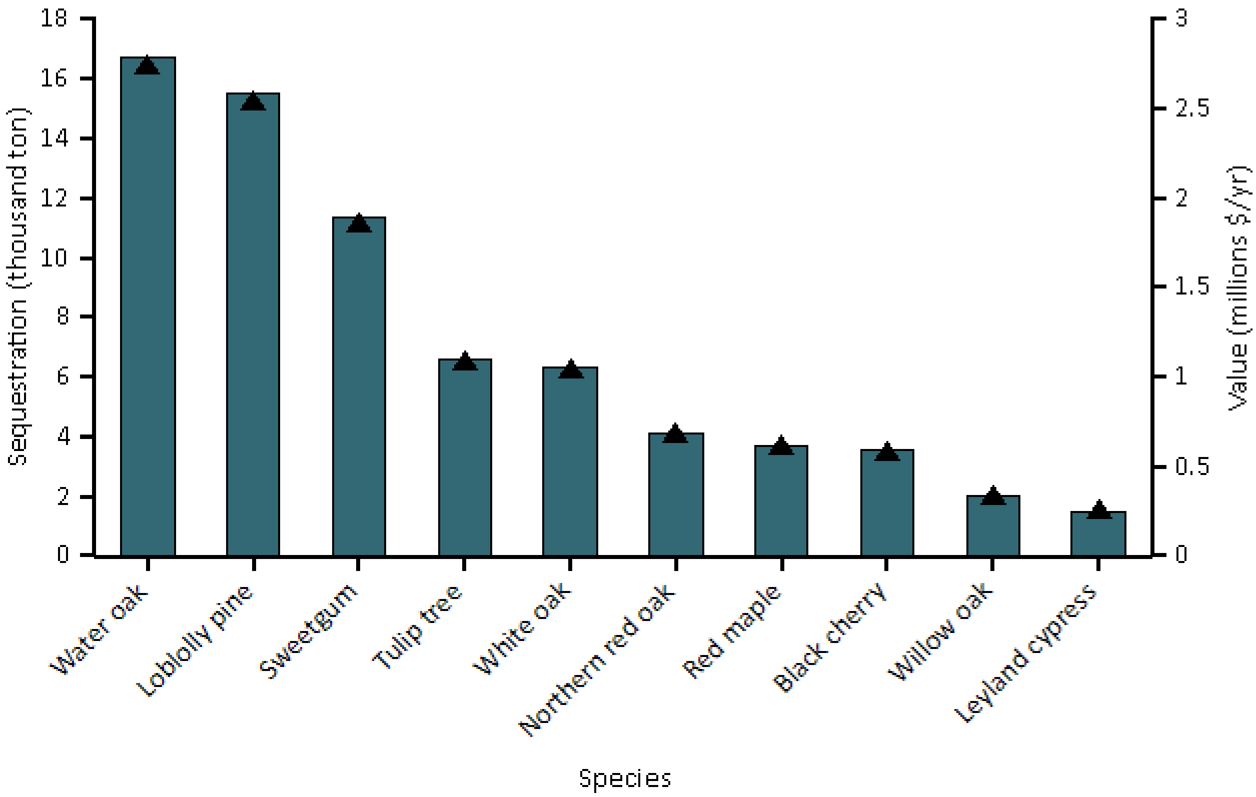


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, ACC Community Tree Study

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases 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 are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in ACC Community Tree Study are estimated to store 1880000 tons of carbon ($320 million). Of the species sampled, Water oak stores and sequesters the most carbon (approximately 20% of the total carbon stored and 17.7% of all sequestered carbon.)

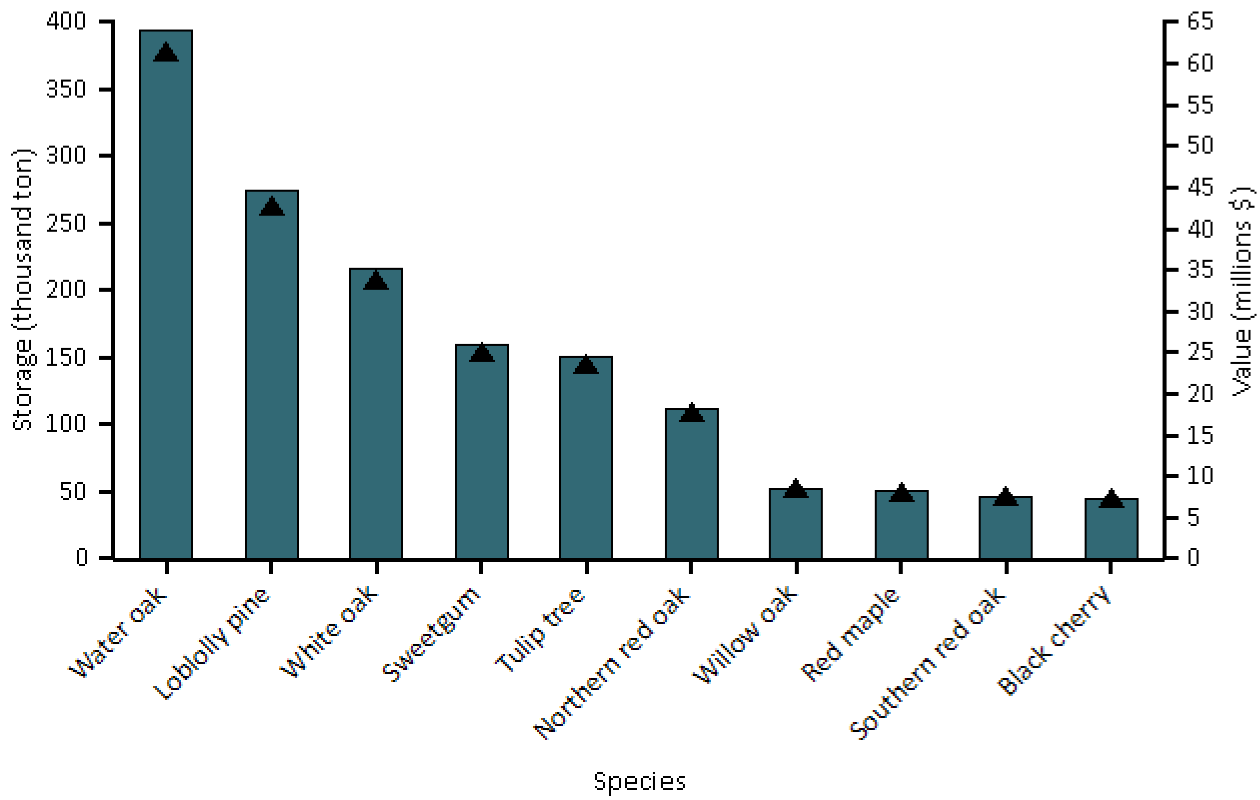


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, ACC Community Tree Study

V. 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 ACC Community Tree Study are estimated to produce 192.3 thousand tons of oxygen per year.[4] However, this tree benefit is relatively 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. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (thousand ton)*	*Net Carbon Sequestration (thousand ton/yr)*	*Number of Trees*	*Leaf Area (square mile)*
Water oak	31.81	11.93	1,460,347	153.20
Loblolly pine	28.83	10.81	1,738,367	88.86
Sweetgum	27.71	10.39	2,804,210	154.73
White oak	13.48	5.05	806,495	145.71
Tulip tree	12.32	4.62	345,520	71.07
Northern red oak	9.00	3.38	202,581	51.81
Red maple	8.73	3.27	398,463	23.76
Black cherry	7.04	2.64	544,500	13.56
Leyland cypress	3.55	1.33	37,853	3.94
Winged elm	3.35	1.26	374,580	16.28
Shortleaf pine	3.05	1.15	100,756	4.73
Photinia	2.49	0.93	232,505	7.69
Willow oak	2.35	0.88	211,658	20.41
N. Kimberly Crepe Myrtle	2.21	0.83	55,206	0.56
'Bradford' callery pear	2.08	0.78	152,677	4.95
Pignut hickory	1.73	0.65	334,237	16.36
American beech	1.65	0.62	202,344	23.25
Eastern hophornbeam	1.63	0.61	629,347	22.56
Southern red oak	1.53	0.57	92,402	17.79
Post oak	1.44	0.54	50,904	8.62

[4] A negative estimate, or oxygen deficit, indicates that trees are decomposing faster than they are producing oxygen. This would be the case in an area that has a large proportion of dead trees.

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees 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 (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of ACC Community Tree Study help to reduce runoff by an estimated 150 million cubic feet a year with an associated value of $10 million (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In ACC Community Tree Study, the total annual precipitation in 2016 was 39.6 inches.

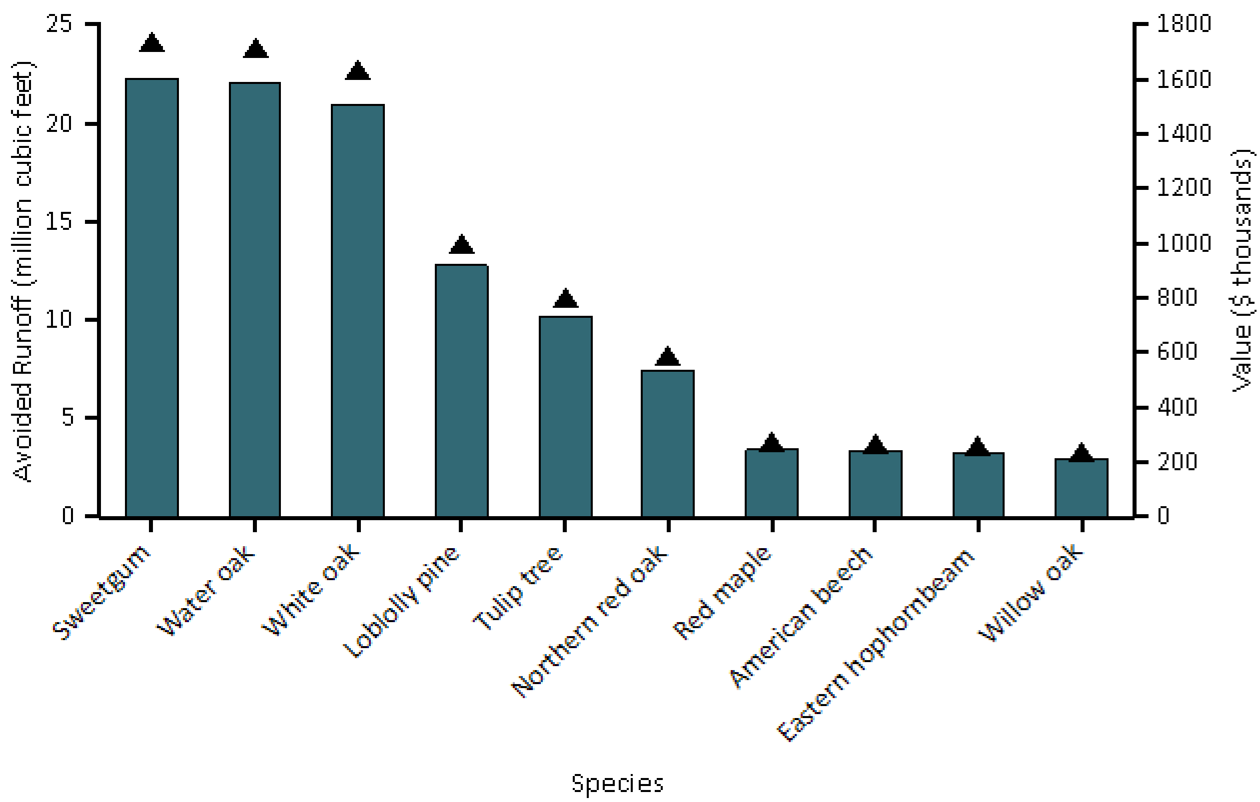


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, ACC Community Tree Study

VII. Trees and Building Energy Use

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

Trees in ACC Community Tree Study are estimated to reduce energy-related costs from residential buildings by $4,780,000 annually. Trees also provide an additional $1,300,000 in value by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of 7600 tons of carbon emissions).

Note: negative numbers indicate that there was not a reduction in carbon emissions and/or value, rather carbon emissions and values increased by the amount shown as a negative value.[5]

Table 3. Annual energy savings due to trees near residential buildings, ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[a]	87,896	N/A	87,896
MWH[b]	1,828	26,127	27,956
Carbon Avoided (tons)	2,590	5,013	7,603

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[b]	1,351,327	N/A	1,351,327
MWH[c]	224,148	3,203,214	3,427,361
Carbon Avoided	441,720	855,013	1,296,734

[b]Based on the prices of $122.6 per MWH and $15.3742400430376 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in ACC Community Tree Study have the following structural values:

- Structural value: $7.12 billion
- Carbon storage: $320 million

Urban trees in ACC Community Tree Study have the following annual functional values:

- Carbon sequestration: $15.8 million
- Avoided runoff: $10 million
- Pollution removal: $2.8 million
- Energy costs and carbon emission values: $6.08 million

(Note: negative value indicates increased energy cost and carbon emission value)

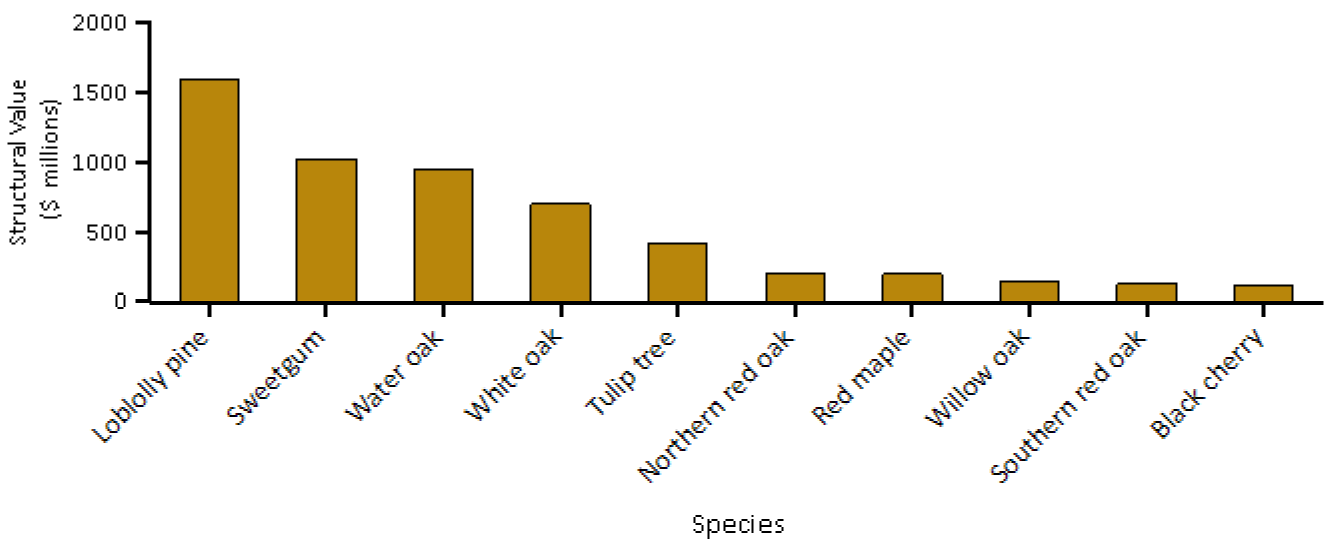


Figure 11. Tree species with the greatest structural value, ACC Community Tree Study

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Clarke County. Five of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

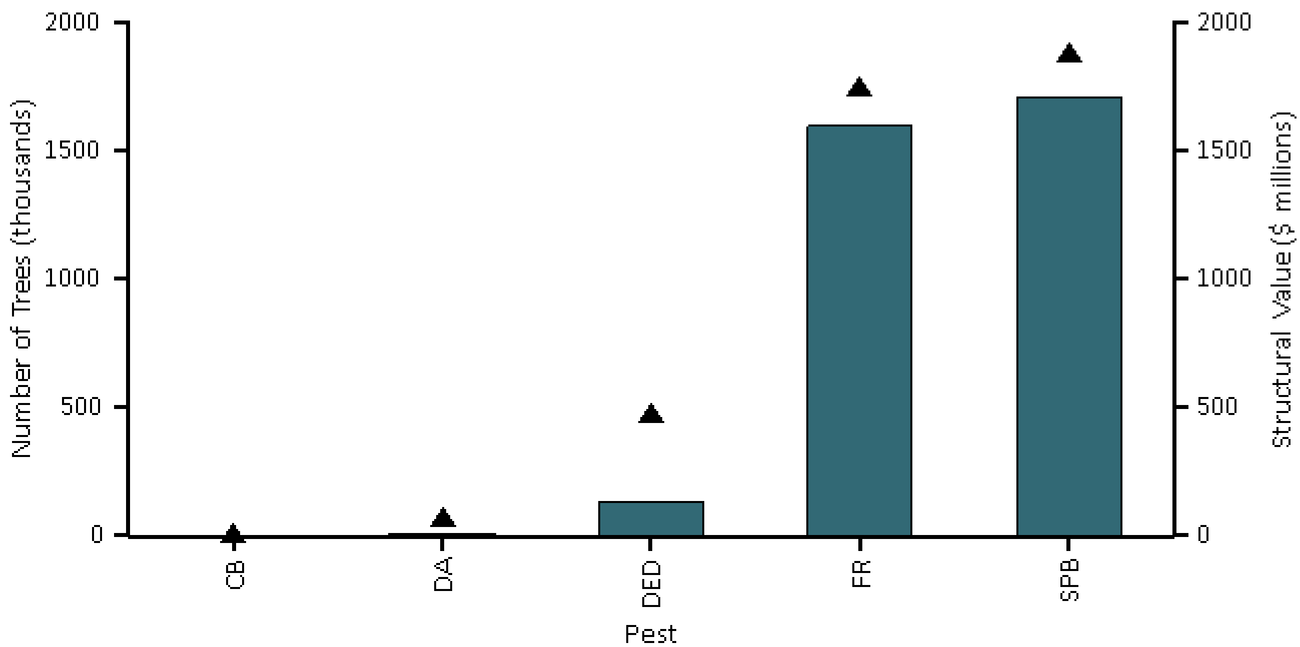


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, ACC Community Tree Study

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population ($0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.5 percent of the population, which represents a potential loss of $7.85 million in structural value.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, ACC Community Tree Study could possibly lose 3.5 percent of its trees to this pest ($136 million in structural value).

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 12.9 percent of the population ($1.6 billion in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 13.9 percent of the population, which represents a potential loss of $1.71 billion in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

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

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Georgia Exotic Pest Plant Council 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (PM10) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area.

Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (Nowak et al 2013). 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 positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 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.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,327 per ton (carbon monoxide), $768 per ton (ozone), $146 per ton (nitrogen dioxide), $55 per ton (sulfur dioxide), $23,739 per ton (particulate matter less than 2.5 microns).

Carbon Storage and Sequestration:

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

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

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 et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

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

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of \$0.07 per ft^3.

Building Energy Use:

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

For this analysis, energy saving value is calculated based on the prices of \$122.60 per MWH and \$15.37 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is

within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are 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 in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, 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) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in ACC Community Tree Study provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in ACC Community Tree Study in 1,123 days
- Annual carbon (C) emissions from 1,330,000 automobiles
- Annual C emissions from 545,000 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 225 automobiles
- Annual carbon monoxide emissions from 621 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 54,200 automobiles
- Annual nitrogen dioxide emissions from 24,400 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 70,100 automobiles
- Annual sulfur dioxide emissions from 185 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in ACC Community Tree Study in 55.0 days
- Annual C emissions from 65,500 automobiles
- Annual C emissions from 26,800 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" 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.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. 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.

Urban forest management strategies to help improve air quality include (Nowak 2000):

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 V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Georgia invasive species list (Georgia Exotic Pest Plant Council 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Chinese privet	186,786	1.4	1,137.8	0.2
Amur honeysuckle	56,227	0.4	256.0	0.0
Chinaberry	44,917	0.3	1,456.5	0.2
Persian silk tree	32,068	0.2	568.9	0.1
Glossy privet	19,854	0.1	1,515.1	0.2
White mulberry	11,335	0.1	119.6	0.0
Japanese holly	9,311	0.1	73.5	0.0
Rose-of-sharon	8,304	0.1	181.8	0.0
Chinese holly	8,304	0.1	21.2	0.0
Tree of heaven	5,495	0.0	134.1	0.0
Autumn olive	1,384	0.0	10.1	0.0
Callery pear	490	0.0	23.3	0.0
Total	**384,476**	**2.86**	**5,497.99**	**0.89**

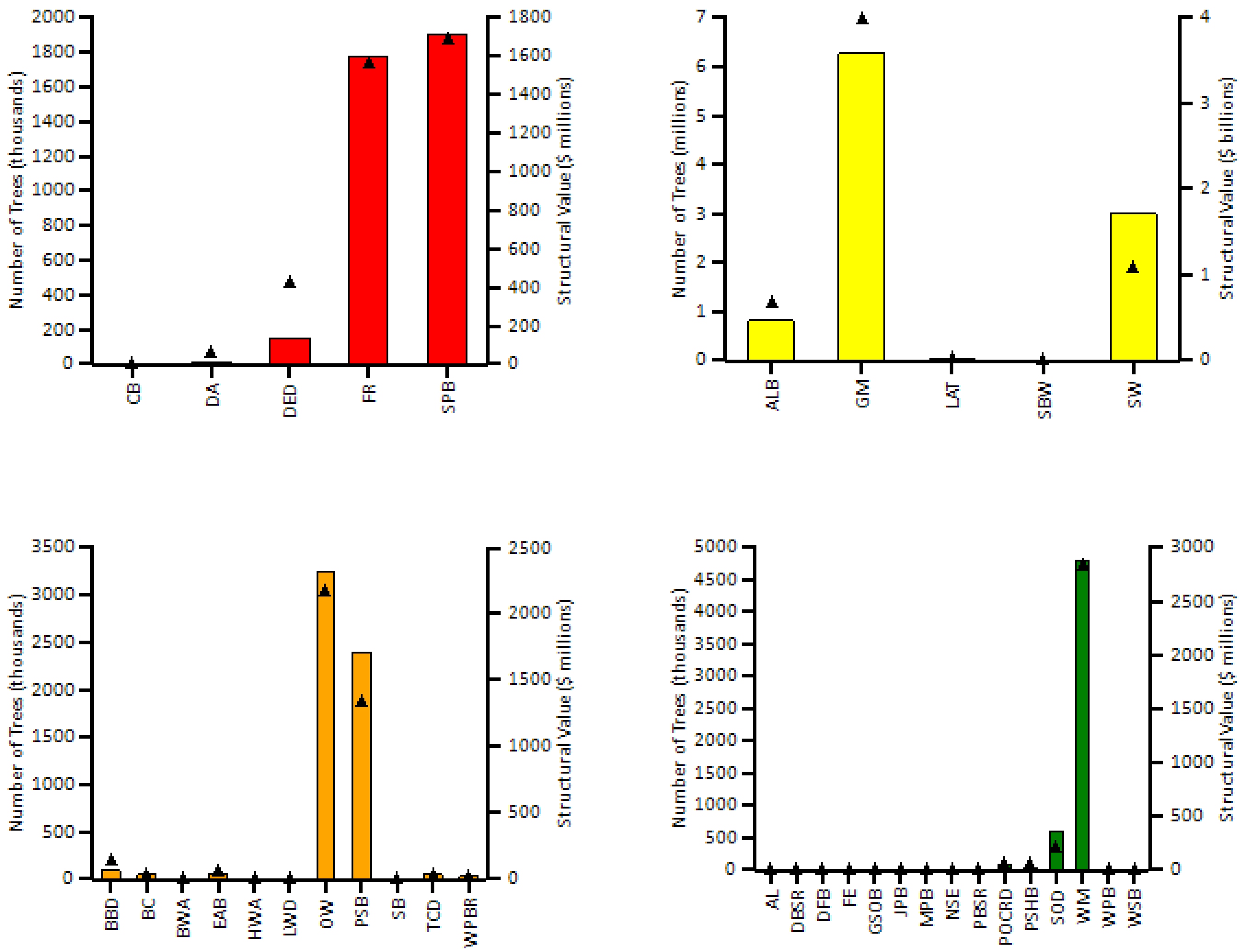
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/ disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ millions)
AL	Phyllocnistis populiella	Aspen Leafminer	7,381	1.04
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	1,167,604	463.40
BBD	Neonectria faginata	Beech Bark Disease	202,344	65.89
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	30,547	34.94
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	64,935	7.85
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	472,081	135.81
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	71,591	47.13
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	1,738,367	1,600.25
GM	Lymantria dispar	Gypsy Moth	6,971,112	3,589.07
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	692	0.10
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	27,984	21.58
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	3,033,765	2,318.95
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	74,488	54.08
PSB	Tomicus piniperda	Pine Shoot Beetle	1,873,803	1,714.61
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	92,357	19.73
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	331,991	353.69
SPB	Dendroctonus frontalis	Southern Pine Beetle	1,874,495	1,714.71
SW	Sirex noctilio	Sirex Wood Wasp	1,873,803	1,714.61
TCD	Geosmithia morbida	Thousand Canker Disease	30,547	34.94
WM	Operophtera brumata	Winter Moth	4,705,047	2,879.16
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	26,473	25.42
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Structural value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
Red	13	Loblolly pine													Red												Orange					Red	Yellow					
Red	12	Eastern white pine																									Orange					Red	Yellow				Orange	
Red	9	Shortleaf pine																									Orange					Red	Yellow					
Red	9	Virginia pine																									Orange					Red	Yellow					
Red	7	Winged elm		Yellow							Red																								Green			
Orange	7	Northern red oak														Yellow								Orange							Green				Green			
Orange	7	Southern red oak														Yellow								Orange							Green				Green			
Red	7	Slippery elm		Yellow							Red																								Green			
Red	7	American elm		Yellow							Red																								Green			
Orange	7	Pin oak														Yellow								Orange							Green				Green			
Yellow	7	River birch		Yellow												Yellow				Yellow															Green			
Red	7	Eastern hemlock																Orange														Red						
Orange	6	Water oak														Yellow								Orange											Green			
Orange	6	White oak														Yellow								Orange											Green			
Orange	6	Willow oak														Yellow								Orange											Green			
Orange	6	Blackjack oak														Yellow								Orange											Green			
Yellow	6	Boxelder		Yellow												Yellow												Green							Green			
Orange	6	Post oak														Yellow								Orange											Green			
Orange	6	Black oak														Yellow								Orange											Green			
Orange	6	Black walnut				Orange																												Orange				
Orange	6	Green ash		Yellow									Orange																						Green			
Orange	6	Scarlet oak														Yellow								Orange											Green			
Orange	6	Turkey oak														Yellow								Orange											Green			
Red	6	elm spp		Yellow							Red																											
Orange	6	Overcup oak														Yellow								Orange											Green			
Orange	6	Swamp white oak														Yellow								Orange											Green			
Orange	6	California white oak														Yellow								Orange											Green			
Orange	6	Shumard oak														Yellow								Orange											Green			
Orange	5	American beech			Orange											Yellow																						
Yellow	5	plum spp	Green	Yellow																Yellow																		
Orange	5	Sawtooth oak														Yellow								Orange														
Red	4	Flowering dogwood							Red																													
Orange	4	White ash											Orange																						Green			
Yellow	4	Chinese elm		Yellow												Yellow																						
Red	4	dogwood spp							Red																													

	3	Red maple
	3	Sugar maple
	3	Chalk maple
	3	Eastern cottonwood
	3	Silver maple
	3	Common chokecherry
	2	Sweetgum
	2	Eastern hophornbeam
	2	'Bradford' callery pear
	2	Persian silk tree
	2	Shining sumac
	2	Rose-of-sharon
	2	Grey poplar
	2	Japanese maple
	2	Trident maple
	2	Armstrong maple
	2	Callery pear
	1	Black cherry
	1	Northern white cedar

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:
- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:
- Red indicates pest is within Clarke county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Clarke county
- Green indicates pest is outside of these ranges

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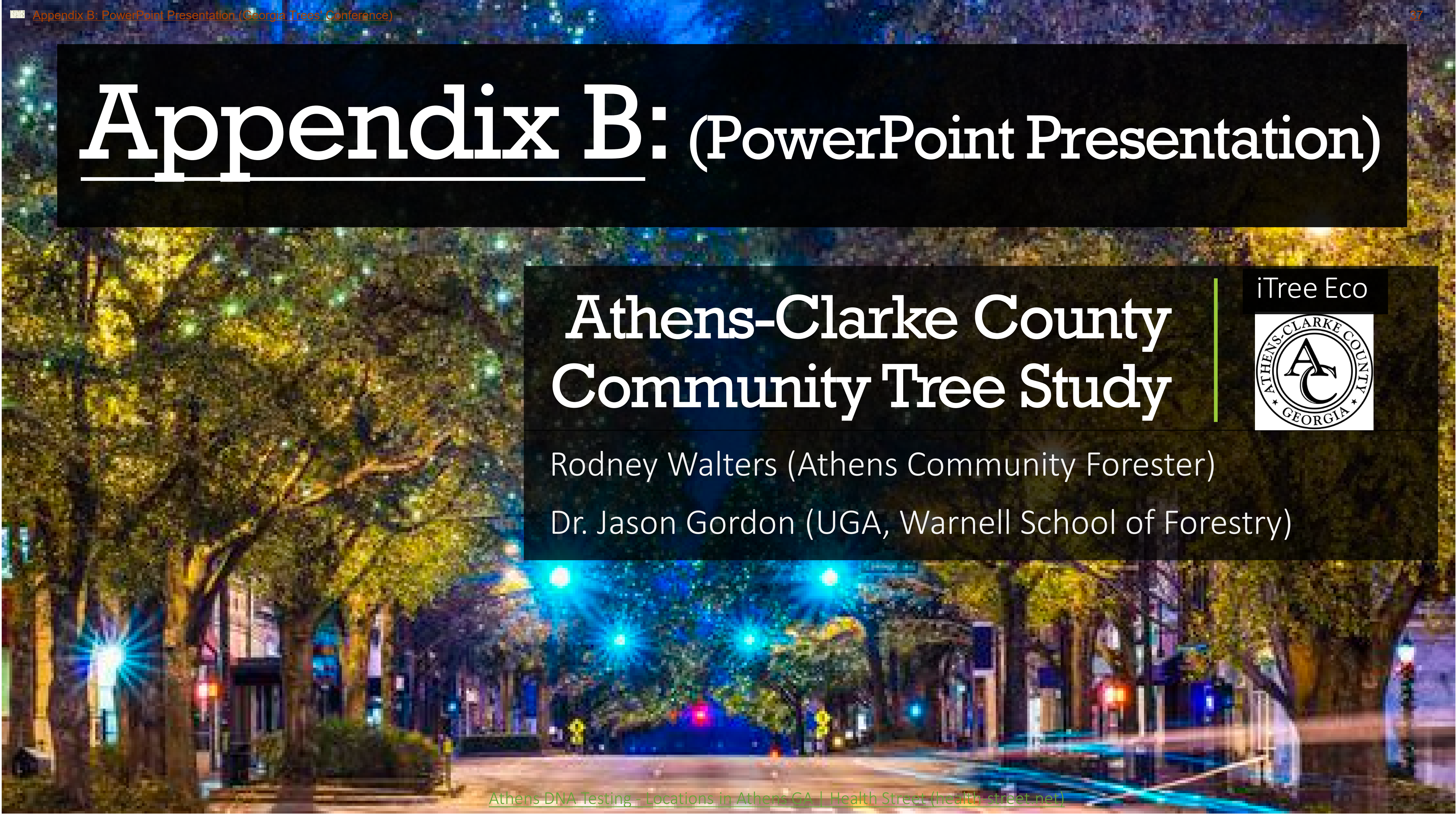
Appendix B: (PowerPoint Presentation)



iTree Eco

Athens-Clarke County Community Tree Study

Rodney Walters (Athens Community Forester)

Dr. Jason Gordon (UGA, Warnell School of Forestry)

Athens DNA Testing - Locations in Athens GA | Health Street (health-street.net)

ACC Community Tree Study

iTree Eco

Process, Results, Takeaways


How many Trees are there?
Where are they?
Why do they cost so much?
How do we keep from loosing them?
How do we prevent risks?
Who is responsible?
Are they really worth to costs?
Citizen Tree Stewards (pre 1980s)
Founders Tree Trust (1980 - 2003)
Athens-Clarke County Community Tree Council (2005 to Present)

Challenges – Don't know what we have (difficult to have productive conversations about policy & management of the community forests) (Don't understand the Community Forests as a whole (structure, function, and value of both public and privately owned trees on a countywide scale).

Growth & Development: Changing Community Forests

People see development occurring, but are in disagreement about extent and impacts of the changes (misperceptions and emotions run high)

Don't really know how many trees there are, relative sizes, or species composition

Many questions about what is out there, but nobody really knows (resulting in a lot of speculation and conjecture)

Don't understand the function and value of the community forest(s)

People cite the trees as a favorite aspect about living in Athens, but are unable to objectively quantify the costs and benefits as a whole for the community

Lack of info. makes it difficult to report the true scope & scale to talk about the impacts of action vs. inaction

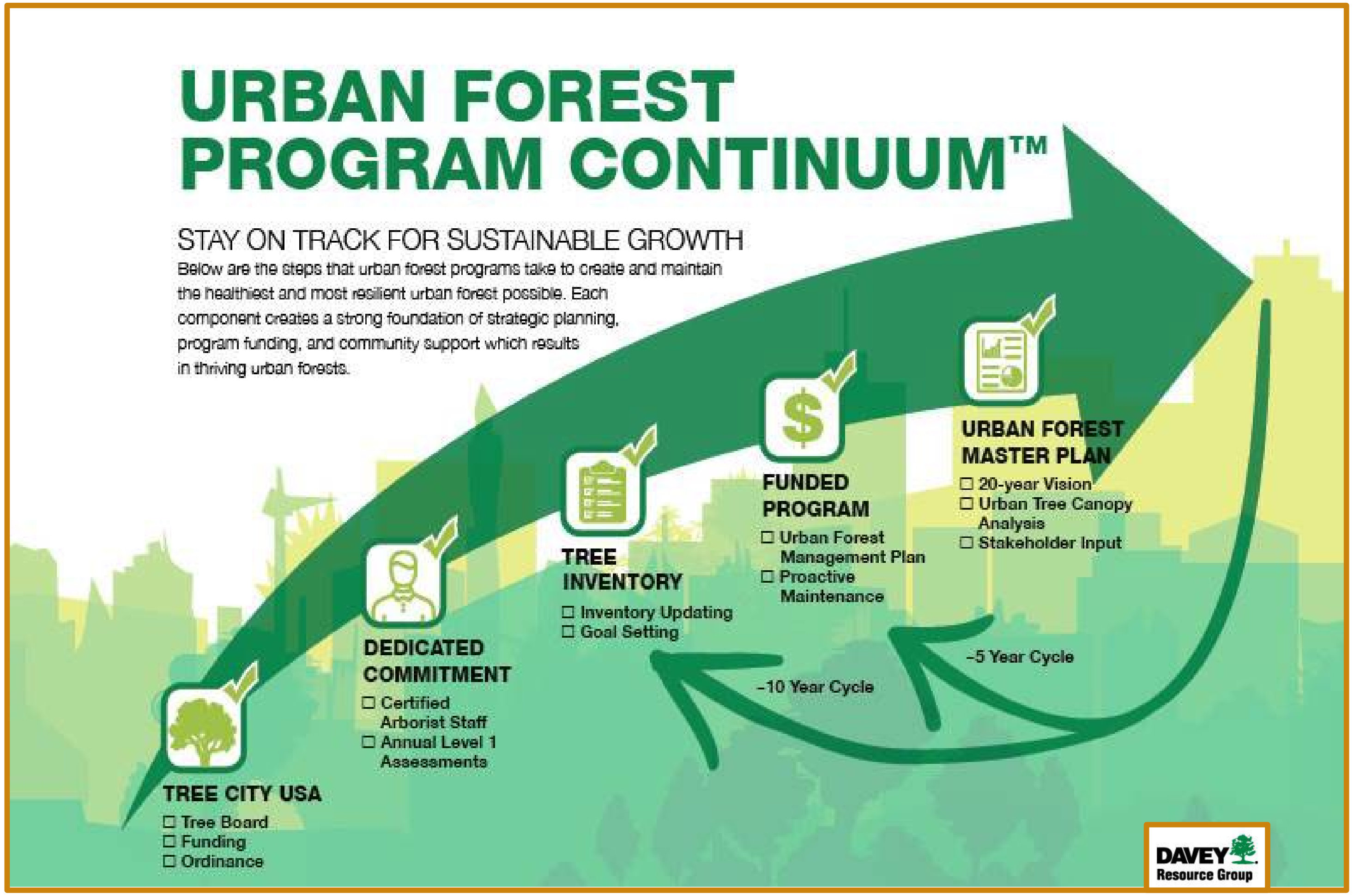
Actual tree numbers are unknown making effective forecasting impossible (hinders ability to make agreements and set goals)

No clear goals or associated plan limits resource allocation and delays maintenance & care

Community becomes vulnerable to receiving less benefits, undergoing higher costs, and enduring higher associated risks

Community Forestry Program Goals and Development of an Urban Forest Master Plan

1. What to we have? (inventory/analyses - Data)
2. What do we want? (goal setting process)
3. How do we get what we want? (plan)
4. Are we getting what we want? (evaluation



American Planning Association; https://www.planning.org/blog/blogpost/9101370/

https://www.davey.com/environmental-consulting-services/resources-news/urban-forest-program-continuum/

Assessment Options:

Top Down

- LIDAR
- Aerial Photography
- Tree Canopy Study

Bottom Up

- Complete Inventory
- Sample Inventory

Structure

Tells us what we have in physical terms

- How many trees
- What kind
- Relative sizes
- Where they are according to land use
- Other useful information (ground cover, etc.)

Function

Explains what the trees do for us

- Energy savings
- Stormwater retention
- Pollution removal
- CO2 storage and sequestration
- O2 production

Value

ACC Community Trees

- Structural value: $7.12 billion
- Carbon storage: $320 million

Annual functional values ($28.91 mil):

- Carbon sequestration: $15.8 million
- Avoided runoff: $10 million
- Pollution removal: $2.8 million
- Energy costs and CO2 emission values: $6.08 million

Decision – Conduct an iTree Eco Study

GEORGIA FORESTRY COMMISSION

Conversations

ATHENS-CLARKE COUNTY GEORGIA

U.S. Forest Service, Urban forestry South	External	Internal
	• GA Forestry Commission • UGA - Warnell	• Boss(s) • • Planning • Public Info

Exploration/ Networking Phase:

iTree Eco Study

- Will it provide needed results?
- Will it be supported?
- What will it take to do it?
- Who is willing to become a partner?
- How is it done?

Athens-Clarke County Community Tree Study Plan iTree Eco

Set Project Goals – Mgmt. of Trees in public space and also to better understand the Community Forest as a whole

- Secure Partners
- Develop a Budget
- *Formulate a Pre-planning/ Setup Plan*
- Develop a Publicity Plan to secure permissions to go on private properties
- Hire Data Collectors
- Train Data Collectors
- Collect Field Plot Data
- Generate Analyses
- Communicate Results

Plan & Timeline:

ACC iTree Eco Study – Statistical Analyses of the Urban/Community Forests

Duration of Project – 100% (October, 2020 – November, 2021)

Kick Off

Checkpoint A
December

Checkpoint C
December

Checkpoint B
March

Checkpoint D
March

Checkpoint E

Milestone #1
April 30th

Milestone #2
May 14th

Milestone #3
July 31st

Milestone #4
Sept. 24

Completion:
Analyses
Presentation

October 2020 | November 2020 | December 2020 | January 2021 | February 2021 | March 2021 | April 2021 | May 2021 | June 2021 | July 2021 | August 2021 | September 2021 | October 2021

Pre-planning and Setup - Phase 1 (October 15th, 2020 – April 2021)

{Monthly Partner Meetings [(PM), Project (PL), & Other Partners]}

- **A. Stratification Zone Map Production**
  [Amy Saxton & Rodney Walters: Dec. 2020]
- **B. iTree Eco Software and hardware setup**
  [Rodney Walters (PM) and Dr. Jason Gordon (PL): Dec. 2020 – March 2021]
- **C. Generate Random Sample Plots and Produce Plot Map**
  [Rodney Walters: Nov. 2020 – Dec. 2020]
- **D. Procure Permissions to Access Private Properties to Collect Plot Data & Publicity Plan** [Rodney Walters, Public Information & Data Collection Teams (Dr. Gordon): Nov. 2020 – March 2021]
- **E. Acquire Data Collection Devices (iPads) and Setup Project (iTree Eco Setup & Mobile Data Collector** [R. Walters: May 2021]

Phase 2 **(March, April) Assemble & Train Data Collection Teams (Dr. Gordon)**

Phase 3 (May – Aug.) **Collect Data** **(Data Collection Teams)**

Phase 4 (Aug. – Sept.) **Conduct Analyses & Generate Reports**

Present Analyses

ACC Tree Study Pre-planning/Setup

A. Stratification Zone Map Production (Dec. 2020)

B. iTree Eco Software and Hardware setup (Dec. 2020 - March 2021)

C. Generate Random Sample Plots & Produce Plot Map (Nov. 2020 - Dec. 2020)

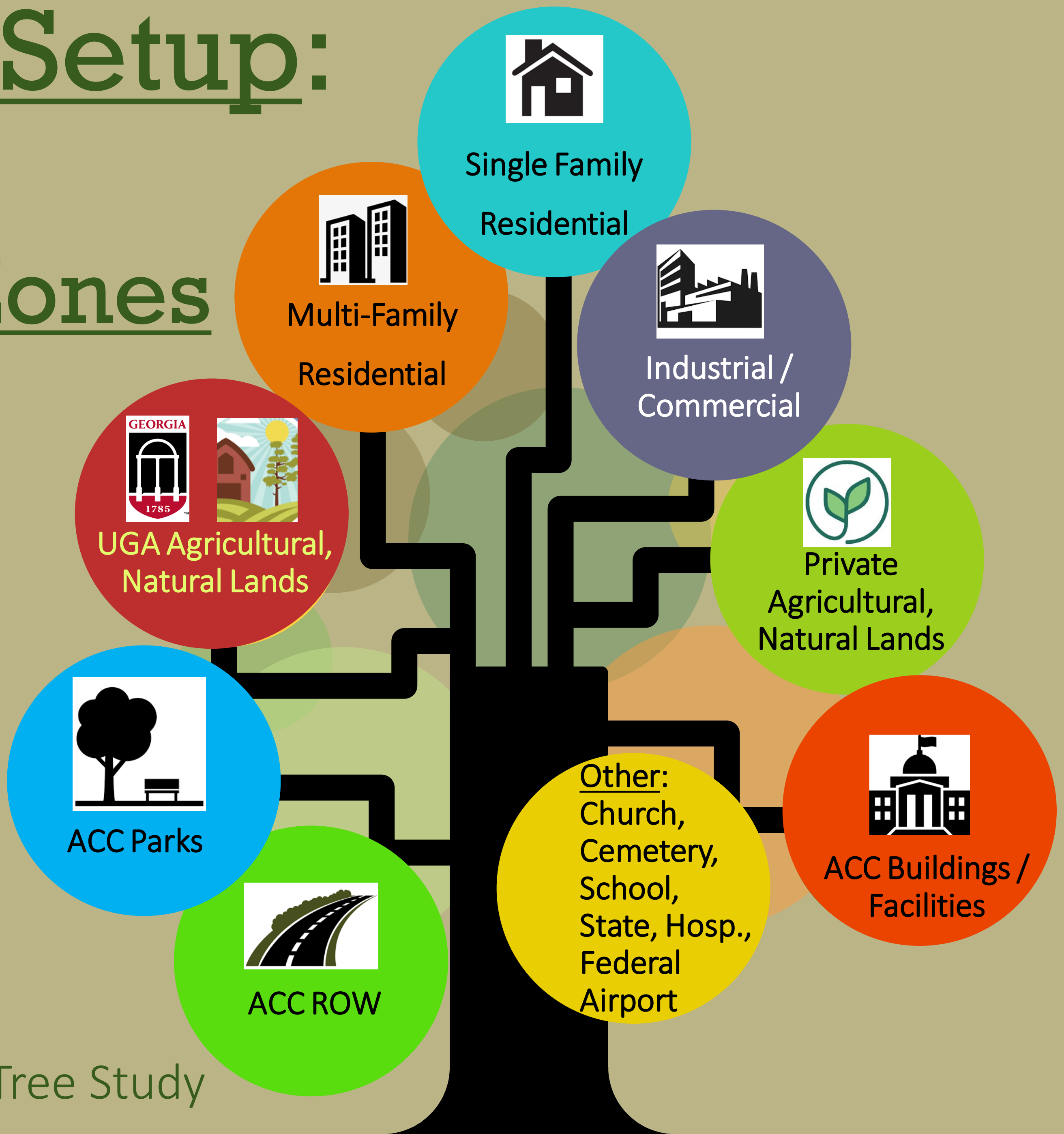
D. Publicity Plan & Procure Permissions to Access Private Properties to Collect Plot Data (Nov. 2020 - Aug. 2021)

E. Acquire Data Collection Devices (iPads) and Setup Project (iTree Eco Setup & Mobile Data Collector Setup) (May 2021)

Pre Planning/Setup:

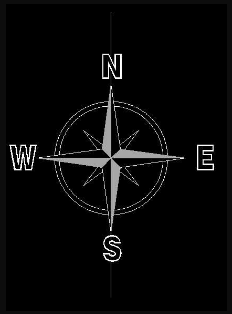
A. Stratification Zones

– Land Use Categories



Athens Clarke County Community Tree Study

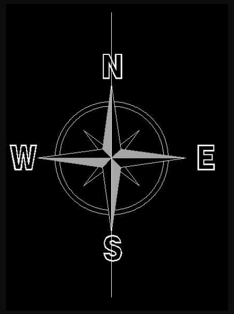
ACC Tree Study Pre-planning
A. Land Use Categories



ACC Total Land Area:
77,440 acres

1. Single Family Residential – 26,173 acres
2. Multi-family Residential – 3,336 acres
3. Industrial/Commercial – 5,576 acres

ACC Tree Study Pre-planning
A. Land Use Categories



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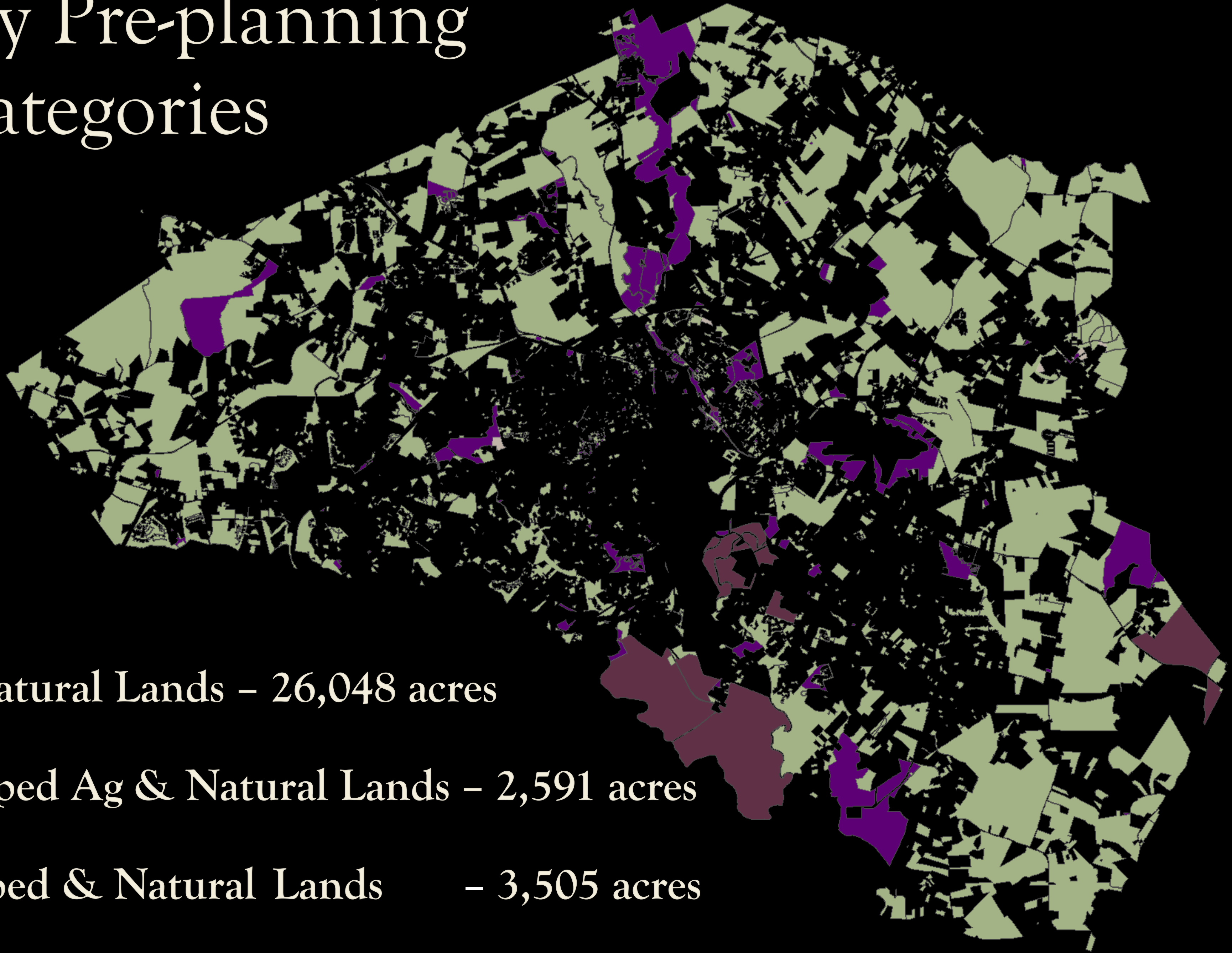


4. Private Ag & Natural Lands – 26,048 acres

5. UGA Undeveloped Ag & Natural Lands – 2,591 acres

9. ACC Undeveloped & Natural Lands – 3,505 acres

ACC Tree Study Pre-Planning
A. Land Use Categories

6. ACC Buildings/Facilities – 630 acres

7. ACC Right-of-Ways – 5,117 acres

9. ACC Parks (maintained areas – 349 acres

10. Other (Church, Cemetery, Hospital, School, State, Federal) – 3,117 acres

ACC Total Land Area: 77,440 acres

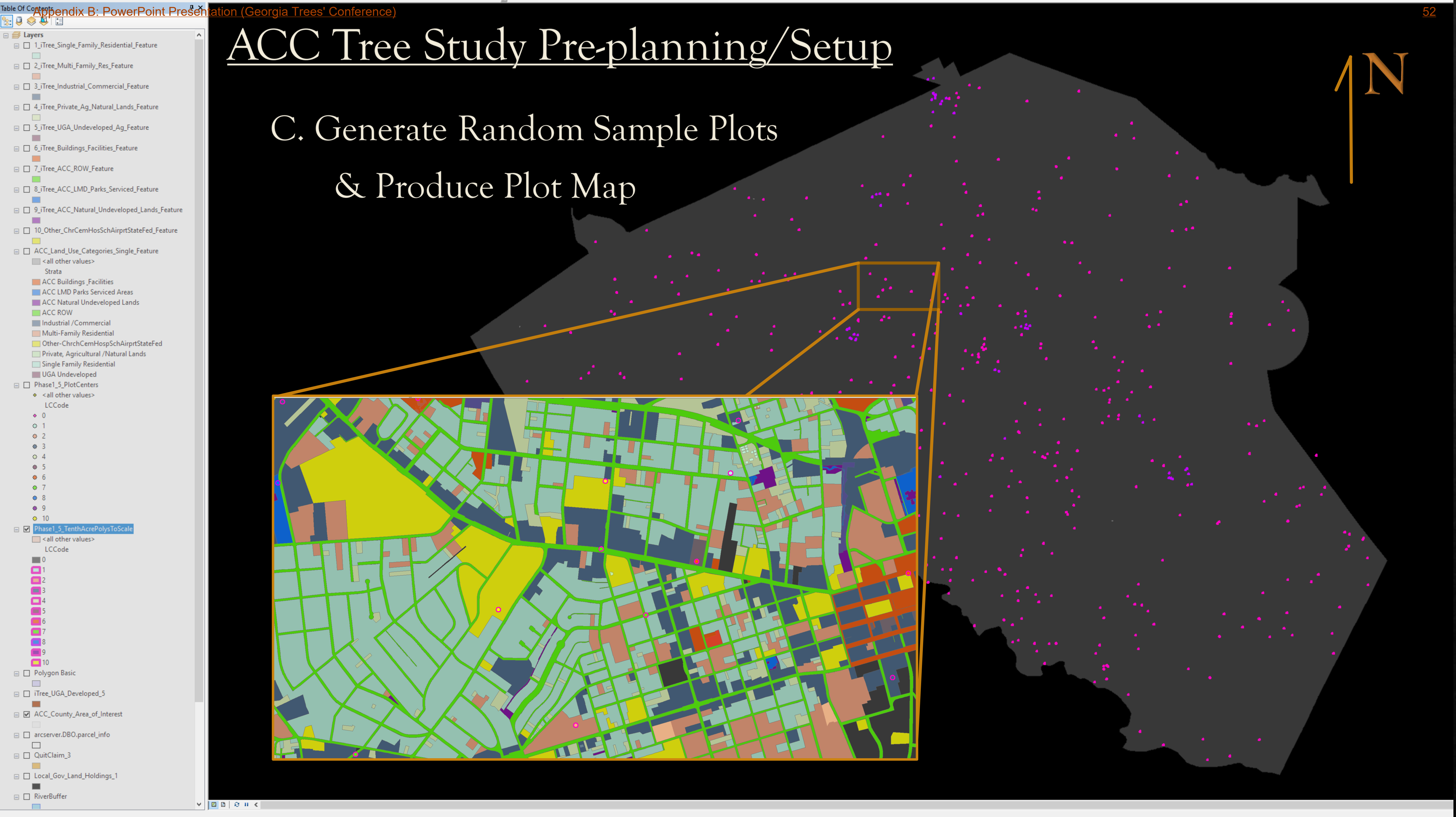
ACC Tree Study Pre-planning/Setup

B. iTree Eco Software & Hardware Setup

- Learn about i-Tree | i-Tree (itreetools.org)
- https://www.itreetools.org/tools/i-tree-eco
  - Learning Resources
    - ✓ Manuals and Guides
      - Project Decision Tree & Planning
      - Setting Up Your Project
      - Collecting Your Field Data
      - Interfacing with the Program
      - Viewing the Reports
    - ✓ Video Learning
    - ✓ Model methods, Technical Papers & Journal Articles

Become an Expert to Create a Powerful Communication Tool!!

- ❑ Quality Data
- ❑ Reports
- ❑ Graphs


ACC Tree Study Pre-planning/Setup
C. Generate Random Sample Plots
& Produce Plot Map
N
Table Of Contents
Layers
1_iTree_Single_Family_Residential_Feature
2_iTree_Multi_Family_Res_Feature
3_iTree_Industrial_Commercial_Feature
4_iTree_Private_Ag_Natural_Lands_Feature
5_iTree_UGA_Undeveloped_Ag_Feature
6_iTree_Buildings_Facilities_Feature
7_iTree_ACC_ROW_Feature
8_iTree_ACC_LMD_Parks_Serviced_Lands_Feature
9_iTree_ACC_Natural_Undeveloped_Lands_Feature
10_Other_ChrCemHosSchAirprtStateFed_Feature
ACC_Land_Use_Categories_Single_Feature
<all other values>
Strata
ACC Buildings_Facilities
ACC LMD Parks Serviced Areas
ACC Natural Undeveloped Lands
ACC ROW
Industrial /Commercial
Multi-Family Residential
Other-ChrchCemHospSchAirprtStateFed
Private, Agricultural /Natural Lands
Single Family Residential
UGA Undeveloped
Phase1_5_PlotCenters
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LCCode
0
1
2
3
4
5
6
7
8
9
10
Phase1_5_TenthAcrePolysToScale
<all other values>
LCCode
0
1
2
3
4
5
6
7
8
9
10
Polygon Basic
iTree_UGA_Developed_5
ACC_County_Area_of_Interest
arcserver.DBO.parcel_info
QuitClaim_3
Local_Gov_Land_Holdings_1
RiverBuffer

ACC Tree Study Pre-planning/Setup

D. Publicity Plan & Permissions to Access Private Properties (letters, e-mail, telephone, knocking on doors)

Videos

Athens Clarke County Community Tree Study

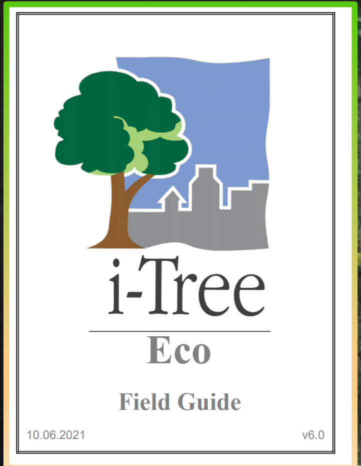
What to expect from the Community Tree Study Team

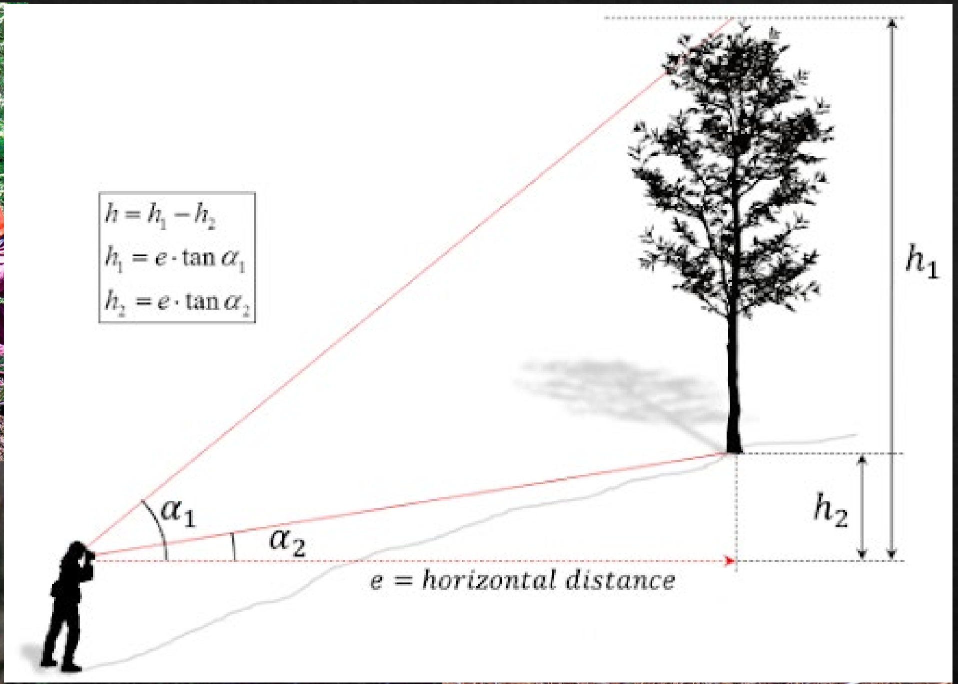
E. Project Setup: (read instructions!) (iTree Eco Setup & MobileData Collector)

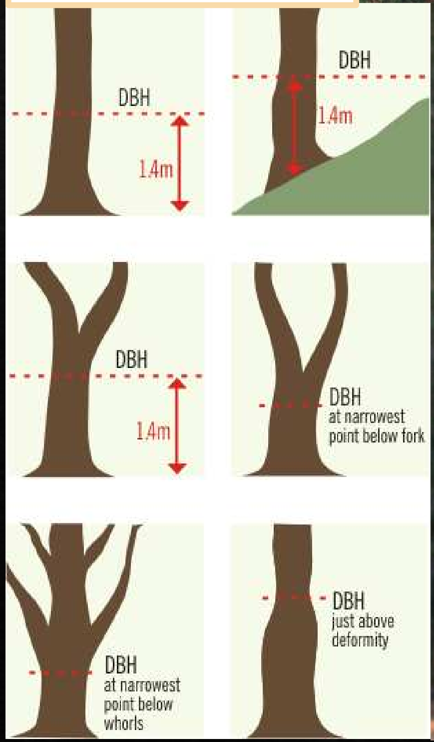
- Download iTree Software
- Select iTree Field Data Options
- Data Collection Devices (iPads)

* Recommend Setting up a Test Project, Gathering some Simple Plot Data, & Running the Model to Better Understand the Big Picture & Work Out the Bugs!

Hire & Train Data Collectors & Collect Field Plot Data







Run the Model to Generate the Analysis

ACC Community Tree Study 2021 Summary (228 Plots- preliminary)

- Number of trees: 13,460,000
- Tree Cover: 58.2 %
- Most common species of trees: Sweetgum, Loblolly pine, Water oak
- Percentage of trees less than 6" (15.2 cm) diameter: 57.3%

- Pollution Removal: 1.875 thousand tons/year ($2.8 million/year)
- Carbon Storage: 1.879 million tons ($320 million)
- Carbon Sequestration: 92.56 thousand tons ($15.8 million/year)
- Oxygen Production: 192.3 thousand tons/year
- Avoided Runoff: 120.1 million cubic feet/year ($10 million/year)
- Building energy savings: $4,780,000/year
- Carbon Avoided: 7.603 thousand tons/year ($1,300,000/year)
- Structural values: $7.12 billion

Avoided Stormwater Runnoff Benefits:

Hydrology Effects of Trees by Stratum

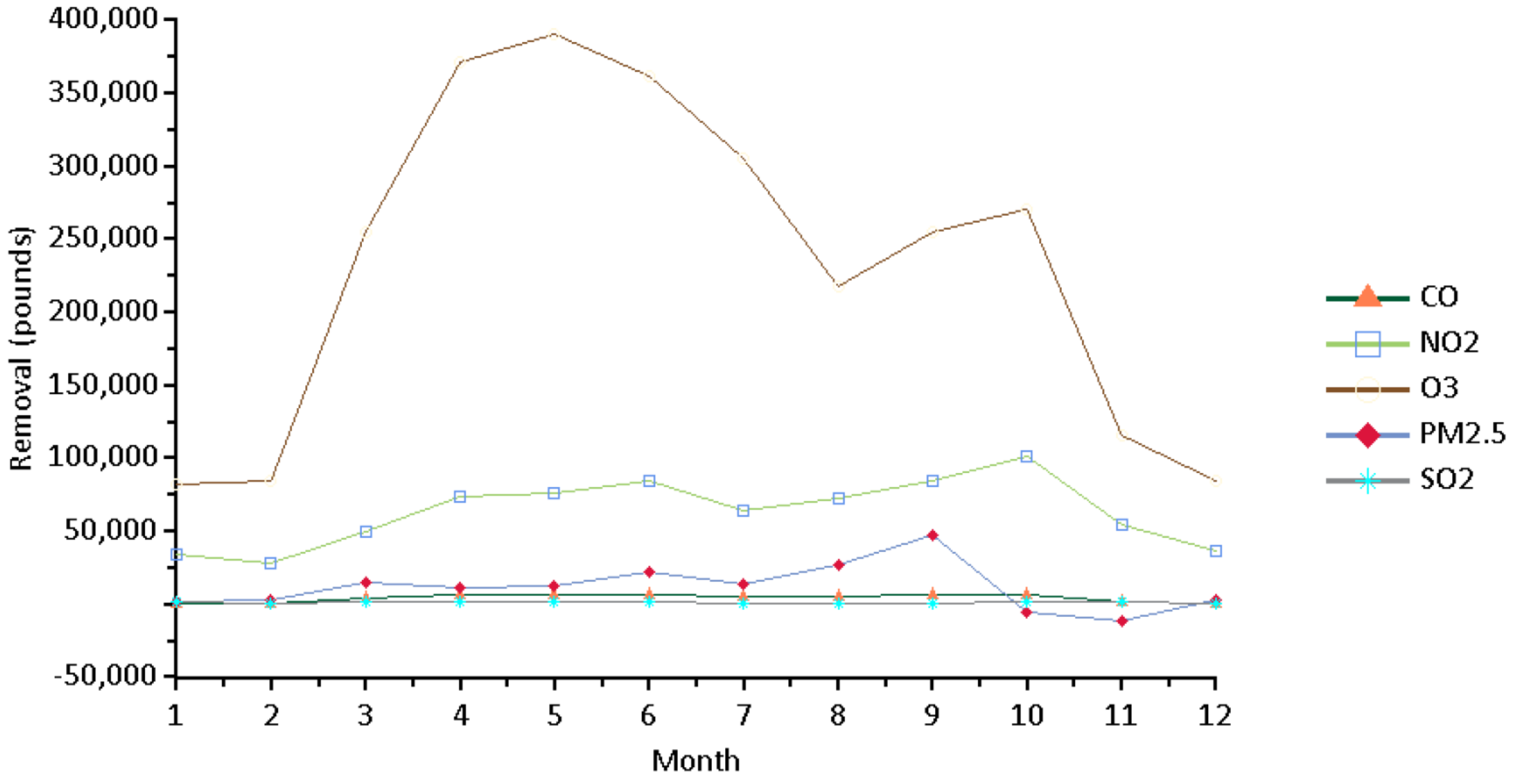
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Stratum	Number of Trees	Leaf Area (ac)	Potential Evapotranspiration (ft^3/yr)	Evaporation (ft^3/yr)	Transpiration (ft^3/yr)	Water Intercepted (ft^3/yr)	Avoided Runoff (ft^3/yr)	Avoided Runoff Value ($/yr)
Private Ag. & Natural Lands	5,931,107	262,017.74	1,549,676,628.88	324,362,296.97	253,180,456.49	324,362,296.97	63,370,038.99	4,236,023.86
Single Family Residential	4,675,017	234,518.68	1,387,036,253.24	290,320,094.34	226,608,871.31	290,320,094.34	56,719,279.24	3,791,448.20
ACC LS Natural & Undev Lands	754,471	32,941.80	194,830,857.85	40,779,981.71	31,830,747.53	40,779,981.71	7,967,106.70	532,567.99
Industrial Commercial	732,182	27,495.31	162,618,148.55	34,037,550.29	26,567,953.80	34,037,550.29	6,649,850.83	444,514.90
UGA Undeveloped	454,005	21,658.02	128,094,082.04	26,811,329.48	20,927,539.05	26,811,329.48	5,238,077.95	350,143.75
Multi Family Residential	358,545	19,875.31	117,550,428.83	24,604,440.95	19,204,955.84	24,604,440.95	4,806,922.37	321,322.79
ACC Right-of-Ways	324,524	11,233.74	66,440,811.12	13,906,703.96	10,854,854.86	13,906,703.96	2,716,926.04	181,615.22
Other:ChrchCemHosSchllStateFed	183,015	8,517.26	50,374,456.02	10,543,860.54	8,229,992.98	10,543,860.54	2,059,933.78	137,698.02
ACC Buildings & Facilities	35,803	1,665.77	9,852,011.67	2,062,121.27	1,609,585.36	2,062,121.27	402,872.67	26,930.36
ACC LMD Parks Serviced	12,994	695.50	4,113,480.94	860,991.32	672,045.36	860,991.32	168,210.22	11,244.15
Total	**13,461,665**	**620,619.13**	**3,670,587,159.14**	**768,289,370.82**	**599,687,002.57**	**768,289,370.82**	**150,099,218.80**	**10,033,509.24**

Avoided runoff value is calculated by the price $0.067/$ft^3$. The user-designated weather station reported 39.6 inches of total annual precipitation. Eco will always use the hourly measurements that have the greatest total rainfall or user-submitted rainfall if provided.

Pollution Removal by Trees – Monthly Removal

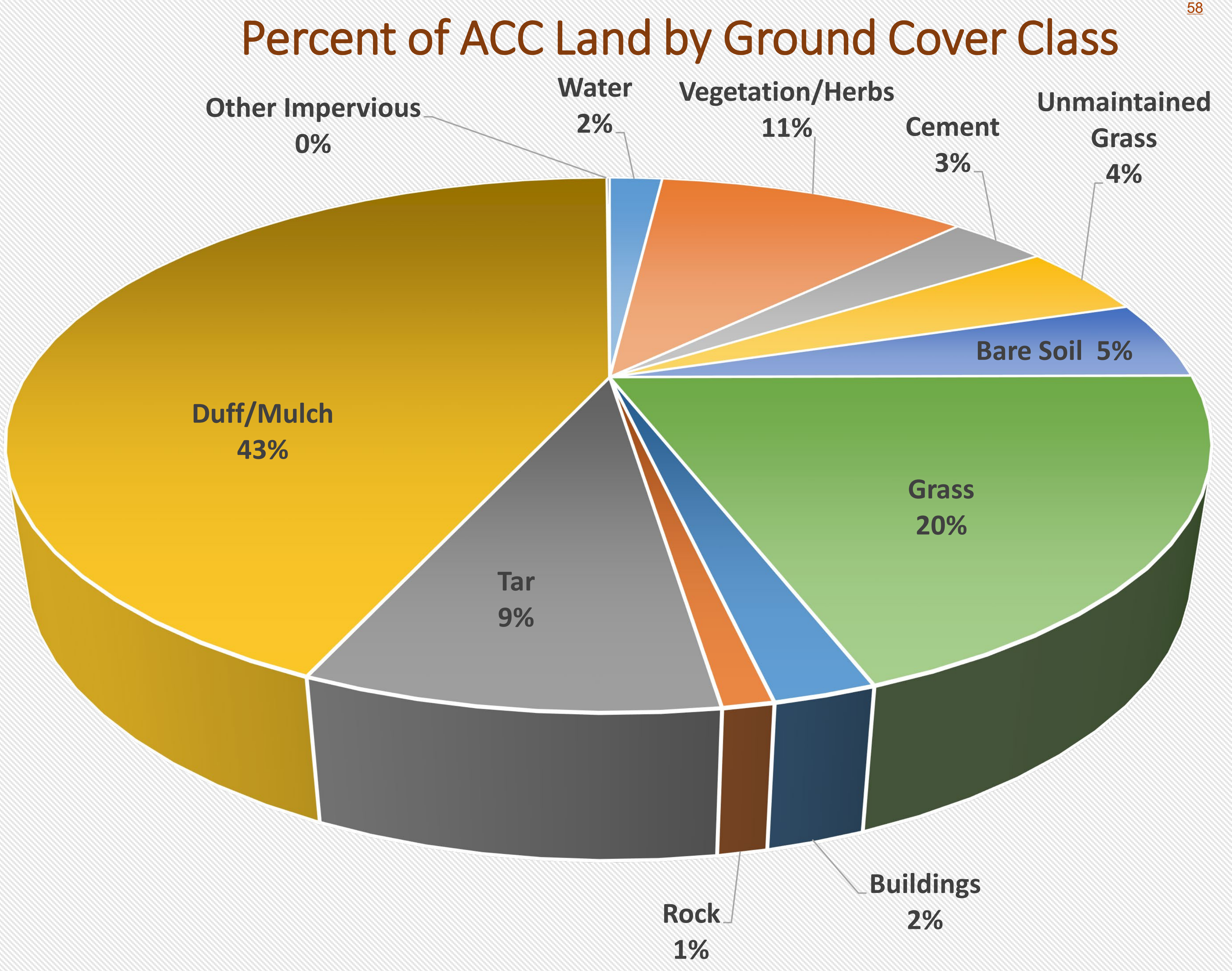
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



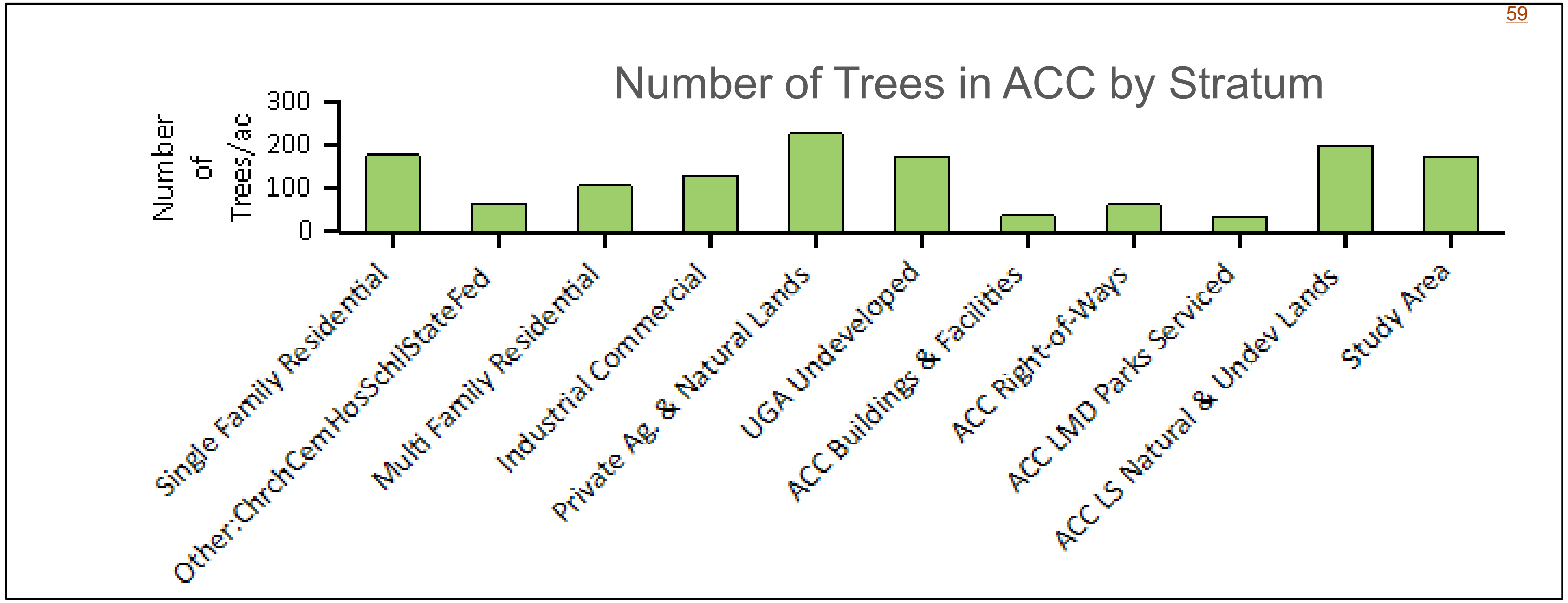
ACC Ground Cover Class Percentages

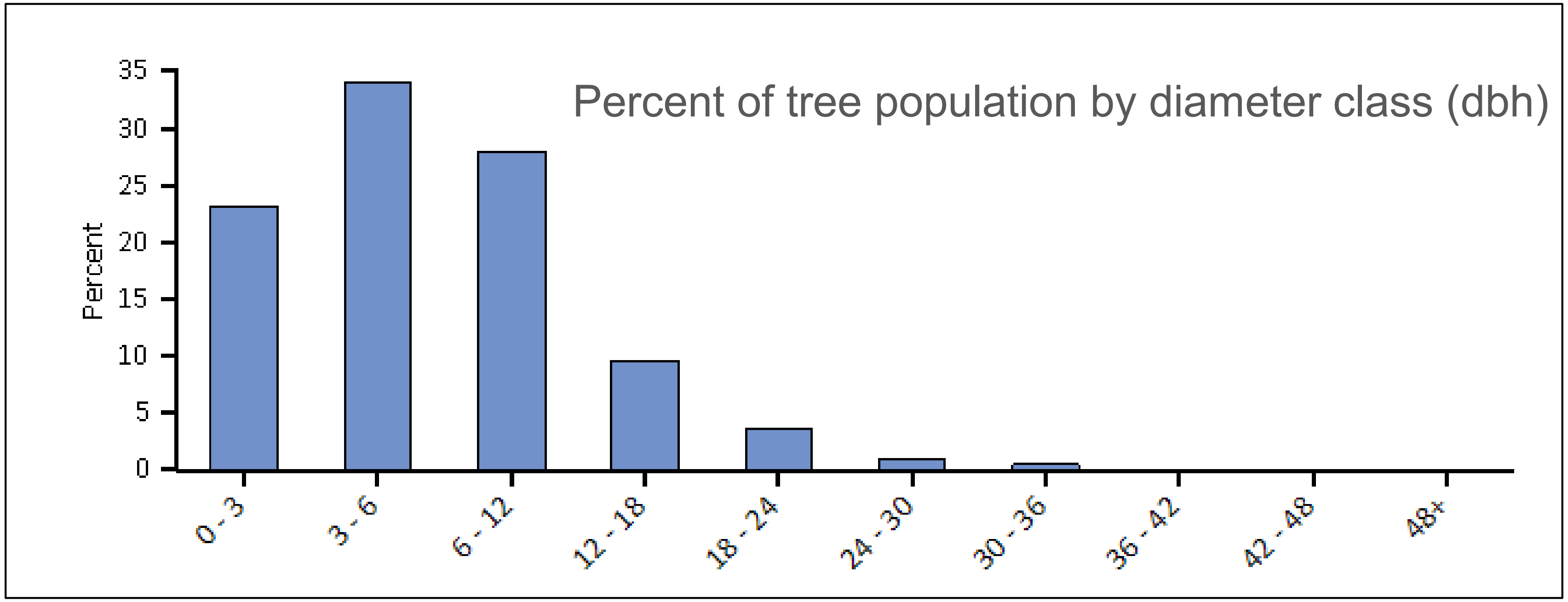
Duff/ Mulch 43.4%
Grass................. 19.5%
Veg./herbs......... 10.6%
Tar..................... 8.8%
Bare Soil........... 4.8%
Unmaint Grass... 4.4%
Cement............. 3.3%
Buildings........... 2.2%
Water................ 1.8%
Rock.................. 1.1%
Other Impervious 0.1%

Plantable Space = 79%



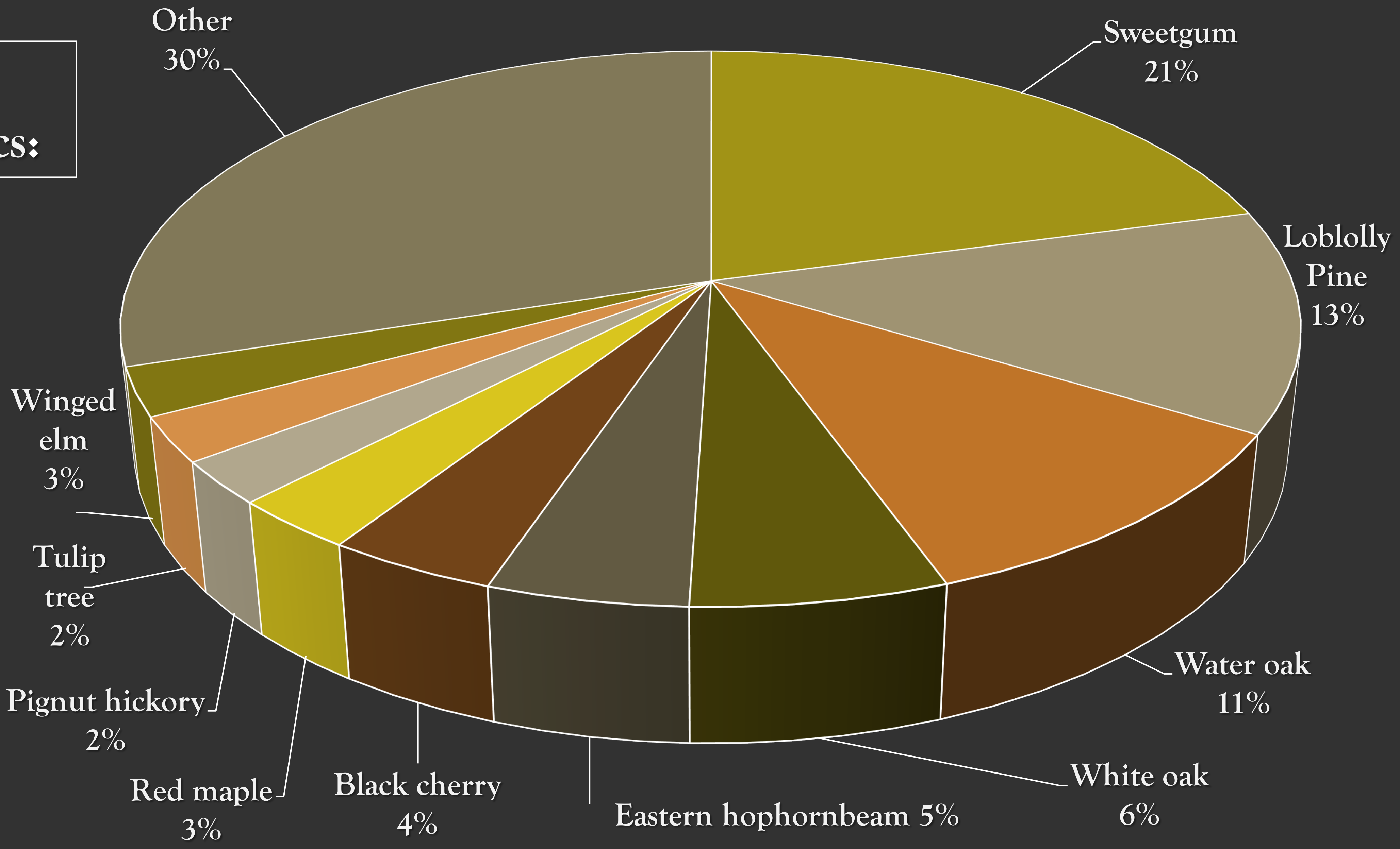
ACC Tree Characteristics



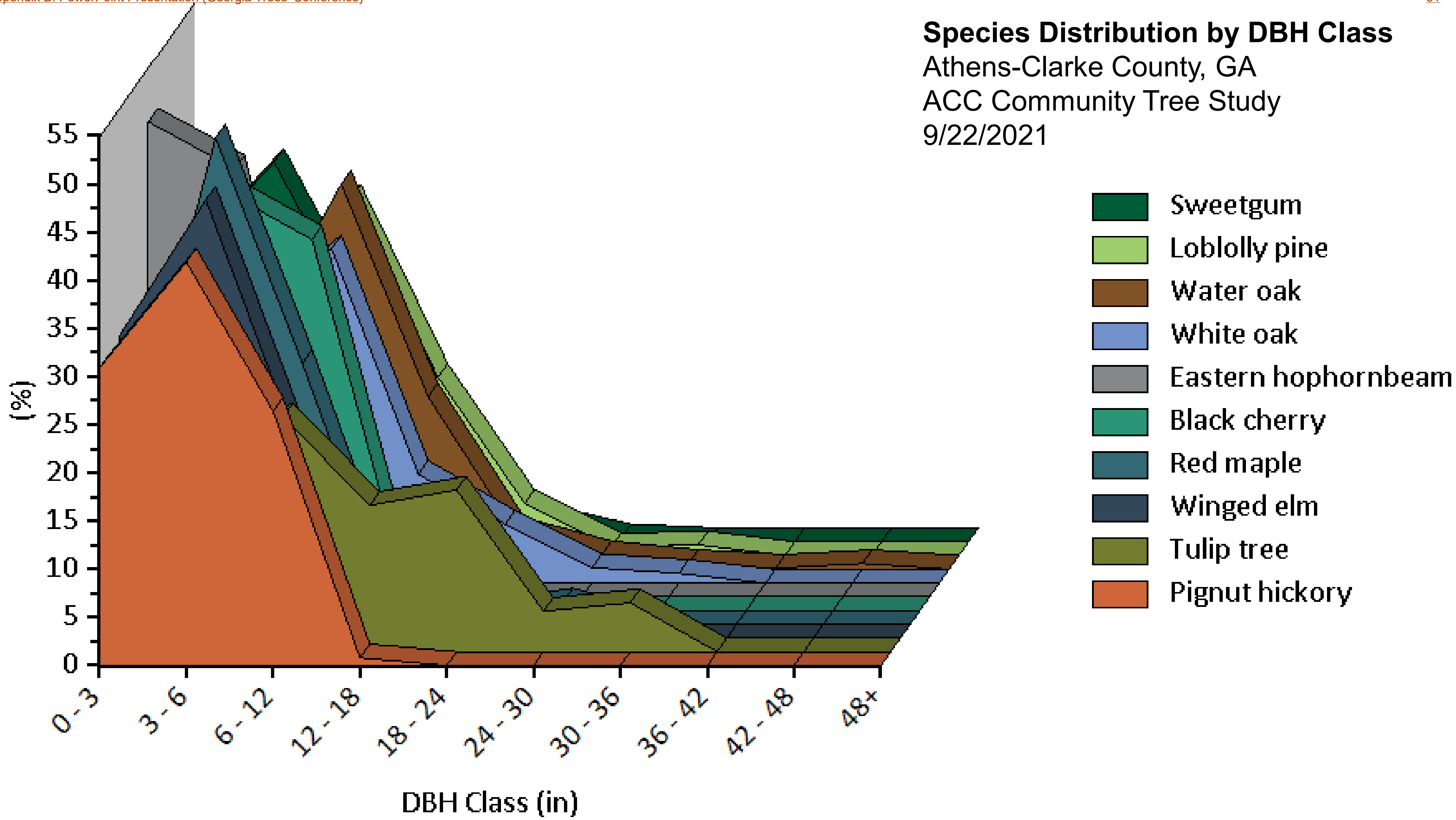


Species Composition of ACC's Community Trees, 2021

ACC Tree Characteristics:



Species Distribution by DBH Class
Athens-Clarke County, GA
ACC Community Tree Study
9/22/2021



Leaf Area = Key Structure of U.F.

Most Important Species By Leaf Area

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Sweetgum	20.8	16.0	36.8
Water oak	10.8	15.8	26.6
Loblolly pine	12.9	9.2	22.1
White oak	6.0	15.0	21.0
Tulip tree	2.6	7.3	9.9
Eastern hophornbeam	4.7	2.3	7.0
Northern red oak	1.5	5.3	6.8
Black cherry	4.0	1.4	5.4
Red maple	3.0	2.4	5.4
Winged elm	2.8	1.7	4.5

Leaf Area by Stratum

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

i-Tree Eco

Stratum	Leaf Area (ac)	Leaf Area (%)
Single Family Residential	234,518.68	37.8%
Other:ChrchCemHosSchllStateFed	8,517.26	1.4%
Multi Family Residential	19,875.31	3.2%
Industrial Commercial	27,495.31	4.4%
Private Ag. & Natural Lands	262,017.74	42.2%
UGA Undeveloped	21,658.02	3.5%
ACC Buildings & Facilities	1,665.77	0.3%
ACC Right-of-Ways	11,233.74	1.8%
ACC LMD Parks Serviced	695.50	0.1%
ACC LS Natural & Undev Lands	32,941.80	5.3%
Study Area	**620,619.13**	**100.0%**

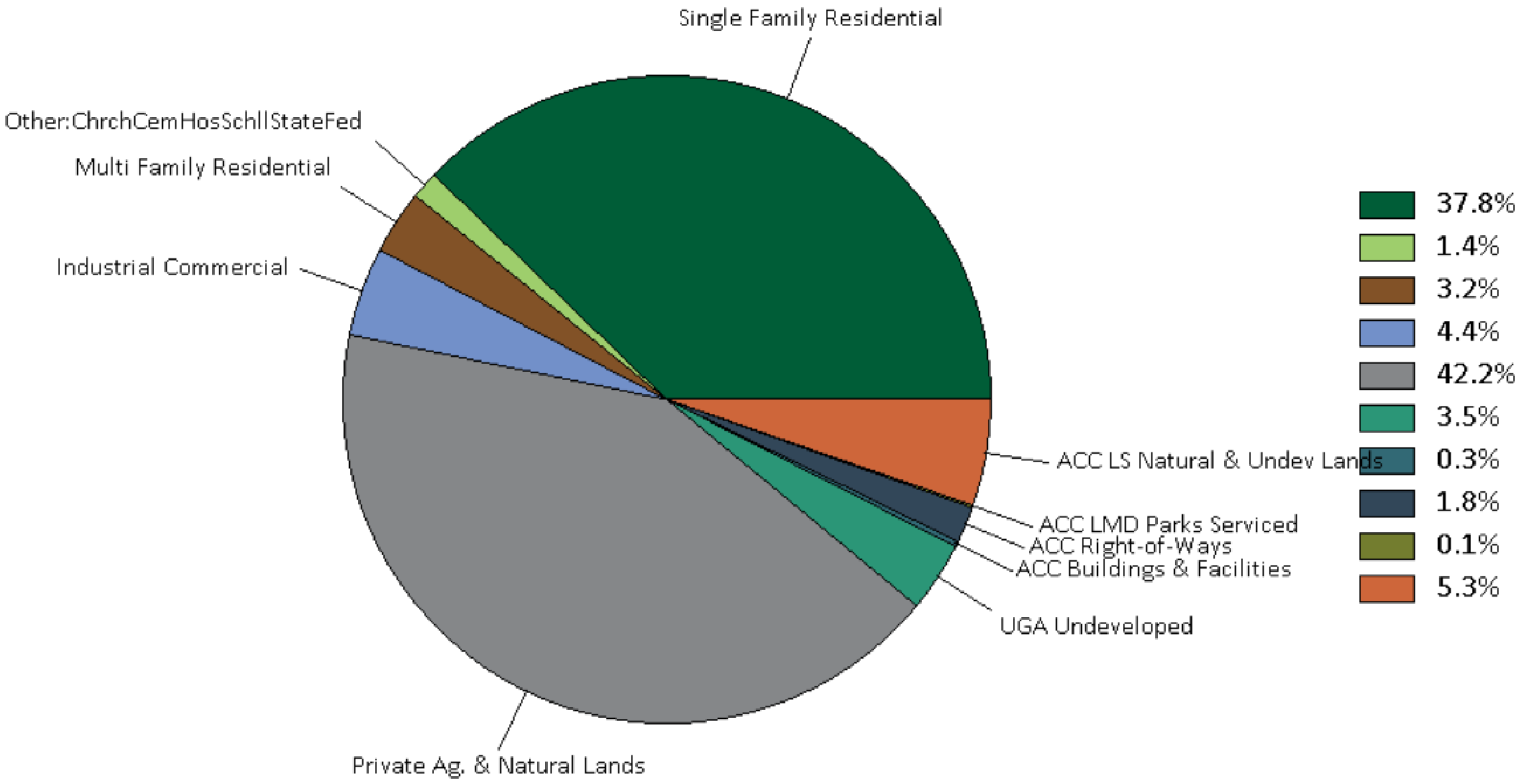
ACC Urban Forest Leaf Area Acres

total leaf area acres (la)

ingle Family Res - 234,519 leaf acres
Multi Family Res - 19,875
Industrial/Commercial - 27,495
Private Ag. & Nat. Lands - 262,018
UGA Undeveloped - 21,658
ACC ROW - 11,234
ACC LMD Bldg./Fac. - 1,665
ACC LMD Parks Serviced - 696
ACC LS Nat. & Undev. Lands - 32,942
Other(Chrch,Cem,Hos, etc) - 8,517

Leaf Area by Stratum

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



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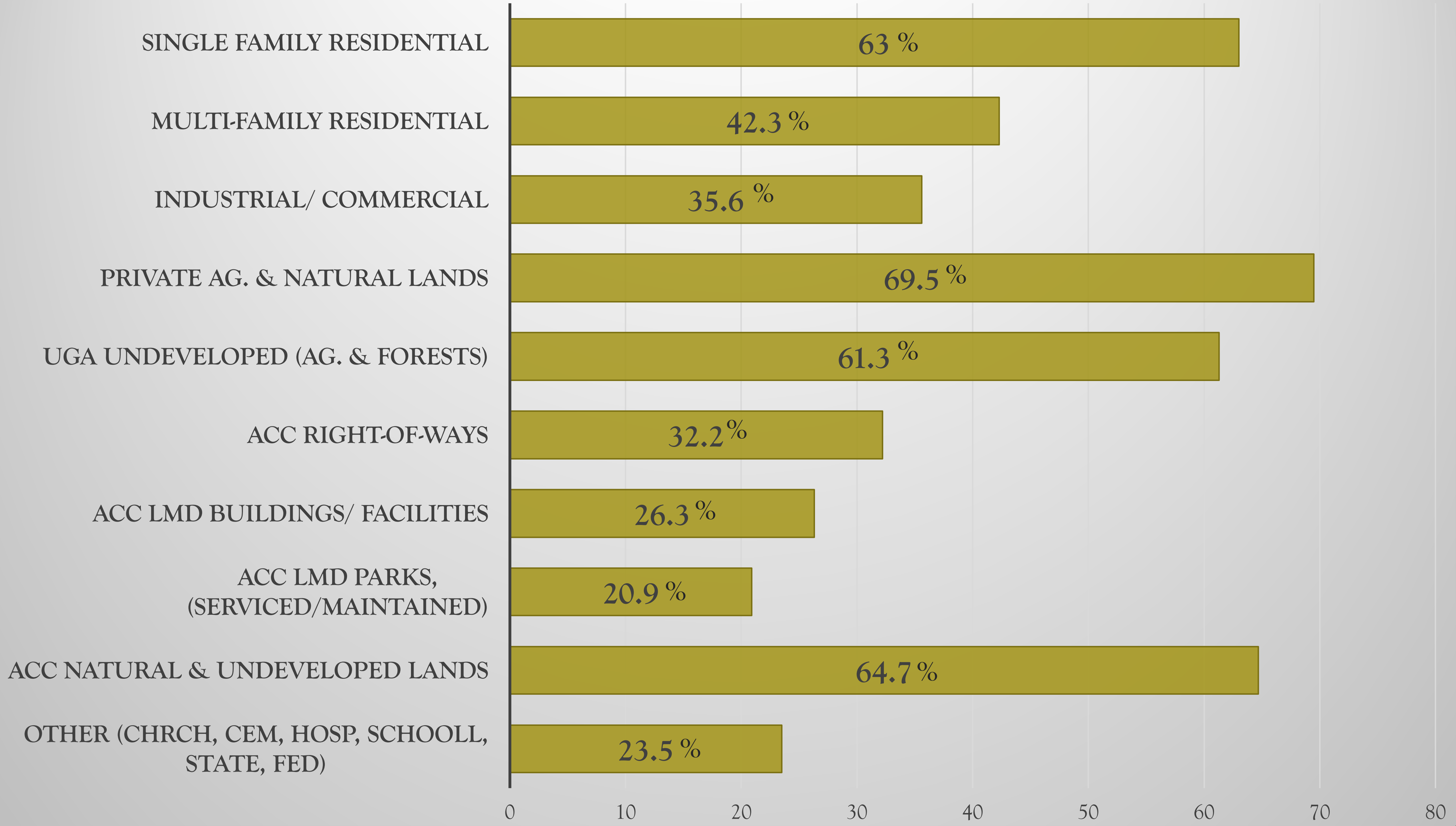
Winged elm	2.8	1.7	4.5

ACC Urban Forest Canopy Cover

58.2 %

Canopy Coverage Percentage (%) of Each Land Use Category



ACC Urban Forest Canopy Cover = 58.2%

ACC Trees per acre = 176 t/ac

Canopy Coverage & Comparison – ACC to Other Cities

Atlanta, GA............36.7% Canopy Cover (112 trees/acre)

Morgantown, WV...35.5% Canopy Cover (119 trees/acre)

Woodbridge, NJ......29.5% Canopy Cover (66 trees/acre)

Oakville, ON, CA....29.1% Canopy Cover (78 trees/acre)

Washington DC.......28.6% Canopy Cover (49 trees/acre)

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in ACC Community Tree Study was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 1.875 thousand tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of $2.8 million (see Appendix I for more details).

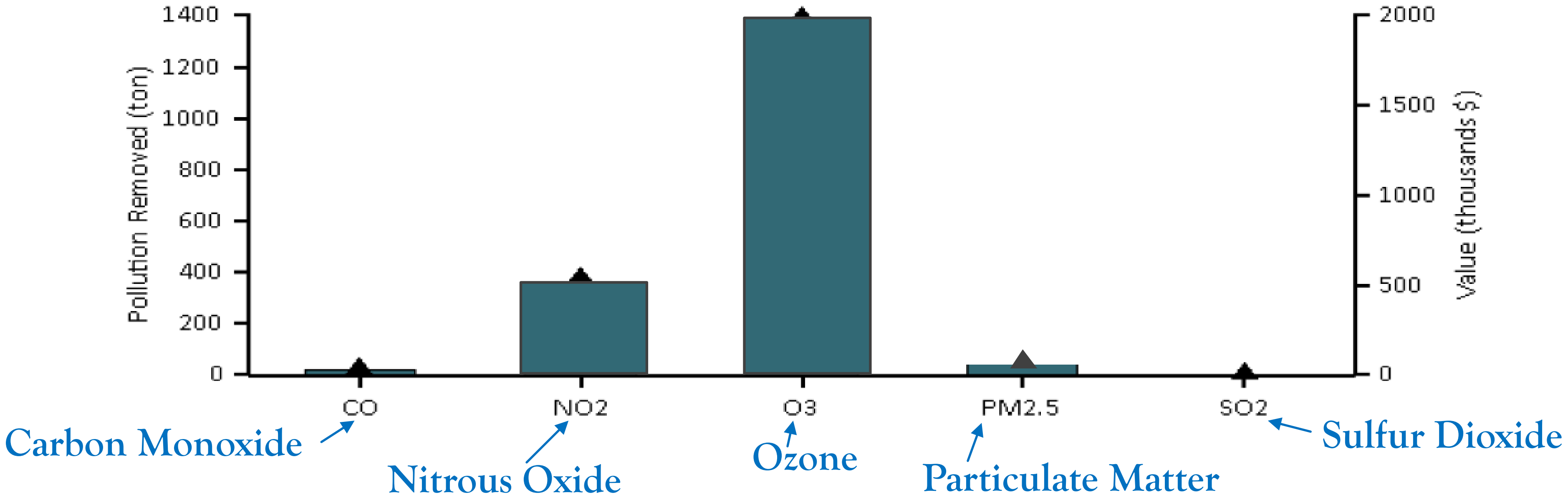


Figure 7. Annual Pollution Removal (points) and values (bars) by urban trees, ACC Community Tree Study

Air Quality Health Impacts and Values by Trees

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

	NO2		O3		PM2.5		SO2	
	Incidence (Reduction/yr)	Value ($/yr)	Incidence (Reduction/yr)	Value ($/yr)	Incidence (Reduction/yr)	Value ($/yr)	Incidence (Reduction/yr)	Value ($/yr)
Acute Bronchitis					0.134	11.84		
Acute Myocardial Infarction					0.062	5,579.30		
Acute Respiratory Symptoms	20.501	647.42	364.703	31,177.81	123.330	12,088.57	0.135	4.26
Asthma Exacerbation	280.859	23,394.13			58.291	4,738.64	1.199	94.29
Chronic Bronchitis					0.069	19,213.65		
Emergency Room Visits	0.377	157.13	0.161	67.41	0.099	40.93	0.008	3.29
Hospital Admissions	1.045	30,999.16	0.478	14,506.95			0.008	257.33
Hospital Admissions, Cardiovascular					0.039	1,479.17		
Hospital Admissions, Respiratory					0.030	934.74		
Lower Respiratory Symptoms					1.594	82.78		
Mortality			0.131	1,018,246.50	0.205	1,593,109.16		
School Loss Days			85.341	8,379.61				
Upper Respiratory Symptoms					1.351	60.66		
Work Loss Days					21.837	2,952.39		
Total	**302.781**	**55,197.84**	**450.814**	**1,072,378.27**	**207.041**	**1,640,291.82**	**1.350**	**359.17**

EPA Environmental Benefits Mapping and Analysis Program http://www.epa.gov/airquality/benmap/index.html
Incidence: the total number of adverse health effects avoided in a year due to a change in pollution concentration
Value: the economic value that is associated with the incidence of adverse health effects

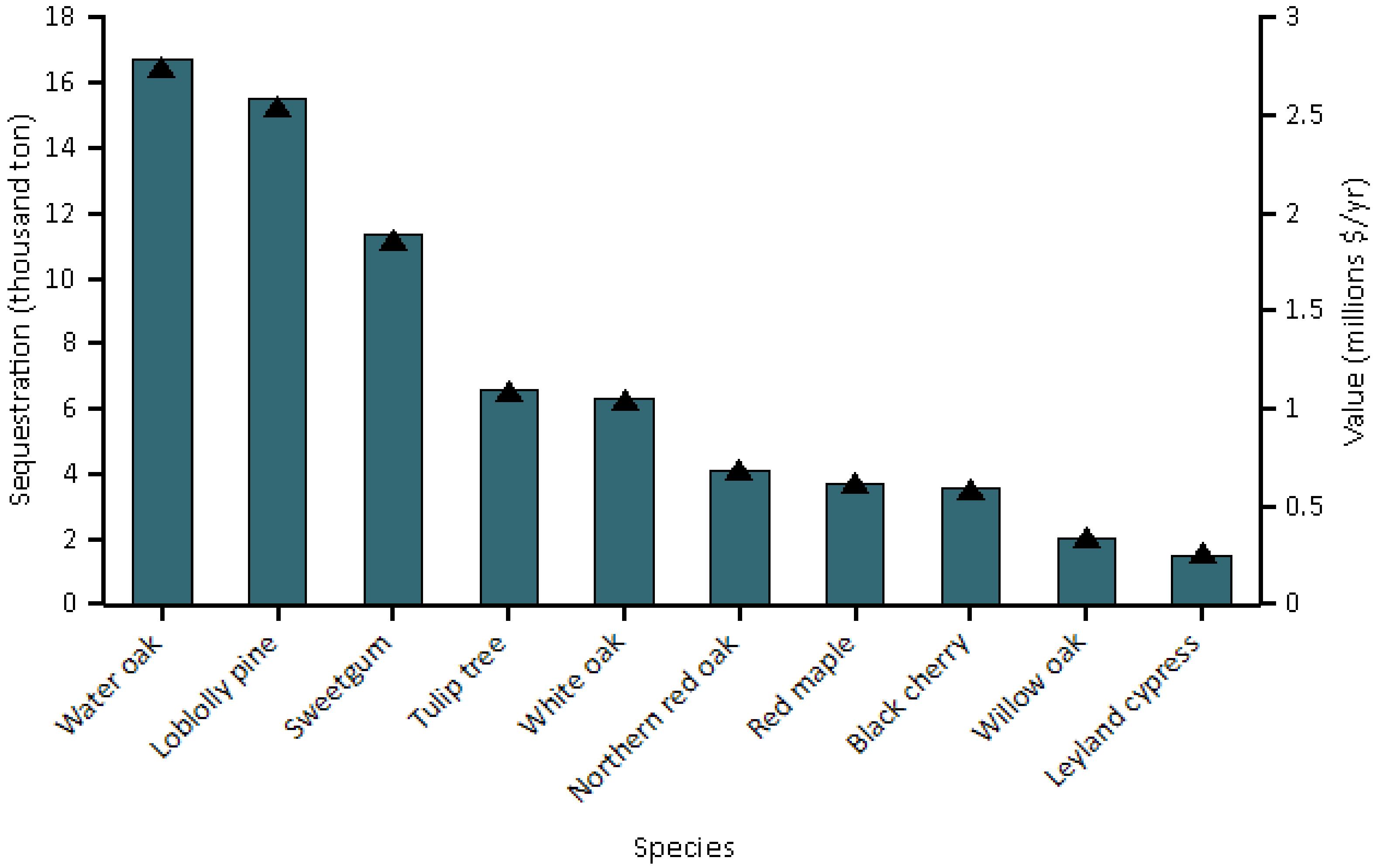


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, ACC Community Tree Study

Carbon Sequestration

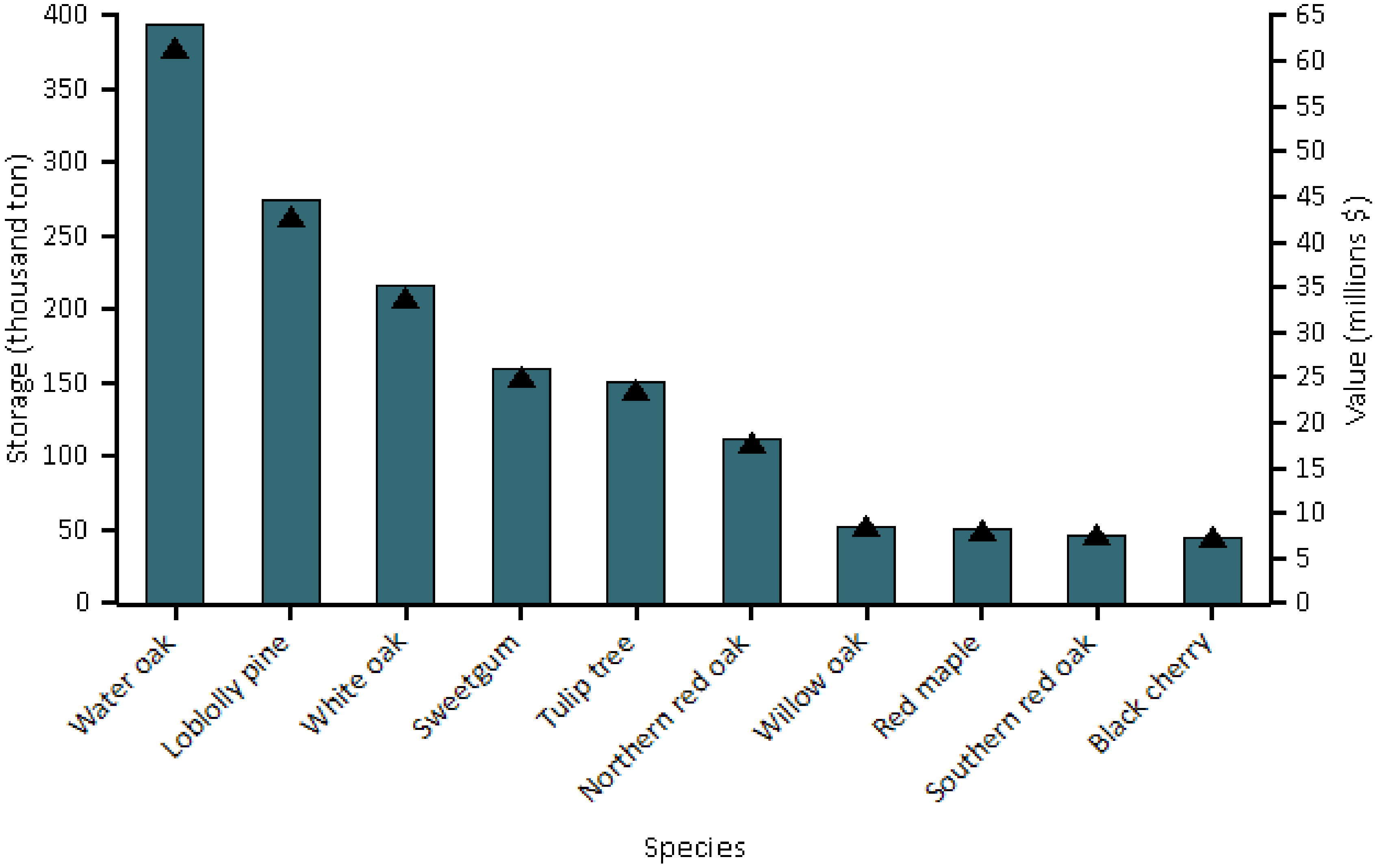


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, ACC Community Tree Study

Carbon Storage

Trees & Building Energy Use

Direct heating/cooling effect on building

Table 3. Annual savings in tons of carbon avoided from trees near residential buildings

Table 3. Annual energy savings due to trees near residential buildings, ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[a]	87,896	N/A	87,896
MWH[b]	1,828	26,127	27,956
Carbon Avoided (tons)	2,590	5,013	7,603

[a]MBTU - one million British Thermal Units
[b]MWH - megawatt-hour

Amount of carbon that does not have to be released from power plants

Table 4. Annual savings in dollars ($) of carbon avoided from trees near residential buildings

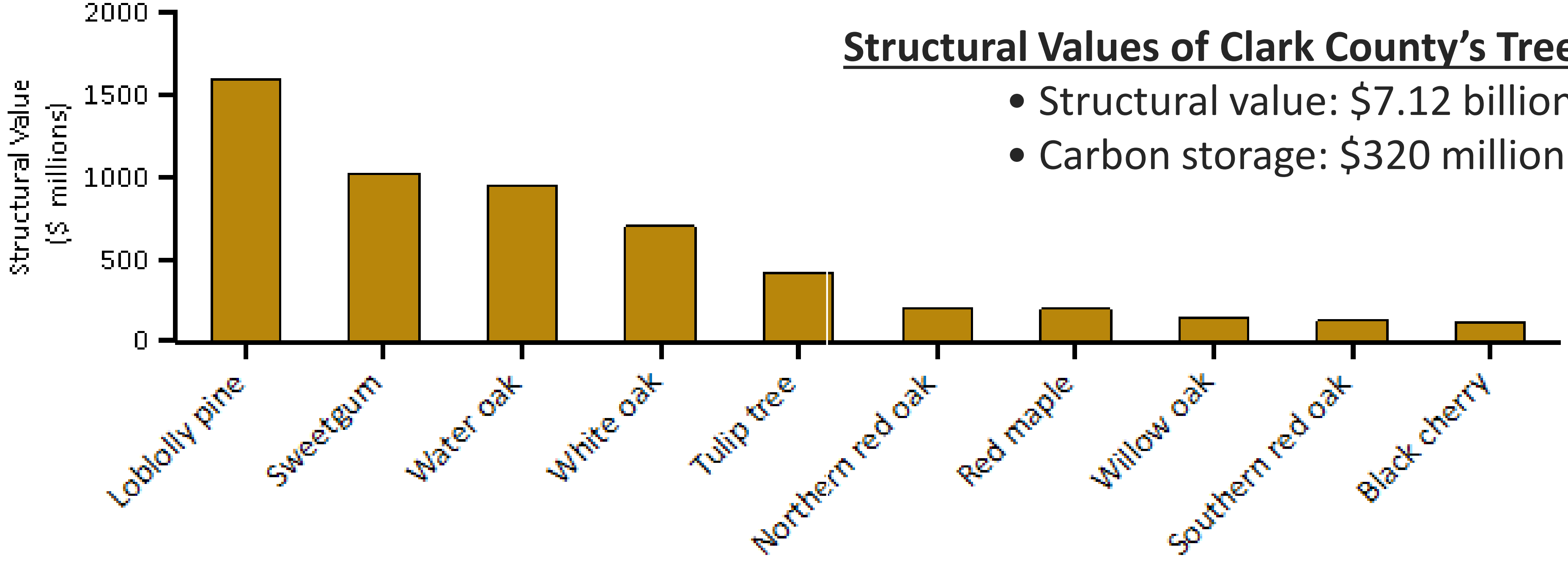
	Heating	*Cooling*	*Total*
MBTU[b]	1,351,327	N/A	1,351,327
MWH[c]	224,148	$ 3,203,214	$ 3,427,361
Carbon Avoided [dollars ($)]	441,720	$ 855,013	$ 1,296,734

[b]Based on the prices of $122.6 per MWH and $15.3742400430376 per MBTU (see Appendix I for more details)
[c]MBTU - one million British Thermal Units
[c]MWH - megawatt-hour

Dollar Value of Energy Savings!!

Total Dollar Value of Energy Savings = $ 4,724,095.00

Structural & Functional Values



Structural Values of Clark County's Trees:

- Structural value: $7.12 billion
- Carbon storage: $320 million

Figure. Tree specie with the greatest structural value, ACC Community Tree Study

Annual Functional Values of Clarke County's Trees:

- Carbon sequestration: $15.8 million
- Avoided runoff: $10 million
- Pollution removal: $2.8 million
- Energy costs and carbon emission values: $6.08 million

Potential Pest Impacts

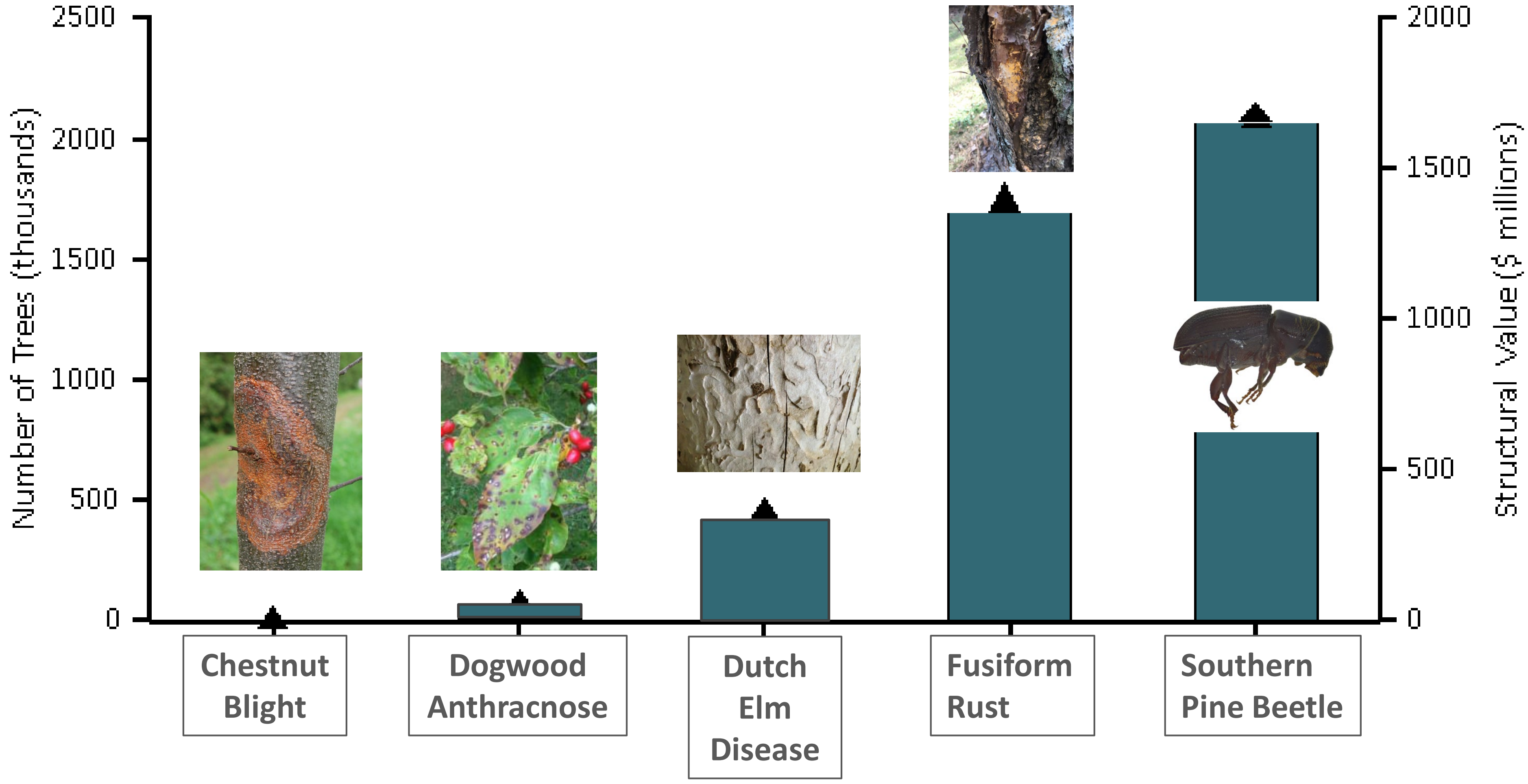


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, ACC Community Tree Study

The Importance of Good Information to Inform the Narrative

https://www.wikiwand.com/en/Tree_That_Owns_Itself (1910)

Photo by Rodney Walters (ACC Community Forester), Oct. 2021)

ACC Community Tree Study

iTree Eco

i-Tree
Eco

Takeaways:

- An iTree Eco study is a complex process: requires planning, determination, assistance, time/$, and patience. It requires becoming an expert with the iTree program
- Result: A valuable set of credible information & analyses about the structure, function, and value of the urban forest
- These analyses can help assemble a narrative about your community's forest(s).

Thank You

ACC COMMUNITY TREE COUNCIL

ATHENS-CLARKE COUNTY GEORGIA

Rodney Walters
+1 (762) 400-7519
rodney.walters@accgov.com
https://www.accgov.com/274/Community-Forestry

UNIVERSITY OF GEORGIA
Warnell School of Forestry & Natural Resources

Dr. Jason Gordon
+1 (470) 252-6879
jason.gordon@uga.edu
https://www.warnell.uga.edu/people/faculty/Jason-gordon

GEORGIA FORESTRY COMMISSION

Joan Scales
+1 (478) 733-2604
jscales@GFC.STATE.GA.US
https://urbanforestrysouth.org/about/contacts/list/joan-scales

Appendix C: (Executive Summary Proposal)

PROPOSAL

Athens-Clarke County Urban Tree Inventory Outreach Publication

Submitted by:

Jason Gordon
Assistant Professor
Warnell School of Forestry & Natural Resources, University of Georgia
108 E. Green St., Athens, GA, 30602

Introduction:

This proposal is submitted in response to a request by Athens-Clarke County Central Services to develop an outreach paper, known as a "white paper", and presentation addressing the Athens-Clarke County iTree urban tree inventory conducted from May to August 2021.

Scope of project:

The proposed project will result in:

(1) a white paper description of data analysis results as well as interpretations and implications from a public tree management perspective and from a private property perspective. Outcomes may include, for example, recommendations for ordinance incentives for conserving soils, tree planting, and other strategies. Presentation to convey highlights of Executive summary (about the ACC Tree Study) and to address Athens decision makers for consideration to officially accept the iTree ACC Community Tree Study.

(2) a presentation to community leaders that summarizes major findings and discussion from the executive summary white paper. This presentation is intended to provide information so community leaders may officially "accept" the tree inventory project and its conclusions.

Timeframe:

This project will take approximately six months complete December 2021-May 2022). The white paper will be submitted to Central Services by April 2022 with the presentation scheduled for May 2022.

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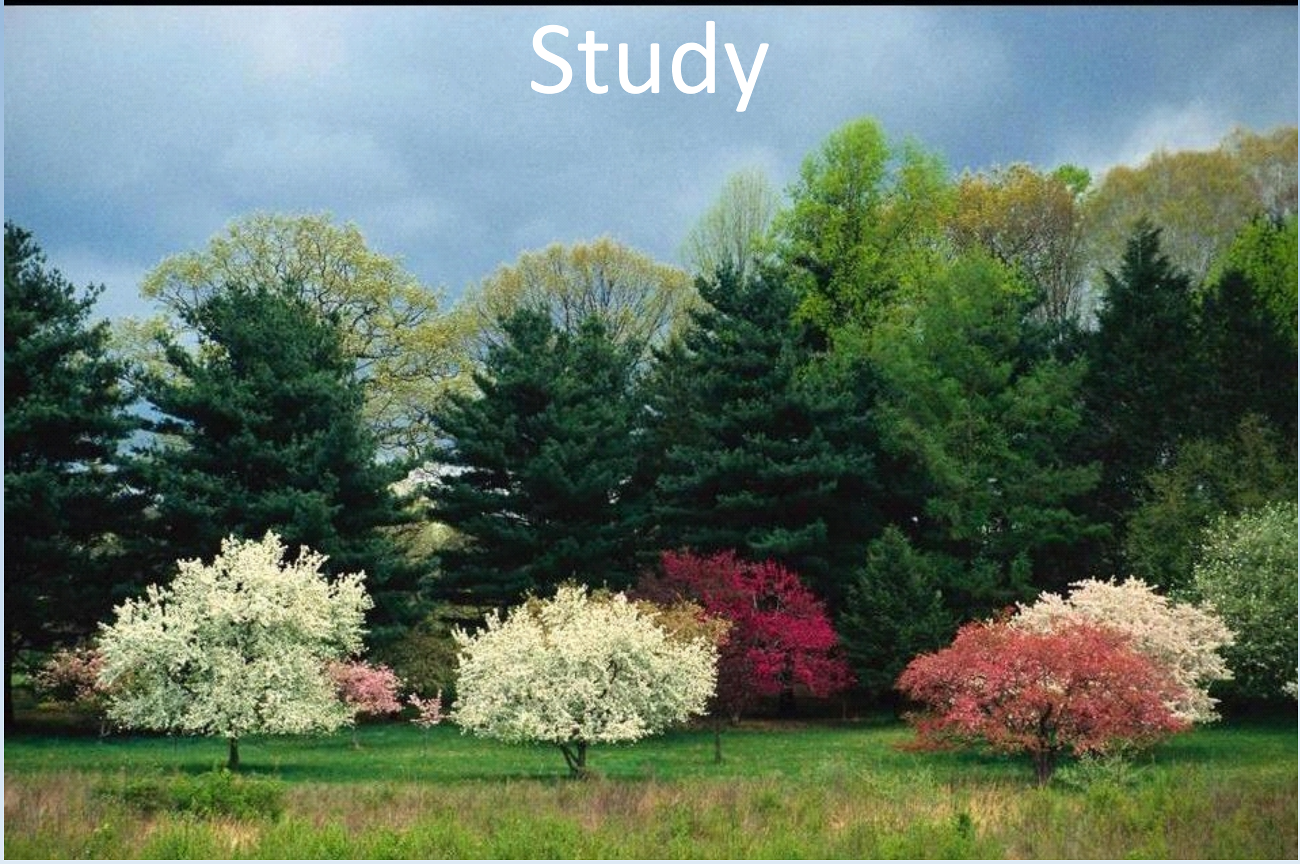
Appendix D: (Right-of-Ways)

i-Tree

Ecosystem Analysis

ROW-ACC Community Tree Study



Urban Forest Effects and Values

November 2021

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the ROW-ACC Community Tree Study urban forest was conducted during 2021. Data from 37 field plots located throughout ROW-ACC Community Tree Study were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 324,500
- Tree Cover: 32.2 %
- Most common species of trees: Loblolly pine, Sweetgum, Eastern white pine
- Percentage of trees less than 6" (15.2 cm) diameter: 60.5%
- Pollution Removal: 57.3 tons/year ($76.3 thousand/year)
- Carbon Storage: 40.42 thousand tons ($6.89 million)
- Carbon Sequestration: 2.381 thousand tons ($406 thousand/year)
- Oxygen Production: 5.255 thousand tons/year
- Avoided Runoff: 4.035 million cubic feet/year ($270 thousand/year)
- Building energy savings: $214,000/year
- Carbon Avoided: 338.5 tons/year ($57700/year)
- Structural values: $181 million

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of ROW-ACC Community Tree Study has an estimated 324,500 trees with a tree cover of 32.2 percent. The three most common species are Loblolly pine (32.2 percent), Sweetgum (12.0 percent), and Eastern white pine (7.7 percent).

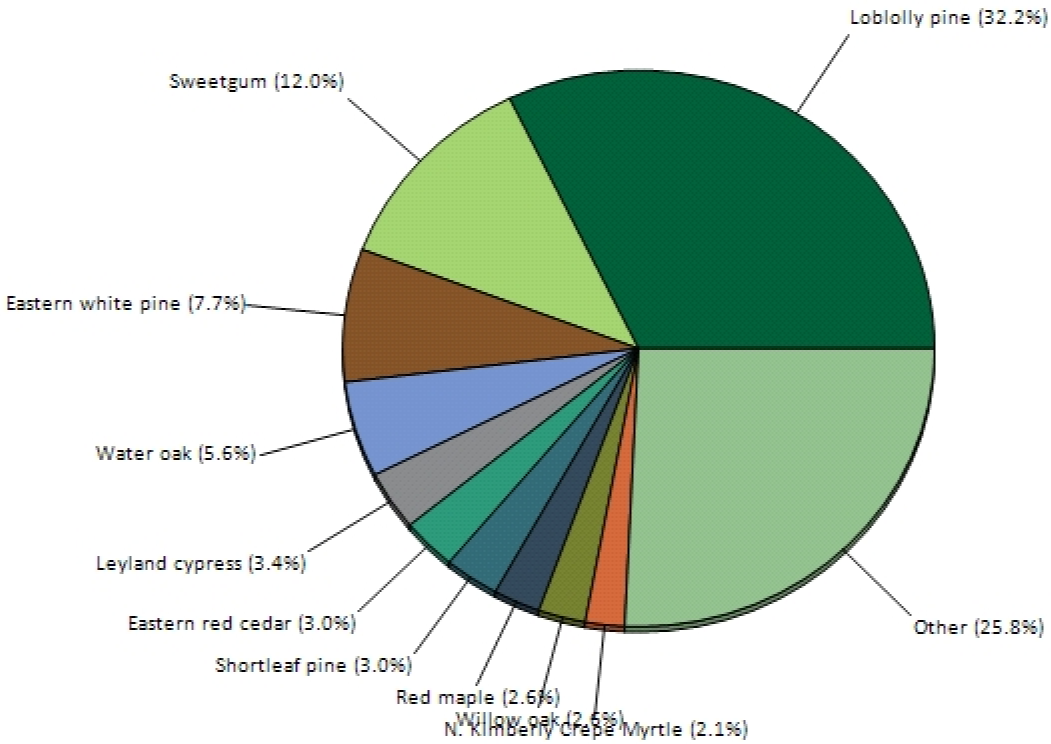


Figure 1. Tree species composition in ROW-ACC Community Tree Study

The overall tree density in ROW-ACC Community Tree Study is 63 trees/acre (see Appendix III for comparable values from other cities).

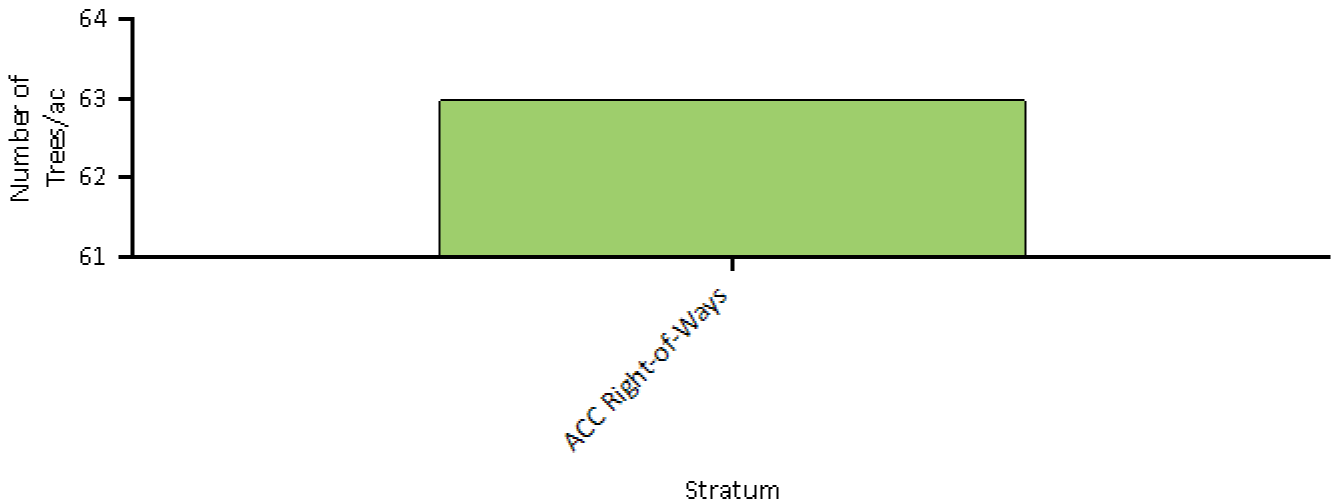


Figure 2. Number of trees/ac in ROW-ACC Community Tree Study by stratum

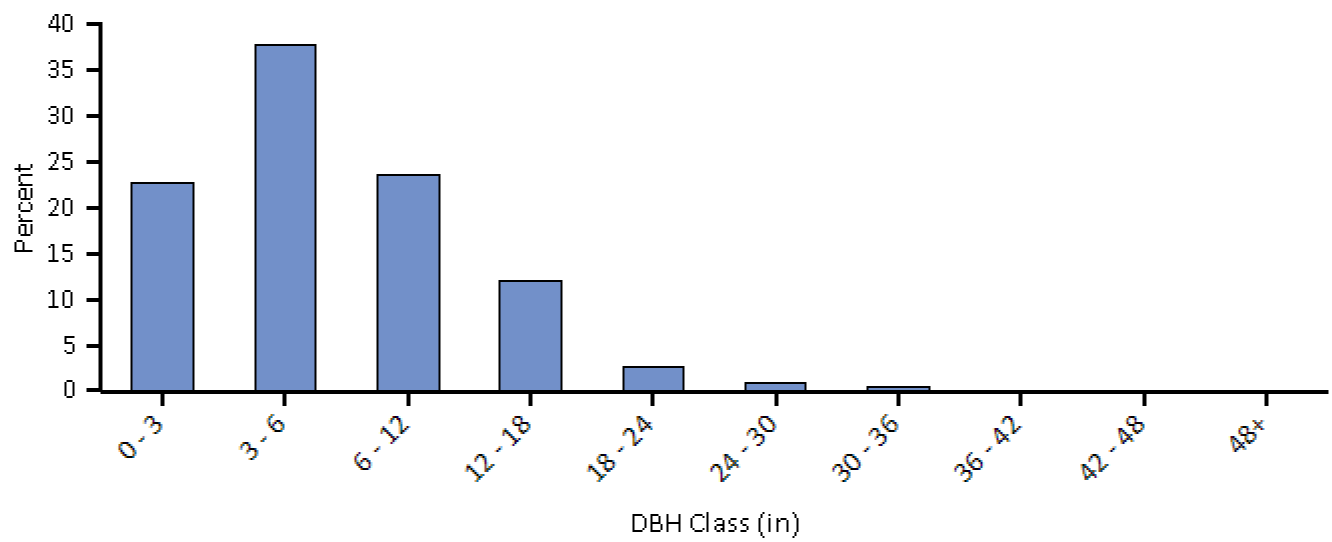


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix 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 by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In ROW-ACC Community Tree Study, about 92 percent of the trees are species native to North America, while 87 percent are native to Georgia. Species exotic to North America make up 8 percent of the population. Most exotic tree species have an origin from Asia (4 percent of the species).

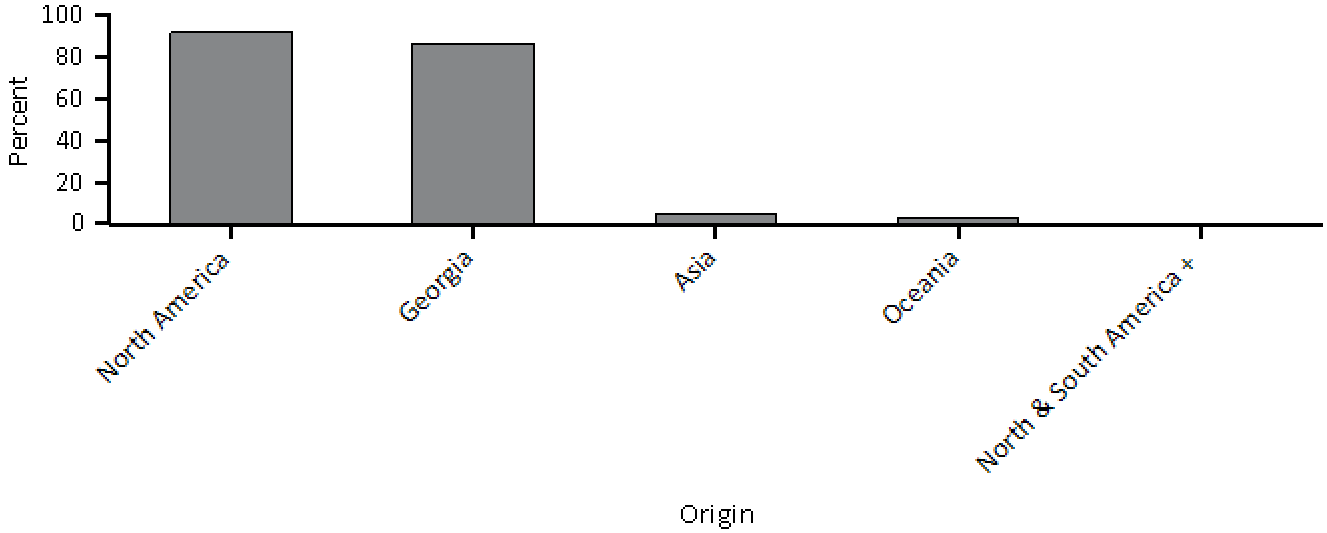


Figure 4. Percent of live tree population by area of native origin, ROW-ACC Community Tree Study

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. Two of the 43 tree species in ROW-ACC Community Tree Study are identified as invasive on the state invasive species list (Georgia Exotic Pest Plant Council 2006). These invasive species comprise 3.0 percent of the tree population though they may only cause a minimal level of impact. These two invasive species are Chinese privet (2.1 percent of population) and Persian silk tree (0.9 percent) (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 32 percent of ROW-ACC Community Tree Study and provide 17.55 square miles of leaf area. Total leaf area is greatest in ACC Right-of-Ways.

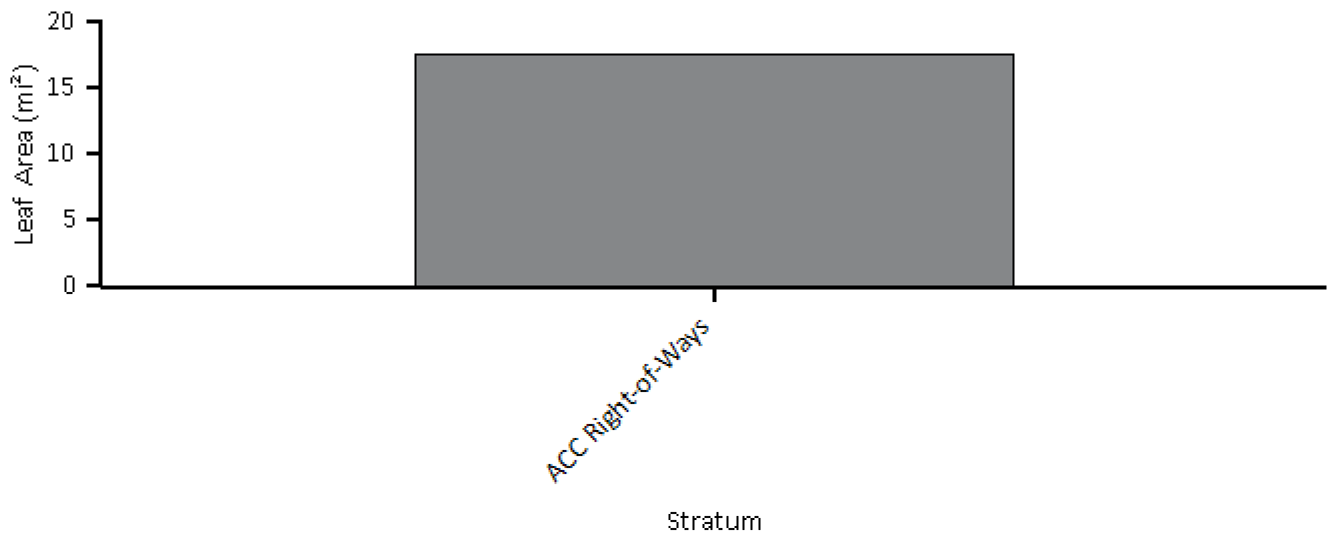


Figure 5. Leaf area by stratum, ROW-ACC Community Tree Study

In ROW-ACC Community Tree Study, the most dominant species in terms of leaf area are Eastern white pine, Loblolly pine, and Sweetgum. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in ROW-ACC Community Tree Study

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Loblolly pine	32.2	11.5	43.6
Sweetgum	12.0	11.4	23.5
Eastern white pine	7.7	13.3	21.0
Water oak	5.6	10.6	16.2
Leyland cypress	3.4	8.5	12.0
Winged elm	2.1	4.9	7.0
Post oak	1.7	4.7	6.4
Willow oak	2.6	3.7	6.2
Black oak	1.3	3.6	4.9
Eastern red cedar	3.0	1.7	4.7

Common ground cover classes (including cover types beneath trees and shrubs) in ROW-ACC Community Tree Study include duff/mulch, unmaintained grass, rock, bare soil, buildings, other impervious, and water, impervious covers such as tar, and cement, and herbaceous covers such as grass, and herbs (Figure 6). The most dominant ground cover types are Tar (46.2 percent) and Grass (19.2 percent).

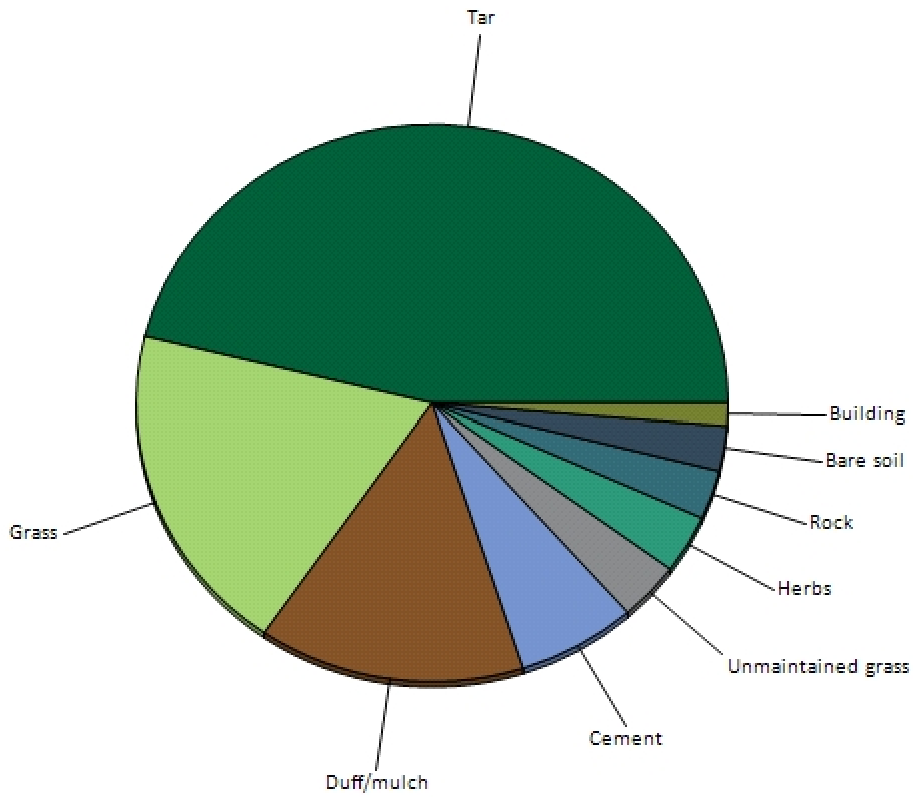


Figure 6. Percent of land by ground cover classes, ROW-ACC Community Tree Study

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in ROW-ACC Community Tree Study was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 57.3 tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of $76.3 thousand (see Appendix I for more details).

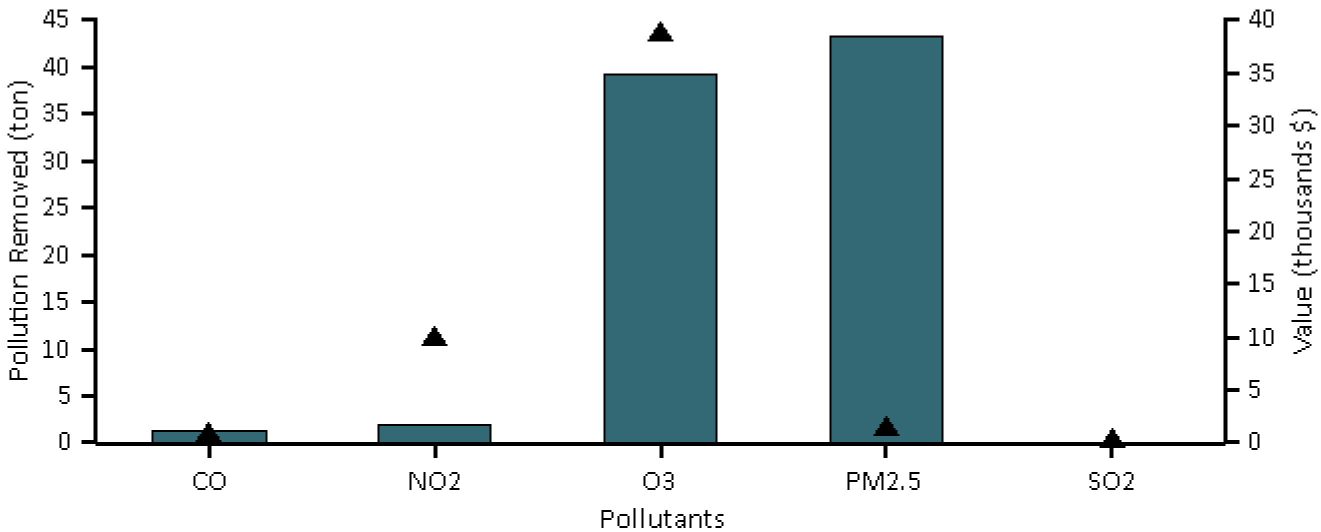


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, ROW-ACC Community Tree Study

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] 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 positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2021, trees in ROW-ACC Community Tree Study emitted an estimated 120.7 tons of volatile organic compounds (VOCs) (56.7 tons of isoprene and 63.99 tons of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Forty percent of the urban forest's VOC emissions were from Water oak and Post oak. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. 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 and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

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 gross sequestration of ROW-ACC Community Tree Study trees is about 2.381 thousand tons of carbon per year with an associated value of $406 thousand. Net carbon sequestration in the urban forest is about 1.971 thousand tons. See Appendix I for more details on methods.

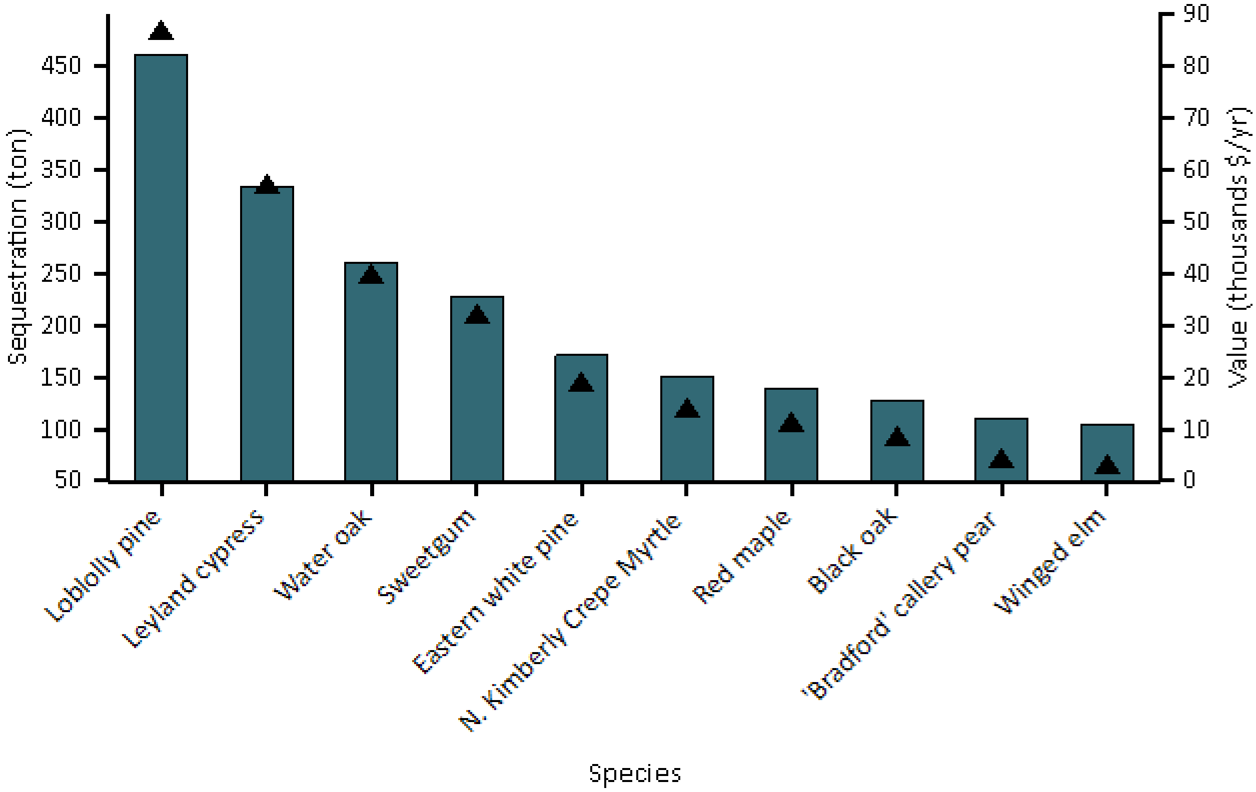


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, ROW-ACC Community Tree Study

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases 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 are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in ROW-ACC Community Tree Study are estimated to store 40400 tons of carbon ($6.89 million). Of the species sampled, Loblolly pine stores and sequesters the most carbon (approximately 16.7% of the total carbon stored and 20.3% of all sequestered carbon.)

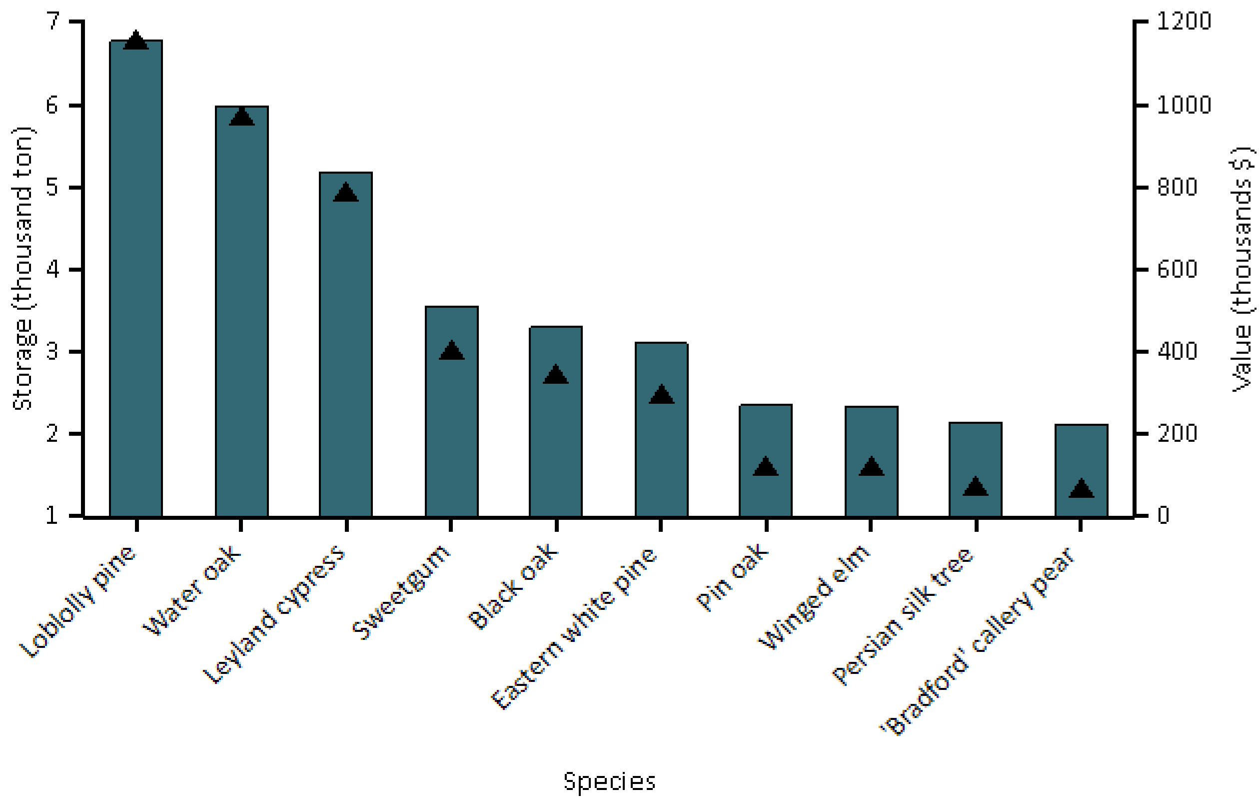


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, ROW-ACC Community Tree Study

V. 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 ROW-ACC Community Tree Study are estimated to produce 5.255 thousand tons of oxygen per year.[4] However, this tree benefit is relatively 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. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (ton)*	*Net Carbon Sequestration (ton/yr)*	*Number of Trees*	*Leaf Area (acre)*
Leyland cypress	837.15	313.93	11,142	959.96
Loblolly pine	639.84	239.94	104,460	1,286.81
Water oak	626.83	235.06	18,106	1,191.18
Sweetgum	515.39	193.27	38,999	1,285.36
Eastern white pine	335.56	125.84	25,070	1,488.88
N. Kimberly Crepe Myrtle	300.06	112.52	6,964	40.11
Red maple	268.22	100.58	8,357	199.23
Black oak	198.02	74.26	4,178	406.55
'Bradford' callery pear	173.50	65.06	1,393	221.41
Pin oak	156.94	58.85	2,786	254.56
Winged elm	152.79	57.30	6,964	546.71
Tulip tree	102.57	38.46	4,178	103.94
Willow oak	98.52	36.95	8,357	411.77
Post oak	75.69	28.38	5,571	528.23
Shortleaf pine	73.65	27.62	9,750	45.80
Eastern cottonwood	71.75	26.91	1,393	461.32
Black cherry	69.27	25.98	5,571	70.60
White ash	62.49	23.43	4,178	192.20
Chinese privet	58.82	22.06	6,964	23.34
Flowering dogwood	47.60	17.85	2,786	34.41

[4] A negative estimate, or oxygen deficit, indicates that trees are decomposing faster than they are producing oxygen. This would be the case in an area that has a large proportion of dead trees.

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees 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 (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of ROW-ACC Community Tree Study help to reduce runoff by an estimated 4.04 million cubic feet a year with an associated value of $270 thousand (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In ROW-ACC Community Tree Study, the total annual precipitation in 2016 was 39.6 inches.

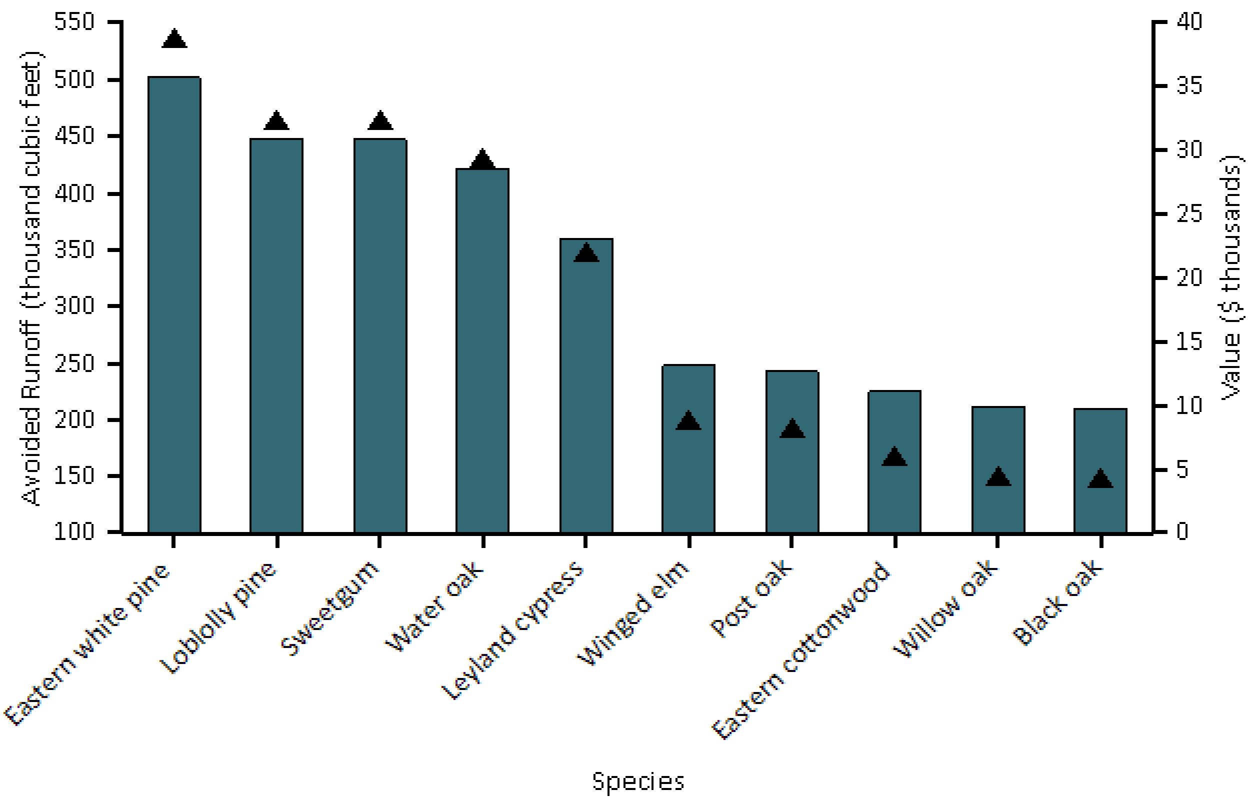


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, ROW-ACC Community Tree Study

VII. Trees and Building Energy Use

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

Trees in ROW-ACC Community Tree Study are estimated to reduce energy-related costs from residential buildings by $214,000 annually. Trees also provide an additional $57,700 in value by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of 339 tons of carbon emissions).

Note: negative numbers indicate that there was not a reduction in carbon emissions and/or value, rather carbon emissions and values increased by the amount shown as a negative value.[5]

Table 3. Annual energy savings due to trees near residential buildings, ROW-ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[a]	2,316	N/A	2,316
MWH[b]	35	1,421	1,457
Carbon Avoided (tons)	66	273	339

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, ROW-ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[b]	35,604	N/A	35,604
MWH[c]	4,349	174,251	178,600
Carbon Avoided	11,223	46,512	57,734

[b]Based on the prices of $122.6 per MWH and $15.3742400430376 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in ROW-ACC Community Tree Study have the following structural values:

- Structural value: $181 million
- Carbon storage: $6.89 million

Urban trees in ROW-ACC Community Tree Study have the following annual functional values:

- Carbon sequestration: $406 thousand
- Avoided runoff: $270 thousand
- Pollution removal: $76.3 thousand
- Energy costs and carbon emission values: $272 thousand

(Note: negative value indicates increased energy cost and carbon emission value)

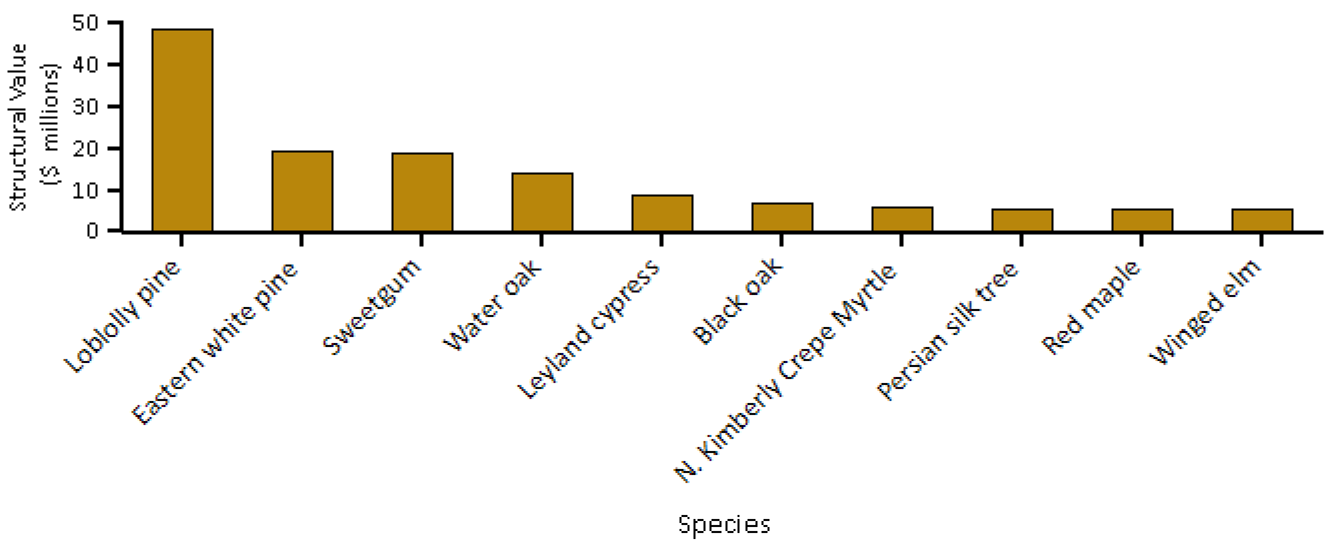


Figure 11. Tree species with the greatest structural value, ROW-ACC Community Tree Study

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Clarke County. Five of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

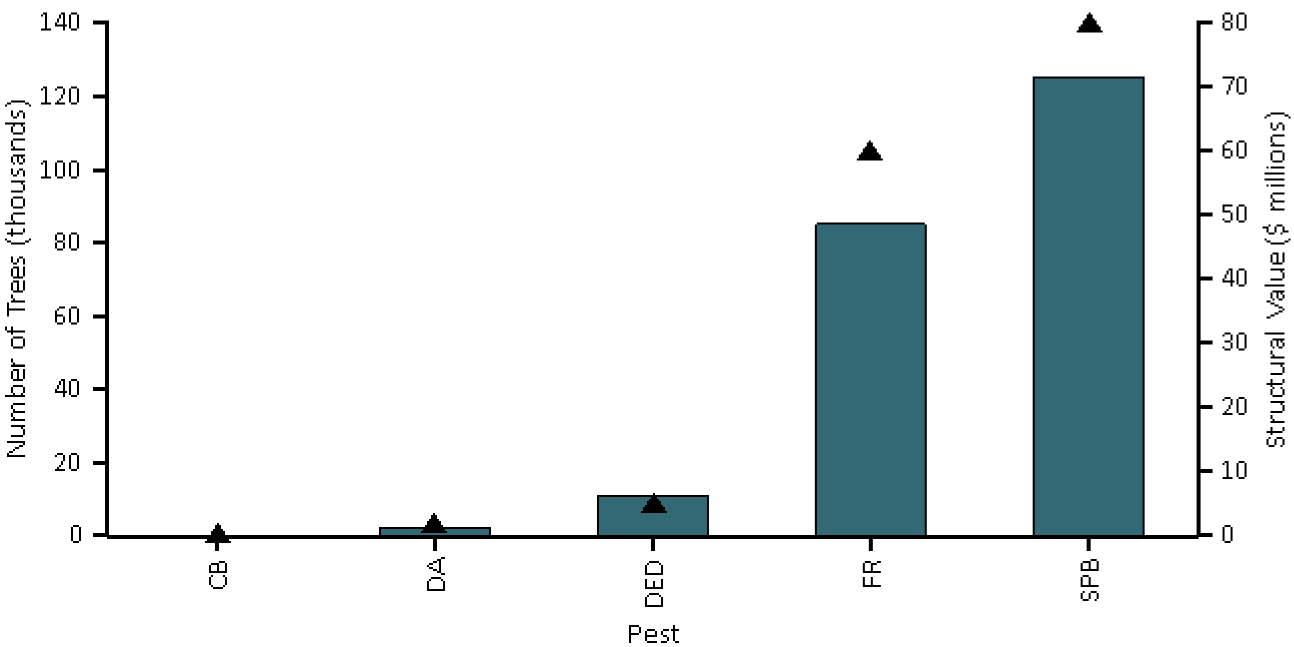


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, ROW-ACC Community Tree Study

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population ($0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.9 percent of the population, which represents a potential loss of $1.28 million in structural value.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, ROW-ACC Community Tree Study could possibly lose 2.6 percent of its trees to this pest ($6.33 million in structural value).

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 32.2 percent of the population ($48.6 million in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 42.9 percent of the population, which represents a potential loss of $71.6 million in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

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

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Georgia Exotic Pest Plant Council 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (PM10) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area.

Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (Nowak et al 2013). 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 positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 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.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,327 per ton (carbon monoxide), $804 per ton (ozone), $150 per ton (nitrogen dioxide), $56 per ton (sulfur dioxide), $25,484 per ton (particulate matter less than 2.5 microns).

Carbon Storage and Sequestration:

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

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

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 et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

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

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

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

For this analysis, energy saving value is calculated based on the prices of $122.60 per MWH and $15.37 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is

within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are 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 in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, 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) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in ROW-ACC Community Tree Study provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in ROW-ACC Community Tree Study in 24 days
- Annual carbon (C) emissions from 28,600 automobiles
- Annual C emissions from 11,700 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 8 automobiles
- Annual carbon monoxide emissions from 23 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 1,600 automobiles
- Annual nitrogen dioxide emissions from 721 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 2,280 automobiles
- Annual sulfur dioxide emissions from 6 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in ROW-ACC Community Tree Study in 1.4 days
- Annual C emissions from 1,700 automobiles
- Annual C emissions from 700 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" 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.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. 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.

Urban forest management strategies to help improve air quality include (Nowak 2000):

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 V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Georgia invasive species list (Georgia Exotic Pest Plant Council 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Chinese privet	6,964	2.1	23.3	0.2
Persian silk tree	2,786	0.9	171.6	1.5
Total	**9,750**	**3.00**	**194.93**	**1.74**

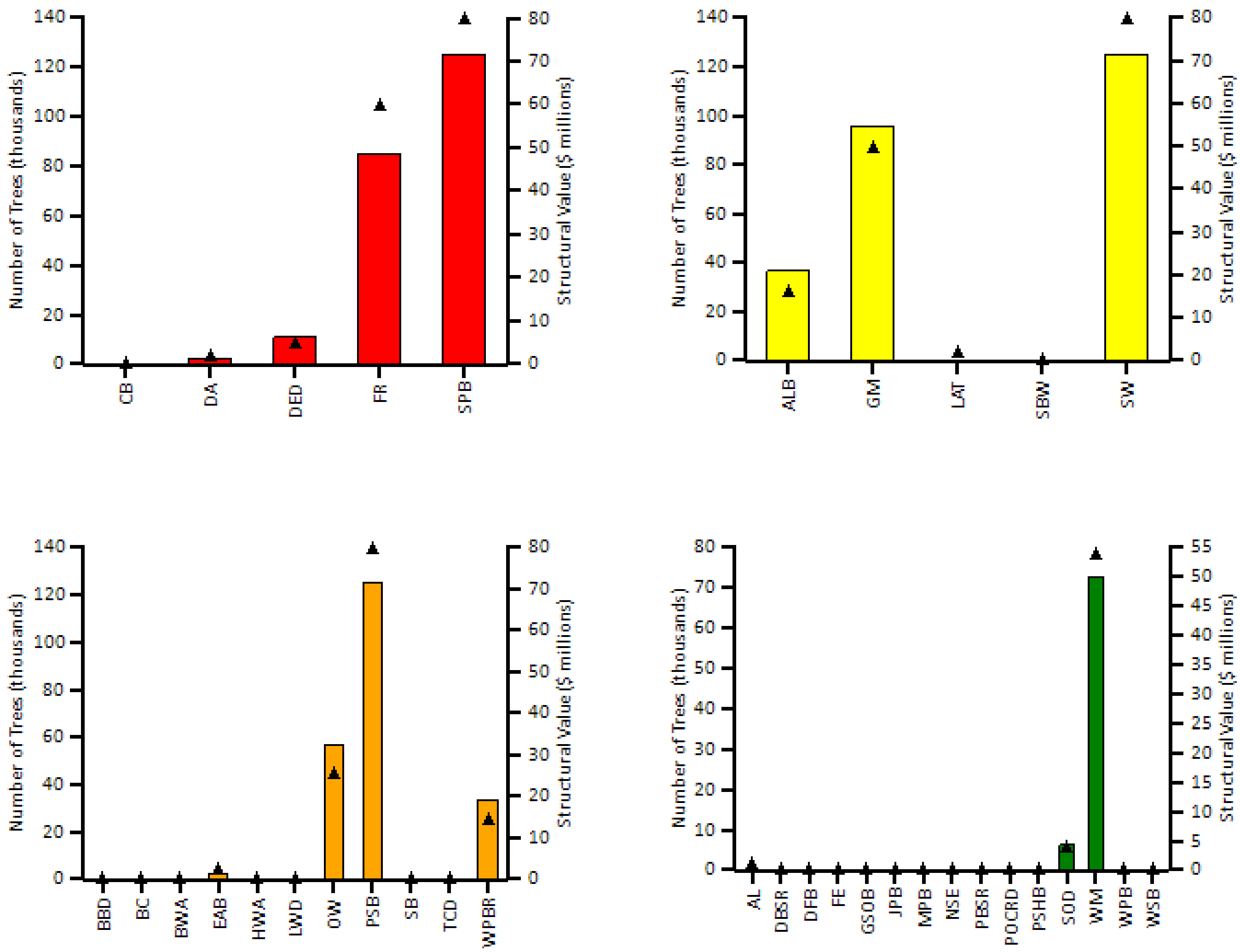
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ millions)
AL	Phyllocnistis populiella	Aspen Leafminer	1,393	0.03
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	27,856	20.96
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	2,786	1.28
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	8,357	6.33
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	4,178	1.41
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	104,460	48.65
GM	Lymantria dispar	Gypsy Moth	86,354	54.84
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	2,786	0.07
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	44,570	32.51
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	139,281	71.56
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	0	0.00
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	5,571	4.27
SPB	Dendroctonus frontalis	Southern Pine Beetle	139,281	71.56
SW	Sirex noctilio	Sirex Wood Wasp	139,281	71.56
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	77,997	50.10
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	25,070	19.33
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Structural value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	13	Loblolly pine																																				
	12	Eastern white pine																																				
	9	Shortleaf pine																																				
	7	Winged elm																																				
	7	Pin oak																																				
	7	Northern red oak																																				
	7	Southern red oak																																				
	7	American elm																																				
	6	Water oak																																				
	6	Willow oak																																				
	6	Post oak																																				
	6	Black oak																																				
	6	Blackjack oak																																				
	6	White oak																																				
	5	plum spp																																				
	4	White ash																																				
	4	Flowering dogwood																																				
	3	Red maple																																				
	3	Sugar maple																																				
	3	Common chokecherry																																				
	3	Eastern cottonwood																																				
	3	Silver maple																																				
	2	Sweetgum																																				
	2	Persian silk tree																																				
	2	Shining sumac																																				
	2	'Bradford' callery pear																																				
	2	Japanese maple																																				
	1	Black cherry																																				

Note:

Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county

- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Clarke county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Clarke county
- Green indicates pest is outside of these ranges

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Appendix E: (Buildings & Facilities)

i-Tree

Ecosystem Analysis

Buidings & Facilities-ACC

Community Tree Study

Urban Forest Effects and Values

November 2021

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Buidings & Facilities-ACC Community Tree Study urban forest was conducted during 2021. Data from 33 field plots located throughout Buidings & Facilities-ACC Community Tree Study were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 35,800
- Tree Cover: 26.3 %
- Most common species of trees: Loblolly pine, Sweetgum, American sycamore
- Percentage of trees less than 6" (15.2 cm) diameter: 44.8%
- Pollution Removal: 8.538 tons/year ($11.3 thousand/year)
- Carbon Storage: 5.85 thousand tons ($998 thousand)
- Carbon Sequestration: 314.2 tons ($53.6 thousand/year)
- Oxygen Production: 648.6 tons/year
- Avoided Runoff: 599.6 thousand cubic feet/year ($40.1 thousand/year)
- Building energy savings: $4,240/year
- Carbon Avoided: 6.017 tons/year ($1030/year)
- Structural values: $27.4 million

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of Buidings & Facilities-ACC Community Tree Study has an estimated 35,800 trees with a tree cover of 26.3 percent. The three most common species are Loblolly pine (20.0 percent), Sweetgum (12.0 percent), and American sycamore (7.2 percent).

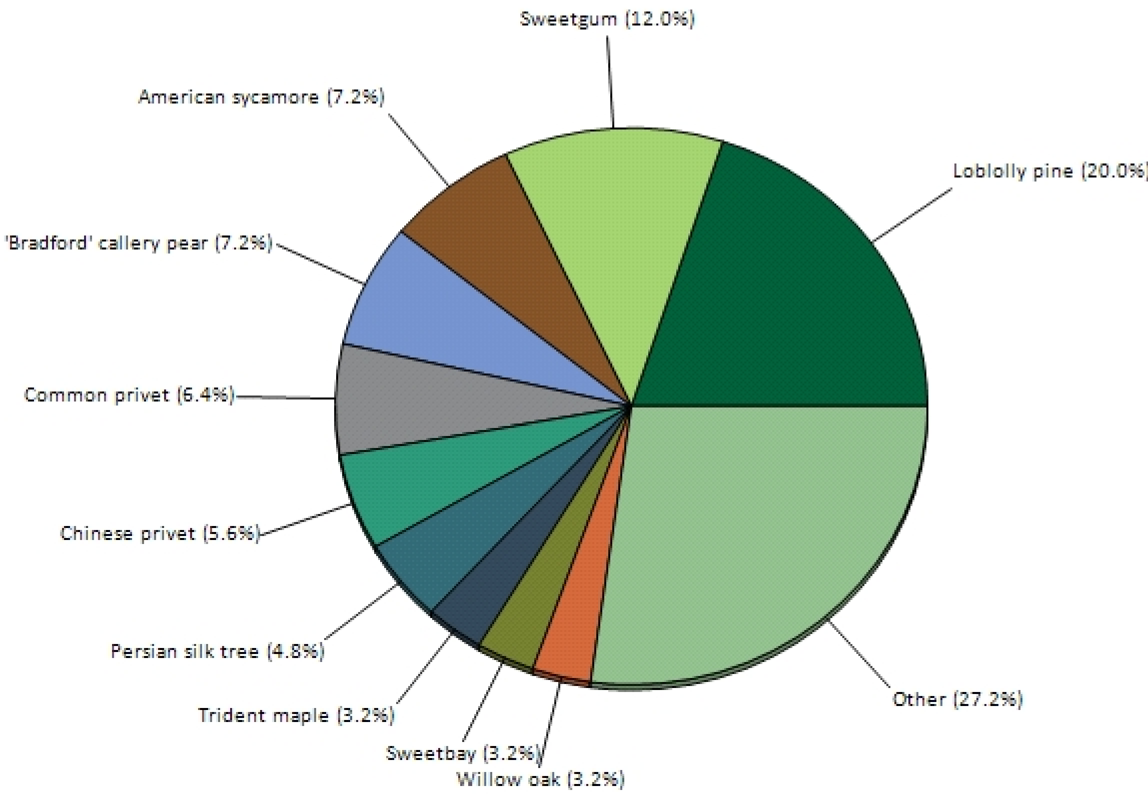


Figure 1. Tree species composition in Buidings & Facilities-ACC Community Tree Study

The overall tree density in Buidings & Facilities-ACC Community Tree Study is 38 trees/acre (see Appendix III for comparable values from other cities).

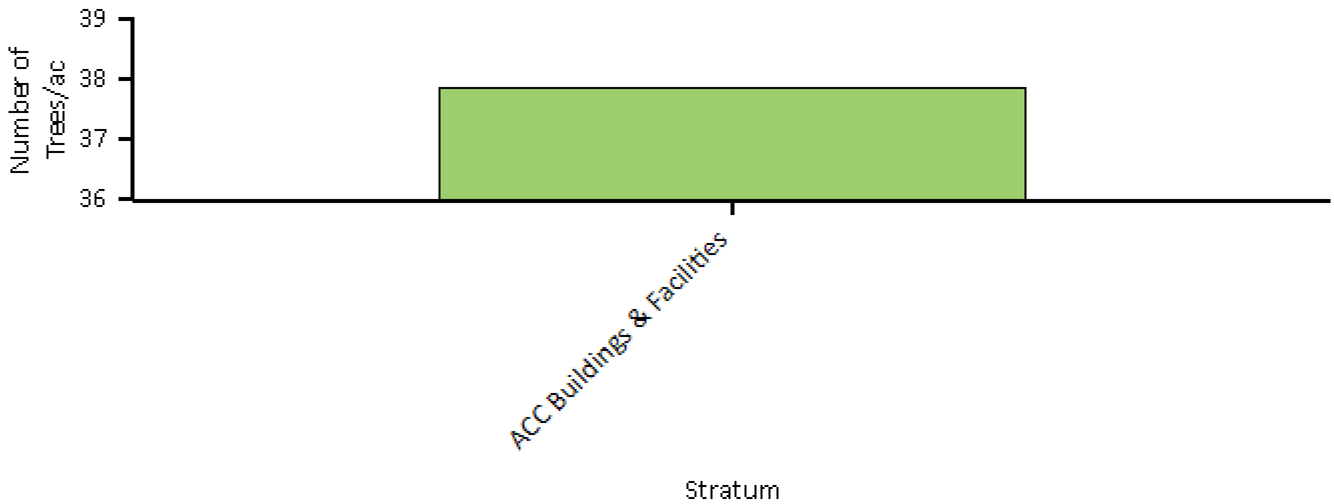


Figure 2. Number of trees/ac in Buidings & Facilities-ACC Community Tree Study by stratum

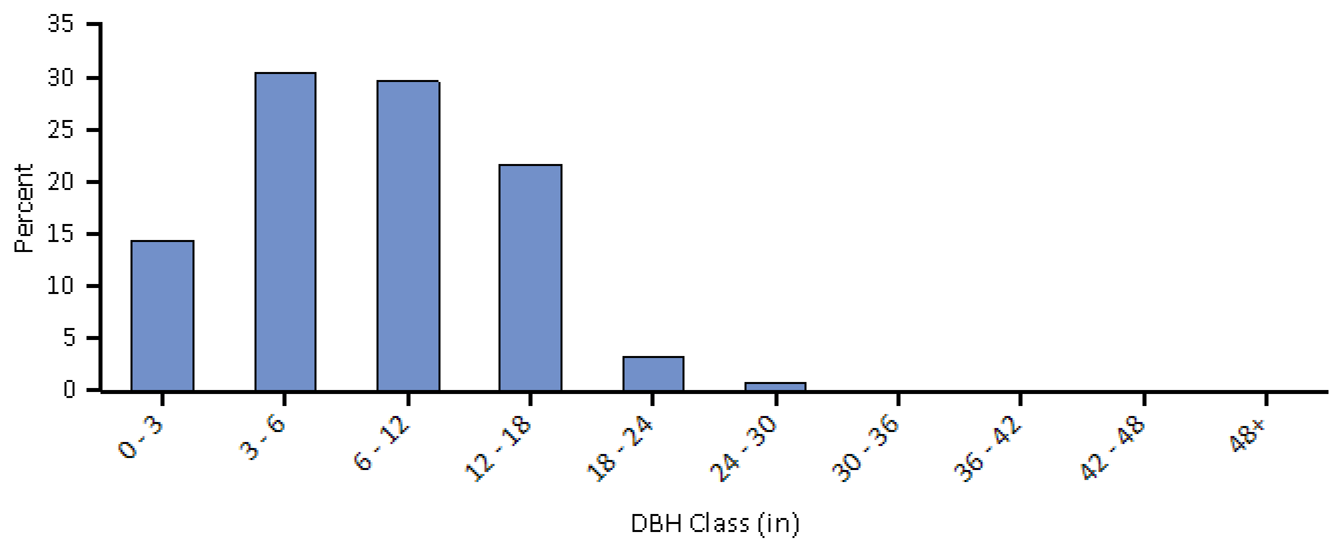


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix 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 by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Buildings & Facilities-ACC Community Tree Study, about 72 percent of the trees are species native to North America, while 71 percent are native to Georgia. Species exotic to North America make up 28 percent of the population. Most exotic tree species have an origin from Asia (22 percent of the species).

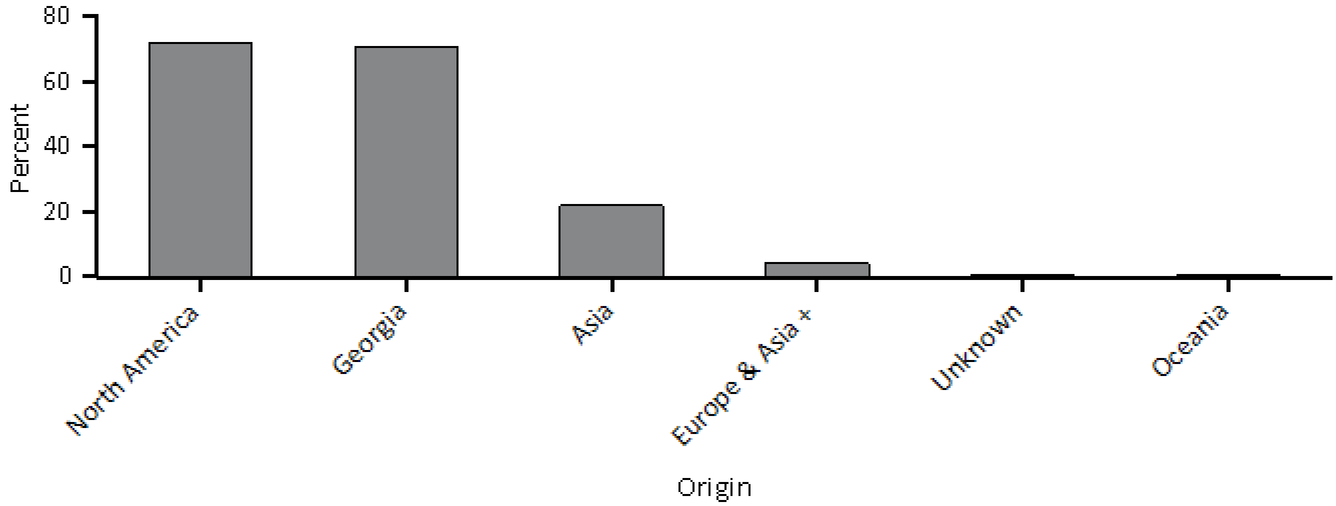


Figure 4. Percent of live tree population by area of native origin, Buidings & Facilities-ACC Community Tree Study

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. Two of the 32 tree species in Buidings & Facilities-ACC Community Tree Study are identified as invasive on the state invasive species list (Georgia Exotic Pest Plant Council 2006). These invasive species comprise 10.4 percent of the tree population though they may only cause a minimal level of impact. These two invasive species are Chinese privet (5.6 percent of population) and Persian silk tree (4.8 percent) (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 26 percent of Buildings & Facilities-ACC Community Tree Study and provide 2.603 square miles of leaf area. Total leaf area is greatest in ACC Buildings & Facilities.

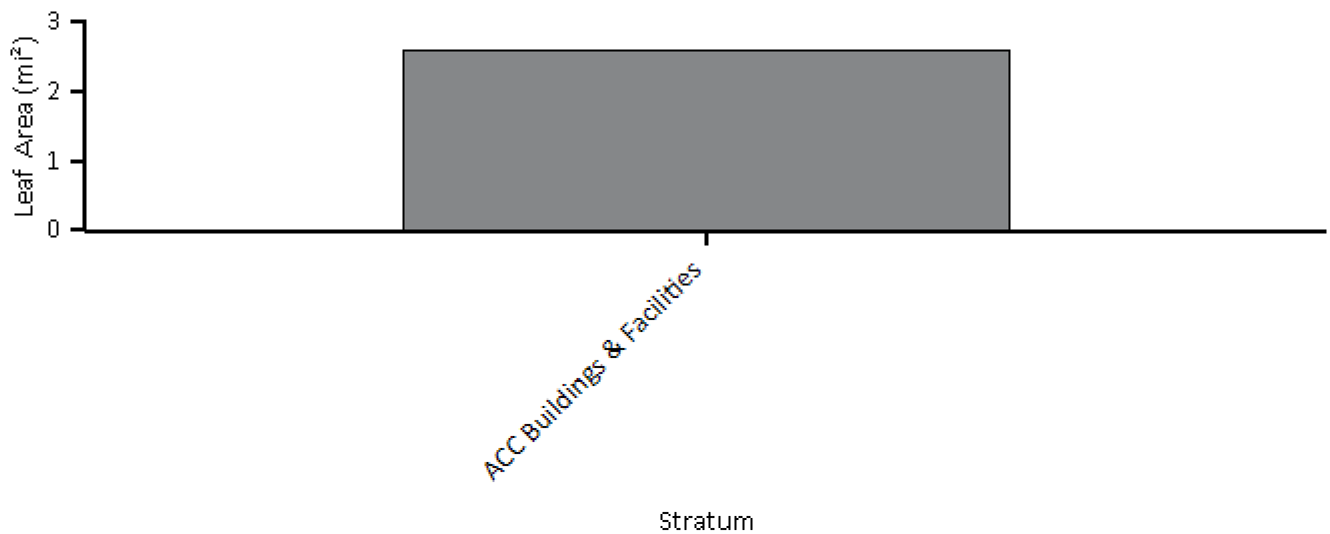


Figure 5. Leaf area by stratum, Buidings & Facilities-ACC Community Tree Study

In Buidings & Facilities-ACC Community Tree Study, the most dominant species in terms of leaf area are Loblolly pine, American sycamore, and 'Bradford' callery pear. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Buidings & Facilities-ACC Community Tree Study

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Loblolly pine	20.0	29.5	49.5
Sweetgum	12.0	3.0	15.0
American sycamore	7.2	7.0	14.2
'Bradford' callery pear	7.2	6.1	13.3
Willow oak	3.2	5.4	8.6
River birch	2.4	5.6	8.0
Water oak	2.4	5.3	7.7
Chinese privet	5.6	1.7	7.3
Common privet	6.4	0.5	6.9
American hornbeam	1.6	4.7	6.3

Common ground cover classes (including cover types beneath trees and shrubs) in Buidings & Facilities-ACC Community Tree Study include duff/mulch, bare soil, buildings, water, rock, unmaintained grass, and other impervious, impervious covers such as tar, and cement, and herbaceous covers such as grass, and herbs (Figure 6). The most dominant ground cover types are Grass (26.1 percent) and Tar (24.1 percent).

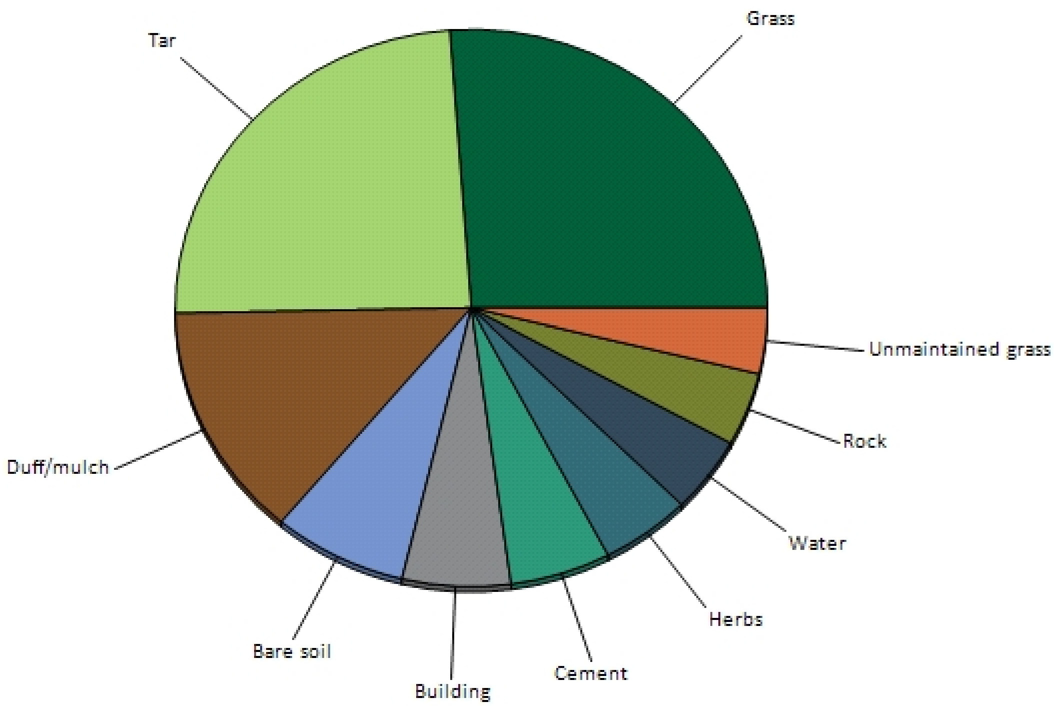


Figure 6. Percent of land by ground cover classes, Buidings & Facilities-ACC Community Tree Study

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Buidings & Facilities-ACC Community Tree Study was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 8.538 tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of $11.3 thousand (see Appendix I for more details).

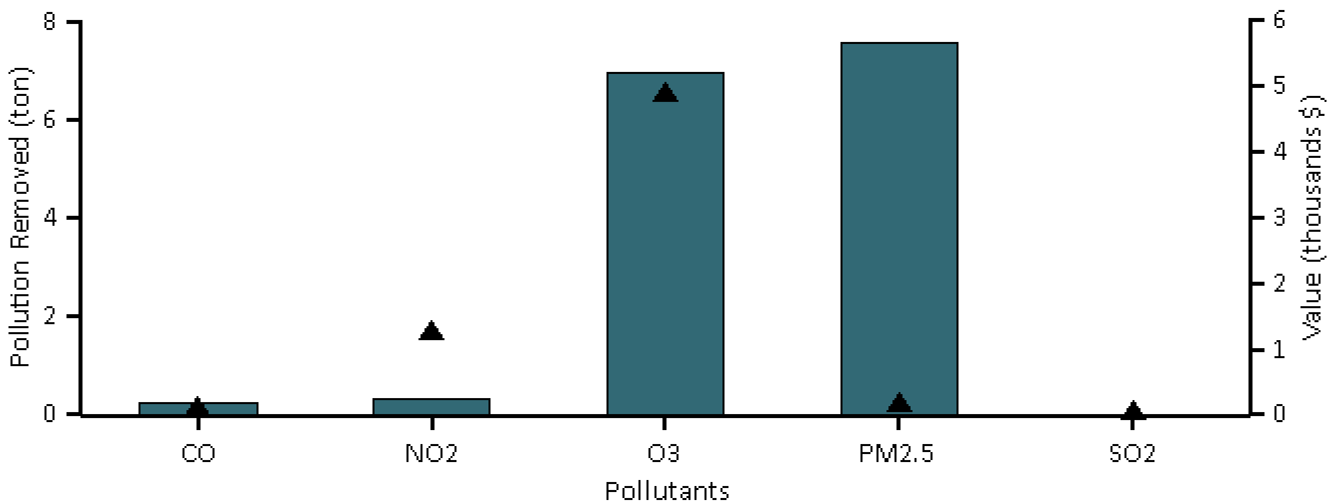


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Buidings & Facilities-ACC Community Tree Study

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] 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 positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2021, trees in Buidings & Facilities-ACC Community Tree Study emitted an estimated 15.94 tons of volatile organic compounds (VOCs) (6.461 tons of isoprene and 9.48 tons of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Thirty-three percent of the urban forest's VOC emissions were from Loblolly pine and Water oak. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. 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 and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

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 gross sequestration of Buidings & Facilities-ACC Community Tree Study trees is about 314.2 tons of carbon per year with an associated value of $53.6 thousand. Net carbon sequestration in the urban forest is about 243.2 tons. See Appendix I for more details on methods.

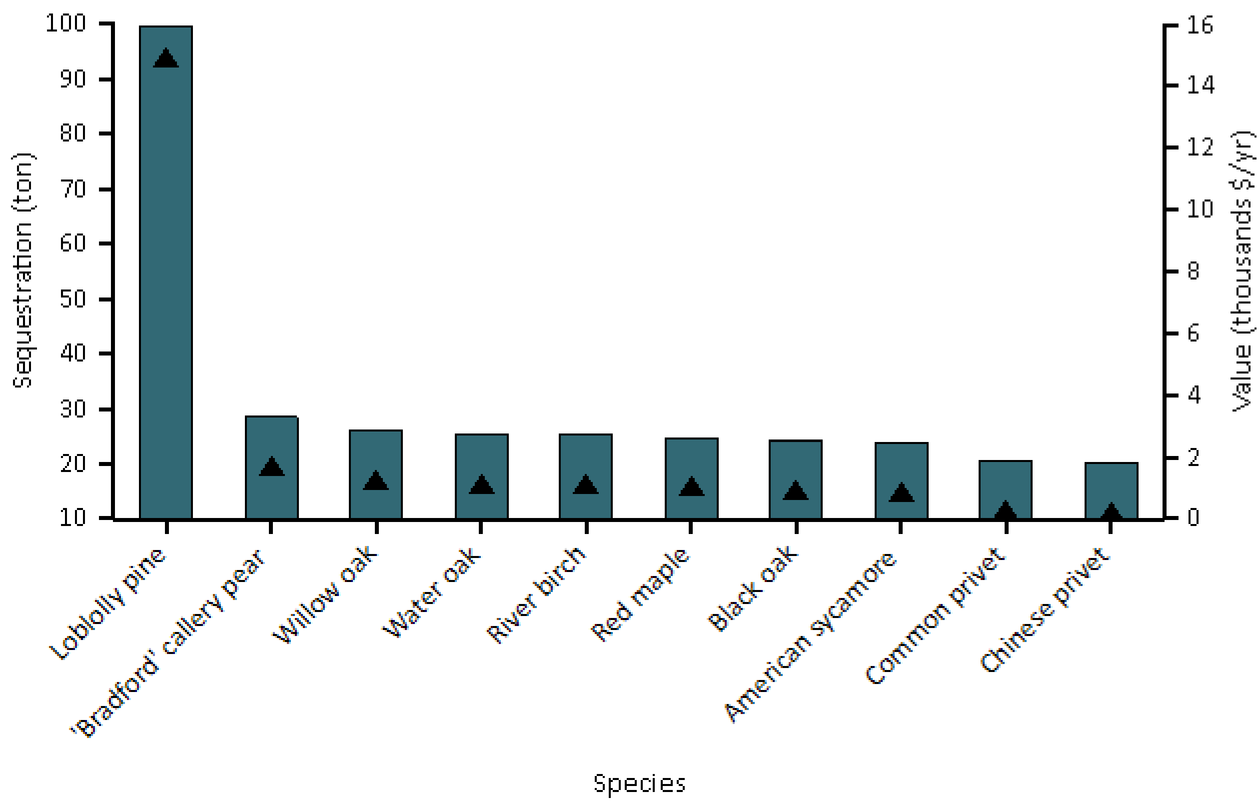


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Buidings & Facilities-ACC Community Tree Study

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases 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 are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Buidings & Facilities-ACC Community Tree Study are estimated to store 5850 tons of carbon ($998 thousand). Of the species sampled, Loblolly pine stores and sequesters the most carbon (approximately 33.5% of the total carbon stored and 29.8% of all sequestered carbon.)

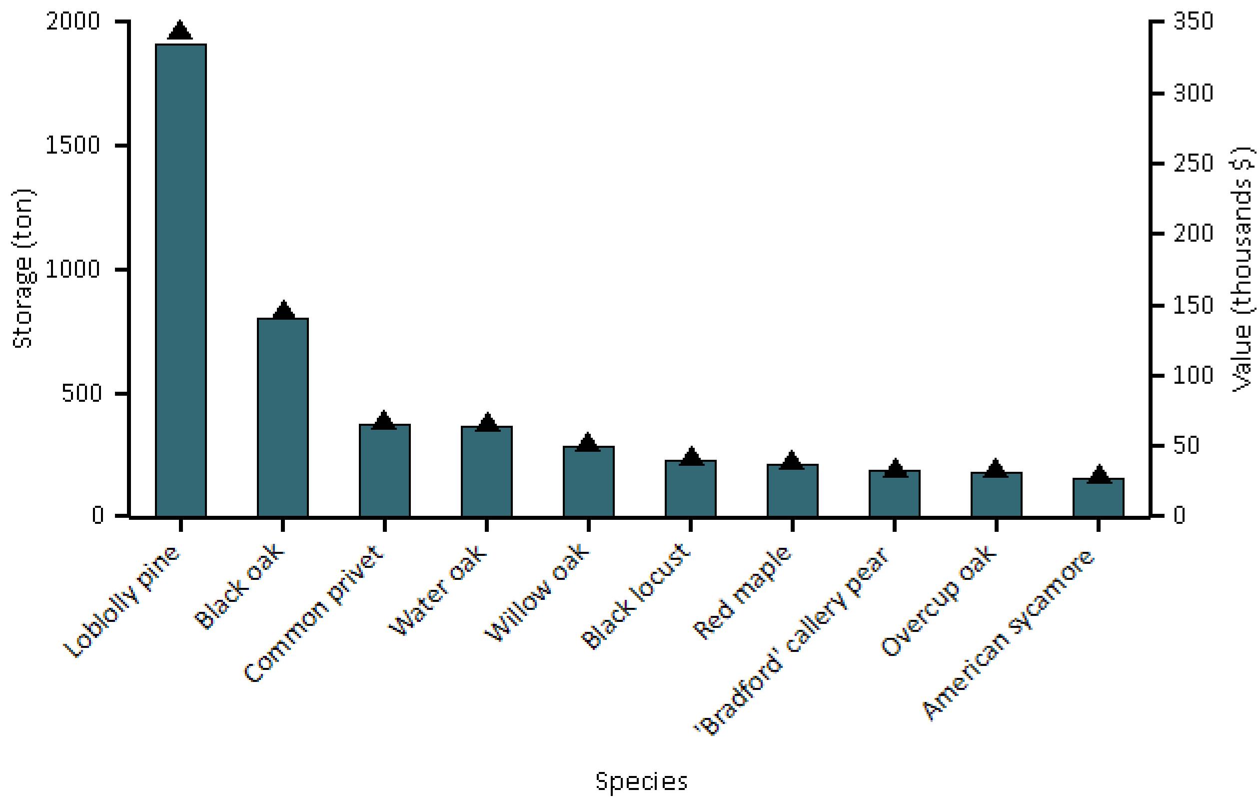


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Buidings & Facilities-ACC Community Tree Study

V. 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 Buidings & Facilities-ACC Community Tree Study are estimated to produce 648.6 tons of oxygen per year.[4] However, this tree benefit is relatively 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. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (ton)*	*Net Carbon Sequestration (ton/yr)*	*Number of Trees*	*Leaf Area (acre)*
Loblolly pine	205.39	77.02	7,161	490.91
'Bradford' callery pear	49.97	18.74	2,578	102.15
River birch	41.37	15.51	859	92.51
Willow oak	41.21	15.45	1,146	89.74
Red maple	38.48	14.43	286	50.49
Water oak	38.48	14.43	859	88.91
American sycamore	36.76	13.79	2,578	116.98
Trident maple	24.47	9.18	1,146	14.56
Sweetbay	21.57	8.09	1,146	34.91
Chinese privet	19.32	7.24	2,005	27.75
Overcup oak	19.22	7.21	573	60.68
Black oak	19.17	7.19	286	66.41
Sweetgum	17.55	6.58	4,296	49.27
Shortleaf pine	16.61	6.23	859	30.04
Black locust	15.35	5.76	286	10.72
Hybrid plum	15.22	5.71	286	13.93
Black cherry	14.96	5.61	573	28.68
Persian silk tree	12.19	4.57	1,719	21.06
Sugar maple	10.10	3.79	859	15.83
Shumard oak	9.12	3.42	286	25.18

[4] A negative estimate, or oxygen deficit, indicates that trees are decomposing faster than they are producing oxygen. This would be the case in an area that has a large proportion of dead trees.

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees 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 (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Buidings & Facilities-ACC Community Tree Study help to reduce runoff by an estimated 600 thousand cubic feet a year with an associated value of $40 thousand (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Buidings & Facilities-ACC Community Tree Study, the total annual precipitation in 2016 was 39.6 inches.

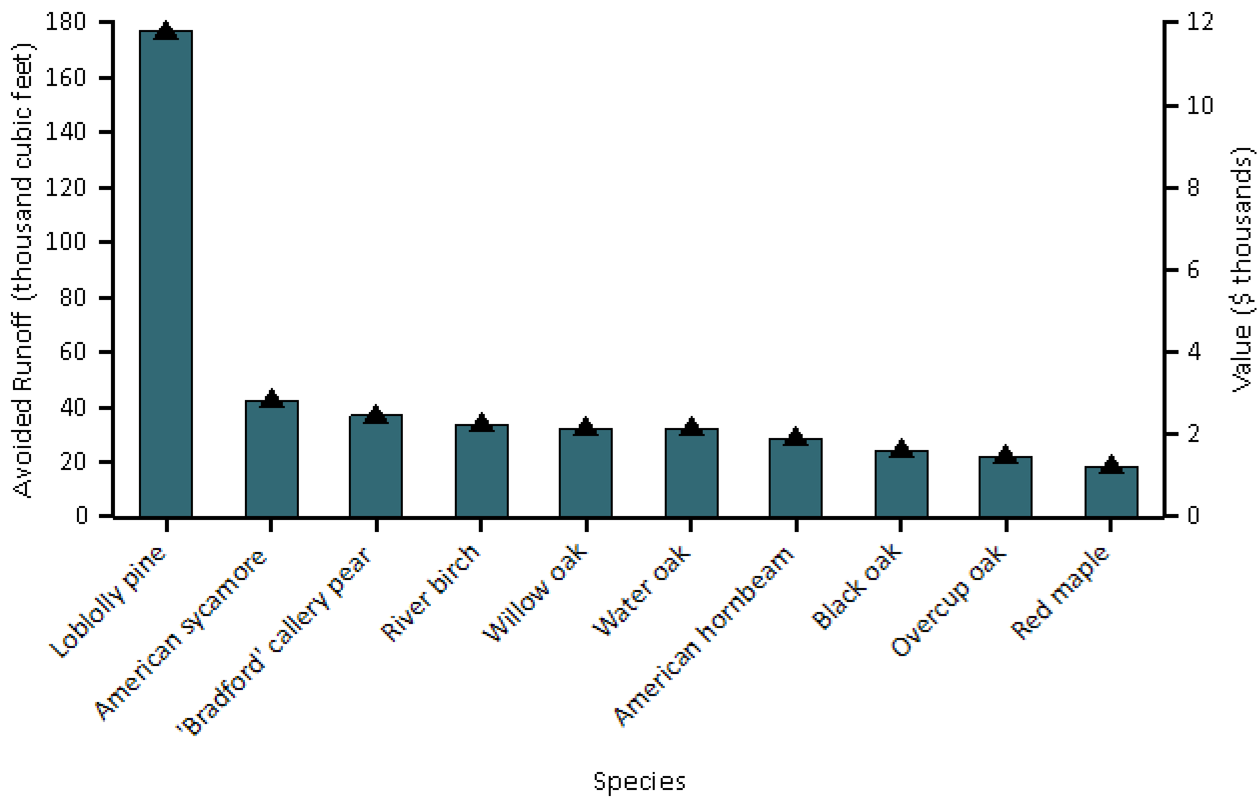


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Buidings & Facilities-ACC Community Tree Study

VII. Trees and Building Energy Use

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

Trees in Buidings & Facilities-ACC Community Tree Study are estimated to reduce energy-related costs from residential buildings by $4,240 annually. Trees also provide an additional $1,030 in value by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of 6.02 tons of carbon emissions).

Note: negative numbers indicate that there was not a reduction in carbon emissions and/or value, rather carbon emissions and values increased by the amount shown as a negative value.[5]

Table 3. Annual energy savings due to trees near residential buildings, Buidings & Facilities-ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[a]	-437	N/A	-437
MWH[b]	-10	100	89
Carbon Avoided (tons)	-13	19	6

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Buidings & Facilities-ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[b]	-6,714	N/A	-6,714
MWH[c]	-1,257	12,210	10,953
Carbon Avoided	-2,233	3,259	1,026

[b]Based on the prices of $122.6 per MWH and $15.3742400430376 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Buidings & Facilities-ACC Community Tree Study have the following structural values:

- Structural value: $27.4 million
- Carbon storage: $998 thousand

Urban trees in Buidings & Facilities-ACC Community Tree Study have the following annual functional values:

- Carbon sequestration: $53.6 thousand
- Avoided runoff: $40.1 thousand
- Pollution removal: $11.3 thousand
- Energy costs and carbon emission values: $5.27 thousand

(Note: negative value indicates increased energy cost and carbon emission value)

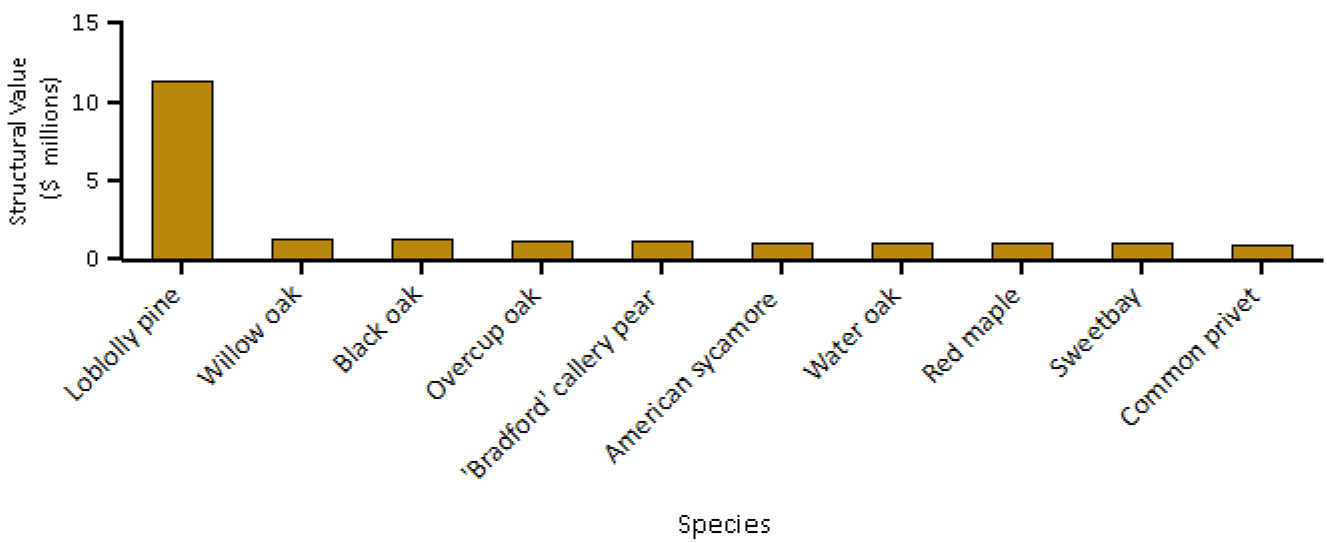


Figure 11. Tree species with the greatest structural value, Buidings & Facilities-ACC Community Tree Study

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Clarke County. Five of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

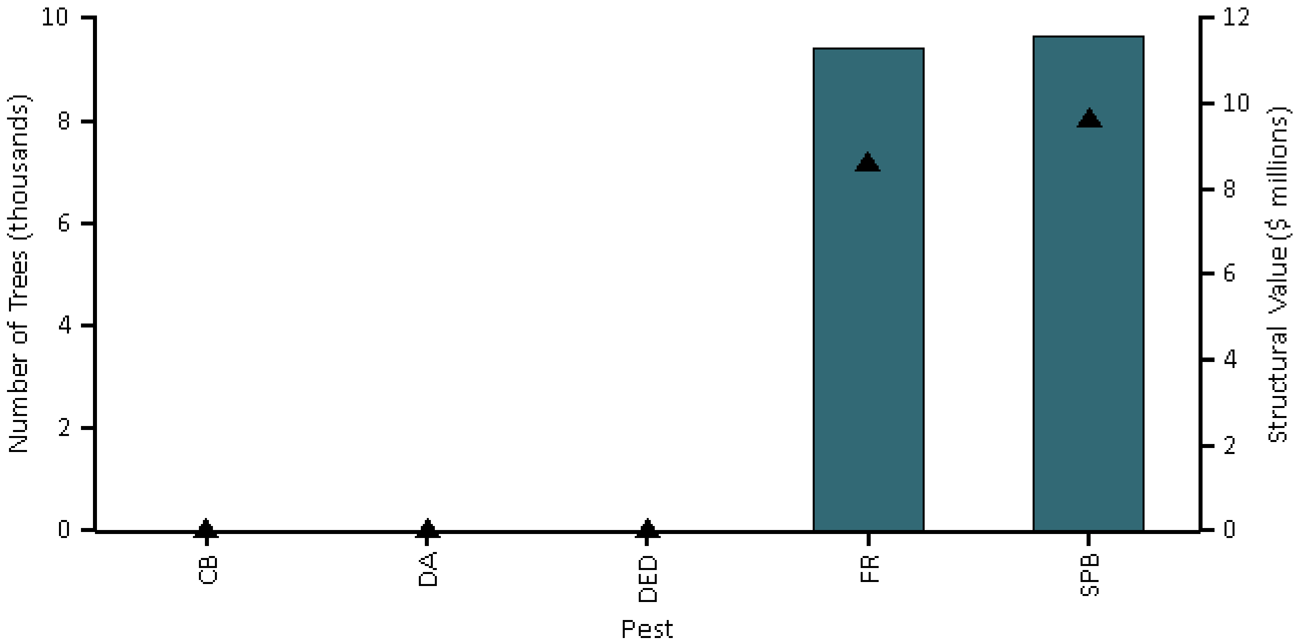


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Buidings & Facilities-ACC Community Tree Study

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population ($0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.0 percent of the population, which represents a potential loss of $0 in structural value.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Buidings & Facilities-ACC Community Tree Study could possibly lose 0.0 percent of its trees to this pest ($0 in structural value).

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 20.0 percent of the population ($11.3 million in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 22.4 percent of the population, which represents a potential loss of $11.6 million in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

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

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Georgia Exotic Pest Plant Council 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (PM10) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area.

Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (Nowak et al 2013). 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 positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 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.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,327 per ton (carbon monoxide), $804 per ton (ozone), $150 per ton (nitrogen dioxide), $56 per ton (sulfur dioxide), $25,453 per ton (particulate matter less than 2.5 microns).

Carbon Storage and Sequestration:

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

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

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 et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

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

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

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

For this analysis, energy saving value is calculated based on the prices of $122.60 per MWH and $15.37 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is

within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are 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 in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, 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) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Buidings & Facilities-ACC Community Tree Study provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Buidings & Facilities-ACC Community Tree Study in 3 days
- Annual carbon (C) emissions from 4,140 automobiles
- Annual C emissions from 1,700 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 1 automobiles
- Annual carbon monoxide emissions from 3 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 238 automobiles
- Annual nitrogen dioxide emissions from 107 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 340 automobiles
- Annual sulfur dioxide emissions from 1 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Buidings & Facilities-ACC Community Tree Study in 0.2 days
- Annual C emissions from 200 automobiles
- Annual C emissions from 100 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" 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.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. 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.

Urban forest management strategies to help improve air quality include (Nowak 2000):

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 V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Georgia invasive species list (Georgia Exotic Pest Plant Council 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Chinese privet	2,005	5.6	27.7	1.7
Persian silk tree	1,719	4.8	21.1	1.3
Total	**3,724**	**10.40**	**48.81**	**2.93**

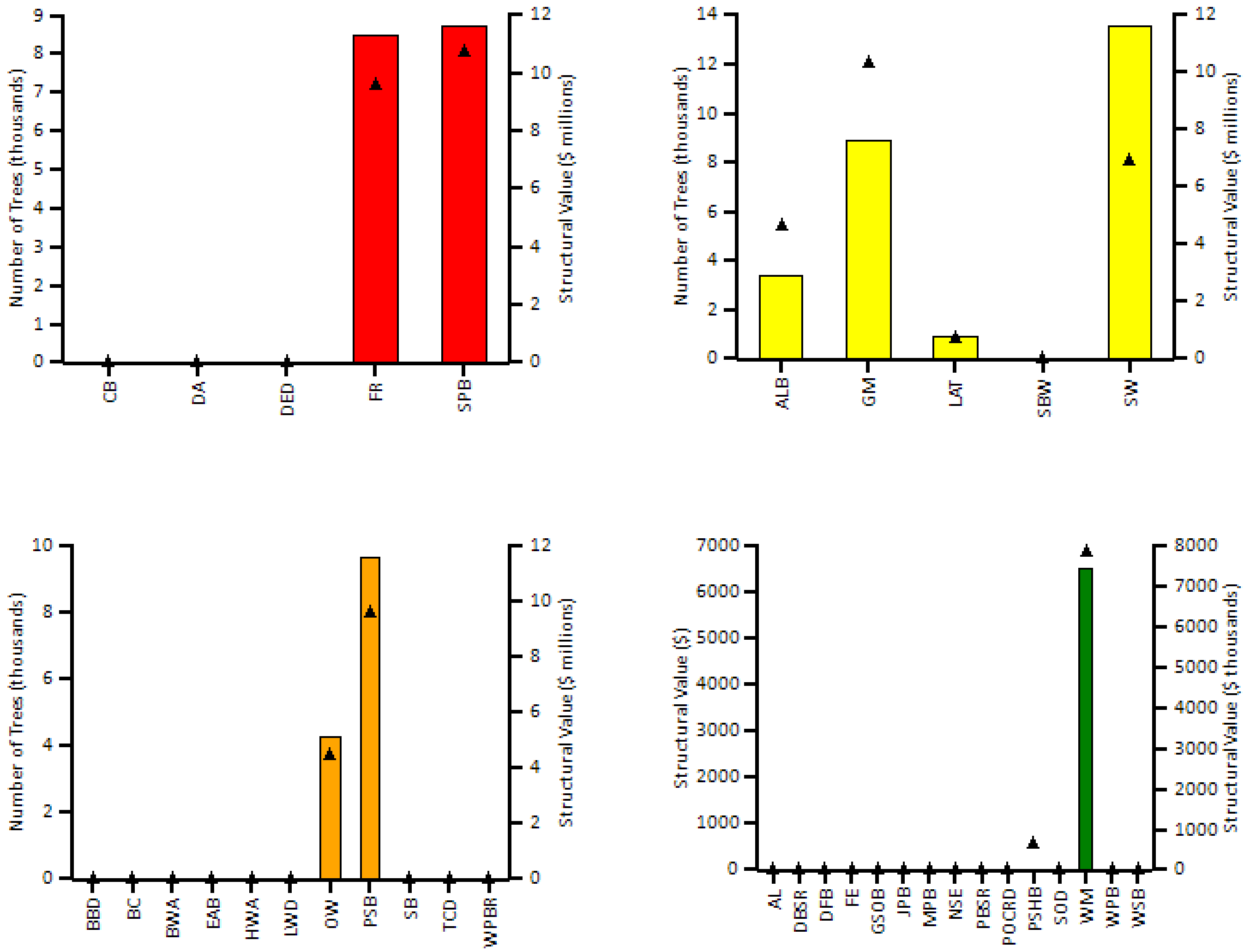
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/ disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ millions)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	5,442	2.88
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	0	0.00
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	0	0.00
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	7,161	11.29
GM	Lymantria dispar	Gypsy Moth	12,030	7.63
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	859	0.81
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	3,724	5.13
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	8,020	11.59
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	573	0.02
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	8,020	11.59
SW	Sirex noctilio	Sirex Wood Wasp	8,020	11.59
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	6,874	7.47
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Structural value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
[red]	13	Loblolly pine													[red]												[orange]					[red]	[yellow]					
[red]	9	Shortleaf pine																									[orange]					[red]	[yellow]					
[yellow]	7	River birch		[yellow]												[yellow]				[yellow]															[green]			
[orange]	6	Willow oak														[yellow]								[orange]											[green]			
[orange]	6	Water oak														[yellow]								[orange]											[green]			
[orange]	6	Overcup oak														[yellow]								[orange]											[green]			
[yellow]	6	Boxelder		[yellow]												[yellow]												[green]							[green]			
[orange]	6	Black oak														[yellow]								[orange]											[green]			
[orange]	6	Post oak														[yellow]								[orange]											[green]			
[orange]	6	Shumard oak														[yellow]								[orange]											[green]			
[orange]	6	White oak														[yellow]								[orange]											[green]			
[yellow]	3	Sugar maple		[yellow]																															[green]			
[yellow]	3	Red maple		[yellow]																															[green]			
[yellow]	2	Sweetgum														[yellow]																						
[yellow]	2	'Bradford' callery pear														[yellow]																						
[yellow]	2	Persian silk tree		[yellow]																																		
[yellow]	2	Trident maple		[yellow]																																		
[green]	1	Black cherry																																	[green]			

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Clarke county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Clarke county
- Green indicates pest is outside of these ranges

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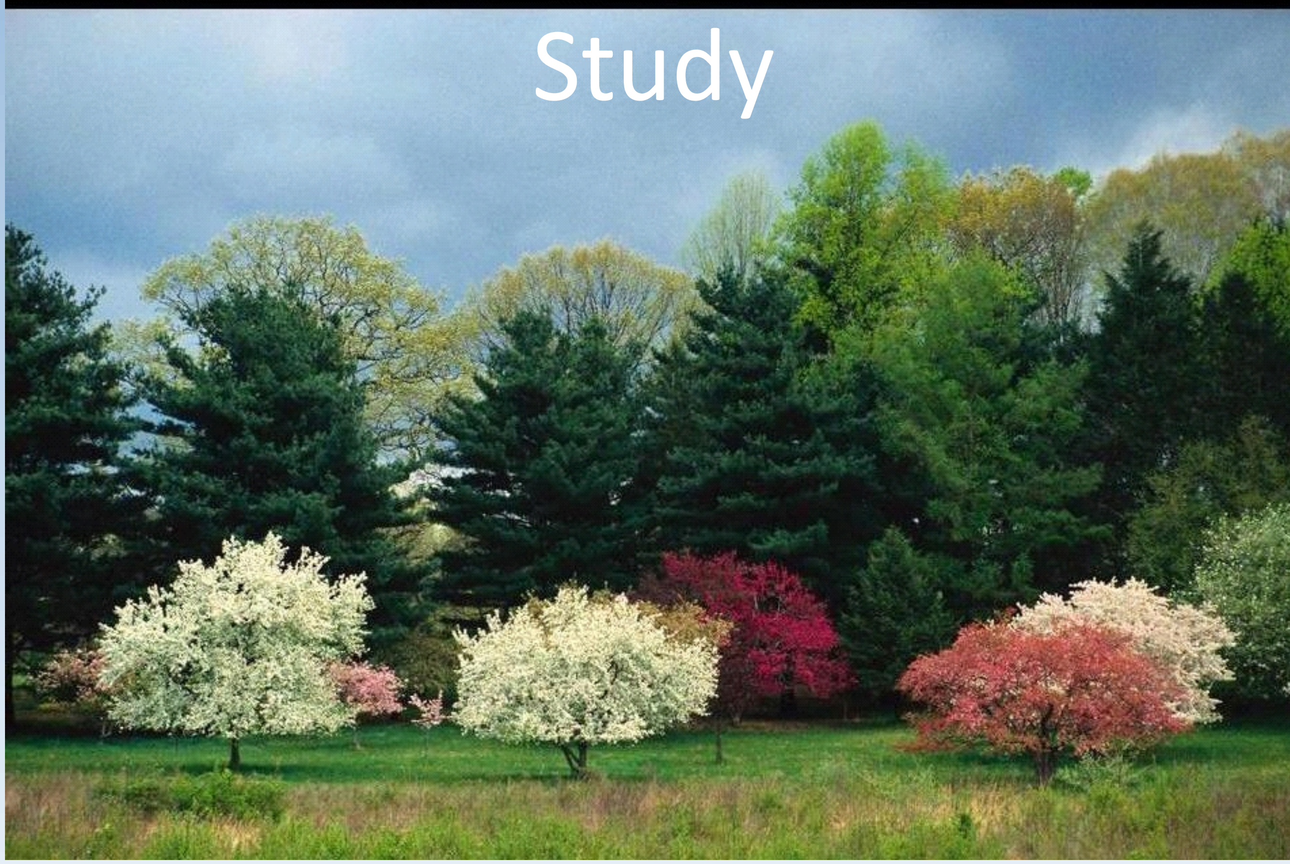
Appendix F:(Maintaned/Mowed Park Areas)

i-Tree
Ecosystem Analysis

Parks - ACC Community Tree Study



Urban Forest Effects and Values
November 2021

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Parks - ACC Community Tree Study urban forest was conducted during 2021. Data from 29 field plots located throughout Parks - ACC Community Tree Study were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 12,990
- Tree Cover: 20.9 %
- Most common species of trees: Loblolly pine, Sweetgum, River birch
- Percentage of trees less than 6" (15.2 cm) diameter: 50.9%
- Pollution Removal: 2.697 tons/year ($3.68 thousand/year)
- Carbon Storage: 3.507 thousand tons ($598 thousand)
- Carbon Sequestration: 99.87 tons ($17 thousand/year)
- Oxygen Production: 225.5 tons/year
- Avoided Runoff: 202.3 thousand cubic feet/year ($13.5 thousand/year)
- Building energy savings: $0/year
- Carbon Avoided: 0 tons/year ($0/year)
- Structural values: $10.5 million

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of Parks - ACC Community Tree Study has an estimated 12,990 trees with a tree cover of 20.9 percent. The three most common species are Loblolly pine (51.9 percent), Sweetgum (10.4 percent), and River birch (9.4 percent).

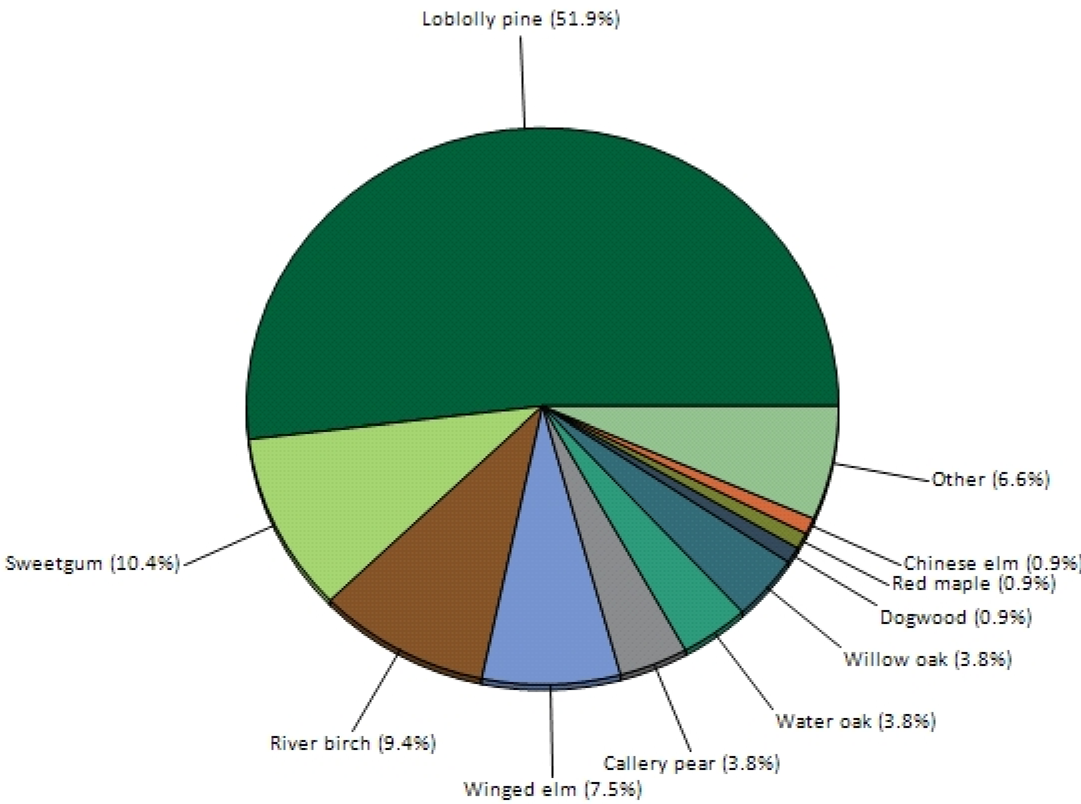


Figure 1. Tree species composition in Parks - ACC Community Tree Study

The overall tree density in Parks - ACC Community Tree Study is 37 trees/acre (see Appendix III for comparable values from other cities).

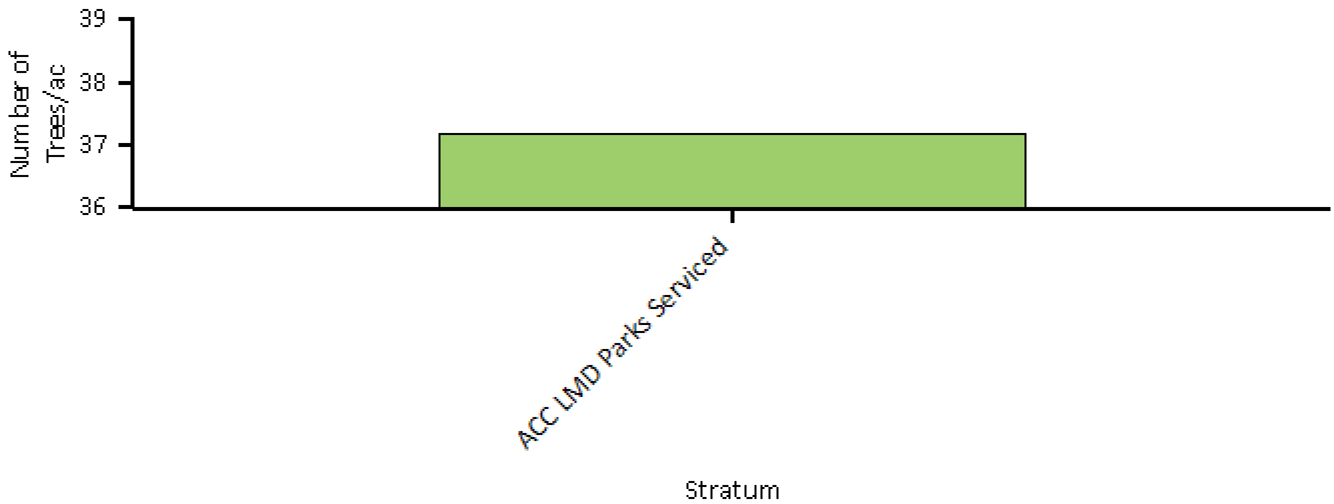


Figure 2. Number of trees/ac in Parks - ACC Community Tree Study by stratum

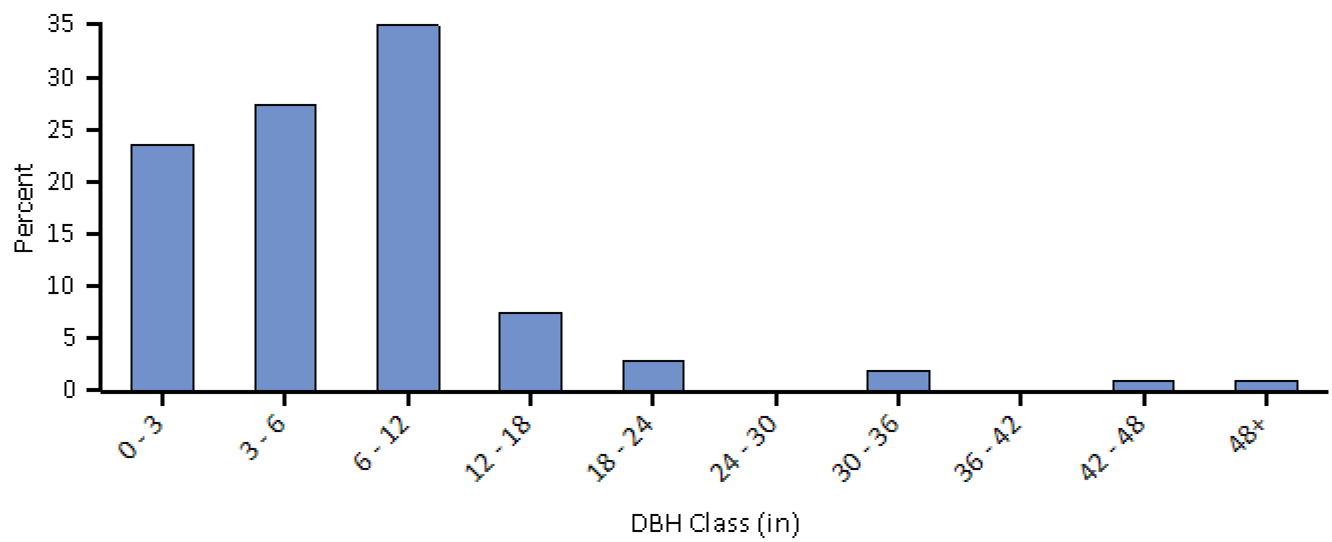


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix 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 by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Parks - ACC Community Tree Study, about 93 percent of the trees are species native to North America, while 92 percent are native to Georgia. Species exotic to North America make up 7 percent of the population. Most exotic tree species have an origin from Asia (5 percent of the species).

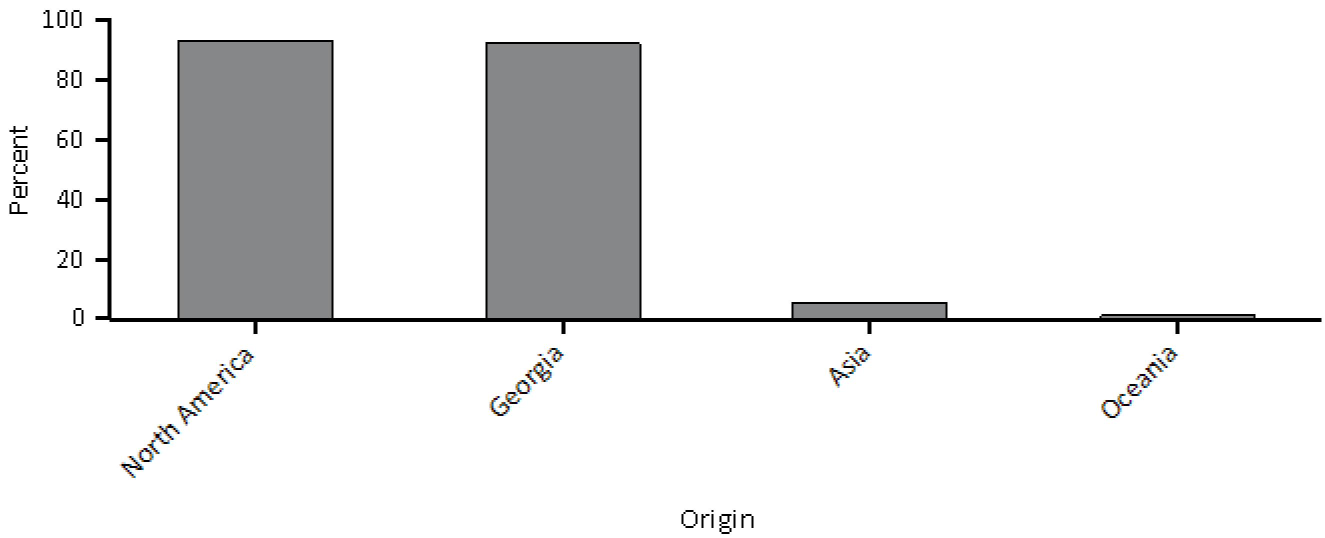


Figure 4. Percent of live tree population by area of native origin, Parks - ACC Community Tree Study

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. One of the 17 tree species in Parks - ACC Community Tree Study are identified as invasive on the state invasive species list (Georgia Exotic Pest Plant Council 2006). This invasive species (Callery pear) comprises 3.8 percent of the tree population though it may only cause a minimal level of impact (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 21 percent of Parks - ACC Community Tree Study and provide 695.5 acres of leaf area. Total leaf area is greatest in ACC LMD Parks Serviced.

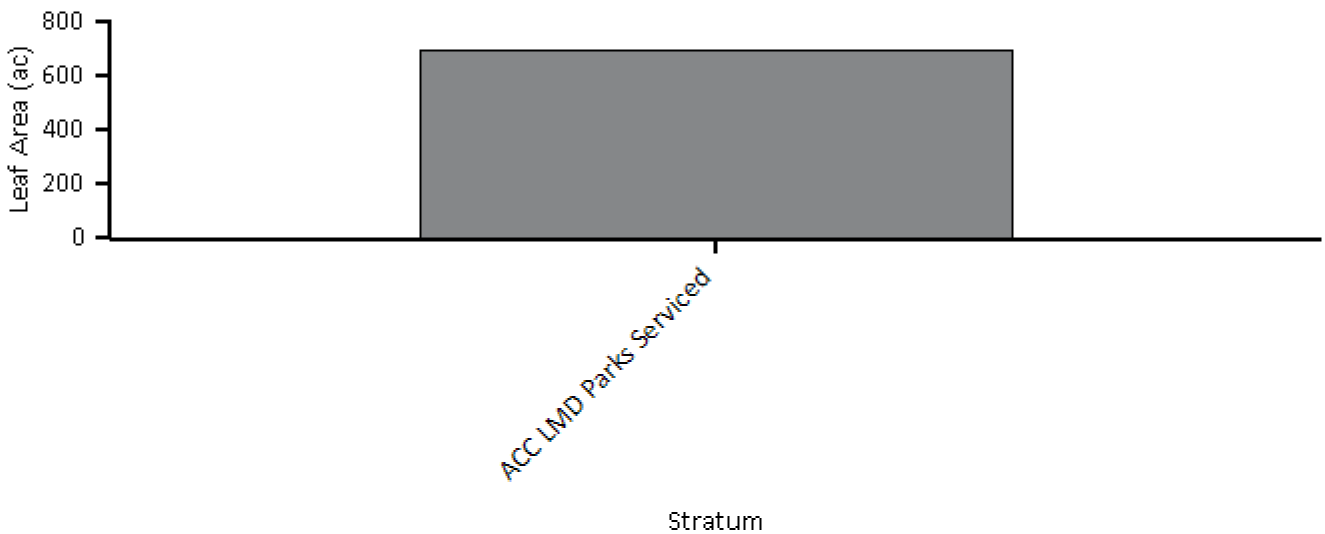


Figure 5. Leaf area by stratum, Parks - ACC Community Tree Study

In Parks - ACC Community Tree Study, the most dominant species in terms of leaf area are River birch, Water oak, and Loblolly pine. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Parks - ACC Community Tree Study

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Loblolly pine	51.9	14.1	66.0
River birch	9.4	24.2	33.6
Water oak	3.8	22.9	26.6
Sweetgum	10.4	11.8	22.2
Willow oak	3.8	12.1	15.9
Winged elm	7.5	0.6	8.1
Callery pear	3.8	3.4	7.1
White oak	0.9	2.7	3.7
Post oak	0.9	2.1	3.0
Shortleaf pine	0.9	1.9	2.8

Common ground cover classes (including cover types beneath trees and shrubs) in Parks - ACC Community Tree Study include unmaintained grass, duff/mulch, bare soil, rock, buildings, water, and other impervious, impervious covers such as tar, and cement, and herbaceous covers such as grass, and herbs (Figure 6). The most dominant ground cover types are Grass (58.4 percent) and Tar (16.3 percent).

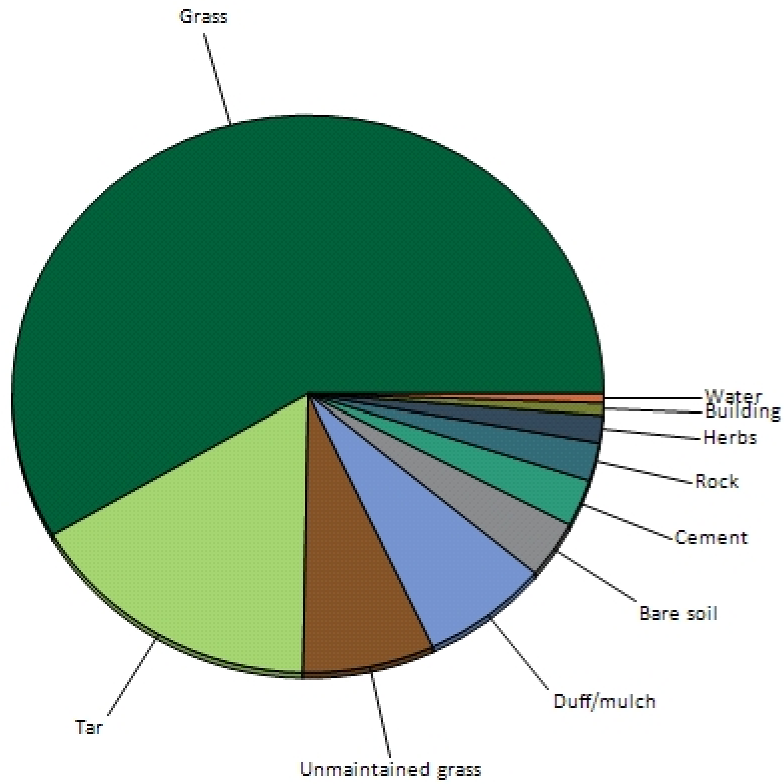


Figure 6. Percent of land by ground cover classes, Parks - ACC Community Tree Study

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Parks - ACC Community Tree Study was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 2.697 tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of $3.68 thousand (see Appendix I for more details).

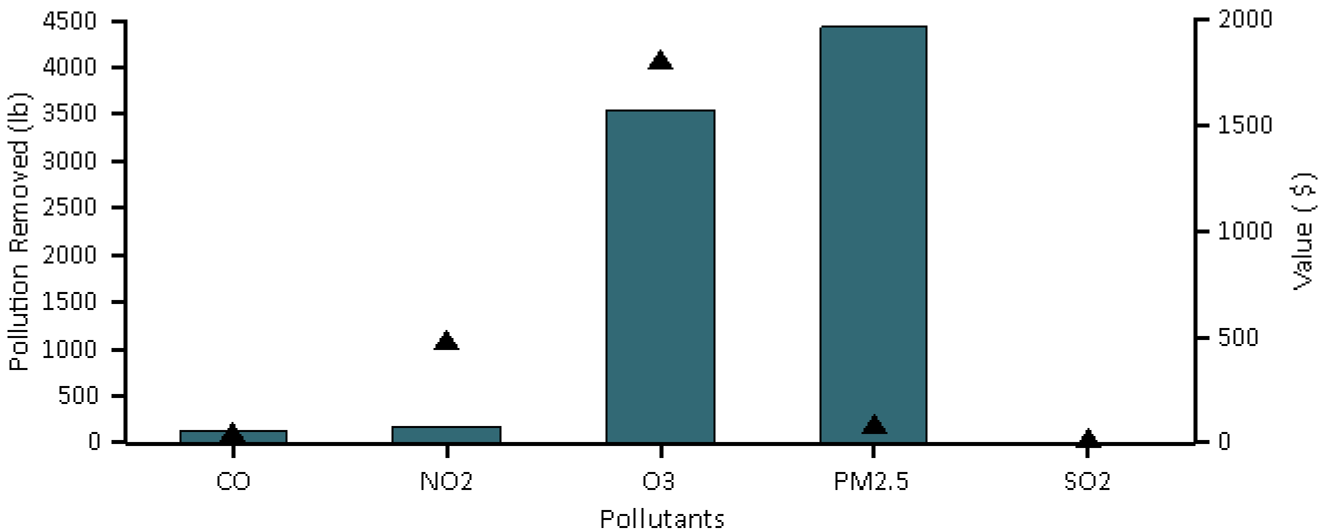


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Parks - ACC Community Tree Study

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] 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 positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2021, trees in Parks - ACC Community Tree Study emitted an estimated 8.501 tons of volatile organic compounds (VOCs) (3.263 tons of isoprene and 5.238 tons of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Seventy- one percent of the urban forest's VOC emissions were from Water oak and Willow oak. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. 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 and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

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 gross sequestration of Parks - ACC Community Tree Study trees is about 99.87 tons of carbon per year with an associated value of $17 thousand. Net carbon sequestration in the urban forest is about 84.57 tons. See Appendix I for more details on methods.

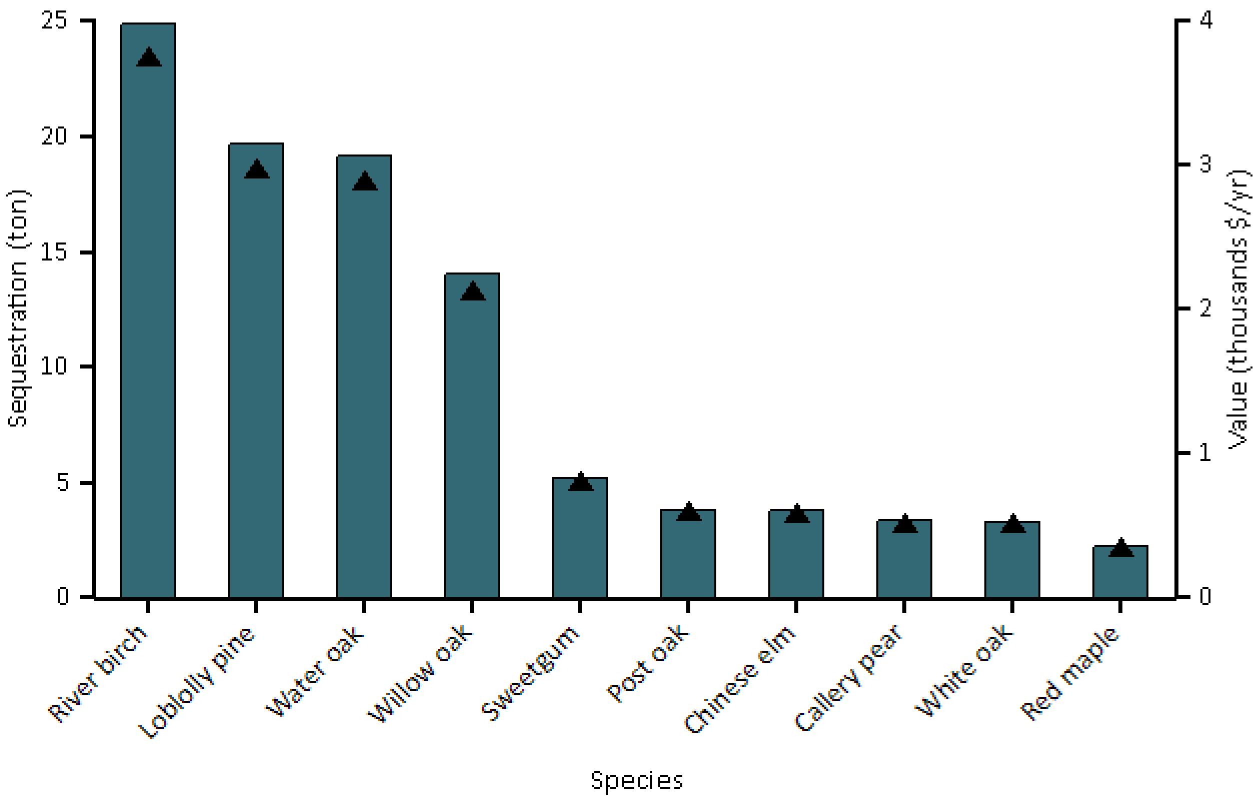


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Parks - ACC Community Tree Study

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases 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 are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Parks - ACC Community Tree Study are estimated to store 3510 tons of carbon ($598 thousand). Of the species sampled, River birch stores and sequesters the most carbon (approximately 40.2% of the total carbon stored and 23.4% of all sequestered carbon.)

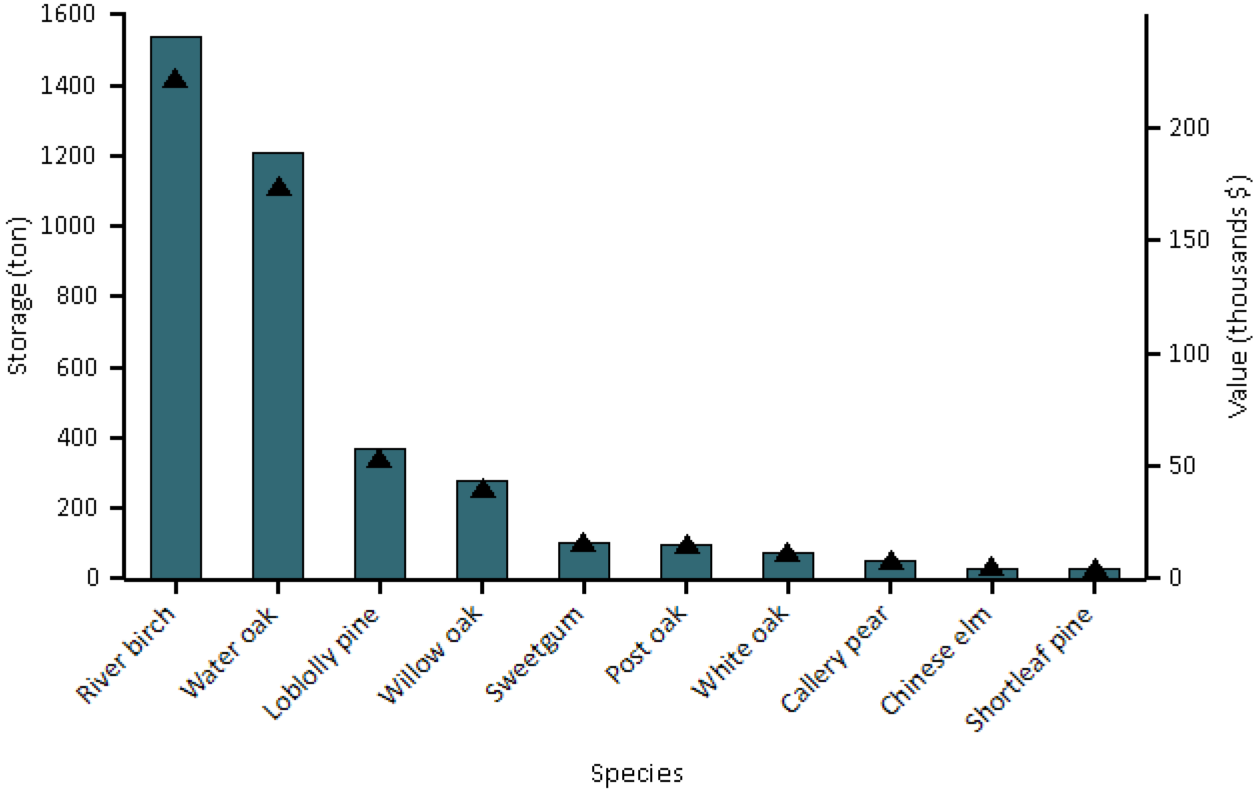


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Parks - ACC Community Tree Study

V. 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 Parks - ACC Community Tree Study are estimated to produce 225.5 tons of oxygen per year.[4] However, this tree benefit is relatively 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. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 17 oxygen production species.

Species	*Oxygen (ton)*	*Net Carbon Sequestration (ton/yr)*	*Number of Trees*	*Leaf Area (acre)*
River birch	52.01	19.50	1,226	168.20
Water oak	39.70	14.89	490	158.97
Willow oak	33.60	12.60	490	84.06
Loblolly pine	31.25	11.72	6,742	97.99
Sweetgum	12.46	4.67	1,348	81.92
Chinese elm	9.28	3.48	123	8.86
Post oak	9.12	3.42	123	14.39
Callery pear	8.14	3.05	490	23.33
White oak	7.84	2.94	123	18.96
Red maple	5.51	2.06	123	8.68
Southern magnolia	4.43	1.66	123	4.91
Shortleaf pine	4.18	1.57	123	13.21
Winged elm	3.65	1.37	981	3.96
Dogwood	1.51	0.57	123	3.36
Boxelder	1.36	0.51	123	3.26
Carolina laurelcherry	1.09	0.41	123	1.30
Fragrant mimosa	0.38	0.14	123	0.14

[4] A negative estimate, or oxygen deficit, indicates that trees are decomposing faster than they are producing oxygen. This would be the case in an area that has a large proportion of dead trees.

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees 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 (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Parks - ACC Community Tree Study help to reduce runoff by an estimated 202 thousand cubic feet a year with an associated value of $14 thousand (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Parks - ACC Community Tree Study, the total annual precipitation in 2016 was 39.6 inches.

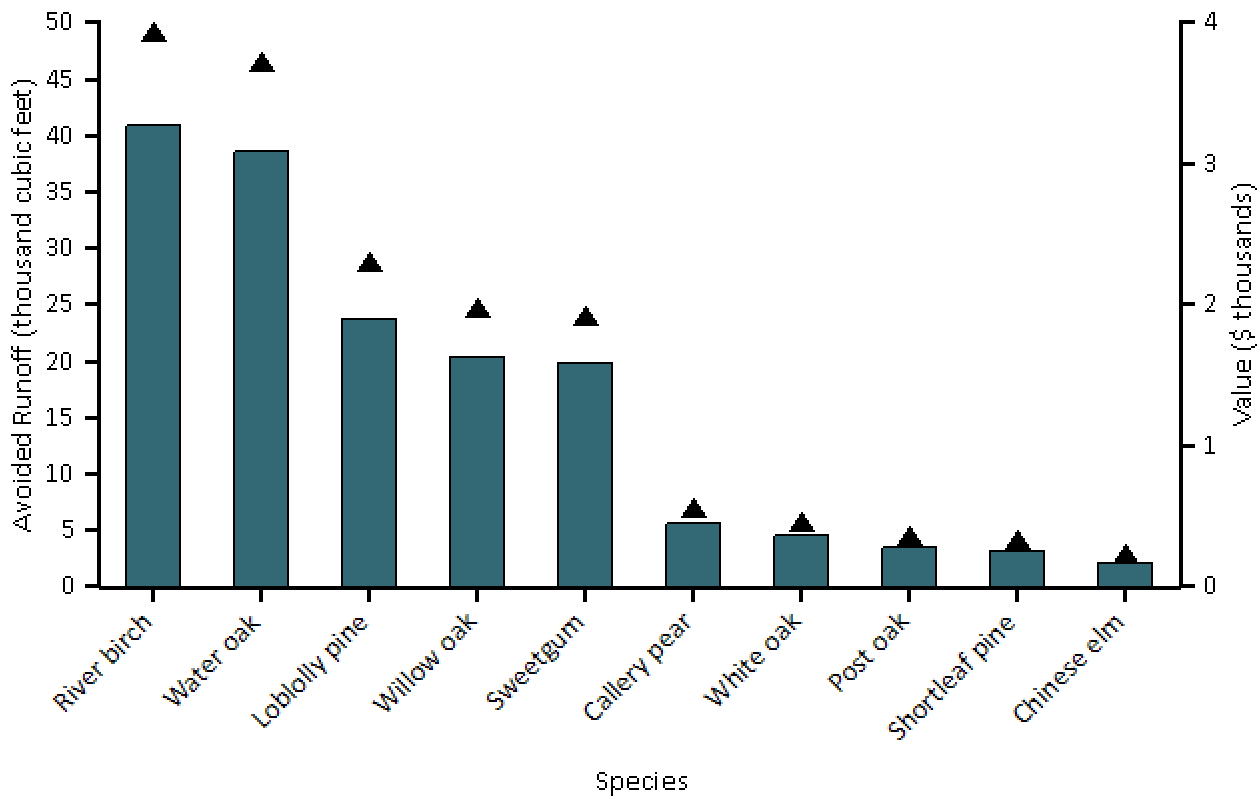


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Parks - ACC Community Tree Study

VII. Trees and Building Energy Use

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

Trees in Parks - ACC Community Tree Study are estimated to reduce energy-related costs from residential buildings by $0 annually. Trees also provide an additional $0 in value by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of 0 pounds of carbon emissions).

Note: negative numbers indicate that there was not a reduction in carbon emissions and/or value, rather carbon emissions and values increased by the amount shown as a negative value.[5]

Table 3. Annual energy savings due to trees near residential buildings, Parks - ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Parks - ACC Community Tree Study

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $122.6 per MWH and $15.3742400430376 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Parks - ACC Community Tree Study have the following structural values:

- Structural value: $10.5 million
- Carbon storage: $598 thousand

Urban trees in Parks - ACC Community Tree Study have the following annual functional values:

- Carbon sequestration: $17 thousand
- Avoided runoff: $13.5 thousand
- Pollution removal: $3.68 thousand
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

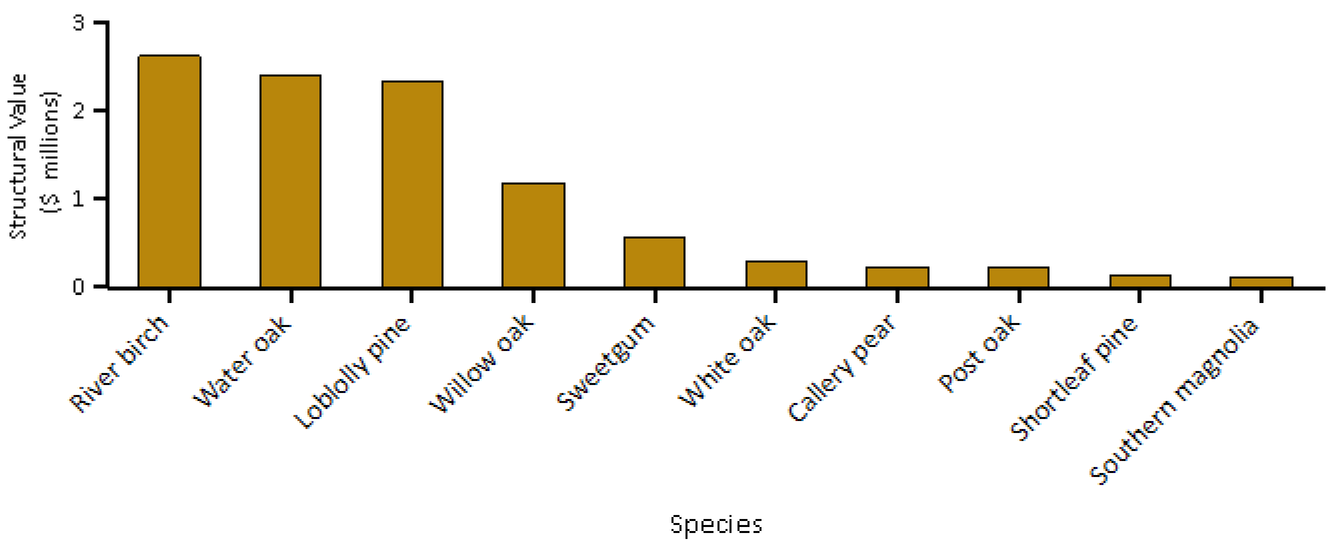


Figure 11. Tree species with the greatest structural value, Parks - ACC Community Tree Study

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Clarke County. Five of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

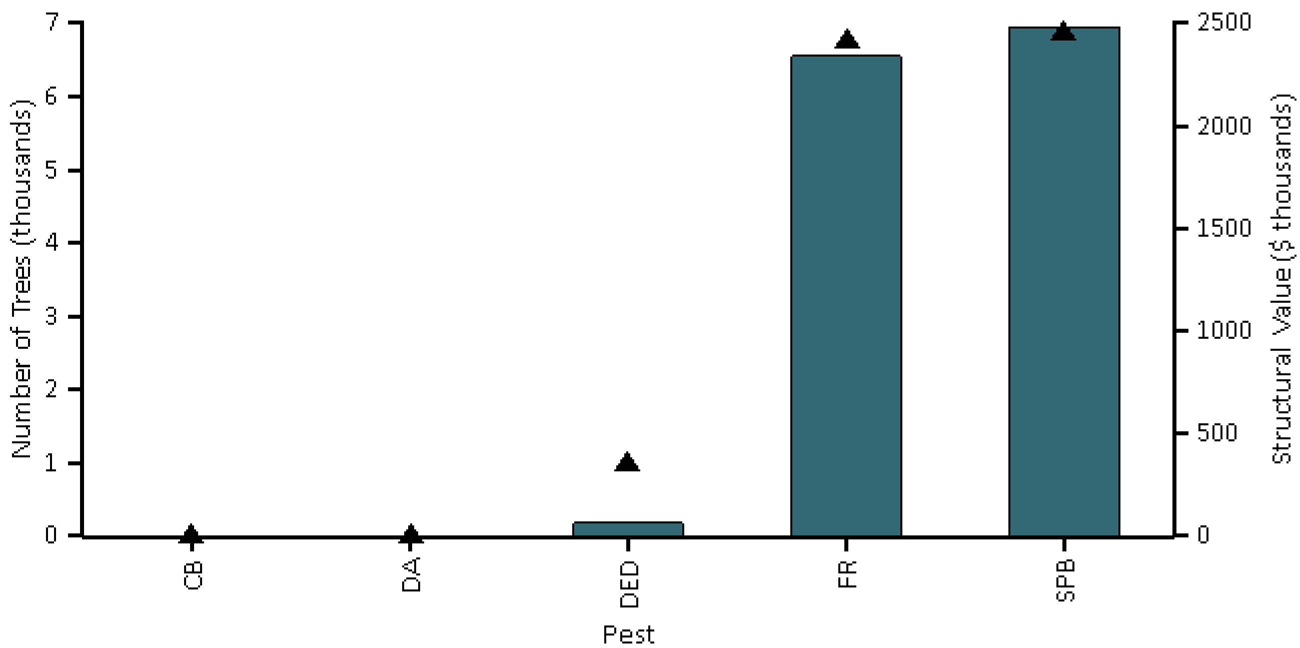


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Parks - ACC Community Tree Study

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population ($0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.0 percent of the population, which represents a potential loss of $0 in structural value.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Parks - ACC Community Tree Study could possibly lose 7.5 percent of its trees to this pest ($66.2 thousand in structural value).

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 51.9 percent of the population ($2.34 million in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 52.8 percent of the population, which represents a potential loss of $2.48 million in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

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

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

<u>Tree Characteristics:</u>

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Georgia Exotic Pest Plant Council 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

<u>Air Pollution Removal:</u>

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (PM10) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area.

Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (Nowak et al 2013). 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 positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 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.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,327 per ton (carbon monoxide), $776 per ton (ozone), $147 per ton (nitrogen dioxide), $55 per ton (sulfur dioxide), $23,845 per ton (particulate matter less than 2.5 microns).

Carbon Storage and Sequestration:

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

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

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 et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

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

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

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

For this analysis, energy saving value is calculated based on the prices of $122.60 per MWH and $15.37 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is

within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are 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 in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, 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) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Parks - ACC Community Tree Study provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Parks - ACC Community Tree Study in 2 days
- Annual carbon (C) emissions from 2,480 automobiles
- Annual C emissions from 1,020 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 1 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 76 automobiles
- Annual nitrogen dioxide emissions from 34 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 103 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Parks - ACC Community Tree Study in 0.1 days
- Annual C emissions from 100 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" 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.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. 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.

Urban forest management strategies to help improve air quality include (Nowak 2000):

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 V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Georgia invasive species list (Georgia Exotic Pest Plant Council 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Callery pear	490	3.8	23.3	3.4
Total	**490**	**3.77**	**23.33**	**3.35**

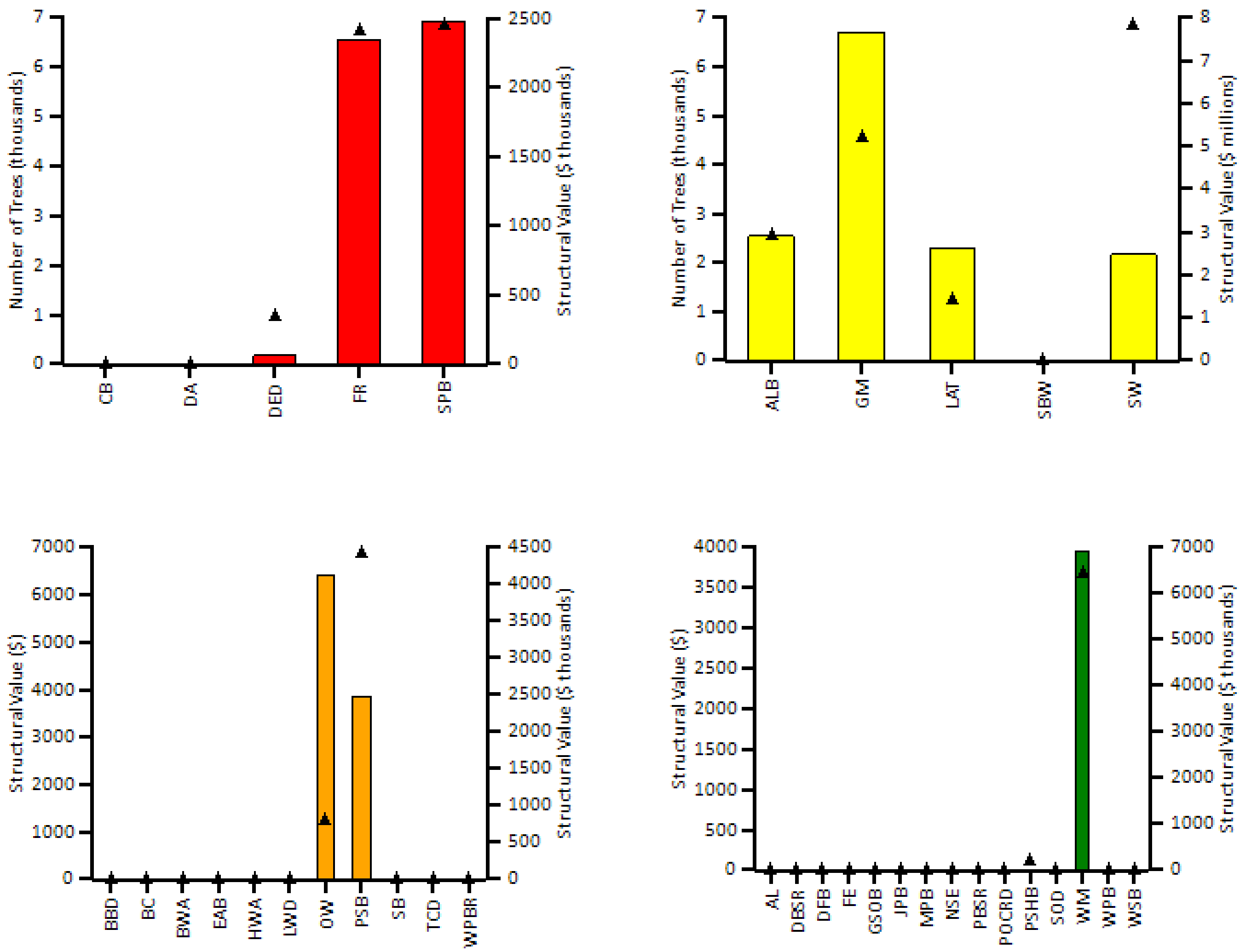
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/ disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	2,574	2,903.55
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	981	66.20
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	0	0.00
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	6,742	2,340.44
GM	Lymantria dispar	Gypsy Moth	4,536	7,676.47
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	1,226	2,628.07
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	1,226	4,133.90
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	6,865	2,479.54
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	123	9.77
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	6,865	2,479.54
SW	Sirex noctilio	Sirex Wood Wasp	6,865	2,479.54
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	3,678	6,930.85
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Structural value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
Red	13	Loblolly pine													Red												Orange					Red	Yellow					
Red	9	Shortleaf pine																									Orange					Red	Yellow					
Yellow	7	River birch		Yellow												Yellow				Yellow															Green			
Red	7	Winged elm		Yellow							Red																								Green			
Orange	6	Water oak														Yellow								Orange											Green			
Orange	6	Willow oak														Yellow								Orange											Green			
Orange	6	White oak														Yellow								Orange											Green			
Orange	6	Post oak														Yellow								Orange											Green			
Yellow	6	Boxelder		Yellow												Yellow												Green							Green			
Yellow	4	Chinese elm		Yellow												Yellow																						
Yellow	3	Red maple		Yellow																															Green			
Yellow	2	Sweetgum														Yellow																						
Yellow	2	Callery pear														Yellow																						

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:
- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:
- Red indicates pest is within Clarke county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Clarke county
- Green indicates pest is outside of these ranges

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Appendix G:
(ACC Leisure Services, Natural, & Undeveloped Lands)

i-Tree
Ecosystem Analysis

ACC LS, Nat, & Undev. Lands -
ACC Comm. Tree Study

Urban Forest Effects and Values
November 2021

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study urban forest was conducted during 2021. Data from 27 field plots located throughout ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 754,500
- Tree Cover: 64.7 %
- Most common species of trees: Sweetgum, Eastern hophornbeam, Water oak
- Percentage of trees less than 6" (15.2 cm) diameter: 57.5%
- Pollution Removal: 101.1 tons/year ($149 thousand/year)
- Carbon Storage: 109.7 thousand tons ($18.7 million)
- Carbon Sequestration: 5.308 thousand tons ($905 thousand/year)
- Oxygen Production: 9.026 thousand tons/year
- Avoided Runoff: 8.045 million cubic feet/year ($538 thousand/year)
- Building energy savings: $0/year
- Carbon Avoided: 0 tons/year ($0/year)
- Structural values: $447 million

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control. Additionally, some of the plot and tree information may not have been collected, so not all of the analyses may have been conducted for this report.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study has an estimated 754,500 trees with a tree cover of 64.7 percent. The three most common species are Sweetgum (18.2 percent), Eastern hophornbeam (10.0 percent), and Water oak (7.8 percent).

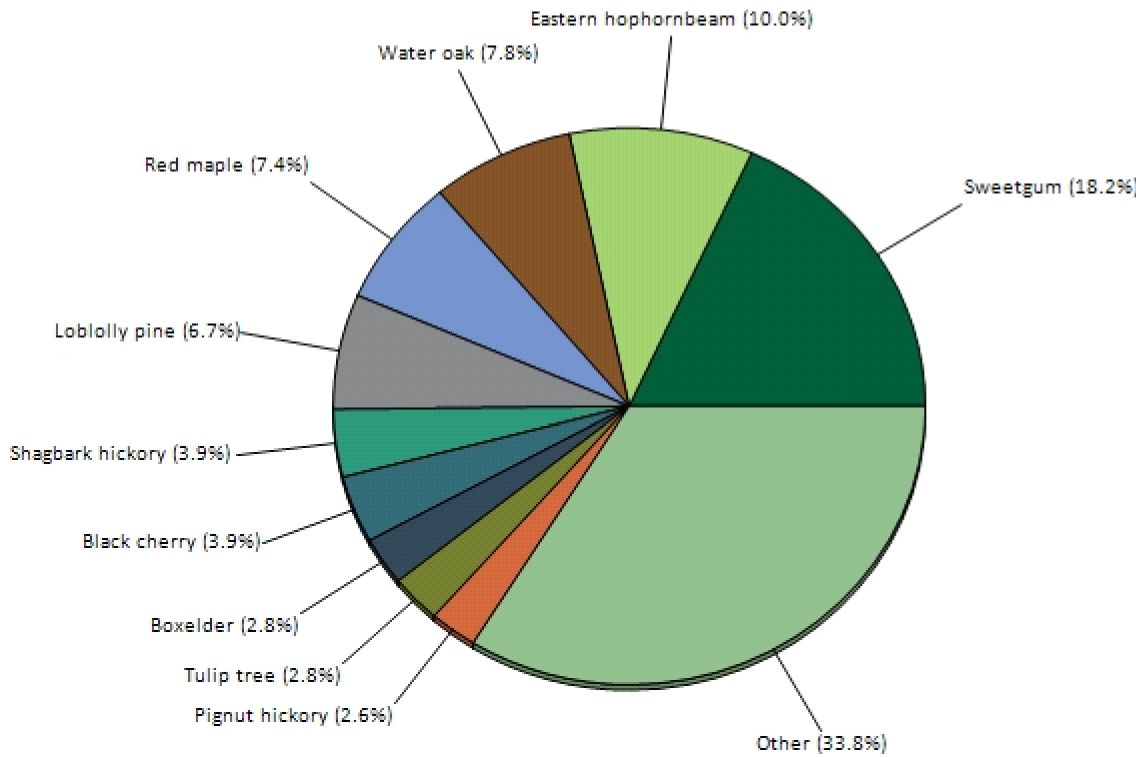


Figure 1. Tree species composition in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

The overall tree density in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study is 199 trees/acre (see Appendix III for comparable values from other cities).

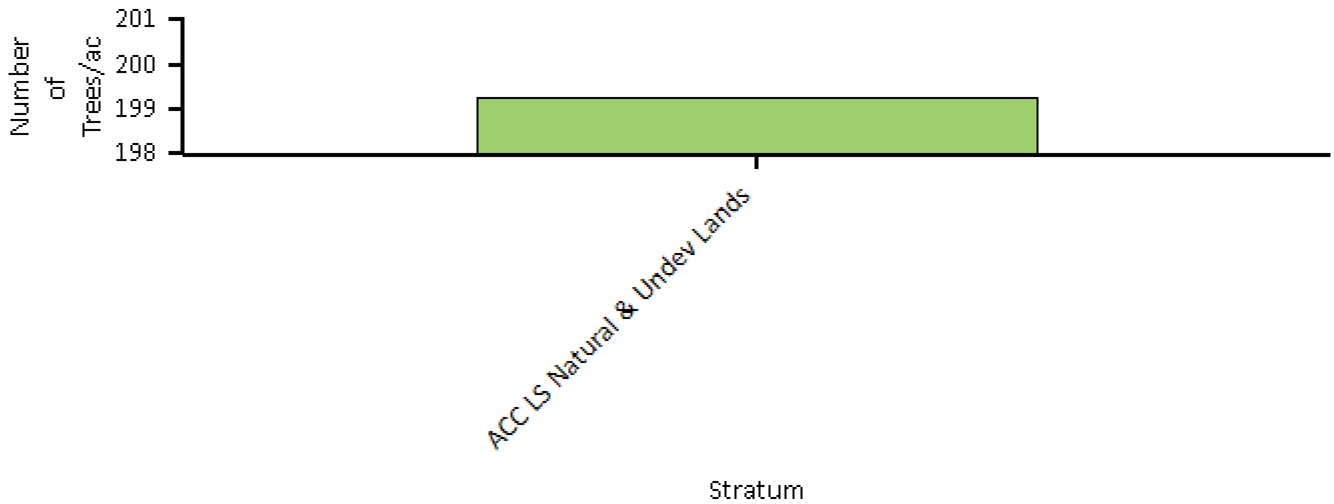


Figure 2. Number of trees/ac in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study by stratum

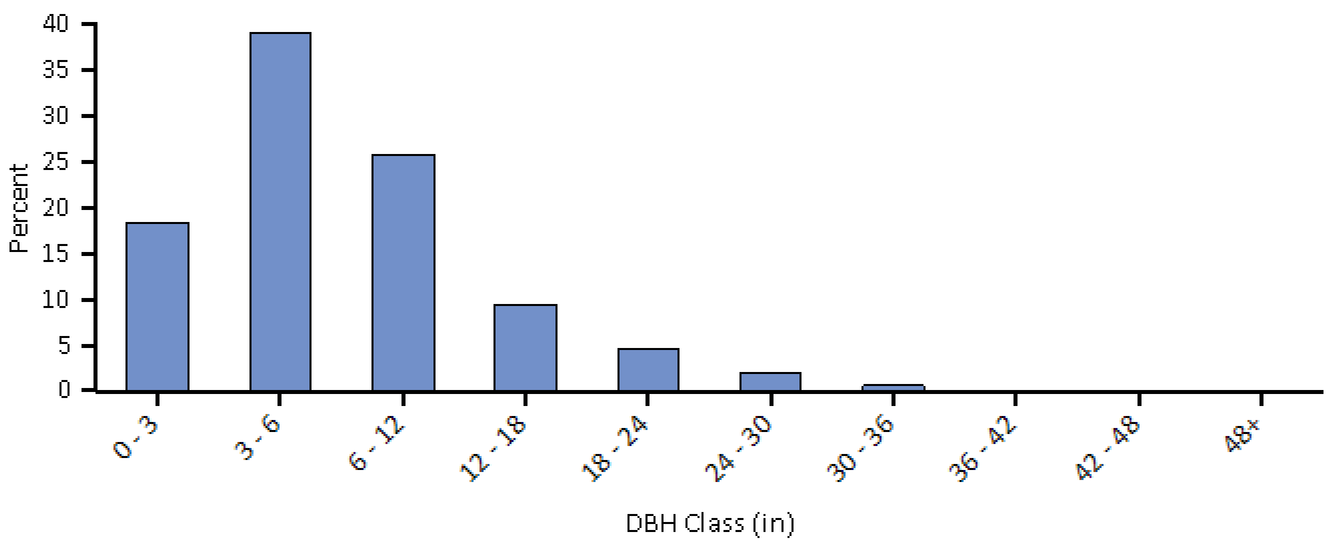


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix 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 by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study, about 93 percent of the trees are species native to North America, while 93 percent are native to Georgia. Species exotic to North America make up 7 percent of the population. Most exotic tree species have an origin from Asia (3 percent of the species).

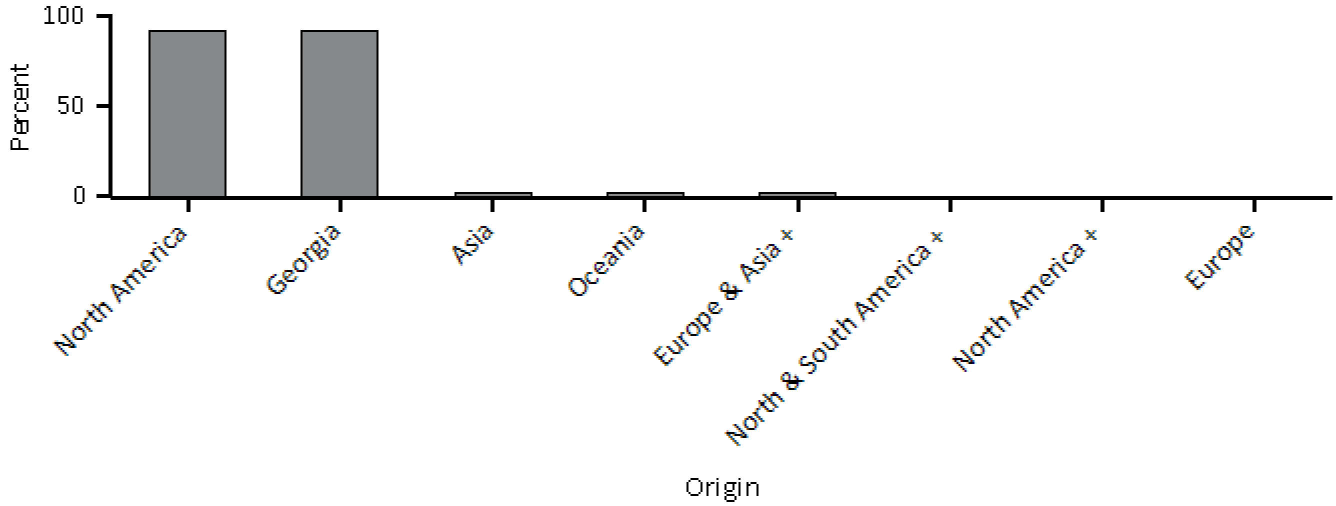


Figure 4. Percent of live tree population by area of native origin, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. Two of the 53 tree species in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study are identified as invasive on the state invasive species list (Georgia Exotic Pest Plant Council 2006). These invasive species comprise 2.2 percent of the tree population though they may only cause a minimal level of impact. These two invasive species are Chinese privet (1.3 percent of population) and Persian silk tree (0.9 percent) (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 65 percent of ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study and provide 51.47 square miles of leaf area. Total leaf area is greatest in ACC LS Natural & Undev Lands.

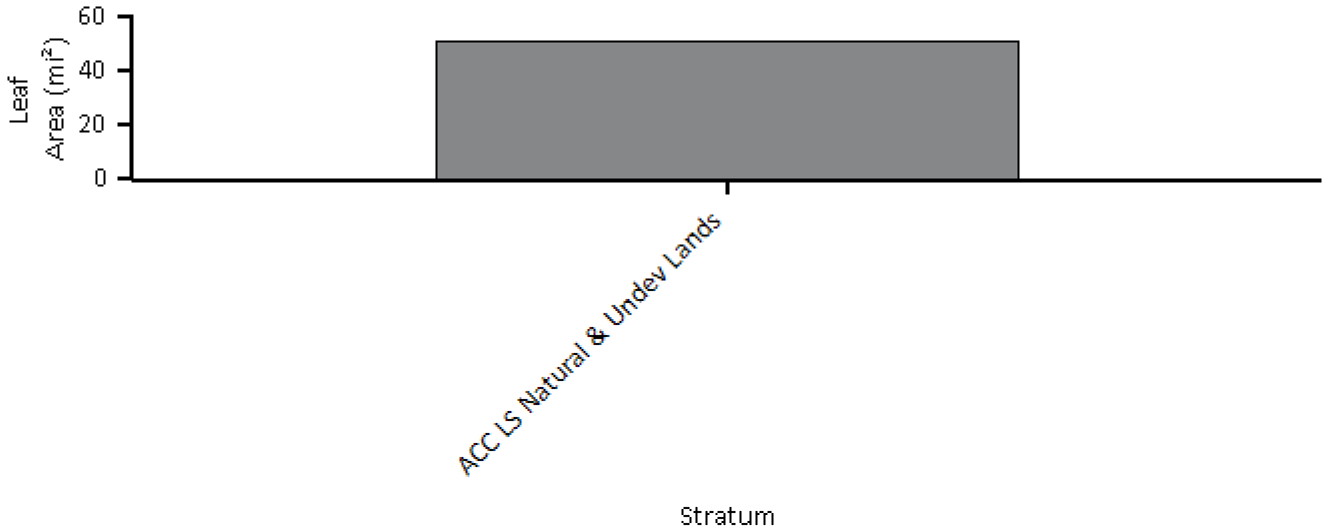


Figure 5. Leaf area by stratum, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

In ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study, the most dominant species in terms of leaf area are Water oak, Sweetgum, and Tulip tree. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Sweetgum	18.2	10.0	28.2
Water oak	7.8	14.1	21.9
Loblolly pine	6.7	8.5	15.2
Eastern hophornbeam	10.0	4.8	14.8
Tulip tree	2.8	9.8	12.5
Green ash	2.6	9.2	11.8
Red maple	7.4	3.0	10.4
White oak	2.0	8.3	10.3
Black cherry	3.9	1.5	5.4
Boxelder	2.8	2.5	5.3

Common ground cover classes (including cover types beneath trees and shrubs) in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study include duff/mulch, water, bare soil, rock, other impervious, unmaintained grass, and buildings, impervious covers such as tar, and cement, and herbaceous covers such as grass, and herbs (Figure 6). The most dominant ground cover types are Duff/Mulch (48.5 percent) and Water (18.6 percent).

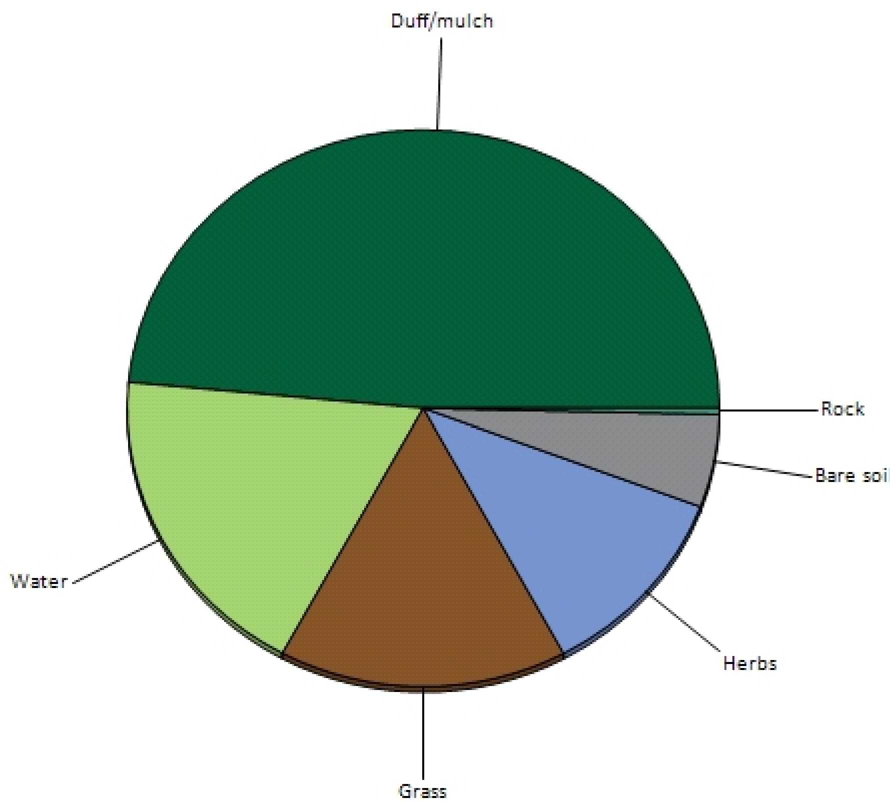


Figure 6. Percent of land by ground cover classes, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 101.1 tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of $149 thousand (see Appendix I for more details).

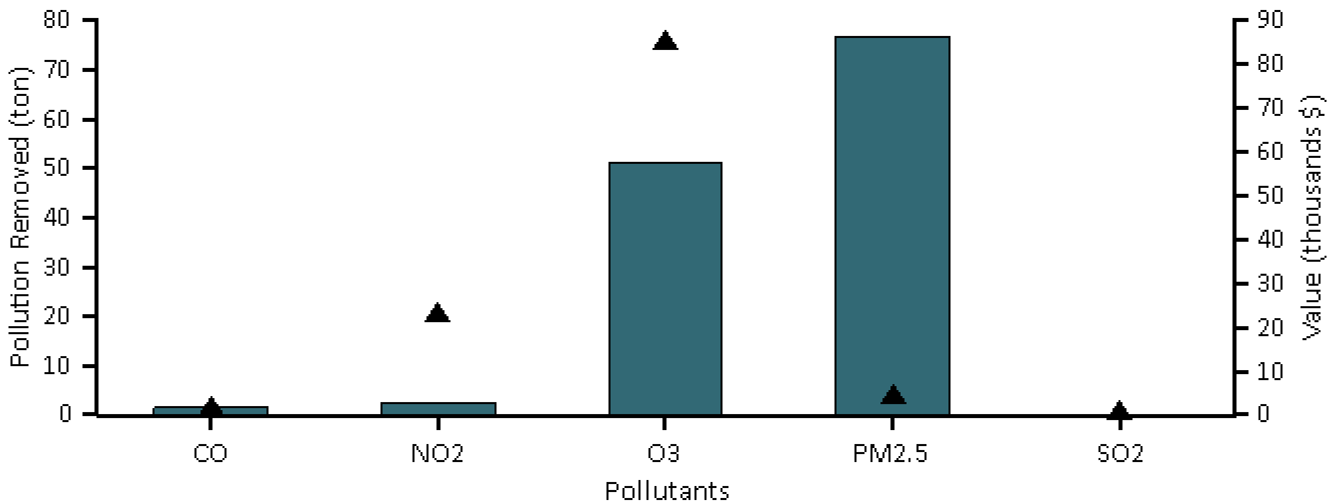


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] 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 positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2021, trees in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study emitted an estimated 238.3 tons of volatile organic compounds (VOCs) (79.31 tons of isoprene and 159 tons of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Sixty- three percent of the urban forest's VOC emissions were from Water oak and White oak. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. 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 and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

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 gross sequestration of ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study trees is about 5.308 thousand tons of carbon per year with an associated value of $905 thousand. Net carbon sequestration in the urban forest is about 3.385 thousand tons. See Appendix I for more details on methods.

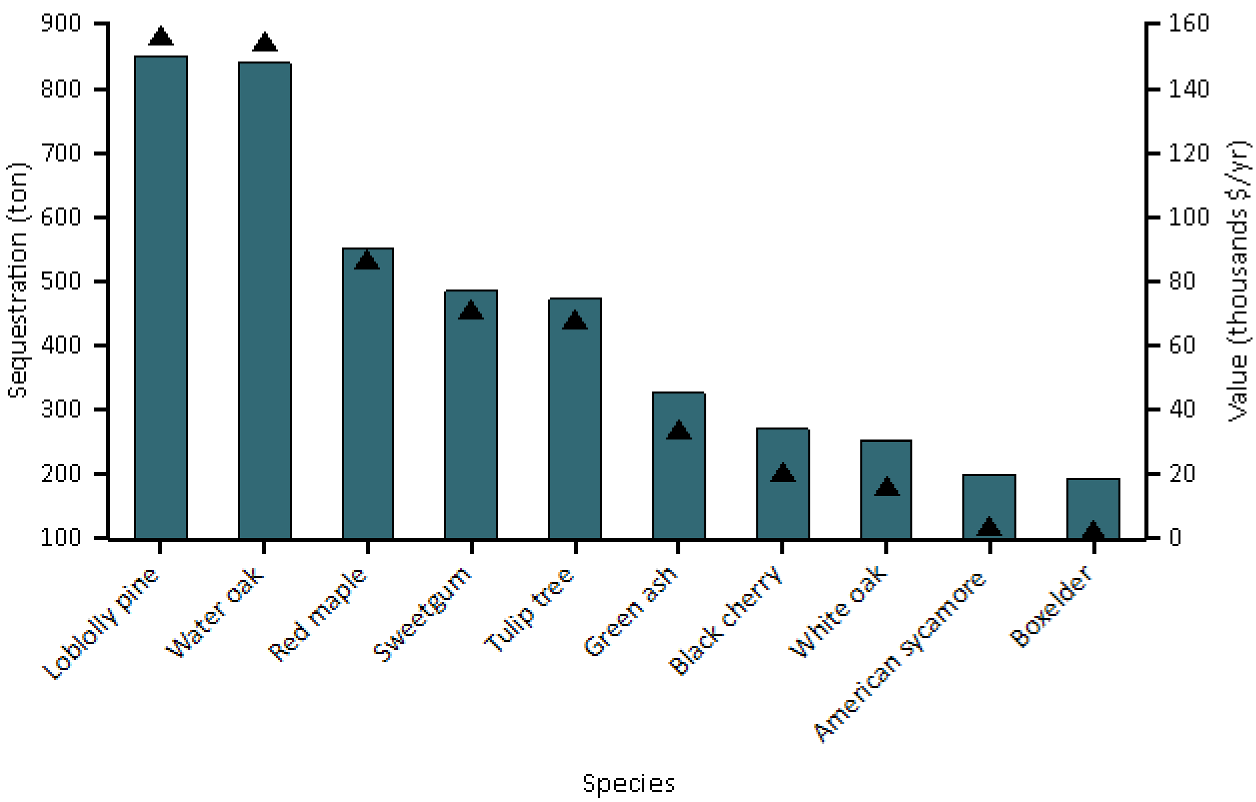


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases 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 are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study are estimated to store 110000 tons of carbon ($18.7 million). Of the species sampled, Water oak stores the most carbon (approximately 21.8% of the total carbon stored) and Loblolly pine sequesters the most (approximately 16.6% of all sequestered carbon.)

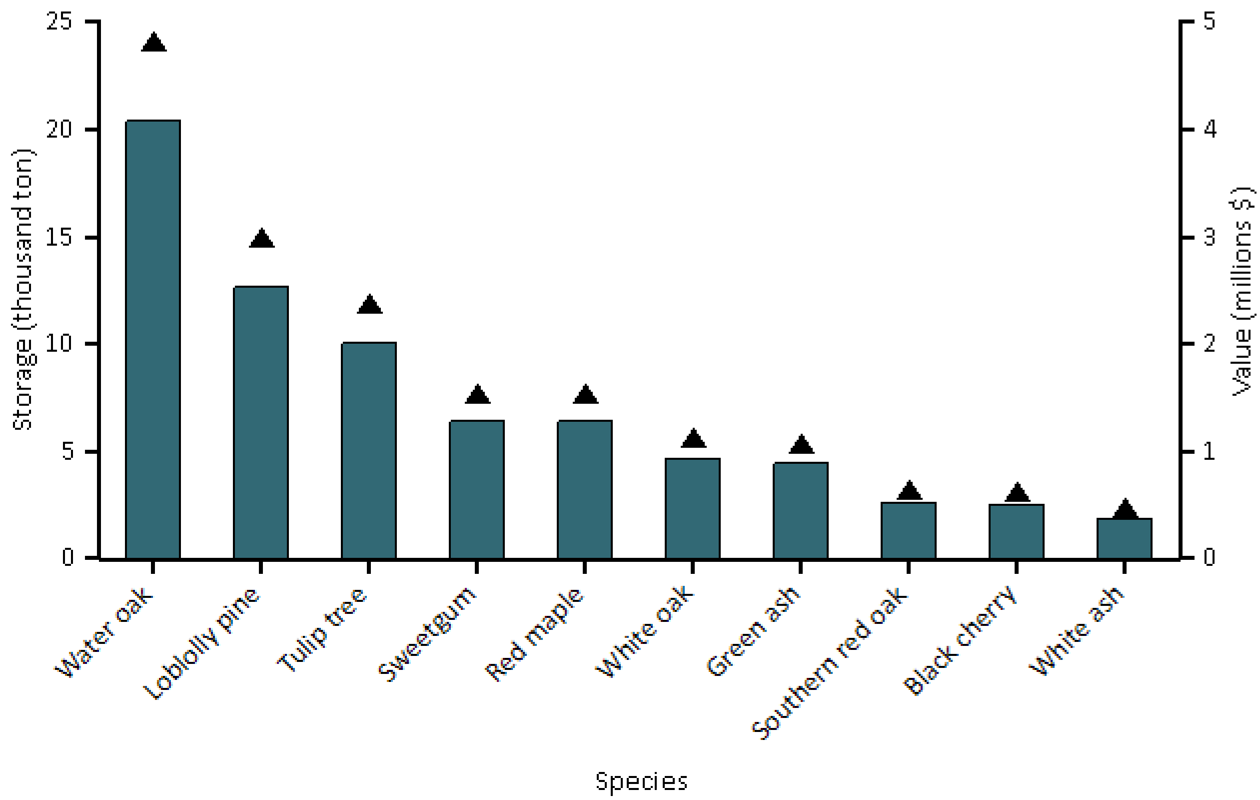


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

V. 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 ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study are estimated to produce 9.026 thousand tons of oxygen per year.[4] However, this tree benefit is relatively 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. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (ton)*	*Net Carbon Sequestration (ton/yr)*	*Number of Trees*	*Leaf Area (square mile)*
Loblolly pine	1,833.14	687.43	50,485	4.38
Water oak	1,564.57	586.71	58,899	7.26
Sweetgum	1,009.30	378.49	137,432	5.16
Red maple	930.29	348.86	56,095	1.54
Green ash	669.67	251.13	19,633	4.71
White oak	394.35	147.88	15,426	4.25
Black cherry	370.91	139.09	29,450	0.77
Tulip tree	370.38	138.89	21,035	5.02
Black walnut	252.05	94.52	2,805	1.91
American sycamore	221.58	83.09	7,012	0.85
Boxelder	212.05	79.52	21,035	1.30
Eastern hophornbeam	208.82	78.31	75,728	2.46
White ash	179.65	67.37	7,012	1.63
Mockernut hickory	172.26	64.60	11,219	0.83
Grey poplar	132.48	49.68	1,402	0.11
Eastern white pine	121.63	45.61	1,402	0.75
Winged elm	116.87	43.83	18,231	0.41
Shortleaf pine	108.84	40.82	4,207	0.20
Post oak	102.82	38.56	4,207	0.69
sycamore spp	101.15	37.93	1,402	0.31

[4] A negative estimate, or oxygen deficit, indicates that trees are decomposing faster than they are producing oxygen. This would be the case in an area that has a large proportion of dead trees.

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees 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 (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study help to reduce runoff by an estimated 8.04 million cubic feet a year with an associated value of $540 thousand (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study, the total annual precipitation in 2016 was 39.6 inches.

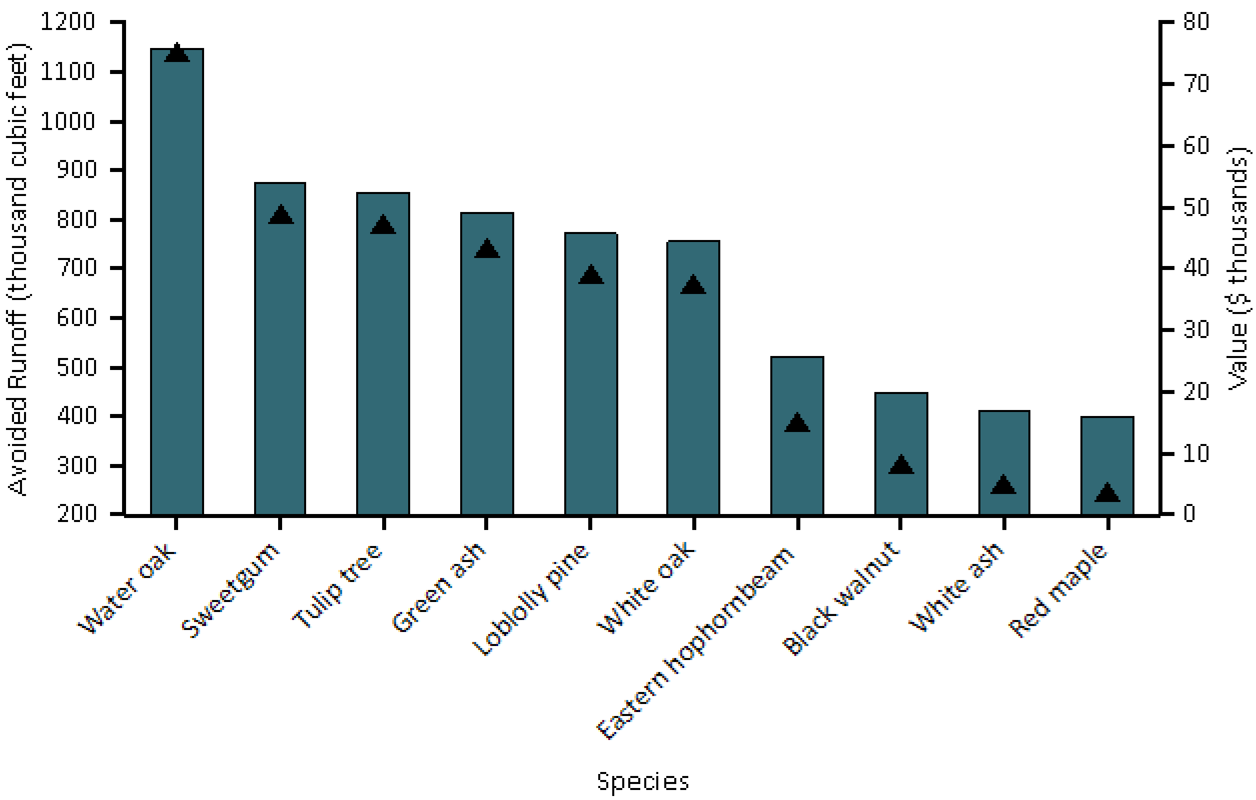


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

VII. Trees and Building Energy Use

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

Trees in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study are estimated to reduce energy-related costs from residential buildings by $0 annually. Trees also provide an additional $0 in value by reducing the amount of carbon released by fossil-fuel based power plants (a reduction of 0 pounds of carbon emissions).

Note: negative numbers indicate that there was not a reduction in carbon emissions and/or value, rather carbon emissions and values increased by the amount shown as a negative value.[5]

Table 3. Annual energy savings due to trees near residential buildings, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $122.6 per MWH and $15.3742400430376 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study have the following structural values:

- Structural value: $447 million
- Carbon storage: $18.7 million

Urban trees in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study have the following annual functional values:

- Carbon sequestration: $905 thousand
- Avoided runoff: $538 thousand
- Pollution removal: $149 thousand
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

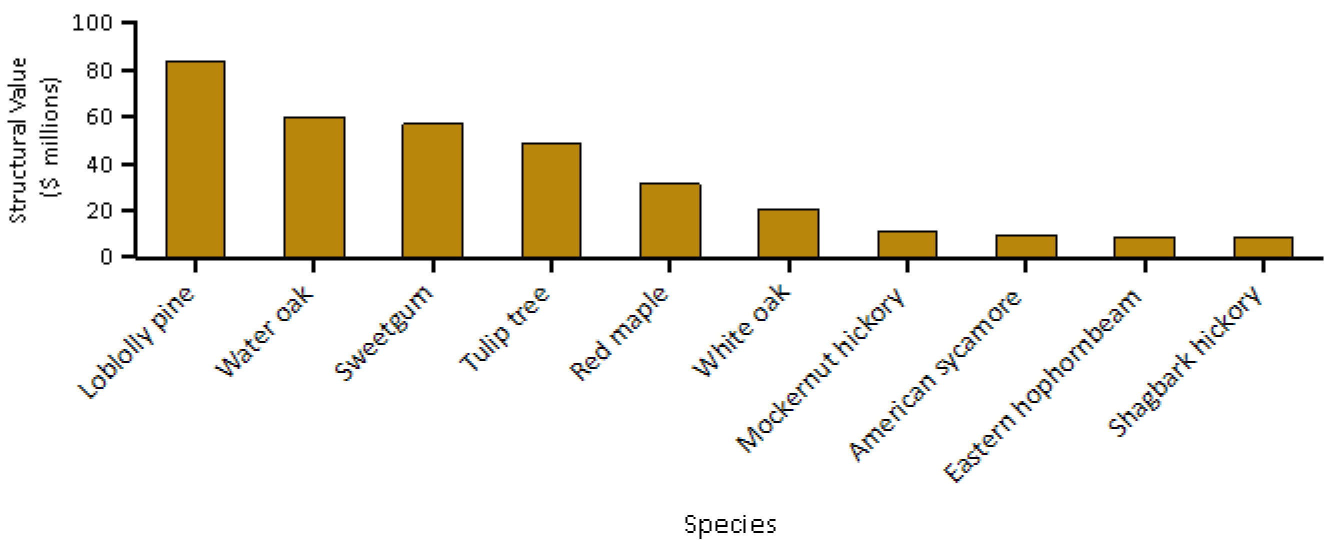


Figure 11. Tree species with the greatest structural value, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Clarke County. Five of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

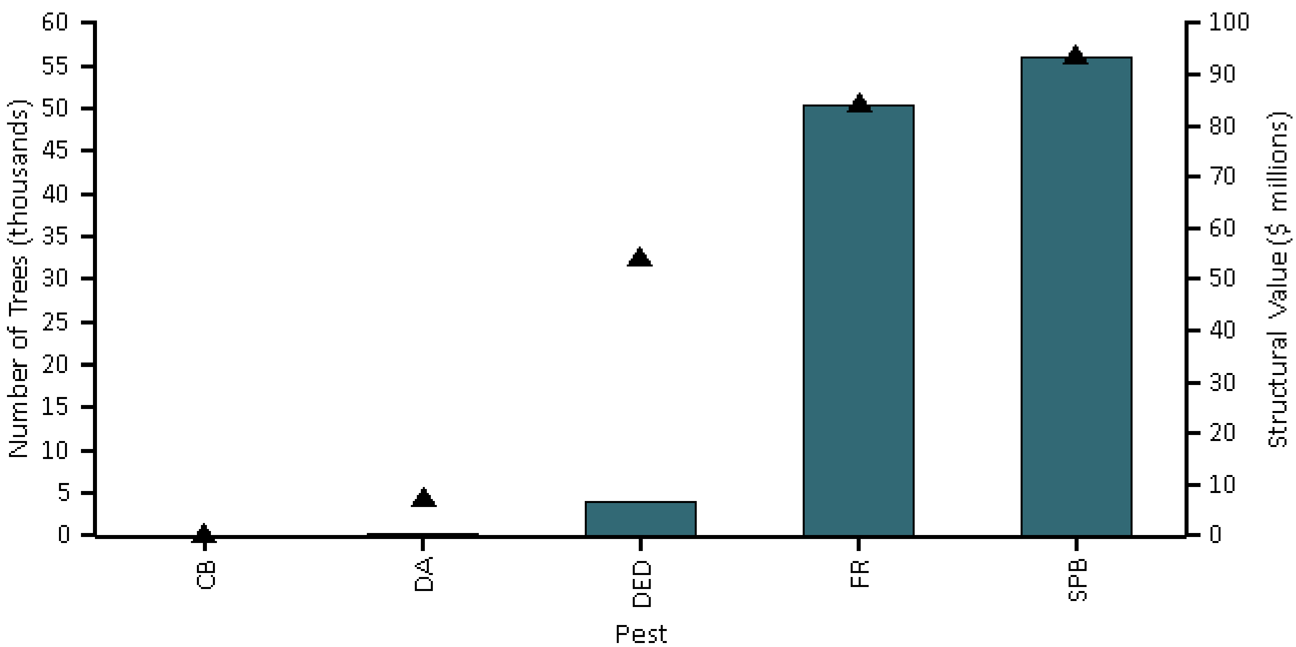


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population ($0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.6 percent of the population, which represents a potential loss of $560 thousand in structural value.

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study could possibly lose 4.3 percent of its trees to this pest ($6.7 million in structural value).

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 6.7 percent of the population ($84.1 million in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 7.4 percent of the population, which represents a potential loss of $93.5 million in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

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

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Georgia Exotic Pest Plant Council 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (PM10) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area.

Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (Nowak et al 2013). 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 positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 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.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,327 per ton (carbon monoxide), $766 per ton (ozone), $146 per ton (nitrogen dioxide), $55 per ton (sulfur dioxide), $23,640 per ton (particulate matter less than 2.5 microns).

<u>Carbon Storage and Sequestration:</u>

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

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

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 et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

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

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of \$0.07 per ft^3.

Building Energy Use:

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

For this analysis, energy saving value is calculated based on the prices of \$122.60 per MWH and \$15.37 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is

within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are 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 in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, 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) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study in 66 days
- Annual carbon (C) emissions from 77,600 automobiles
- Annual C emissions from 31,800 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 12 automobiles
- Annual carbon monoxide emissions from 34 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 2,910 automobiles
- Annual nitrogen dioxide emissions from 1,310 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 3,770 automobiles
- Annual sulfur dioxide emissions from 10 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in ACC LS, Nat, & Undev. Lands -ACC Comm. Tree Study in 3.2 days
- Annual C emissions from 3,800 automobiles
- Annual C emissions from 1,500 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" 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.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. 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.

Urban forest management strategies to help improve air quality include (Nowak 2000):

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 V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Georgia invasive species list (Georgia Exotic Pest Plant Council 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Chinese privet	9,817	1.3	27.4	0.1
Persian silk tree	7,012	0.9	110.7	0.3
Total	**16,828**	**2.23**	**138.09**	**0.42**

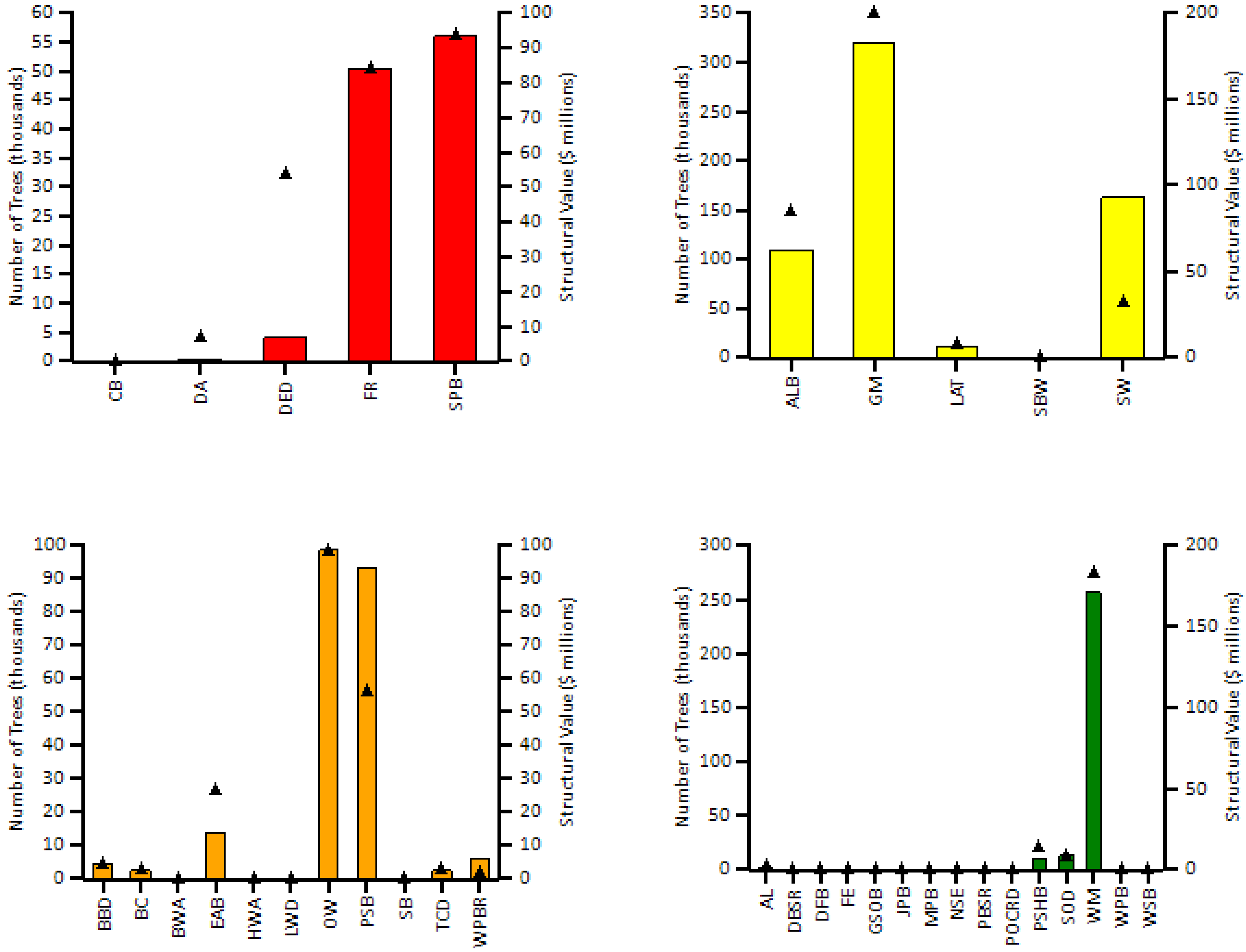
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/ disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ millions)
AL	Phyllocnistis populiella	Aspen Leafminer	2,805	0.95
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	148,650	62.48
BBD	Neonectria faginata	Beech Bark Disease	4,207	4.64
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	2,805	2.52
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	4,207	0.56
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	32,254	6.70
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	26,645	14.09
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	50,485	84.10
GM	Lymantria dispar	Gypsy Moth	349,188	183.06
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	12,621	6.29
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	98,165	98.68
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	56,095	93.45
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	21,035	7.37
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	11,219	8.94
SPB	Dendroctonus frontalis	Southern Pine Beetle	56,095	93.45
SW	Sirex noctilio	Sirex Wood Wasp	56,095	93.45
TCD	Geosmithia morbida	Thousand Canker Disease	2,805	2.52
WM	Operophtera brumata	Winter Moth	273,461	171.16
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	1,402	6.09
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Structural value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
Red	13	Loblolly pine													Red												Orange					Red	Yellow					
Red	12	Eastern white pine																									Orange					Red	Yellow				Orange	
Red	9	Shortleaf pine																									Orange					Red	Yellow					
Red	7	Winged elm		Yellow							Red																								Green			
Yellow	7	River birch		Yellow												Yellow				Yellow															Green			
Orange	7	Southern red oak														Yellow								Orange							Green				Green			
Red	7	Slippery elm		Yellow							Red																								Green			
Red	7	American elm		Yellow							Red																								Green			
Orange	7	Northern red oak														Yellow								Orange							Green				Green			
Orange	6	Water oak														Yellow								Orange											Green			
Yellow	6	Boxelder		Yellow												Yellow												Green							Green			
Orange	6	Green ash		Yellow									Orange																						Green			
Orange	6	White oak														Yellow								Orange											Green			
Orange	6	Willow oak														Yellow								Orange											Green			
Orange	6	Post oak														Yellow								Orange											Green			
Orange	6	Black walnut				Orange																												Orange				
Orange	6	Scarlet oak														Yellow								Orange											Green			
Orange	6	Black oak														Yellow								Orange											Green			
Orange	5	American beech			Orange											Yellow																						
Yellow	5	plum spp	Green	Yellow																Yellow																		
Orange	4	White ash											Orange																						Green			
Red	4	Flowering dogwood							Red																													
Red	4	dogwood spp							Red																													
Yellow	3	Red maple		Yellow																															Green			
Yellow	2	Sweetgum														Yellow																						
Yellow	2	Eastern hophornbeam														Yellow																						
Yellow	2	Persian silk tree		Yellow																																		
Yellow	2	'Bradford' callery pear														Yellow																						
Yellow	2	Grey poplar														Yellow																						
Green	1	Black cherry																																	Green			

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250

miles from the county

- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:

Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Clarke county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Clarke county
- Green indicates pest is outside of these ranges

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Appendix H:

(Dozens of Spreadsheets, Graphs, & Charts - Generated From the Complete ACC iTree Eco Study Model (316 Plots)

Appendix H.1: (Health Impacts and Values by Trees)

Air Quality Health Impacts and Values by Trees

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

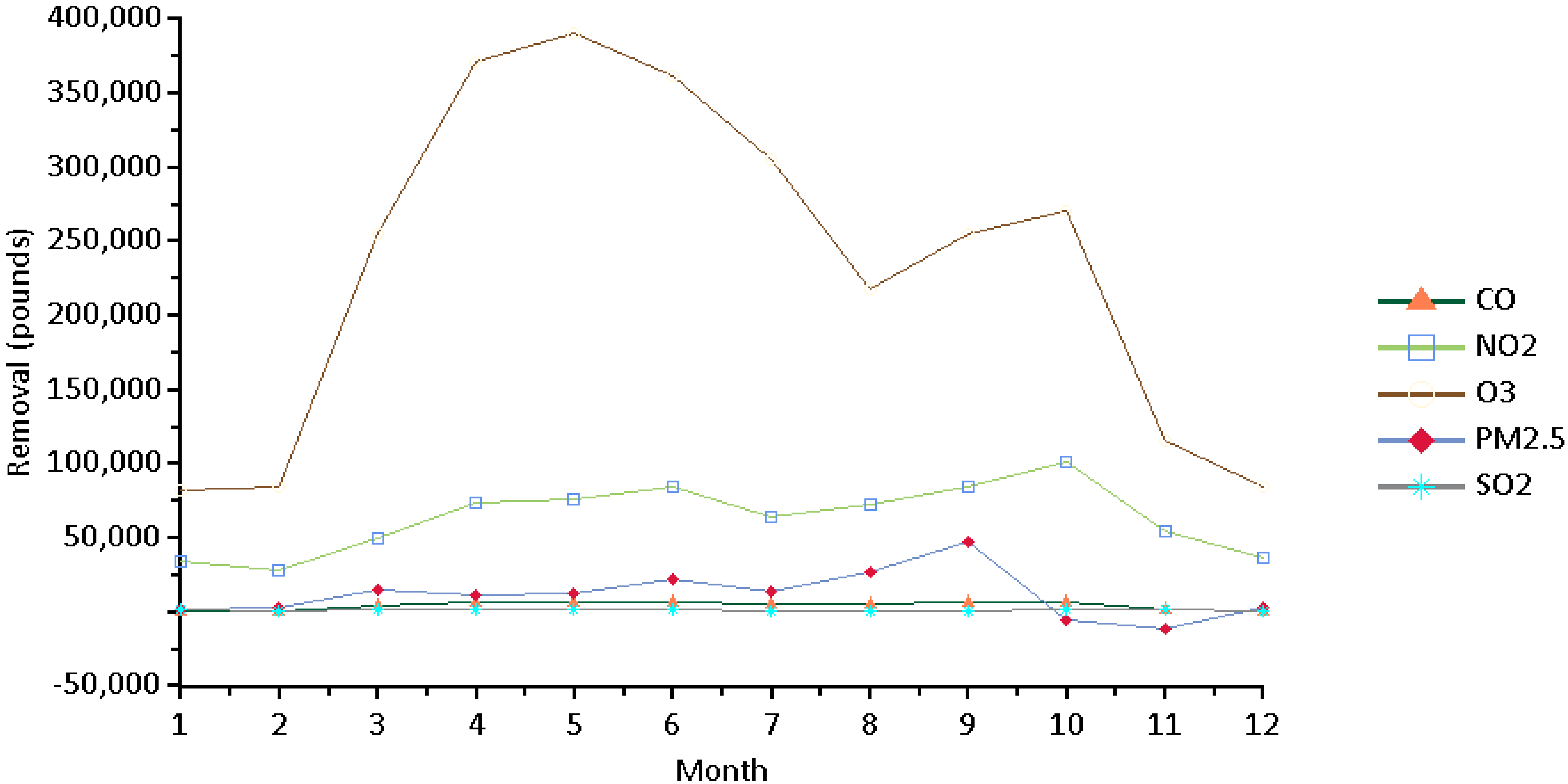
	NO2		O3		PM2.5		SO2	
	Incidence (Reduction/yr)	Value ($/yr)	Incidence (Reduction/yr)	Value ($/yr)	Incidence (Reduction/yr)	Value ($/yr)	Incidence (Reduction/yr)	Value ($/yr)
Acute Bronchitis					0.134	11.84		
Acute Myocardial Infarction					0.062	5,579.30		
Acute Respiratory Symptoms	20.501	647.42	364.703	31,177.81	123.330	12,088.57	0.135	4.26
Asthma Exacerbation	280.859	23,394.13			58.291	4,738.64	1.199	94.29
Chronic Bronchitis					0.069	19,213.65		
Emergency Room Visits	0.377	157.13	0.161	67.41	0.099	40.93	0.008	3.29
Hospital Admissions	1.045	30,999.16	0.478	14,506.95			0.008	257.33
Hospital Admissions, Cardiovascular					0.039	1,479.17		
Hospital Admissions, Respiratory					0.030	934.74		
Lower Respiratory Symptoms					1.594	82.78		
Mortality			0.131	1,018,246.50	0.205	1,593,109.16		
School Loss Days			85.341	8,379.61				
Upper Respiratory Symptoms					1.351	60.66		
Work Loss Days					21.837	2,952.39		
Total	**302.781**	**55,197.84**	**450.814**	**1,072,378.27**	**207.041**	**1,640,291.82**	**1.350**	**359.17**

EPA Environmental Benefits Mapping and Analysis Program http://www.epa.gov/airquality/benmap/index.html
Incidence: the total number of adverse health effects avoided in a year due to a change in pollution concentration
Value: the economic value that is associated with the incidence of adverse health effects

Appendix H.2.1: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.2.2: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Pollutant Removal

Month	Pollutant	Amount (pounds)
1	CO	394.330
	NO2	34,243.907
	O3	82,189.995
	PM2.5	1,683.883
	SO2	1,057.935
2	CO	340.388
	NO2	28,491.211
	O3	84,845.506
	PM2.5	2,614.001
	SO2	796.693
3	CO	3,982.891
	NO2	49,307.821
	O3	254,355.705
	PM2.5	15,077.660
	SO2	1,160.051
4	CO	6,743.363
	NO2	73,214.203
	O3	371,357.747
	PM2.5	10,648.906
	SO2	1,618.777
5	CO	5,969.307
	NO2	75,463.278
	O3	390,068.590
	PM2.5	12,767.043
	SO2	1,146.326

Appendix H.2.3: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Pollutant Removal

Month	Pollutant	Amount (pounds)
6	CO	5,902.715
	NO2	83,855.518
	O3	361,356.955
	PM2.5	22,301.672
	SO2	1,542.323
7	CO	5,333.955
	NO2	64,228.489
	O3	305,498.445
	PM2.5	13,312.536
	SO2	883.849
8	CO	5,050.426
	NO2	72,429.376
	O3	217,452.090
	PM2.5	26,437.587
	SO2	778.045
9	CO	6,758.752
	NO2	83,912.819
	O3	254,233.930
	PM2.5	47,643.062
	SO2	824.775
10	CO	6,395.532
	NO2	101,682.171
	O3	270,741.069
	PM2.5	-5,333.713
	SO2	1,501.045

Appendix H.2.4: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

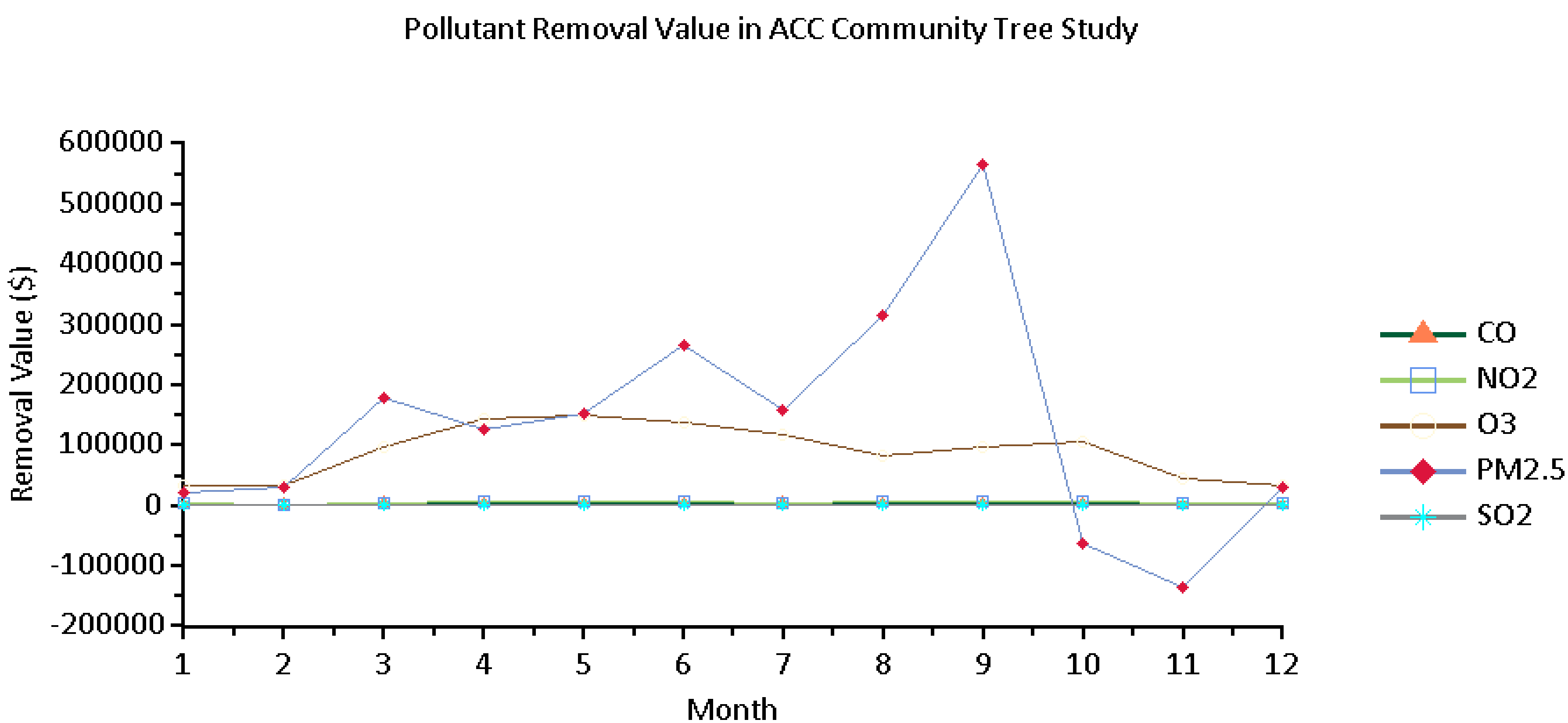
Pollutant Removal

Month	Pollutant	Amount (pounds)
11	CO	1,945.057
	NO2	53,920.267
	O3	115,323.542
	PM2.5	-11,558.146
	SO2	1,496.854
12	CO	282.342
	NO2	36,279.349
	O3	84,260.193
	PM2.5	2,601.806
	SO2	235.116

Appendix H.2.5: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Pollution removal value is calculated based on the prices of $0.66 per pound (CO), $0.38 per pound (O3), $0.07 per pound (NO2), $0.03 per pound (SO2), $11.87 per pound (PM2.5).
A value of zero may indicate that ancillary data (pollution, weather, energy, etc.) is not available for this location or that the reported amounts are too small to be shown.

Appendix H.2.6: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Pollutant Removal Value

Month	Pollutant	Value ($)
1	CO	261.639
	NO2	2,496.855
	O3	31,571.901
	PM2.5	19,986.497
	SO2	29.135
2	CO	225.848
	NO2	2,077.403
	O3	32,591.971
	PM2.5	31,026.338
	SO2	21.941
3	CO	2,642.657
	NO2	3,595.222
	O3	97,706.458
	PM2.5	178,961.106
	SO2	31.948
4	CO	4,474.235
	NO2	5,338.328
	O3	142,650.820
	PM2.5	126,394.939
	SO2	44.581
5	CO	3,960.647
	NO2	5,502.317
	O3	149,838.275
	PM2.5	151,535.725
	SO2	31.570

Appendix H.2.7: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Pollutant Removal Value

Month	Pollutant	Value ($)
6	CO	3,916.463
	NO2	6,114.227
	O3	138,809.185
	PM2.5	264,704.999
	SO2	42.475
7	CO	3,539.090
	NO2	4,683.145
	O3	117,352.079
	PM2.5	158,010.343
	SO2	24.341
8	CO	3,350.968
	NO2	5,281.103
	O3	83,530.556
	PM2.5	313,795.361
	SO2	21.427
9	CO	4,484.446
	NO2	6,118.405
	O3	97,659.680
	PM2.5	565,489.285
	SO2	22.714
10	CO	4,243.449
	NO2	7,414.037
	O3	104,000.619
	PM2.5	-63,307.384
	SO2	41.339

Appendix H.2.8: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Pollutant Removal Value

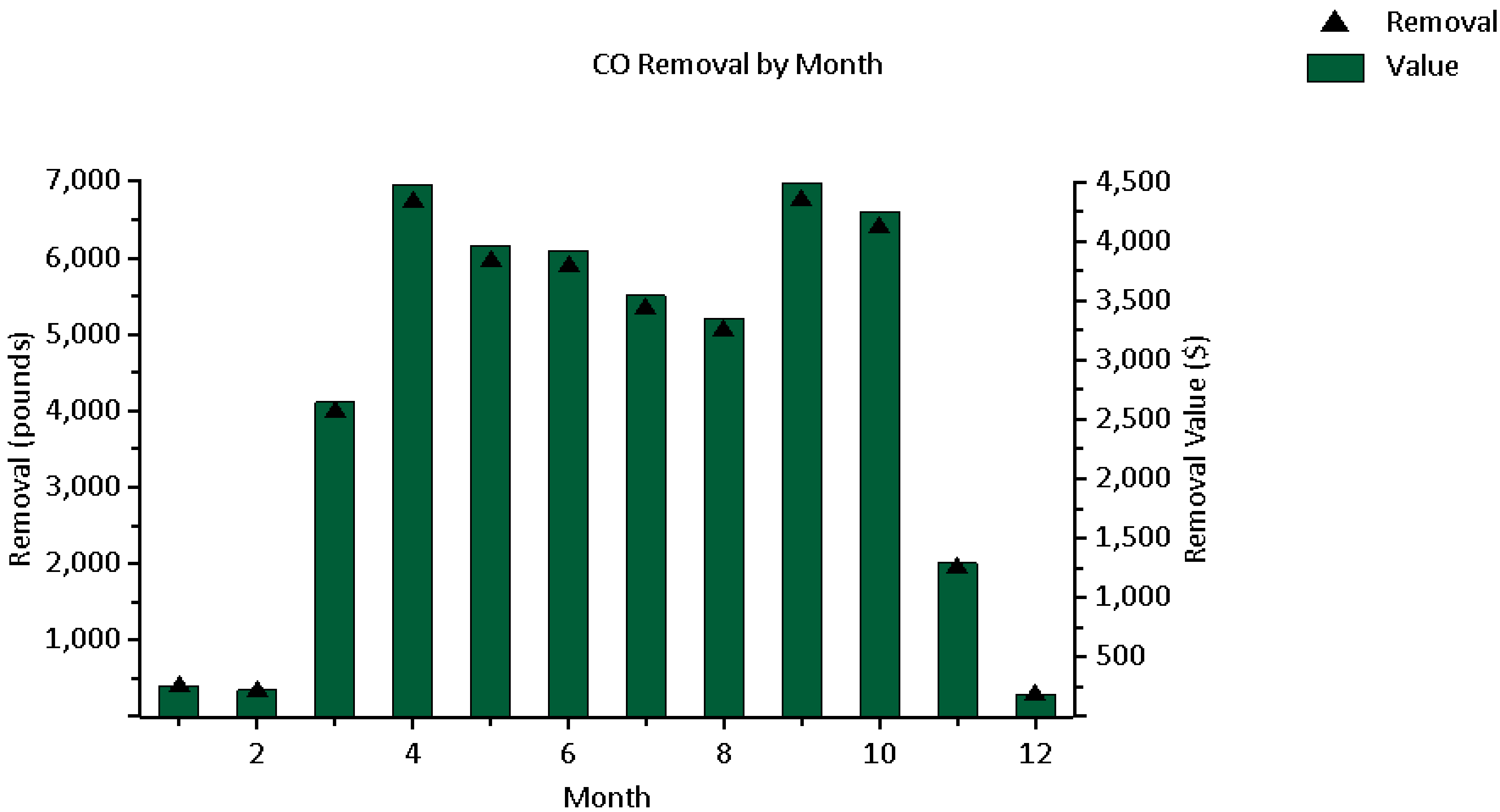
Month	Pollutant	Value ($)
11	CO	1,290.549
	NO2	3,931.533
	O3	44,299.595
	PM2.5	-137,186.977
	SO2	41.223
12	CO	187.335
	NO2	2,645.266
	O3	32,367.133
	PM2.5	30,881.591
	SO2	6.475

Pollution removal value is calculated based on the prices of $0.66 per pound (CO), $0.38 per pound (O3), $0.07 per pound (NO2), $0.03 per pound (SO2), $11.87 per pound (PM2.5).
A value of zero may indicate that ancillary data (pollution, weather, energy, etc.) is not available for this location or that the reported amounts are too small to be shown.

Appendix H.2.9: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

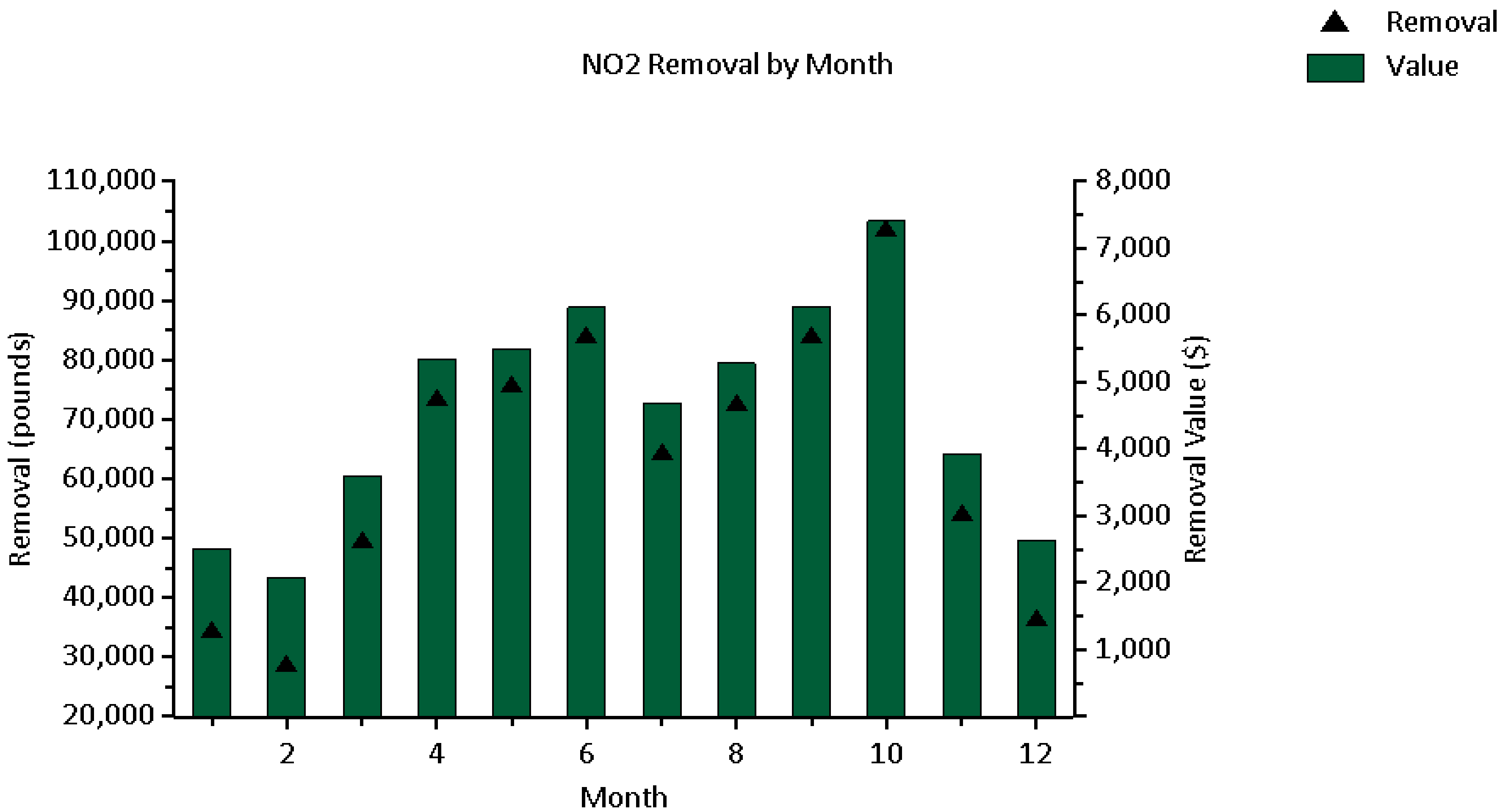


CO value is calculated based on the price of $0.66 per pound.

Appendix H.2.10: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

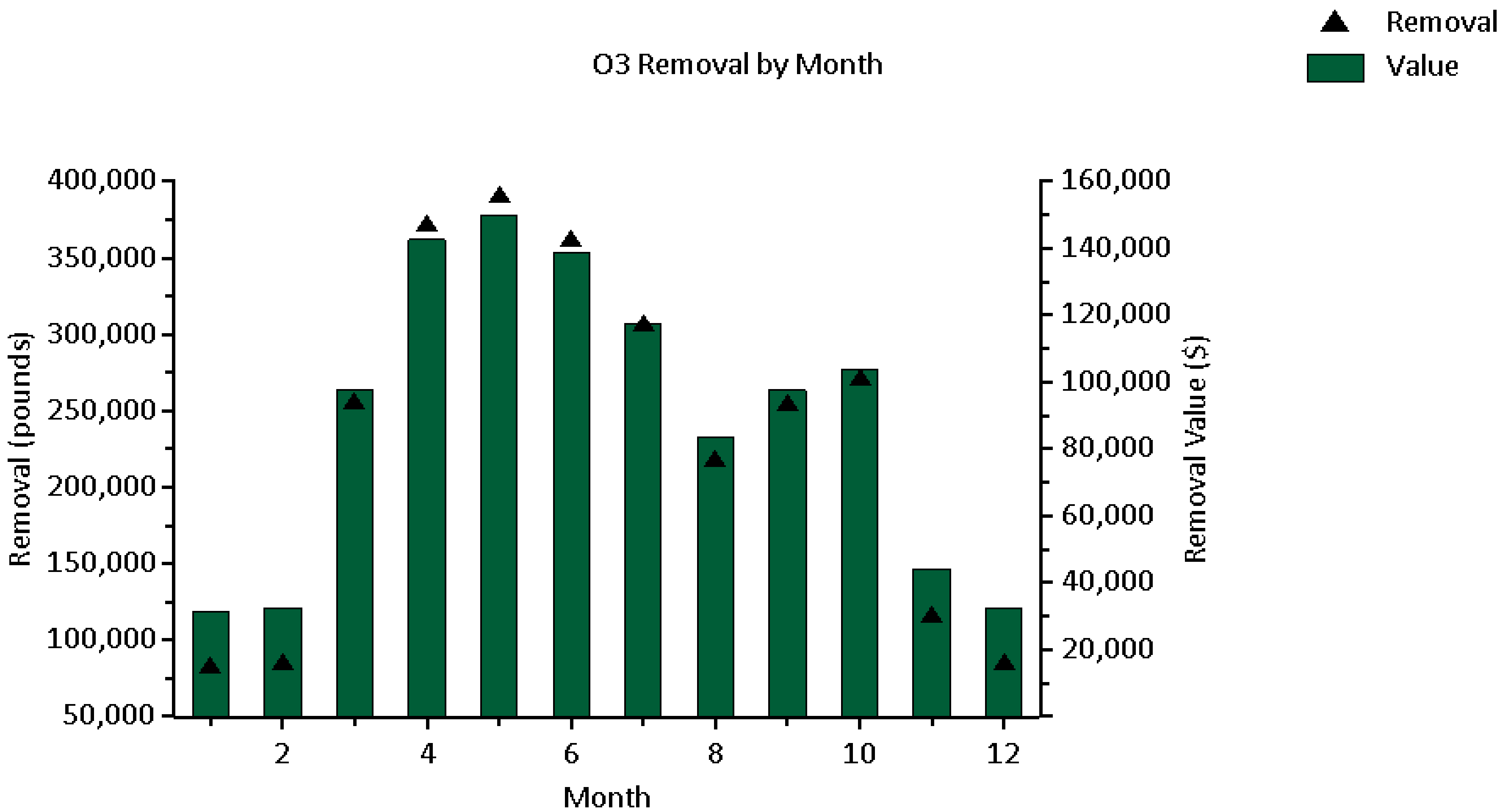


NO2 value is calculated based on the price of $0.07 per pound.

Appendix H.2.11: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

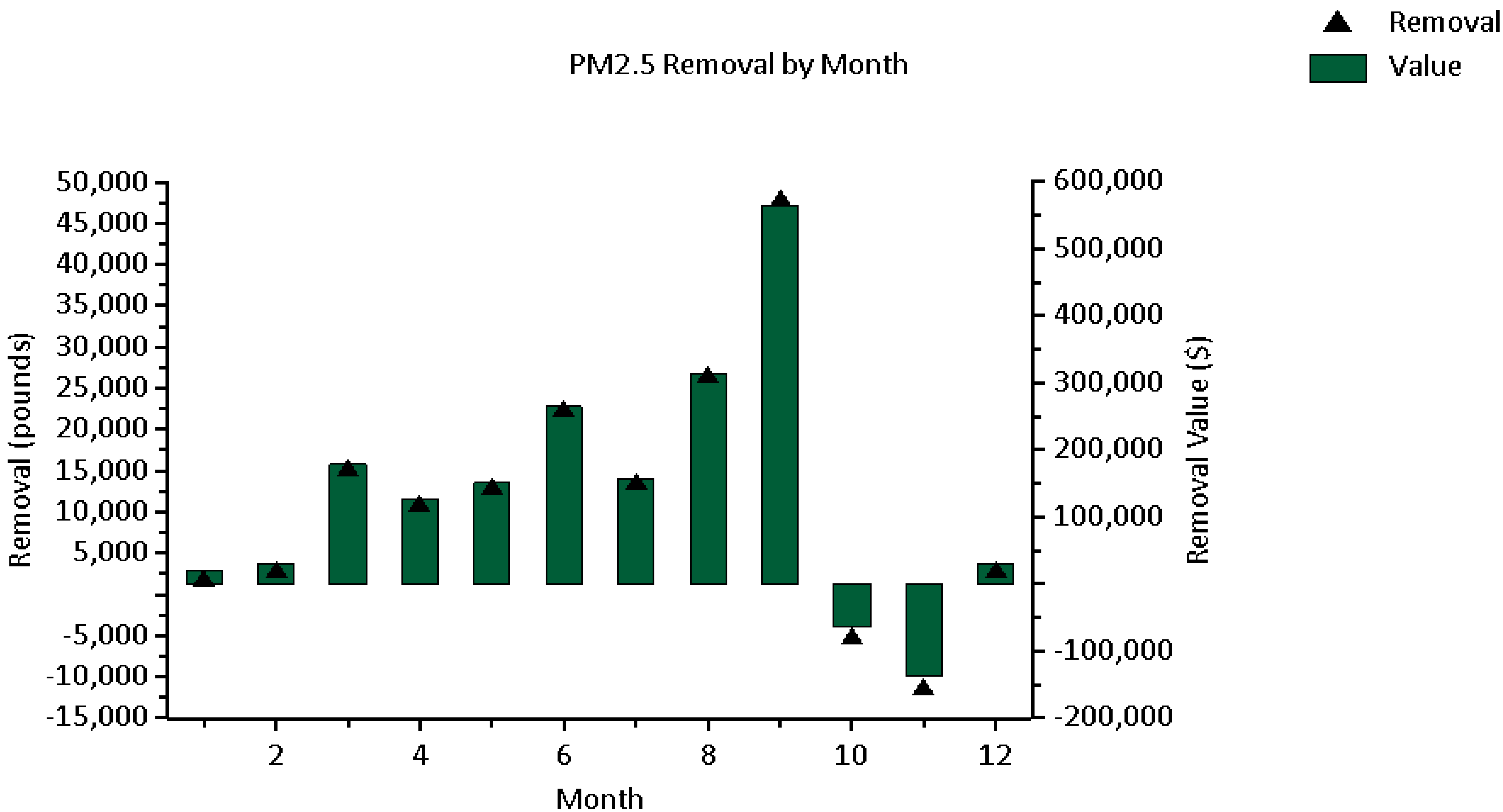


O3 value is calculated based on the price of $0.38 per pound.

Appendix H.2.12: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

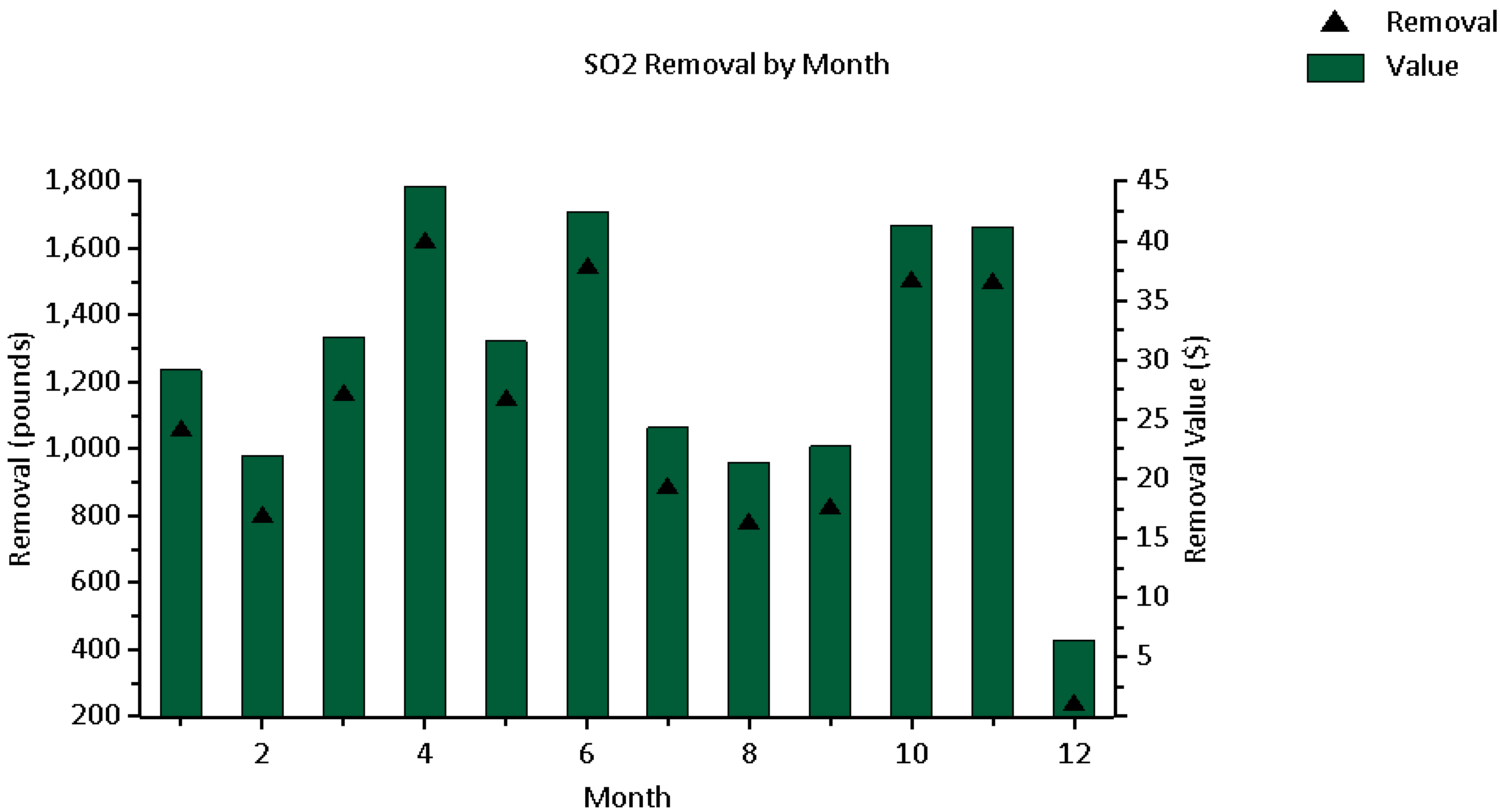


PM2.5 value is calculated based on the price of $11.87 per pound.

Appendix H.2.13: (Monthly Pollution Removal by Trees)

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



SO2 value is calculated based on the price of $0.03 per pound.

Appendix H.3.1: (Leaf Area by Stratum)

Leaf Area by Stratum

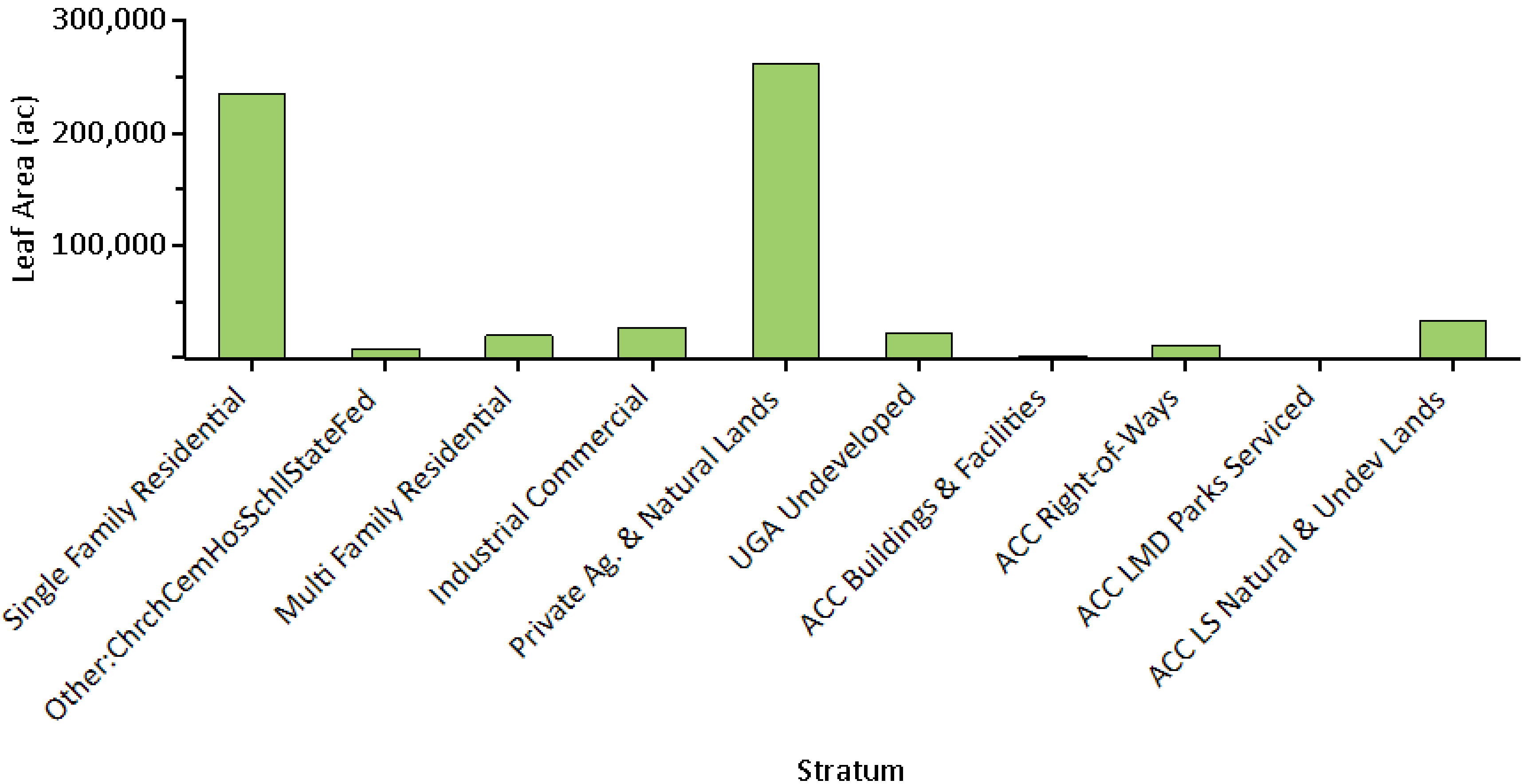
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Stratum	Leaf Area (ac)	Leaf Area (%)
Single Family Residential	234,518.68	37.8%
Other:ChrchCemHosSchllStateFed	8,517.26	1.4%
Multi Family Residential	19,875.31	3.2%
Industrial Commercial	27,495.31	4.4%
Private Ag. & Natural Lands	262,017.74	42.2%
UGA Undeveloped	21,658.02	3.5%
ACC Buildings & Facilities	1,665.77	0.3%
ACC Right-of-Ways	11,233.74	1.8%
ACC LMD Parks Serviced	695.50	0.1%
ACC LS Natural & Undev Lands	32,941.80	5.3%
Study Area	**620,619.13**	**100.0%**

Appendix H.3.2: (Leaf Area by Stratum)

Leaf Area by Stratum

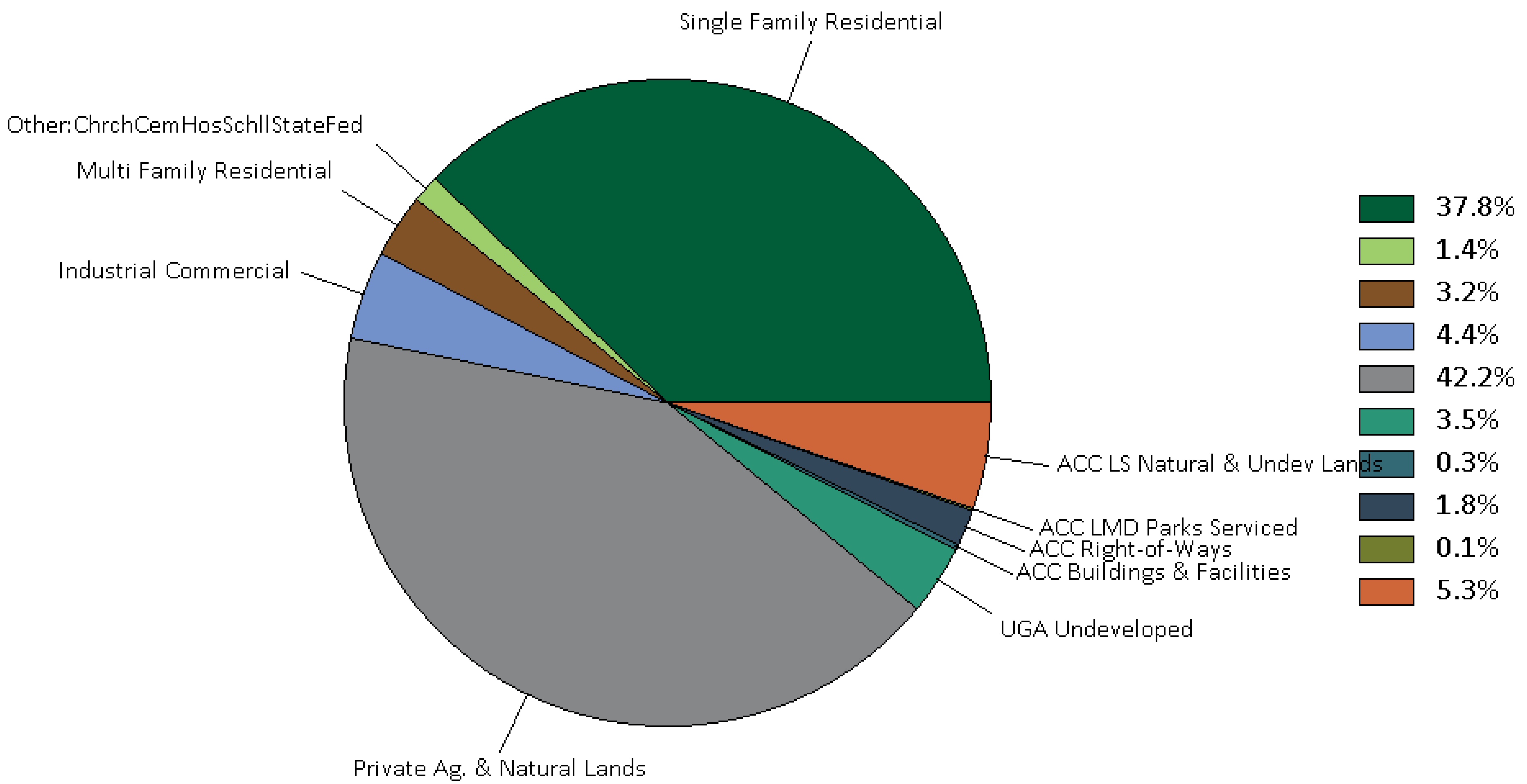
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.3.3: (Leaf Area by Stratum)

Leaf Area by Stratum

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.3.4: (Leaf Area by Stratum Per Unit Area)

Leaf Area by Stratum per Unit Area

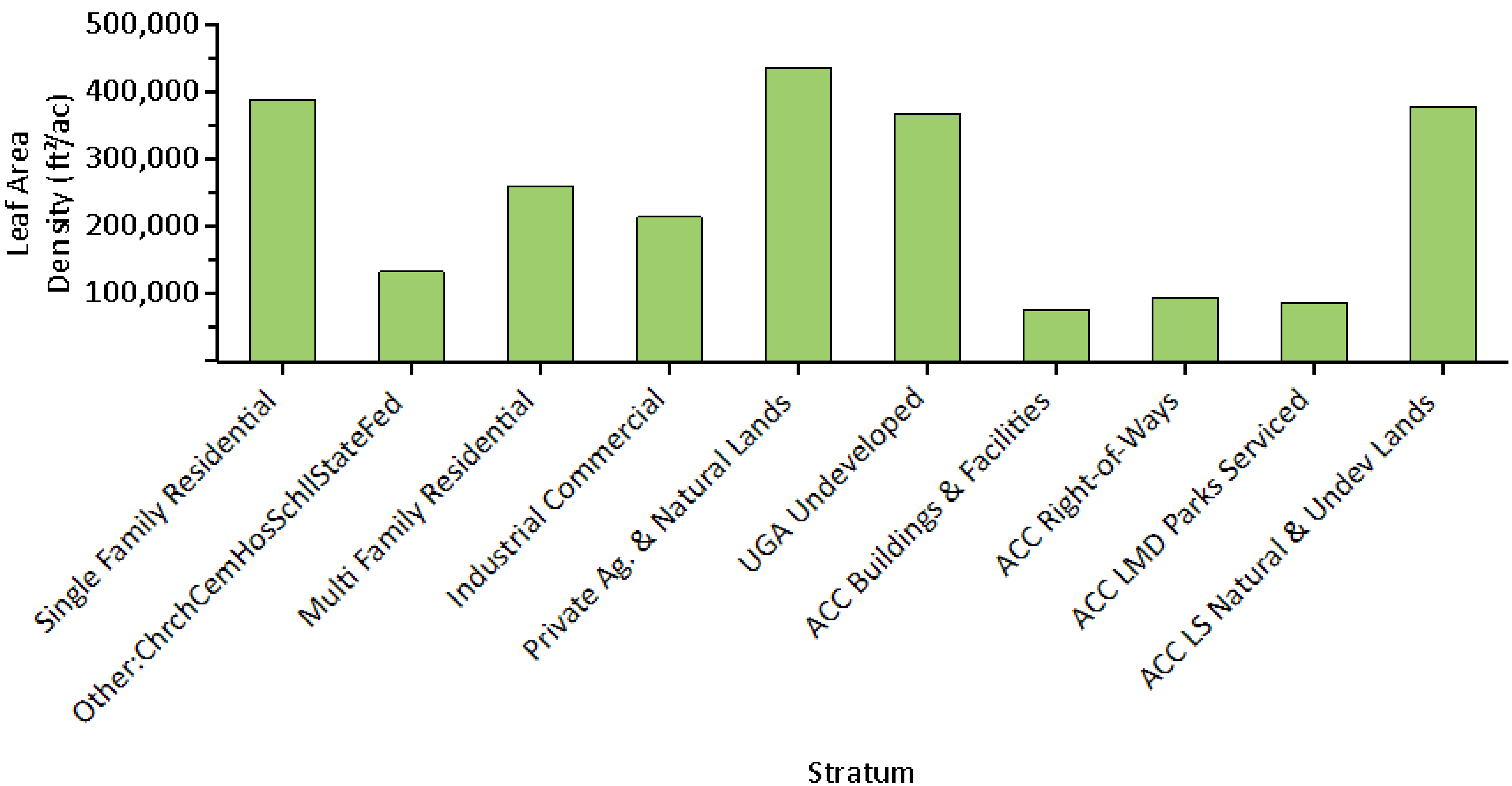
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Stratum	Leaf Area Density (ft^2/ac)
Single Family Residential	390,415.75
Other:ChrchCemHosSchllStateFed	132,957.03
Multi Family Residential	260,238.79
Industrial Commercial	214,755.92
Private Ag. & Natural Lands	437,773.50
UGA Undeveloped	368,411.46
ACC Buildings & Facilities	76,765.12
ACC Right-of-Ways	94,952.31
ACC LMD Parks Serviced	86,711.00
ACC LS Natural & Undev Lands	378,962.57
Study Area	**352,340.05**

Appendix H.3.5: (Leaf Area by Stratum Per Unit Area)

Leaf Area by Stratum per Unit Area

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.4.1: (Trees Per Acre by Stratum)

Population Summary by Stratum per Unit Area

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

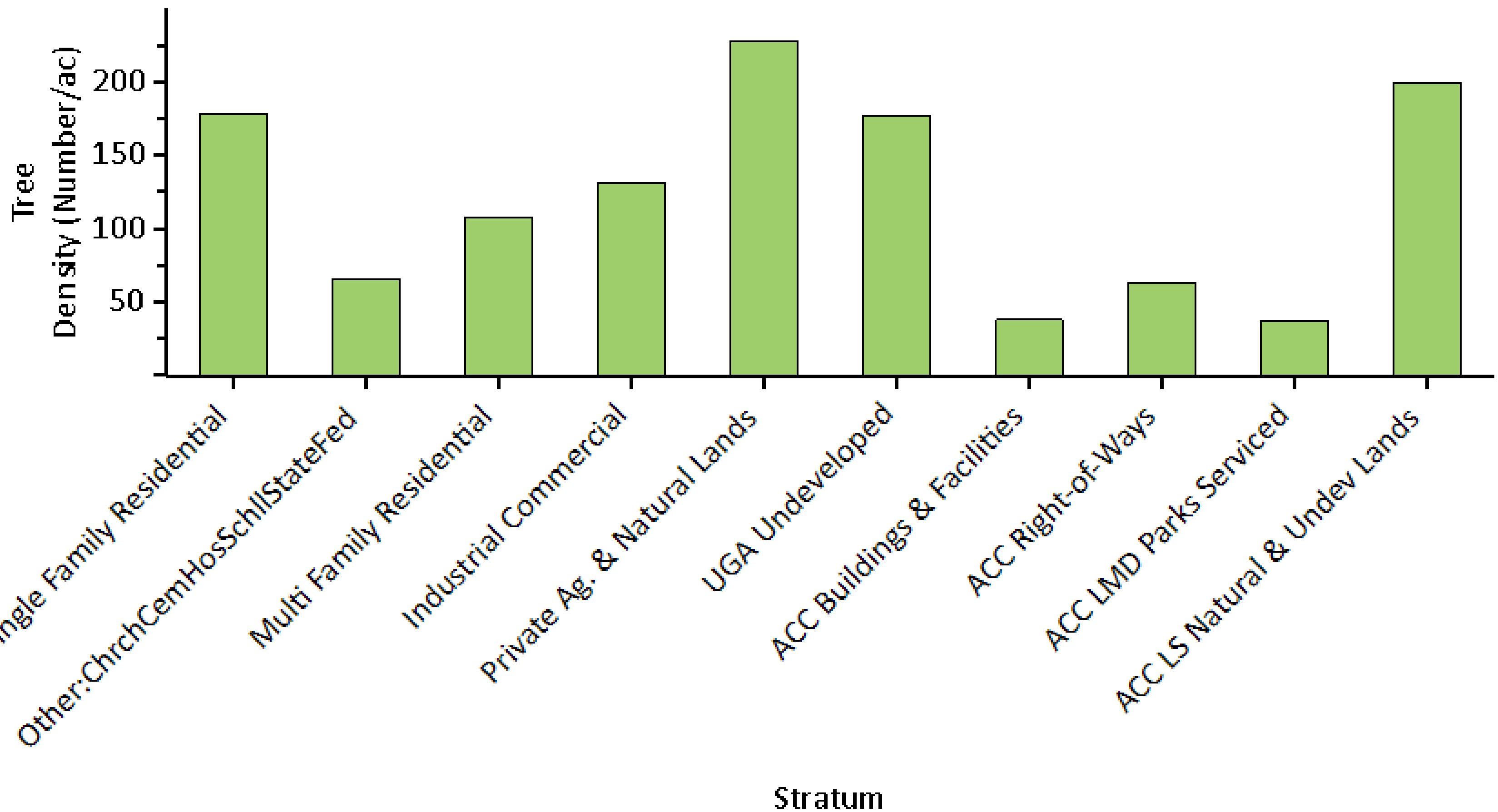
i-Tree Eco

Stratum	Tree Density (Number/ac)
Single Family Residential	178.7
Other:ChrchCemHosSchllStateFed	65.6
Multi Family Residential	107.8
Industrial Commercial	131.3
Private Ag. & Natural Lands	227.5
UGA Undeveloped	177.3
ACC Buildings & Facilities	37.9
ACC Right-of-Ways	63.0
ACC LMD Parks Serviced	37.2
ACC LS Natural & Undev Lands	199.3
Study Area	**175.4**

Appendix H.4.2: (Trees Per Acre by Stratum)

Population Summary by Stratum per Unit Area

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.6.1: (Number of Trees by Stratum)

Population Summary by Stratum

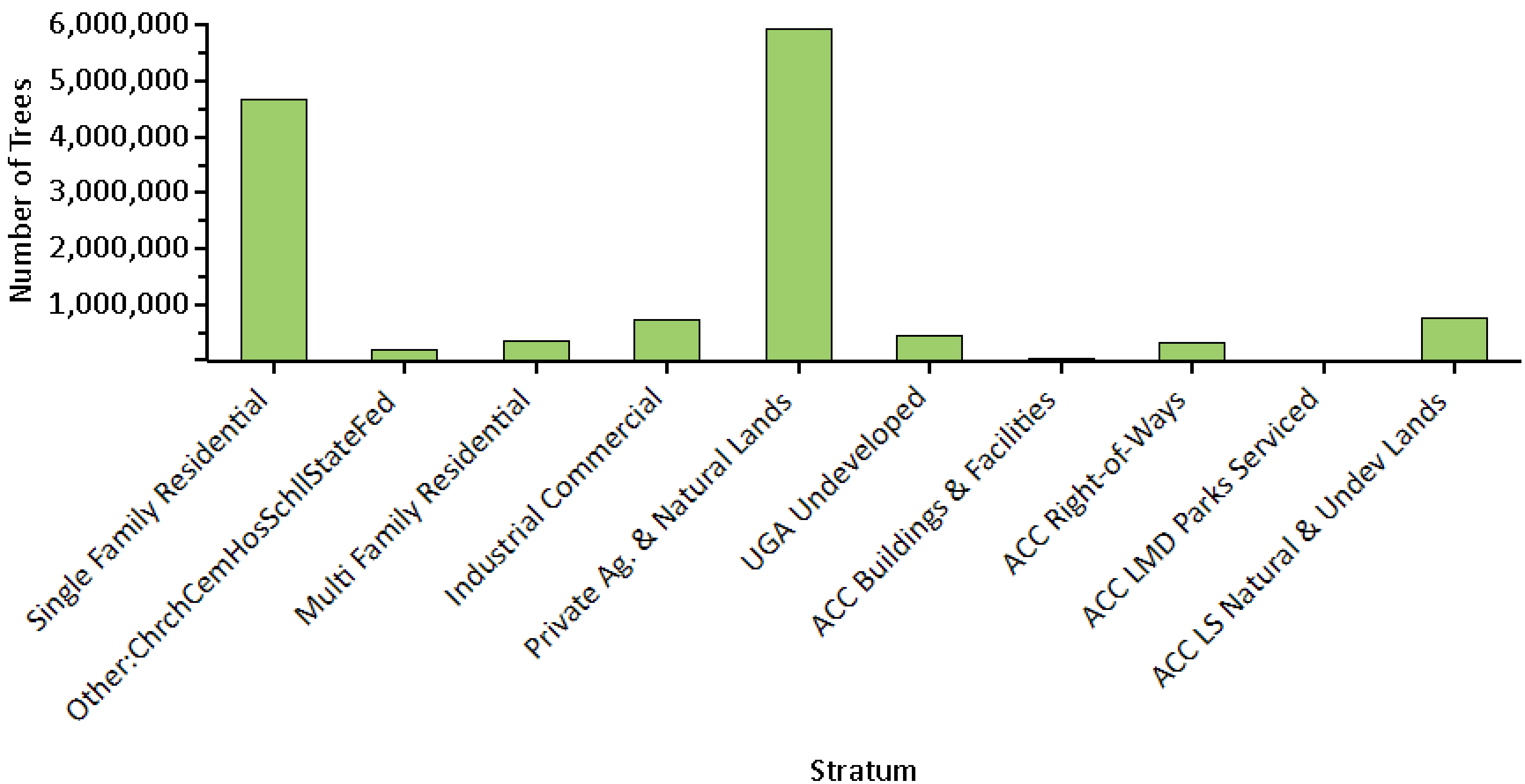
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Stratum	Number of Trees	Percent of Population
Single Family Residential	4,675,017	34.7%
Other:ChrchCemHosSchllStateFed	183,015	1.4%
Multi Family Residential	358,545	2.7%
Industrial Commercial	732,182	5.4%
Private Ag. & Natural Lands	5,931,107	44.1%
UGA Undeveloped	454,005	3.4%
ACC Buildings & Facilities	35,803	0.3%
ACC Right-of-Ways	324,524	2.4%
ACC LMD Parks Serviced	12,994	0.1%
ACC LS Natural & Undev Lands	754,471	5.6%
Study Area	**13,461,665**	**100.0%**

Appendix H.6.2: (Number of Trees by Stratum)

Population Summary by Stratum

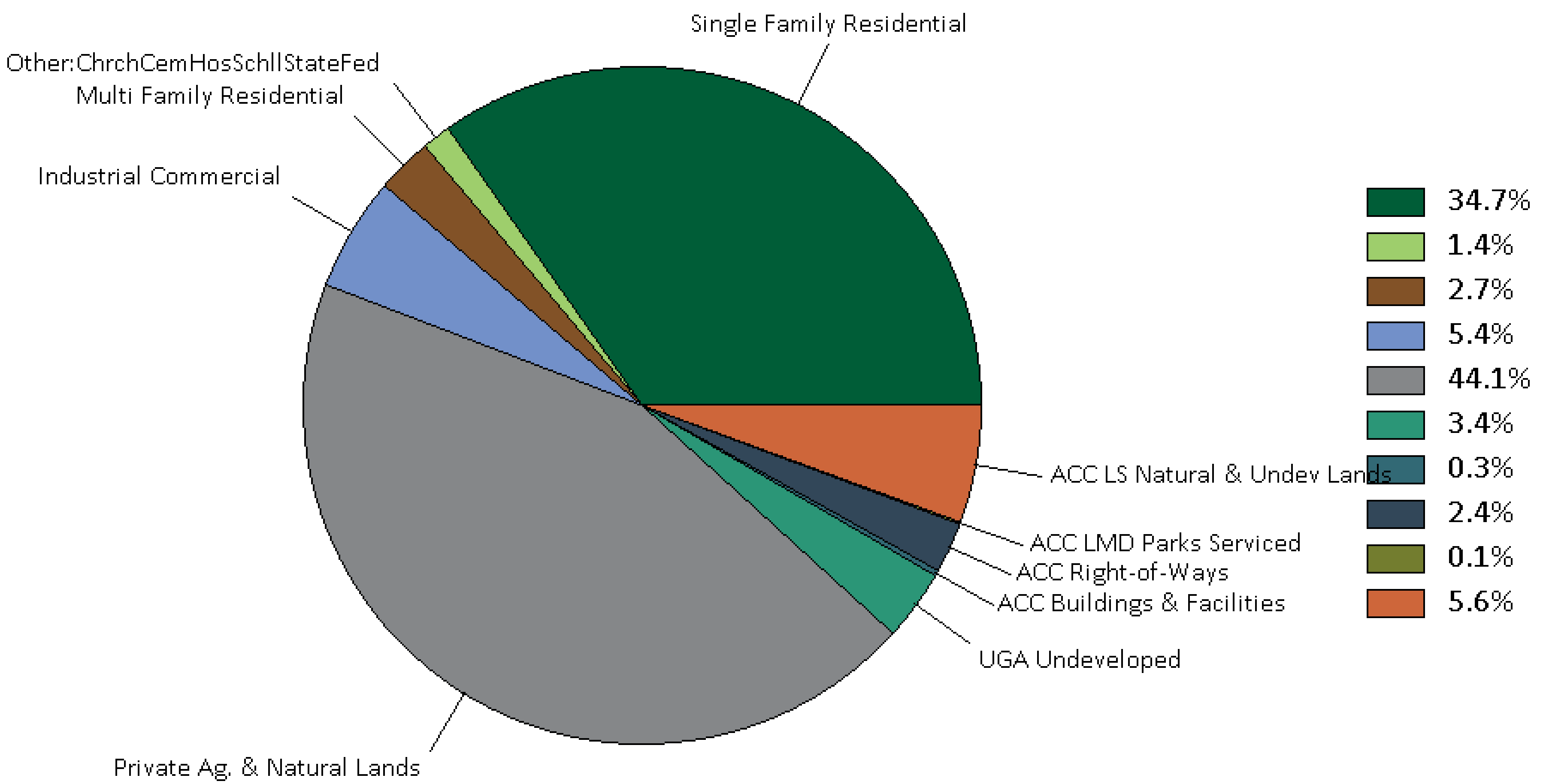
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.7: (Percent of Tree Population by Stratum)

Population Summary by Stratum

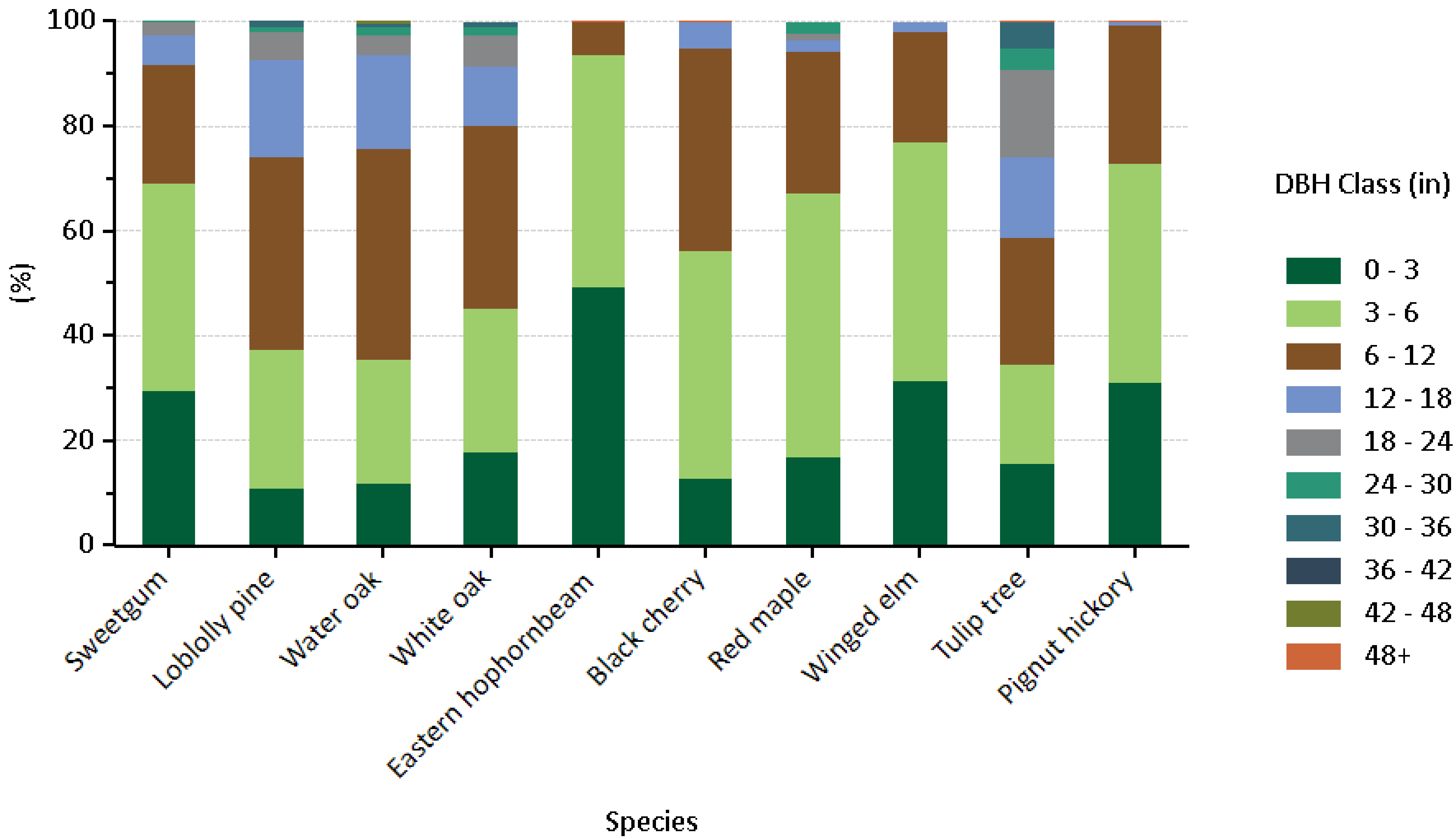
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.1: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.2: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

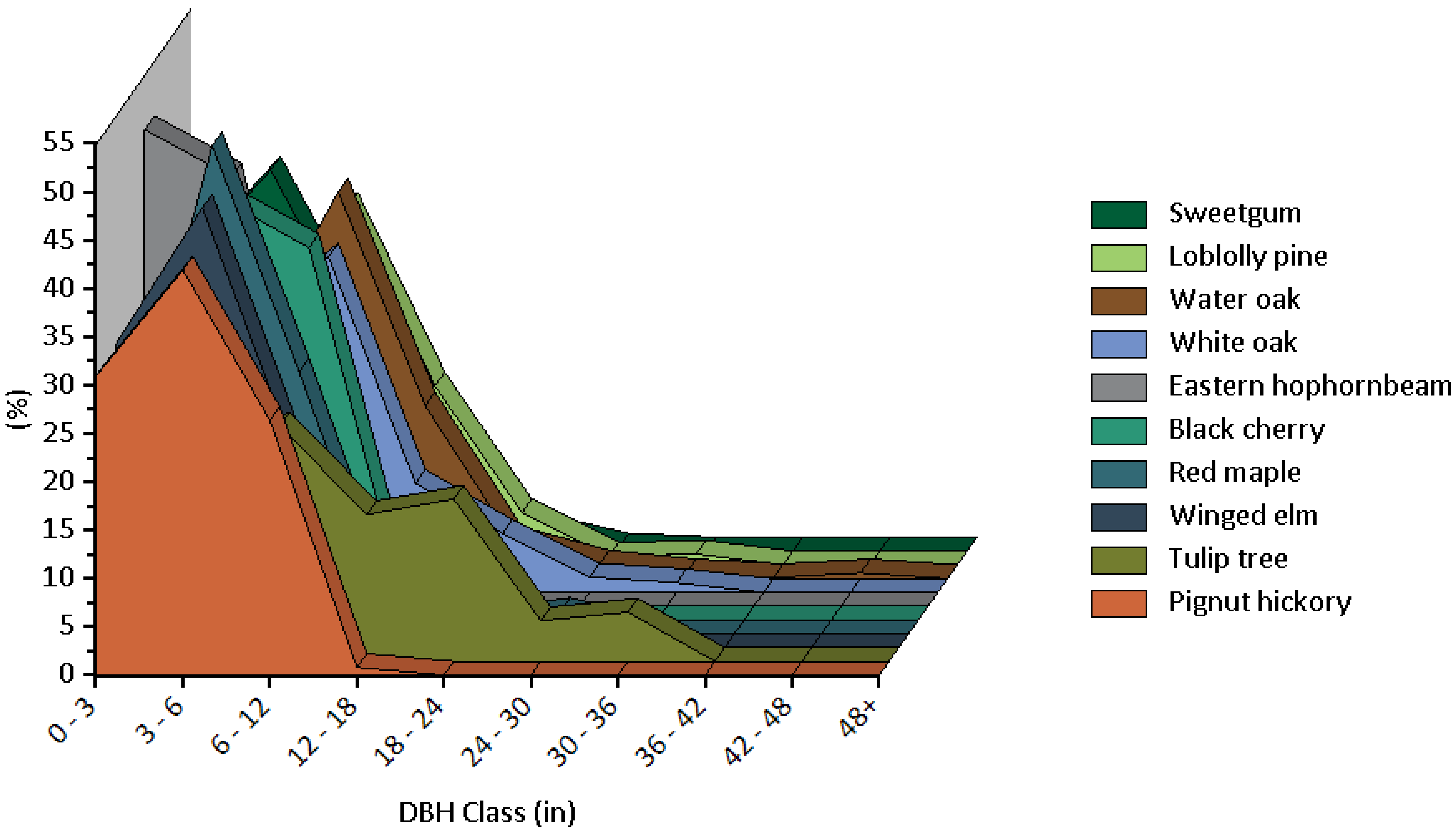
Table1. Top 10 most populated species in the project area

Species Name	*DBH Class (in)*									
	0 - 3 (%)	*3 - 6 (%)*	*6 - 12 (%)*	*12 - 18 (%)*	*18 - 24 (%)*	*24 - 30 (%)*	*30 - 36 (%)*	*36 - 42 (%)*	*42 - 48 (%)*	*48+ (%)*
Sweetgum	29.5	39.4	22.7	5.6	2.5	0.4	0.0	0.0	0.0	0.0
Loblolly pine	10.8	26.3	37.1	18.5	5.4	0.9	1.1	0.0	0.0	0.0
Water oak	11.9	23.6	40.0	17.9	3.9	1.5	0.6	0.1	0.6	0.0
White oak	17.8	27.4	34.7	11.3	6.1	1.6	1.0	0.0	0.0	0.0
Eastern hophornbeam	49.3	44.4	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black cherry	12.7	43.5	38.5	5.1	0.2	0.0	0.0	0.0	0.0	0.0
Red maple	16.7	50.5	27.1	2.2	1.1	2.3	0.0	0.0	0.0	0.0
Winged elm	31.3	45.5	21.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Tulip tree	15.6	18.7	24.4	15.2	16.8	4.2	5.1	0.0	0.0	0.0
Pignut hickory	30.9	41.9	26.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0

Appendix H.8.3: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

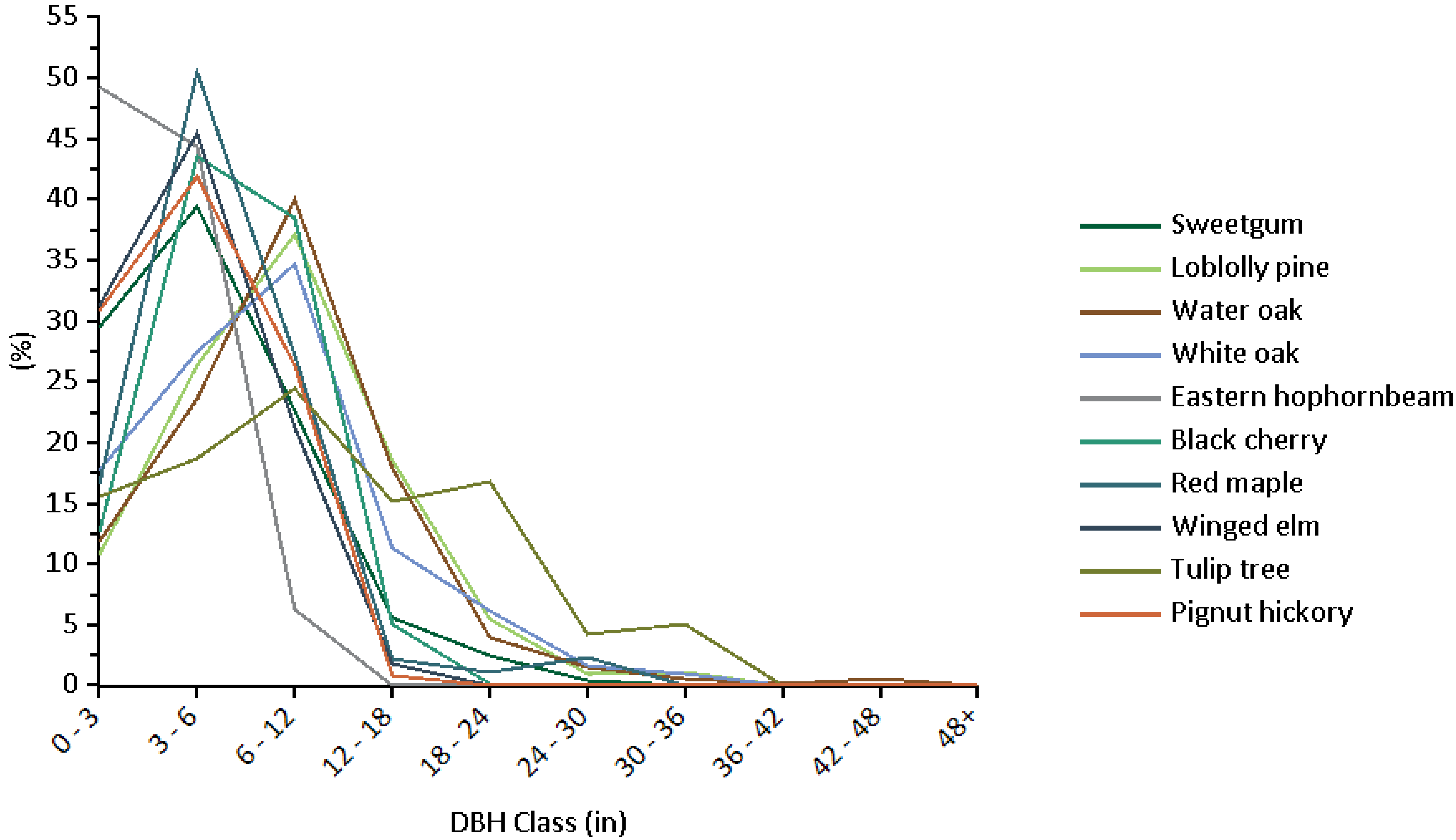
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.4: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

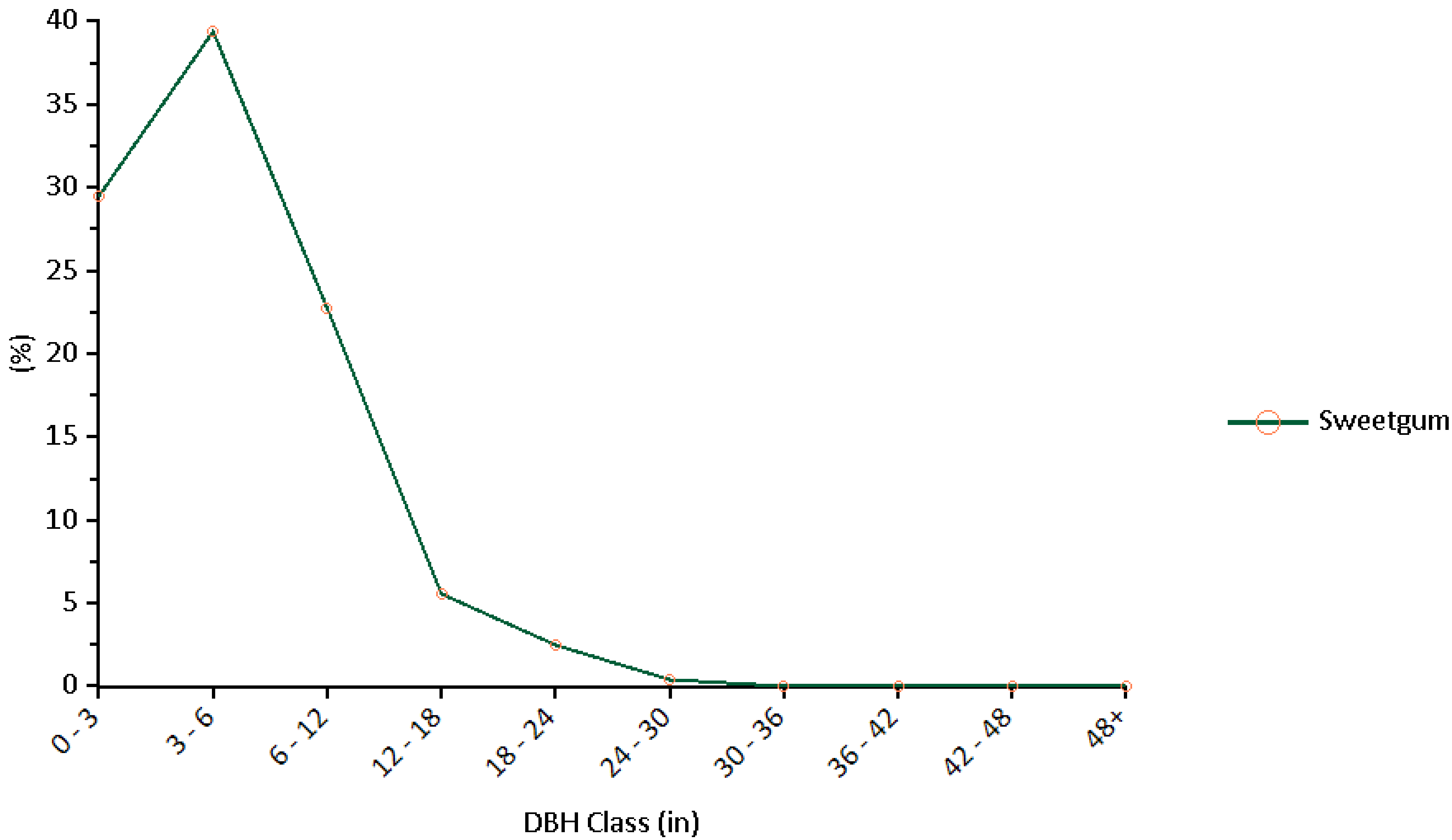
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.5: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

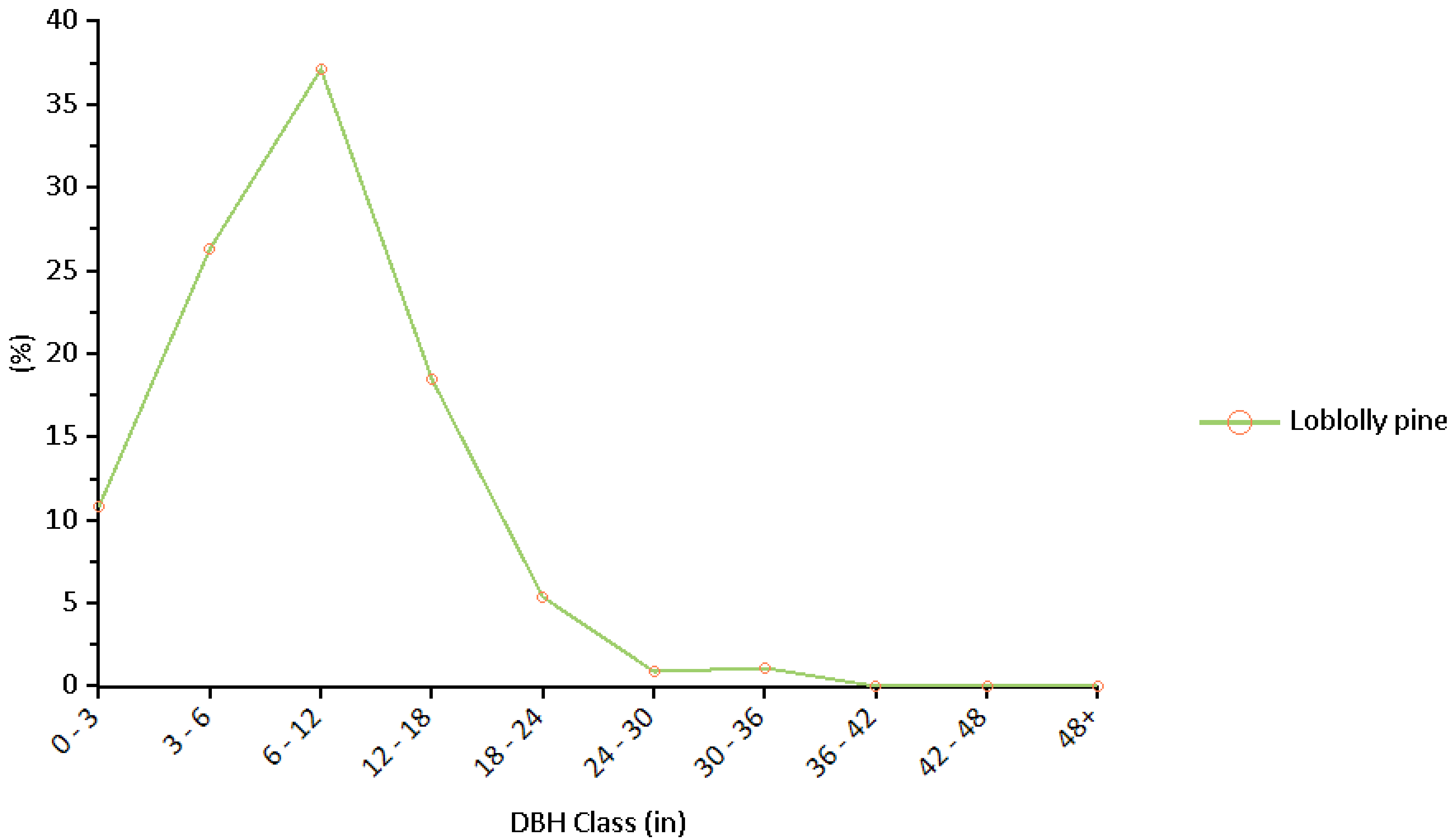
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.6: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

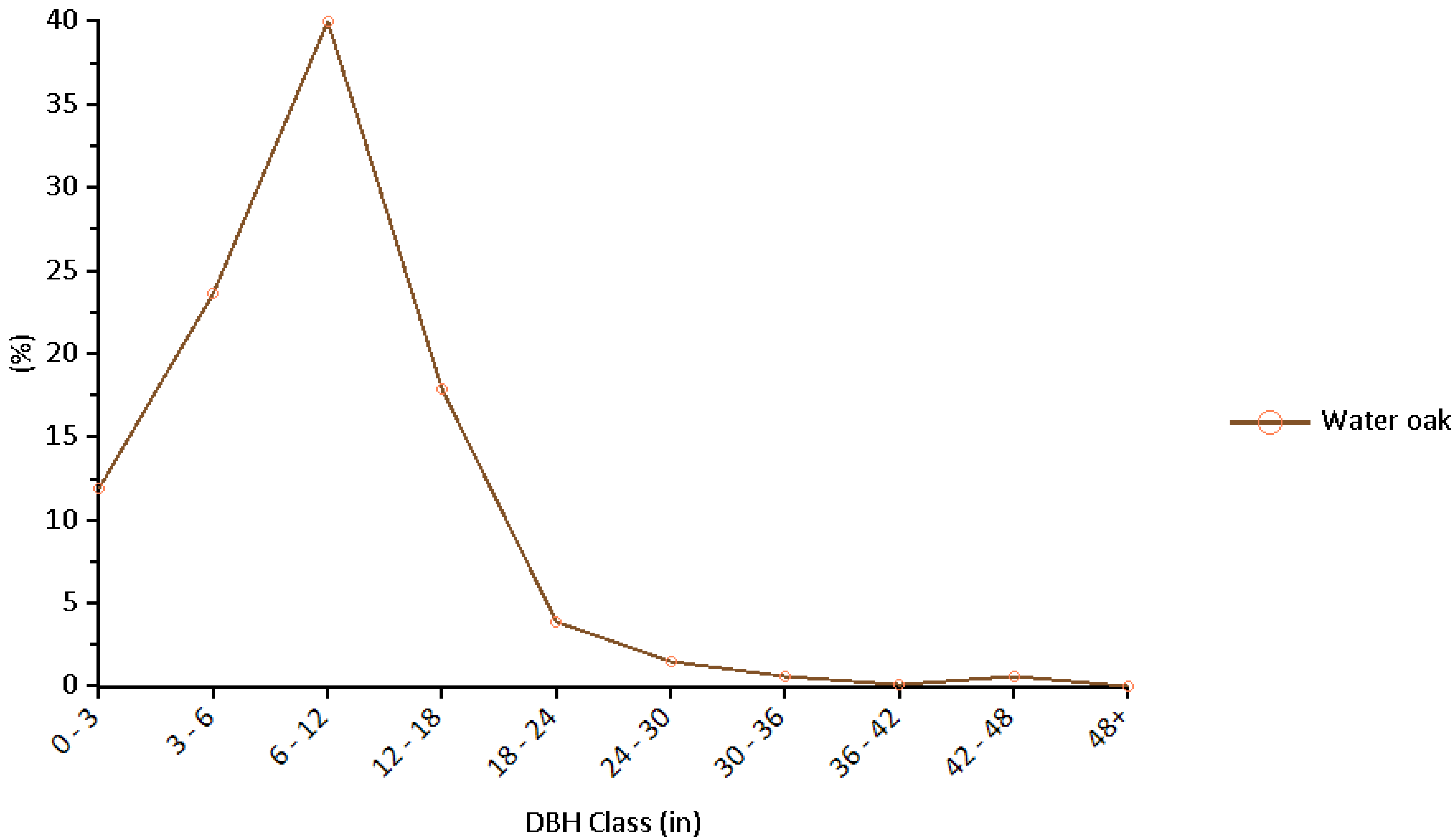
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.7: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

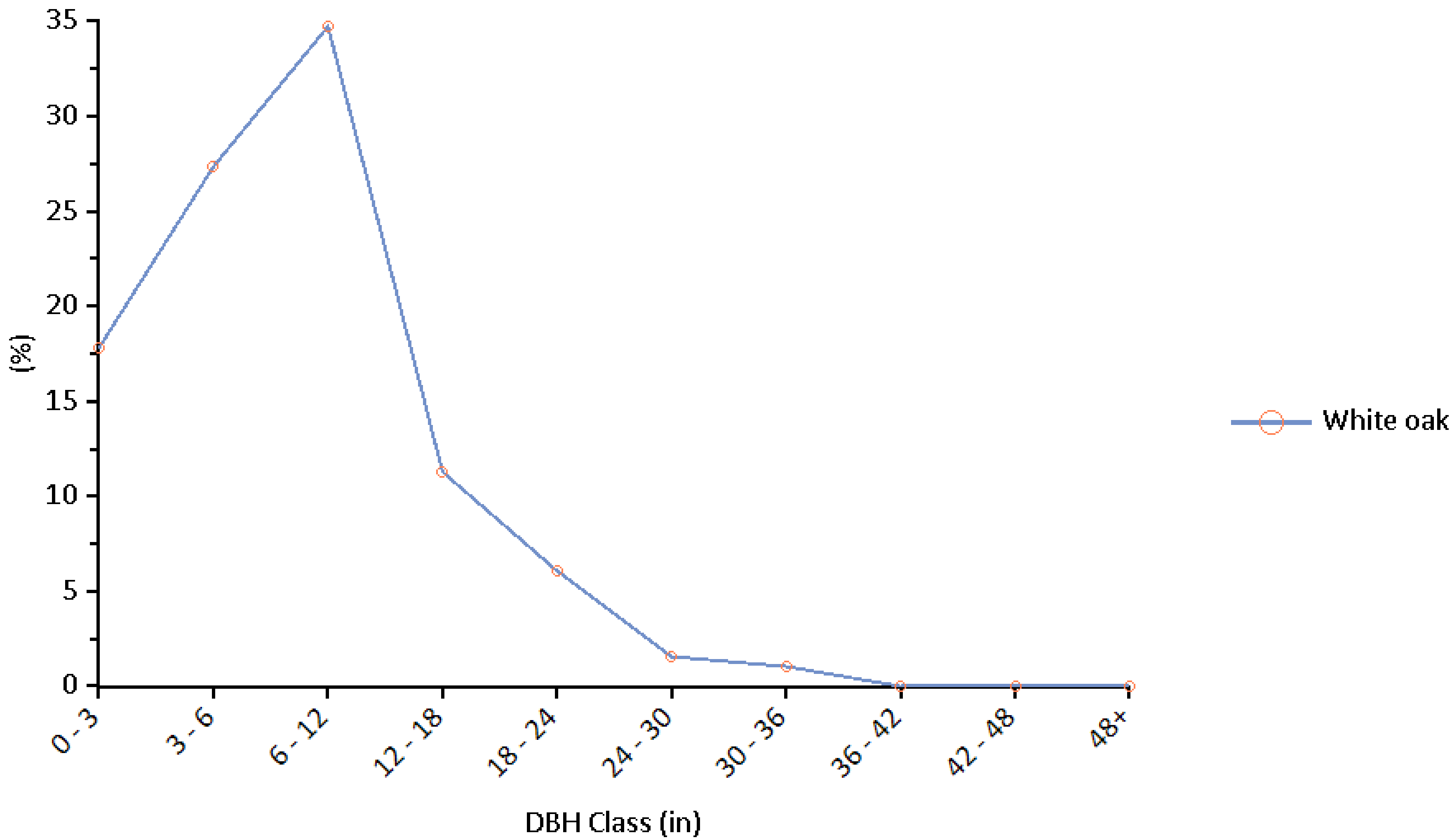
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.8: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

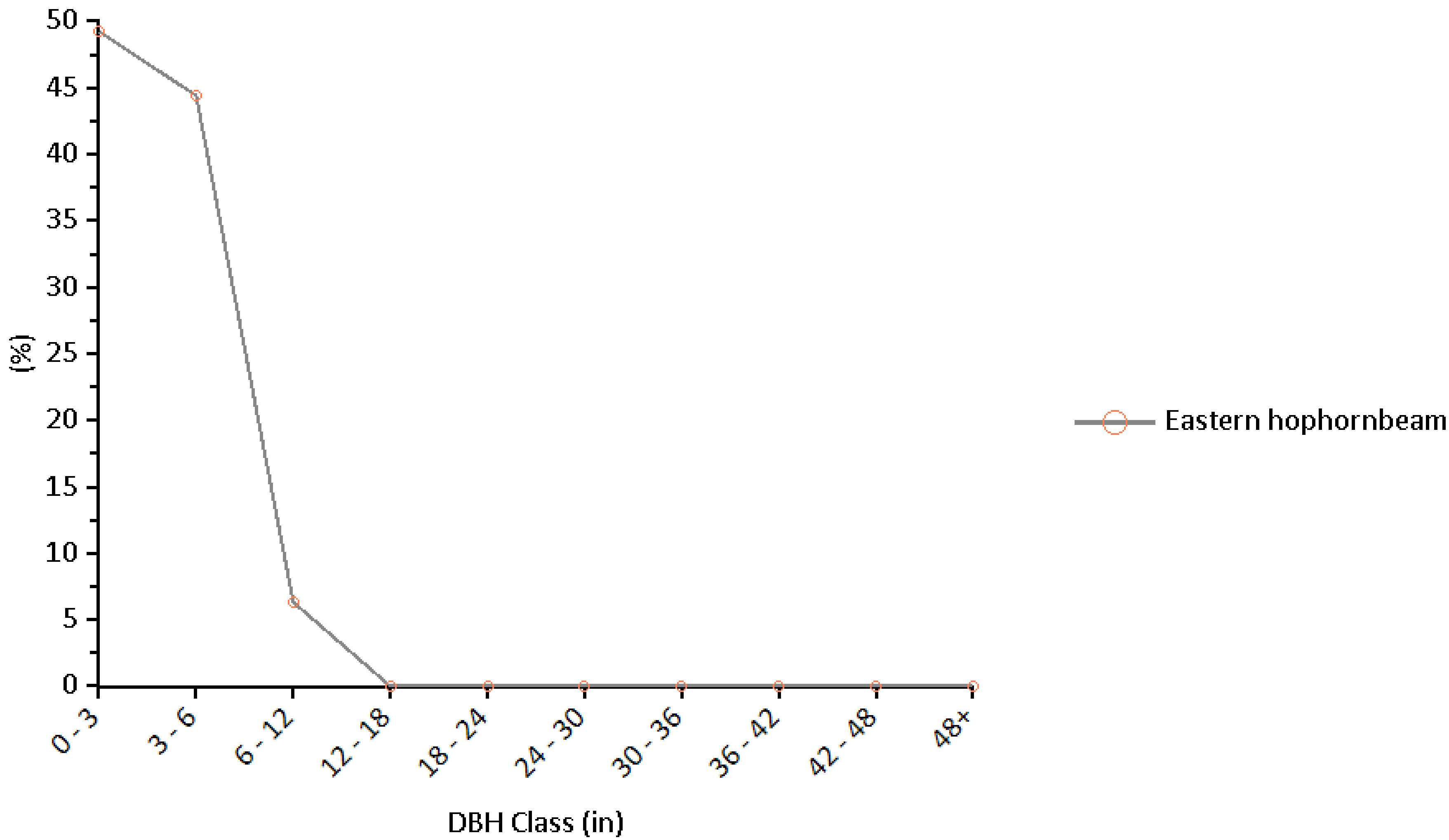
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.9: (Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

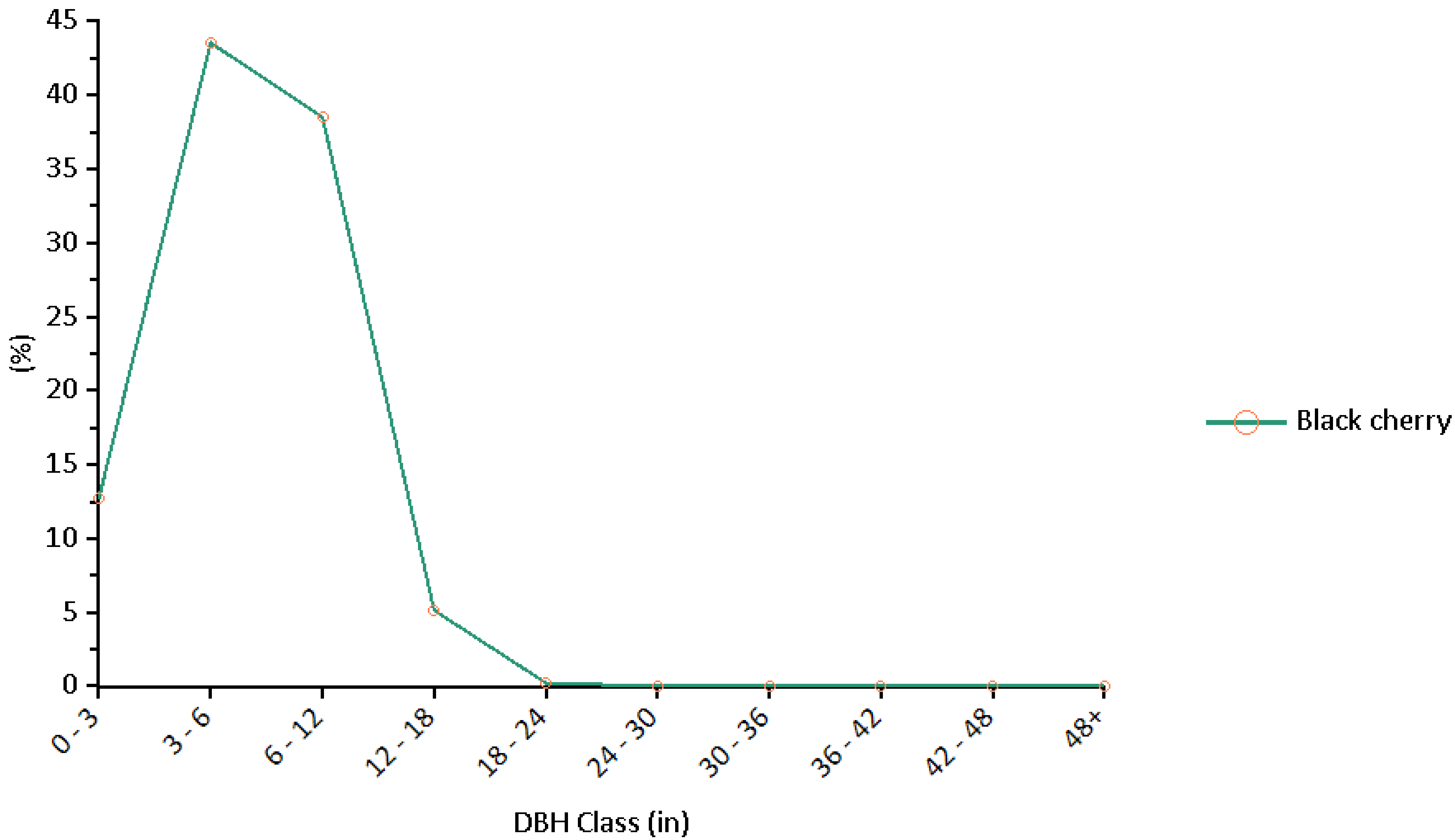
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.10:(Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

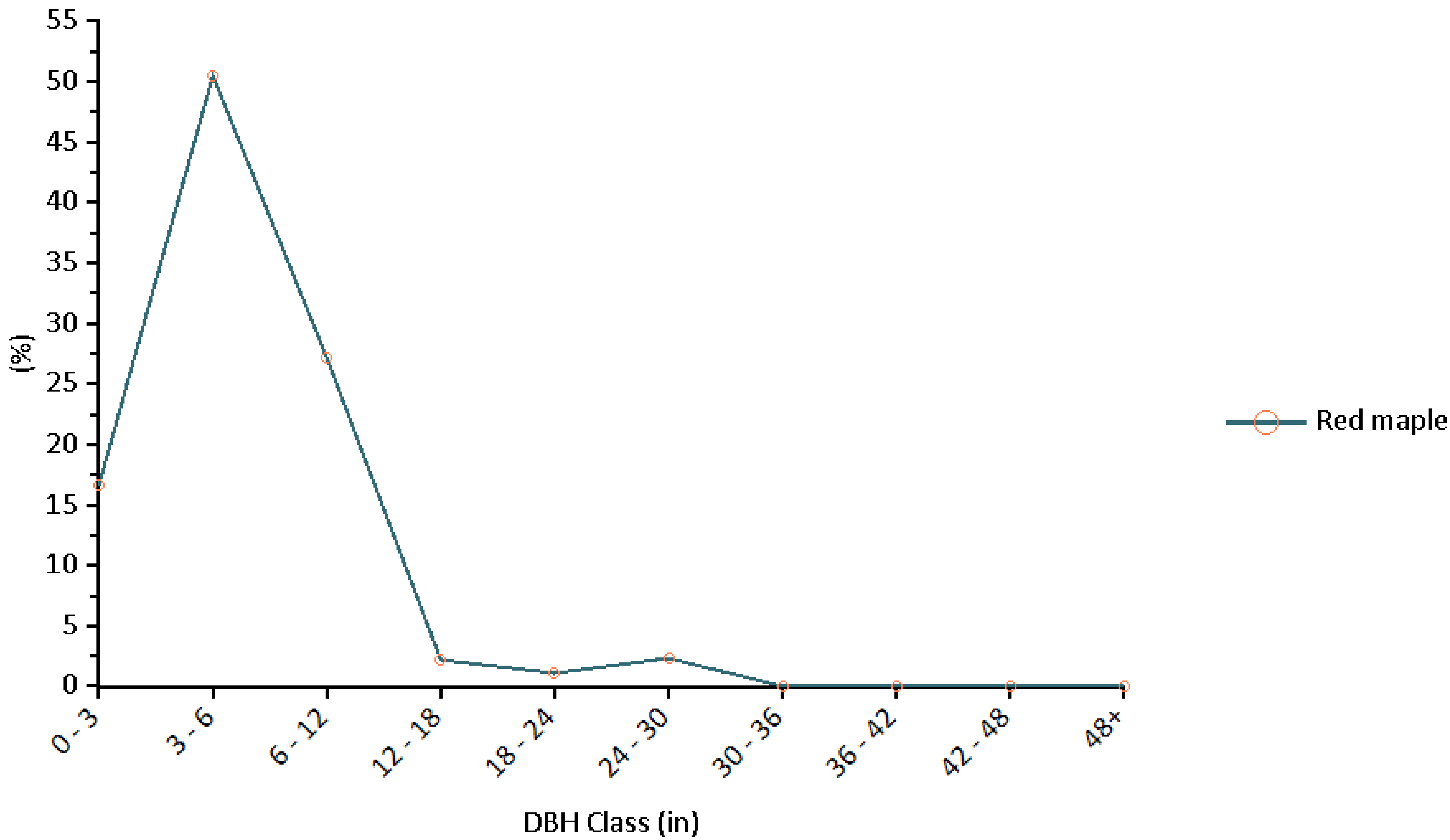
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.11:(Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

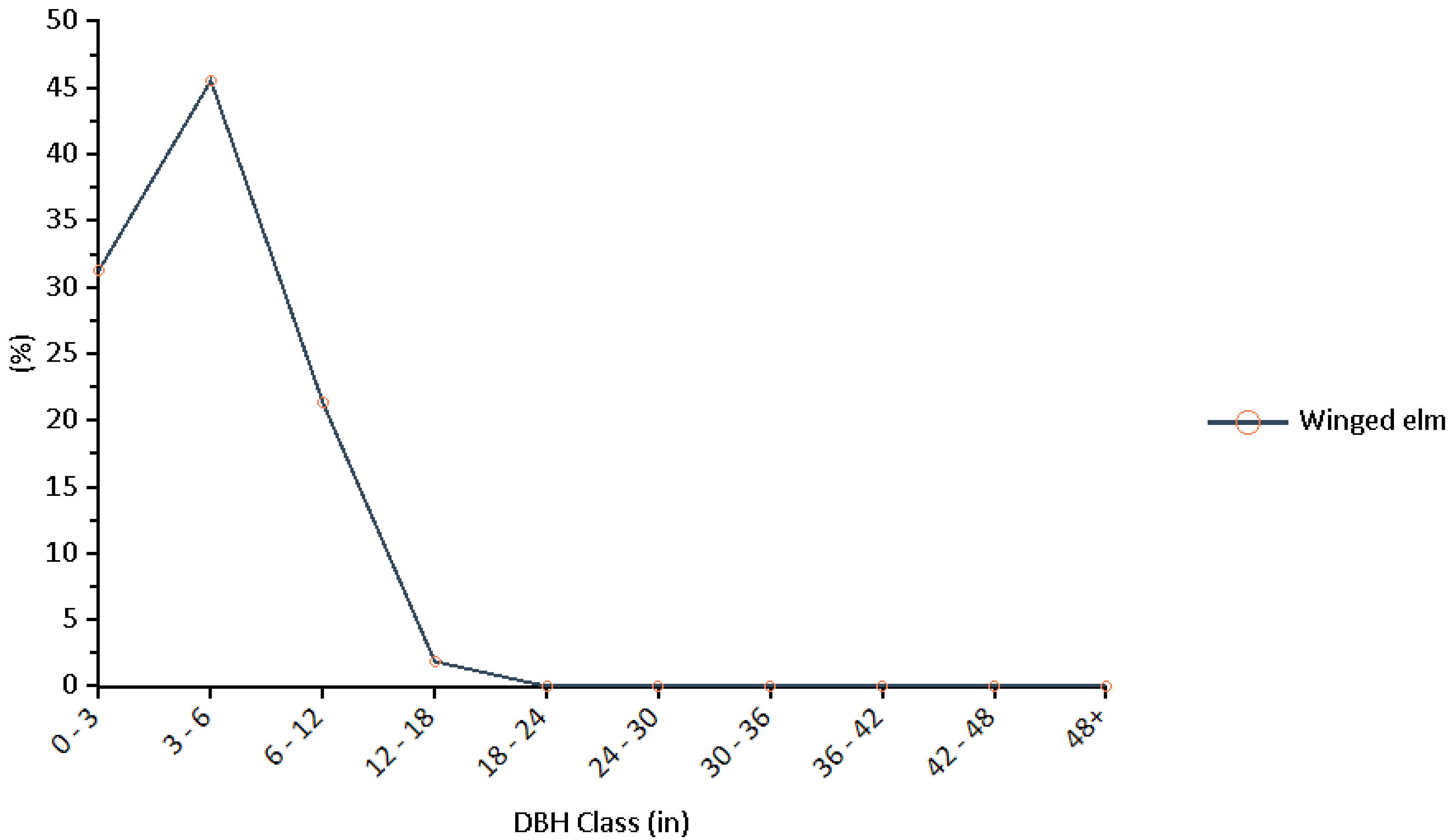
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.12:(Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

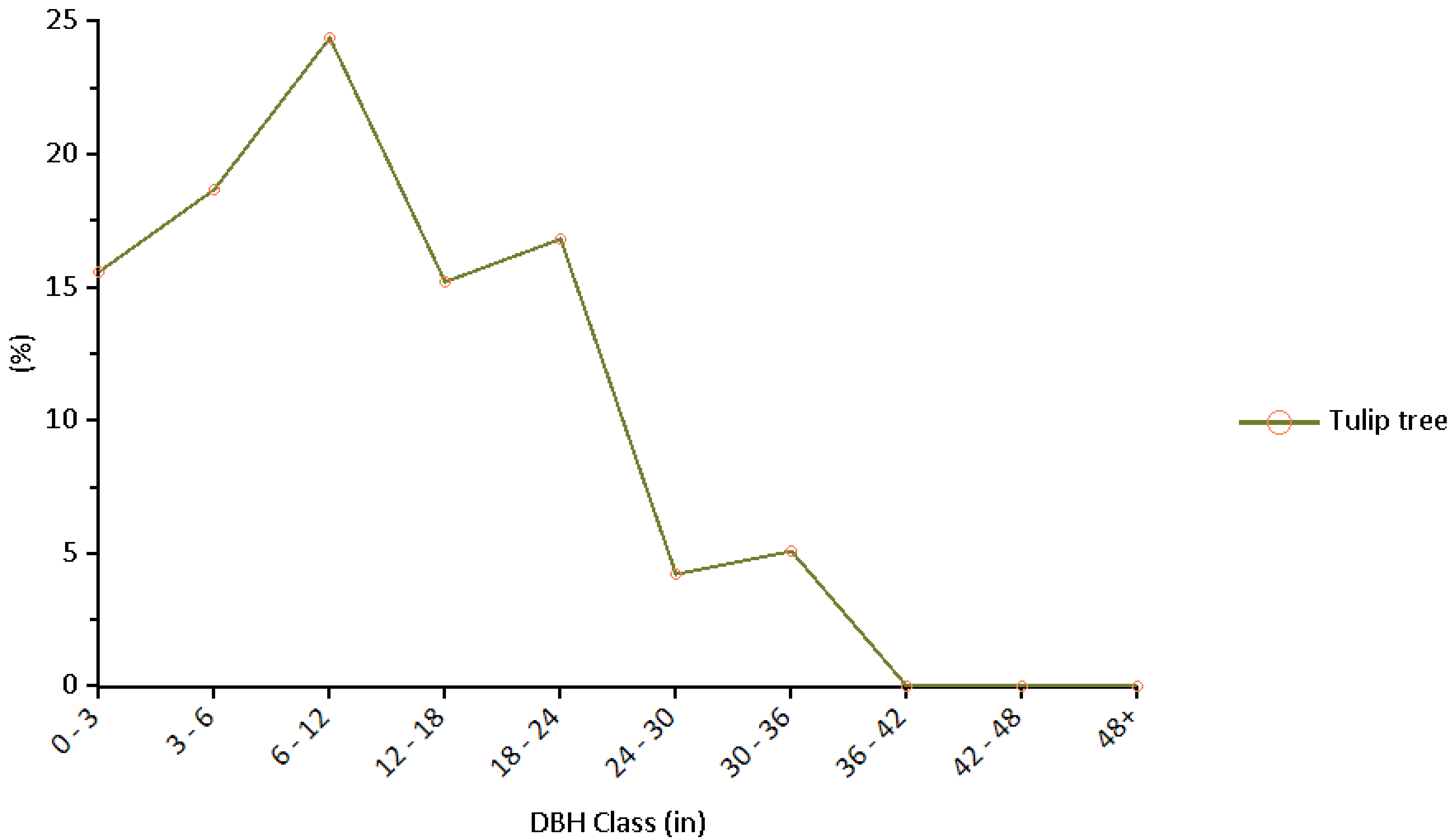
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.13:(Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

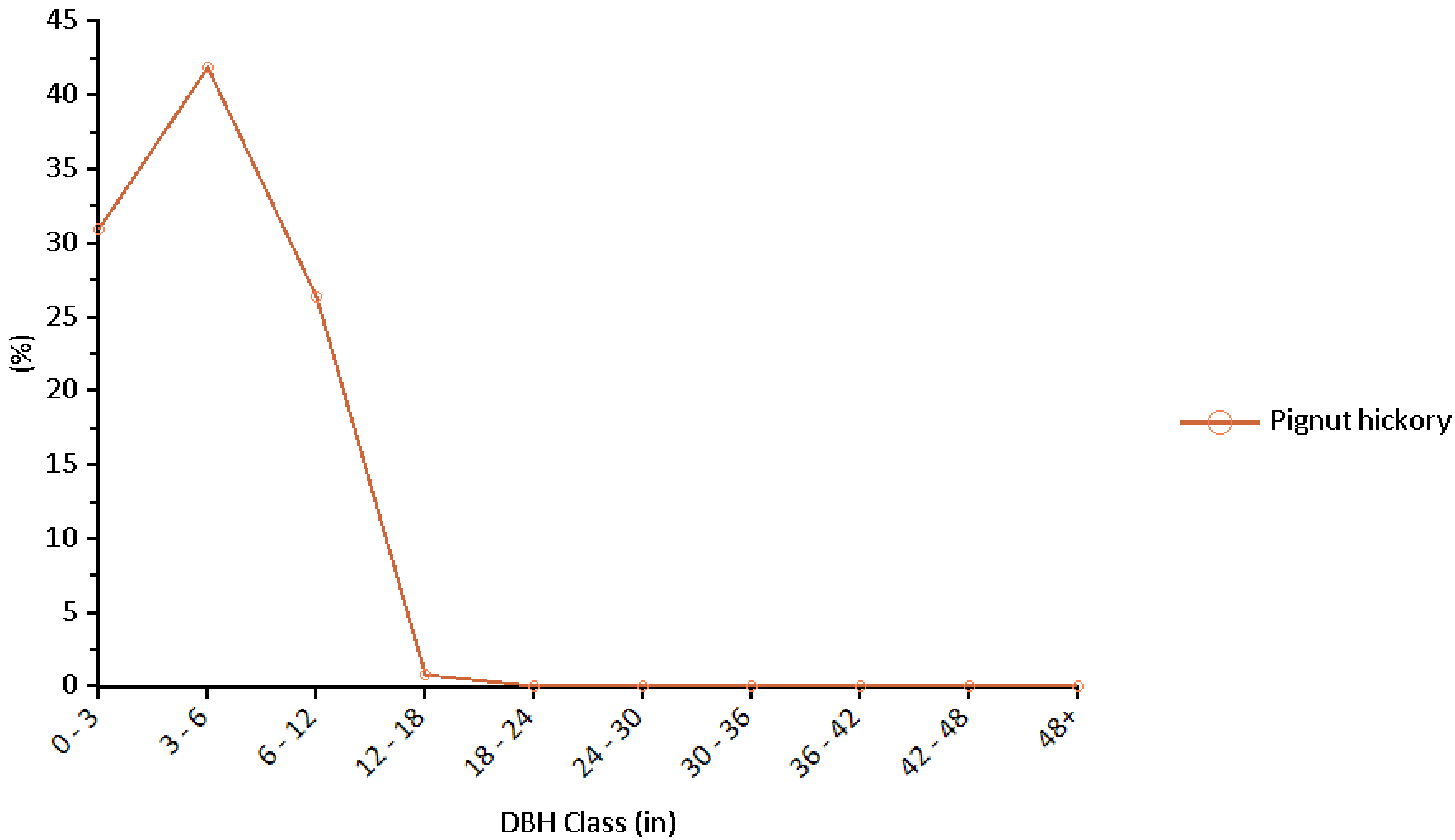
Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.8.14:(Tree Species Distribution by DBH Class)

Species Distribution by DBH Class

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021



Appendix H.9.1:(Hydrology Effects of Trees by Stratum)

Hydrology Effects of Trees by Stratum

Location: Athens-Clarke County (balance), Clarke, Georgia, United States of America
Project: ACC Community Tree Study, Series: ACC Community Tree Study, Year: 2021
Generated: 11/16/2021

Stratum	Number of Trees	Leaf Area (ac)	Potential Evapotranspiration (ft³/yr)	Evaporation (ft³/yr)	Transpiration (ft³/yr)	Water Intercepted (ft³/yr)	Avoided Runoff (ft³/yr)	Avoided Runoff Value ($/yr)
Private Ag. & Natural Lands	5,931,107	262,017.74	1,549,676,628.88	324,362,296.97	253,180,456.49	324,362,296.97	63,370,038.99	4,236,023.86
Single Family Residential	4,675,017	234,518.68	1,387,036,253.24	290,320,094.34	226,608,871.31	290,320,094.34	56,719,279.24	3,791,448.20
ACC LS Natural & Undev Lands	754,471	32,941.80	194,830,857.85	40,779,981.71	31,830,747.53	40,779,981.71	7,967,106.70	532,567.99
Industrial Commercial	732,182	27,495.31	162,618,148.55	34,037,550.29	26,567,953.80	34,037,550.29	6,649,850.83	444,514.90
UGA Undeveloped	454,005	21,658.02	128,094,082.04	26,811,329.48	20,927,539.05	26,811,329.48	5,238,077.95	350,143.75
Multi Family Residential	358,545	19,875.31	117,550,428.83	24,604,440.95	19,204,955.84	24,604,440.95	4,806,922.37	321,322.79
ACC Right-of-Ways	324,524	11,233.74	66,440,811.12	13,906,703.96	10,854,854.86	13,906,703.96	2,716,926.04	181,615.22
Other:ChrchCemHosSchllStateFed	183,015	8,517.26	50,374,456.02	10,543,860.54	8,229,992.98	10,543,860.54	2,059,933.78	137,698.02
ACC Buildings & Facilities	35,803	1,665.77	9,852,011.67	2,062,121.27	1,609,585.36	2,062,121.27	402,872.67	26,930.36
ACC LMD Parks Serviced	12,994	695.50	4,113,480.94	860,991.32	672,045.36	860,991.32	168,210.22	11,244.15
Total	**13,461,665**	**620,619.13**	**3,670,587,159.14**	**768,289,370.82**	**599,687,002.57**	**768,289,370.82**	**150,099,218.80**	**10,033,509.24**

Avoided runoff value is calculated by the price $0.067/ft³. The user-designated weather station reported 39.6 inches of total annual precipitation. Eco will always use the hourly measurements that have the greatest total rainfall or user-submitted rainfall if provided.

Appendix I.1: ACC Community Tree Study Publicity Plan

ACC Community Tree Study (iTree Eco Statistical Analyses)
Publicity Plan and Plan to Acquire Permissions to Access Private Properties

UPDATED 3/25/2021

- **Public Notifications** Notice and information that project will be taking place (Jeff Montgomery-Public Information Office, "build up" approach)
  - Water bill inserts (going out in March)- Kick off **- COMPLETE**
  - Media Releases – **IN PROCESS. SEND OUT IN COMING WEEKS. SOME INFORMATION INCLUDED IN ARBOR DAY MEDIA RELEASE.**
  - Social Media - **LATER**
  - Other? – **ARTICLE IN ACCENT EMPLOYEE NEWSLETTER – APRIL 2021**

- **Webpage** (Public Information Office)
  - Community Tree Study Information
    - **Introduction and explanation** about Community Tree Study
    - Notice that project will be taking place
      - Value statement "Athens has the highest **documented** canopy coverage **percentage** of any known **community** of 100,000 people or more in the United States"
      - Tree Benefits
    - **Links to informational documents**
    - **Video(s) Link** (ACC Public Information)
      - **How to Video** featuring student teams (here's what happens)
        - Show residential front yard & 2 or three large trees
        - Show "home owner" greeting the student data collection teams
        - Show Students wearing their safety vests and taking measurements
        - Graphics showing end results of other projects
      - Community video
      - **VIDEO CONFIRMED WITH RADAR PRODUCTIONS. WORKING ON INTRODUCTIONS FOR LOCATIONS & SHOOTING SCHEDULE.**
    - **Maps** (GIS Office)
      - **Permissions and progress Maps**
        - Real time display of plots that need permission to access (updated and maintained by Rodney)

- Progress view layer may have blurred effect to hide exact location of plots

- Plots features that have an attached permission form
- Plots "disappear" once owner has given permission to access the property

- **Survey 123 Permission forms** (GIS Office)
  plot features)
  - Address locator
  - Option to enter at any time
  - Owner must be present during data collection
  - Safety awareness box (dogs, pits, wells, fences, etc.)

- **Letter from ACC Forester Requesting Permission** to Access Properties and collect data

  - Letter with permission form and return envelope
    - Forster Letter requesting permission to access property to collect plot data
      - Forester Contact information
      - Webpage Address
    - Permission forms
    - Self-addressed stamped envelope

- **Information Brochure** for Student Data Collection Teams

- **Hang Tag Brochure** Notice

  - Notice that data collection teams have collected data
  - Thank you for their assistance in participating in the Community Tree Study

Appendix I.2: ACC Community Tree Study Announcement (Water bill Flyer)

Community Tree Study

This summer, ACCGov's Community Forestry Program will take part in a Community Tree Study with UGA and the Georgia Forestry Commission.

The study will help better understand the composition, structure, function, and benefits of Athens-Clarke County's trees. It will consist of a survey followed by a set of analyses to understand better the Athens community forest on a countywide scale.

Athens-Clarke County has the highest documented tree canopy coverage of any city with a population of 100,000 or more.

Tree data will be collected on 228 randomly generated $\frac{1}{10}$ acre plots. UGA student field teams led by Dr. Jason Gordon will collect data on trees on these plots.

Some of these plots will be on private property. Residents will be contacted for permission to use their trees as part of the study.

The Georgia Forestry Commission is providing matching grant funding and support. The goal is to undertake similar studies around Georgia.

accgov.com/communitytreestudy | 762-400-7519

Appendix I.3: ACC Community Tree Study Announced in Arbor Day Celebration Medial Release)

News Flash Home

The original item was published from 2/24/2021 4:49:29 PM to 3/15/2021 12:00:01 AM.

ACCGov Public Information Office News

Posted on: February 23, 2021

[ARCHIVED] Arbor Day Celebrated on Feb. 19 with Tree Plantings, Awards & Announcement of Community Tree Study

The Athens Community Tree Council celebrated Arbor Day in Athens-Clarke County with community partners on February 19 on a segment of the Firefly Trail. The program included a reading of the proclamation signed by Mayor Kelly Girtz to declare February 19 as Athens' official Arbor Day for 2021.

As part of the ceremony, the ACC Landscape Management Division planted seven new trees donated by the Community Tree Council for the Trees for Tomorrow program along the Firefly Trail.

The program recognized Athens-Clarke County's designation as a Tree City USA for the 21st year in a row by the National Arbor Day Foundation. This honor was presented to Athens-Clarke County in recognition of Athens' dedication to the care of the trees that help define the character of the community and make it such a special place.

The National Arbor Day Foundation also presented a Growth Award to Athens- Clarke County - its 15th Growth Award overall - for the development of an innovative tree inventory system that is compatible with geospatial mapping technology and platform

The Arbor Day event is a celebration of the collaboration of community partners to improve the quality of life for Athens-Clarke County's residents through the planting and maintenance of trees. Partners include the Athens-Clarke County Unified Government (ACCGov), the University of Georgia (UGA), the Community Tree Council (CTC), the Georgia Forestry Commission (GFC), and Keep Athens-Clarke County Beautiful (KACCB).

During the program, ACC Community Forester Rodney Walters announced a new initiative launching this summer. In striving for excellence through continuous improvement and innovation, ACCGov's Community Forestry Program led by Walters will engage in a collaborative project with UGA and the Georgia Forestry Commission to conduct a Community Tree Study.

"According to research by the ACCGov Sustainability Office," said Walters, "Athens-Clarke County has the highest documented tree canopy coverage of any city with a population of 100,000 or more. We're very proud of that statistic and hope that this new study will help us better understand the composition, structure, function, and benefits of our community's trees."

The Community Tree Study will involve a statistical survey followed by a set of analyses to understand better the Athens community forest on a countywide scale. This summer, tree data will be collected on 228 random generated 1/10 acres plots around the county. UGA student field teams led by Dr. Jason Gordon will collect the tree information that will inform the Community Tree Study analyses. The Georgia Forestry Commission is providing matching grant funding and support for the project with the goal of replicating similar future efforts around Georgia.

Photo of Walters with Tree City USA sign

For more information, contact Rodney Walters, ACCGov Community Forester, at 762-400-7519 or rodney.walters@accgov.com.

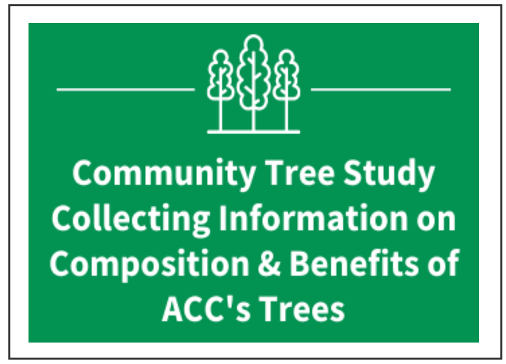
Appendix I.4:
ACC Community Tree Study Medial Release)

News Flash Home

The original item was published from 4/20/2021 11:23:00 AM to 7/4/2021 12:00:02 AM.

ACCGov Public Information Office News

Posted on: April 20, 2021



[ARCHIVED] Community Tree Study Collecting Information on Composition & Benefits of ACC's Trees

ACCGov's Community Forestry Program is launching a collaborative Community Tree Study to collect information on the composition and environmental benefits of Athens-Clarke County's trees. Led by Community Forester Rodney Walters, the program is partnering with the University of Georgia, the Georgia Forestry Commission, and the Athens Community Tree Council to conduct the study.

The project will help researchers and ACCGov staff to understand better the structure and function of ACC's trees, as well as the benefits they provide. Tree benefits include stormwater runoff reduction, residential energy savings, and improved air quality. The project will also be used to inform future conversations and decisions about trees and the community tree canopy."According to research by the ACCGov Sustainability Office," said Walters,"Athens-Clarke County has the highest documented tree canopy coverage of any community with a population of 100,000 or more. We're very proud of that statistic and hope that this new study will help us better understand the composition, structure, function, and benefits of our community's trees."

The Community Tree Study will involve a statistical survey beginning in the next two months, followed by a set of analyses to understand better the local community forest on a countywide scale. Data will be gathered using iTree, a tool developed by the USDA Forest Service that provides forestry analysis and benefits assessment tools.

Throughout the summer, tree data will be collected on 228 randomly generated 1/10 acre plots around the county. Each plot may contain large trees, small trees, or no trees. Data gathered will include tree species, size, and health. UGA student field teams of two led by Dr. Jason Gordon will collect the tree information that will inform the Community Tree Study analyses.

The generated plots cover areas on both private and public land. The Community Forestry Program will contact residents or owners of any included private properties to obtain permission to collect data on their trees. Data collection is expected to take approximately one hour and will not harm the trees or the property.

"We're excited to undertake this project for the first time and hope that residents and owners who have plots on their properties will be excited as well," says Walters. "This is a great opportunity to have their trees represented in the Athens-Clarke County Community Tree Study to benefit many future generations."

The Georgia Forestry Commission is providing matching grant funding and support for the project with the goal of replicating similar future efforts around Georgia. The final study is expected to be released in fall 2021.

For more information, contact Rodney Walters, ACCGov Community Forester, at 762-400-7519 or rodney.walters@accgov.com or visitwww.accgov.com/communitytreestudy.

Appendix I.5.:ACC Study Announced in Arbor Day Press Release

ACCENT
April 2021 · Vol. 24, Issue 4
The ACCGov Employee & Retiree Newsletter

A-Corps Program focuses on workforce development & skills

The Athens Community Corps Program, or A-Corps, is a new program funded initially for a year by the Mayor and Commission as part of COVID-19 community relief resiliency package funds. Coordinated by **Economic Development**, A-Corps focuses on workforce development. The intent of the program is to help empower a team of community members to meet high-demand local workforce needs while also improving the community.

"[A-Corps] will prepare its members to enter higher paying jobs and benefit the local community by improving a variety of features and attractions," says Crew Coordinator **Akilah Blount** (Economic Development).

The program focuses on community projects, exploring career options, professional development, and life skills for the crew while the members enjoy the security of a temporary full-time job with benefits.

By the end of the program, the goal is for each of the crew members to not only have completed a number of meaningful community projects and experienced a full-time employment opportunity, but also to have gained new skills for permanent employment in the public or private sector and new life skills.

The eight A-Corps crew members, plus a coordinator, participate in community service and beautification projects. Crew Member Jasmine Woods (left) cuts a downed tree at Dudley Park.

Crew members will be trained in and exposed to various kinds of careers and work activities while learning and developing interpersonal, professional, and technical skills that align with local high-demand workforce needs.

These skills include learning about resume building, teamwork, and technical skills, as well as earning specific work-based certifications and participating in job shadowing.

Crew Leader **Jesus Ozuna** (Economic Development), who is job shadowing with **Wellness**, is developing a wide variety of skills.

"I supervise the crew, record attendance, order supplies, and keep track of tools," he says. "Unofficially, I listen to my peers, understand their concerns, and do my best to find solutions."

A-Corps has already completed invasive plant removal at Dudley Park, removed environmentally-hazardous railroad ties, assisted with clearing a boardwalk trail, cleared out part of the North Oconee Greenway to accommodate a boat launch site, and assisted at the Northeast

continued on p. 4 ►

Community Tree Study to develop inventory, benefits of local trees

Last fall, the Georgia Forestry Commission (GFC) awarded ACCGov a $10,000 matching funds grant to conduct a countywide Community Tree Study. The study has started and is scheduled to be completed by October 2021.

Athens-Clarke County has the highest documented tree canopy coverage of any city with a population of 100,000 or more. The Community Tree Study will help ACCGov better understand the structure, function, and benefits of the tree resources.

"The study essentially answers the question: 'What do we have,' regarding the trees and allows the Athens community to engage in conversations about 'What do we want,'" says Community Forester **Rodney Walters** (Central Services).

An initial step of the project was to create GIS-based maps identifying publicly-owned lands with full or partial tree cover. Staff will use this information to establish areas of responsibility for tree inspections and maintenance on public property.

Beginning this summer, teams of University of Georgia students will conduct a statistical inventory by collecting tree information from 228 randomly generated 1/10 acre plots on both public and private property.

This inventory will allow staff to make useful calculations in the future without having to measure every single tree in Athens-Clarke County.

Over the long term, the study will provide a basis for developing

Community Forester Rodney Walters measures a tree trunk. Teams will gather data on trees located on 228 plots during the summer.

strategies related to the cultivation and maintenance of community trees.

The GFC's goal is to use the study as a basis for replicating similar future efforts around Georgia.

For more information, visit accgov.com/communitytreestudy.

Appendix I.6: ACC Community Tree Study Social Media Posts

Athens-Clarke County - Unified Government, GA

Archive

From 5:00 on Nov 30, 2020 UTC to 4:59 on Dec 1, 2021 UTC

community_tree_study

Generated on 12/08/2021 UTC

community_tree_study generated at 19:52:10 on 12/08/2021 UTC

Athens-Clarke County, GA Unified Government
at 14:35:03 on 2/25/2021 UTC

The Athens Community Tree Council celebrated Arbor Day in Athens-Clarke County with community partners on February 19 on a segment of the Firefly Trail. The program included a reading of the proclamation signed by Athens-Clarke County Mayor Kelly Girtz to declare February 19 as Athens' official Arbor Day for 2021.

As part of the ceremony, the ACCGov Landscape Management Division planted seven new trees donated by the Community Tree Council for the Trees for Tomorrow program along the Firefly Trail (Athens-Clarke County Leisure Services Athens-Clarke County Trails and Open Space).

The program recognized Athens-Clarke County's designation as a Tree City USA for the 21st year in a row by the National Arbor Day Foundation. This honor was presented to Athens-Clarke County in recognition of Athens' dedication to the care of the trees that help define the character of the community and make it such a special place.

The National Arbor Day Foundation also presented a Growth Award to Athens-Clarke County - its 15th Growth Award overall - for the development of an innovative tree inventory system that is compatible with geospatial mapping technology and platforms.

The Arbor Day event is a celebration of the collaboration of community partners to improve the quality of life for Athens-Clarke County's residents through the planting and maintenance of trees. Partners include the Athens-Clarke County Unified Government (ACCGov), the University of Georgia, the Community Tree Council, the Georgia Forestry Commission, and Keep Athens-Clarke County Beautiful.

During the program, ACCGov Community Forester Rodney Walters announced a new initiative launching this summer. In striving for excellence through continuous improvement and innovation, ACCGov's Community Forestry Program led by Walters will engage in a collaborative project with UGA and the Georgia Forestry Commission to conduct a Community Tree Study.

"According to research by the ACCGov Sustainability Office," said Walters, "Athens-Clarke County has the highest documented tree canopy coverage of any city with a population of 100,000 or more. We're very proud of that statistic and hope that this new study will help us better understand the composition, structure, function, and benefits of our community's trees."

Arbor Day Celebration - 2021

T L B what types of trees were planted? at 18:50:39 on 2/25/2021 UTC

Athens-Clarke County, GA Unified Government These are chalk maples (Acer Leucoderme), which are native to the southeastern United States. In nature, they live in the understory in moist, rocky soils on river banks, ravines, woods, and cliffs. These trees were selected because they are very hardy and will do well in the poor soils of the old railroad bed.
at 14:09:35 on 2/26/2021 UTC

T L B I have one planted in my suburban Athens yard and in the fall their vivid red-orange color is just gorgeous. If you can find a source, I highly recommend this tree. Mine is growing understory to 2 white oak trees.
at 14:12:36 on 2/26/2021 UTC

Athens-Clarke County, GA Unified Government Although Tree City USA recognition is not directly related to this, Athens-Clarke County strives to maintain a 45% tree canopy. As of 2019, our canopy coverage is 63% overall from a tree canopy coverage study that examined 20,000 points across the county.

Indeed, Athens-Clarke County has the highest documented tree canopy coverage of any city with a population of 100,000 or more that we've found.

That canopy is a mix between new plantings and older trees. Sometimes, street views do not indicate how big a site actually is; trees may be saved on the overall site as part of this percentage.

Each zoning district also has a specific percentage of the overall site that must be planted and conserved. In C-G (Commercial General) that is 40% conserved and planted. In AR (Agricultural Residential) that is 0%.

Trees that are planted are to be protected in perpetuity. If it is on a Tree Management Plan, which is required for new commercial construction, new subdivisions and any changes over 10%, the Planning Department inspects sites to make sure those trees are alive and healthy. Although it will take time, all new development will fill in their required canopy over the next 20 years.

Athens-Clarke County is fortunate to have both an Arborist in our Planning Department who works with developments and checks on tree management plans and a Community Forester who helps provide education and management of the Community Tree Program.
at 21:59:27 on 2/26/2021 UTC

T L B We are so lucky to have a progressive community that funds the 2 positions mentioned above. I have called Rodney with questions about tree spacing in my suburban yard and he was very helpful.
at 23:23:46 on 2/26/2021 UTC

H S S Athens-Clarke County, GA Unified Government Thank you for responding.
at 0:39:36 on 2/27/2021 UTC

M H Great job!at 2:36:35 on 2/28/2021 UTC

R W at 3:35:52 on 2/28/2021 UTC

R W Great job Rod!!! at 3:37:13 on 2/28/2021 UTC

/

Arbor Day 2021

Uploaded by Athens-Clarke County
Published on Feb 25, 2021
Duration: 00:00:27
Privacy: Public, Embedding On

Athens-Clarke County Community Forester Rodney Walters details some recent accomplishments of the Unified Government, including being named a Tree City USA award recipient and speaks about the Community Tree Council's efforts to plant trees for the Trees for Tomorrow program.

Athens-Clarke County @accgov

WATCH: Athens-Clarke County celebrated Arbor Day on Feb. 19 with tree plantings along the Firefly Trail, Tree City USA / Growth Awards & the announcement of an upcoming Community Tree Study. accgov.com/forester pic.twitter.com/YmtbjKI2X3

at 16:47:10 on 2/25/2021 UTC

accgov The Athens Community Tree Council celebrated Arbor Day in Athens-Clarke County with community partners on February 19 on a segment of the Firefly Trail. The program included a reading of the proclamation signed by Athens-Clarke County Mayor Kelly Girtz to declare February 19 as Athens' official Arbor Day for 2021. . As part of the ceremony, the ACCGov Landscape Management Division planted seven new trees donated by the Community Tree Council for the Trees for Tomorrow program along the Firefly Trail. . The program recognized Athens-Clarke County's designation as a Tree City USA for the 21st year in a row by the National Arbor Day Foundation. This honor was presented to Athens-Clarke County in recognition of Athens' dedication to the care of the trees that help define the character of the community and make it such a special place. . The National Arbor Day Foundation also presented a Growth Award to Athens-Clarke County - its 15th Growth Award overall - for the development of an innovative tree inventory system that is compatible with geospatial mapping technology and platforms. . The Arbor Day event is a celebration of the collaboration of community partners to improve the quality of life for residents through the planting and maintenance of trees. Partners include the Athens-Clarke County Unified Government (ACCGov), the @universityofga, @gatrees, @athenstreecouncil and @kaccb. . During the program, ACCGov Community Forester Rodney Walters announced a new initiative launching this summer. In striving for excellence through continuous improvement and innovation, ACCGov's Community Forestry Program led by Walters will engage in a collaborative project with UGA and the Georgia Forestry Commission to conduct a Community Tree Study. . "According to research by the ACCGov Sustainability Office," said Walters, "Athens-Clarke County has the highest documented tree canopy coverage of any city with a population of 100,000 or more. We're very proud of that statistic and hope that this new study will help us better understand the composition, structure, function, and benefits of our community's trees." . Details at www.accgov.com/forester. #athensga
at 16:52:27 on 2/25/2021 UTC

Athens-Clarke County, GA Unified Government

at 19:11:50 on 4/20/2021 UTC

ACCGov’s Community Forestry Program is launching a collaborative Community Tree Study to collect information on the composition and environmental benefits of Athens-Clarke County’s trees. Led by Community Forester Rodney Walters, the program is partnering with the University of Georgia, the Georgia Forestry Commission, and the Athens Community Tree Council to conduct the study.

The project will help researchers and ACCGov staff to understand better the structure and function of ACC’s trees, as well as the benefits they provide. Tree benefits include stormwater runoff reduction, residential energy savings, and improved air quality. The project will also be used to inform future conversations and decisions about trees and the community tree canopy.

"According to research by the ACC Sustainability Office," said Walters, "Athens-Clarke County has the highest documented tree canopy coverage of any community with a population of 100,000 or more. We're very proud of that statistic and hope that this new study will help us better understand the composition, structure, function, and benefits of our community's trees."

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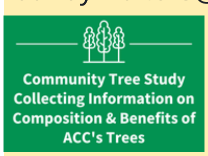
The generated plots cover areas on both private and public land. The Community Forestry Program will contact residents or owners of any included private properties to obtain permission to collect data on their trees. Data collection is expected to take approximately one hour and will not harm the trees or the property.

"We're excited to undertake this project for the first time and hope that residents and owners who have plots on their properties will be excited as well," says Walters. "This is a great opportunity to have their trees represented in the Athens-Clarke County Community Tree Study to benefit many future generations."

The Georgia Forestry Commission is providing matching grant funding and support for the project with the goal of replicating similar future efforts around Georgia. The final study is expected to be released in fall 2021.

For more information, contact Rodney Walters, ACCGov Community Forester, at 762-400-7519 or rodney.walters@accgov.com or visit www.accgov.com/communitytreestudy.



S W Love the trees in Cedar Creek Subdivision. Lots of pollen though, and leaves. at 20:22:37 on 4/20/2021 UTC

T L B I look forward to reading the results when the study is completed. at 23:45:34 on 4/22/2021 UTC

/

accgov ACCGov's Community Forestry Program is launching a collaborative Community Tree Study to collect information on the composition and environmental benefits of Athens-Clarke County's trees. Led by Community Forester Rodney Walters, the program is partnering with the @universityofga, @gatrees, and the Athens Community Tree Council to conduct the study. . The project will help researchers and ACCGov staff to understand better the structure and function of ACC's trees, as well as the benefits they provide. Tree benefits include stormwater runoff reduction, residential energy savings, and improved air quality. The project will also be used to inform future conversations and decisions about trees and the community tree canopy. . "According to research by the ACCGov Sustainability Office," said Walters, "Athens-Clarke County has the highest documented tree canopy coverage of any community with a population of 100,000 or more. We're very proud of that statistic and hope that this new study will help us better understand the composition, structure, function, and benefits of our community's trees." . The Community Tree Study will involve a statistical survey beginning in the next two months, followed by a set of analyses to understand better the local community forest on a countywide scale. Data will be gathered using iTree, a tool developed by the USDA Forest Service that provides forestry analysis and benefits assessment tools. . Throughout the summer, tree data will be collected on 228 randomly generated 1/10 acre plots around the county. The generated plots cover areas on both private and public land. The Community Forestry Program will contact residents or owners of any included private properties to obtain permission to collect data on their trees. Data collection is expected to take approximately one hour and will not harm the trees or the property. . For more information, contact Rodney Walters, ACCGov Community Forester, at 762-400-7519 or rodney.walters@accgov.com or visit www.accgov.com/communitytreestudy.

at 19:19:08 on 4/20/2021 UTC

Athens-Clarke County @accgov

ACCGov's Community Forestry Program is launching a collaborative Community Tree Study to collect info on the composition & environmental benefits of Athens-Clarke County's trees. Data collection will take place over the next two months. Learn more at accgov.com/communitytrees…. pic.twitter.com/k4pNQmNDLM

at 19:28:53 on 4/20/2021 UTC

Appendix I.7: ACC Community Tree Information Document

Information about the Community Tree Study and request for help from property owners where study plots are located.

What is the Athens Clarke County Community Tree Study?

According to the Southern Group of State Foresters, urban trees are worth billions of dollars and annually provide tens of millions of dollars' worth of environmental benefits. Athens Clarke County has the highest known tree canopy coverage percentage of any other municipal government of 100,000 people or more in the United States! Yet, there are many things we do not know about our Community Trees. The Community Tree Study will allow us to better understand the benefits provided by our community's trees.

The Unified Government of Athens Clarke County, in partnership with The University of Georgia (UGA), The Georgia Forestry Commission, and the Athens Community Tree Council, will be conducting a Community Tree Study beginning May 2021 and concluding in the fall. The study team has generated 228 randomly generated 1/10 acre sample plots throughout Clarke County for this study. The random sample helps to ensure scientifically valid results. Plots are located on public and private property because the community forest includes public and private trees. The trees and ground surface will be measured in each of these plots.

UGA student Teams from the Warnell School of Forestry and Natural Resources will be collecting tree data across the Clarke County. This project will utilize the i-Tree Eco model developed by the US Forest Service to quantify the composition (for example, tree type, size, and health) and environmental benefits of Athens Clarke County's trees.

We are requesting permission from private property owners to access the private properties where these plots are located to collect information on the trees within the sample plot. The measurements will take about 60 minutes, will not harm the trees in any way, and only the trees and ground cover within the plot will be measured. If you would like your trees to be included in the Community Tree Study, please complete the **Community Tree Study online permission form.**

Thank you very much for your consideration.

This is a great opportunity to have your trees represent Athens Clarke County!

Sincerely,

Rodney Walters
Athens-Clarke County Community Forestry Coordinator
(762) 400-7519, rodney.walters@accgov.com

Appendix I.8: University of Georgia Tree Inventory Fact Sheet

UNIVERSITY OF GEORGIA
Warnell School of Forestry & Natural Resources

Publication WSFNR-19-27

October 2019

STEM-UP COMMUNITY TREE INVENTORY INSTRUCTIONS

Jason S. Gordon, *UGA Warnell School of Forestry and Natural Resources*

This publication provides a step-by-step guide to conducting measurements for use in an urban tree inventory. In general, this guide reflects the measurements included in the U.S. Forest Service's i-Tree Eco software program; however, the measurements are fairly standard variables used in bottom-up urban forest inventories.

URBAN TREE INVENTORIES, i-TREE, AND EQUIPMENT

What is a community tree inventory?

A community tree inventory performs three primary functions:

1. As a ***database*** consisting of information about individual trees. This information includes tree location, diameter, height, canopy width, condition, and hazards.
2. As a ***maintenance tool***, the community tree inventory enables managers to identify trees that need to be pruned, staked, fertilized, cabled, or removed. Urban forest managers use the inventory to periodically review trees that have been identified as hazards.
3. As a ***management tool***, the inventory enables aggregation of individual tree data to provide information about a population of trees – also known as the urban forest. Tree population information includes species distribution and canopy cover. A tree map enables community forest managers to identify and prioritize community canopy goals (e.g., planting and maintenance), while accounting for the condition of the community forest (i.e., dead, critical, poor, fair, good, very good, or excellent). Inventories are used in risk assessment to compare pre- and post-disaster forest conditions and prioritize removals.

Creating a visual map of how urban forest benefits are distributed across the landscape is known as benefit mapping. A key aspect of benefit mapping is applying a dollar value to trees based on their individual characteristics. Using computer software, economic value can be assigned to ecosystem service benefits of urban trees such as pollution removal (e.g., ozone, sulfur dioxide, nitrogen dioxide), carbon sequestration, and energy savings.

What is a bottom-up tree inventory?

A bottom-up inventory generates primary data from on-the-ground inventory methods as opposed to aerial or satellite imagery (i.e., top-down inventory). This approach requires a process of measuring individual tree characteristics and quality assurance/control. Field data collection requires extensive planning, management, and time. Although it can be somewhat costly, the results can provide more information than possible through top-down analyses. For these reasons, it is beneficial to perform a bottom-up inventory at some stage of the community tree inventory.

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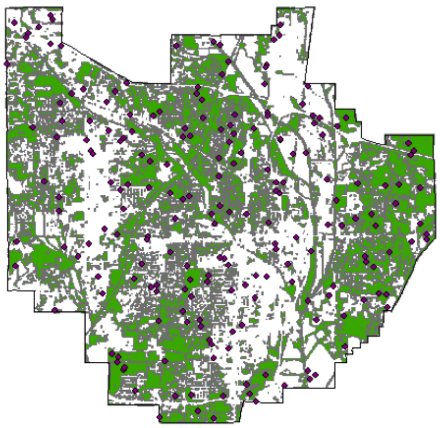
Stem-Up Community Tree Inventory Instructions

What is the scope of the bottom-up inventory (or how much is enough)?

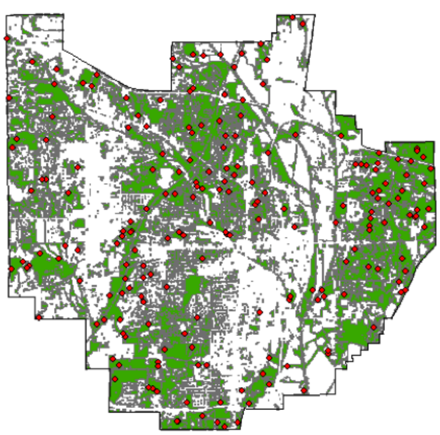
The scope, also known as the sample, is one the most important decisions made in planning a bottom-up urban forest inventory. Determining the scope of the survey depends on available resources and goals. Inventory projects have ranged from parks to small neighborhoods to cities to counties.

A statistical representation of the urban forest requires a random sample, whereby plots are placed randomly across the landscape within the boundaries of the study area (e.g., the official city limits). A simple random sample is the most basic form of random sample. A ***simple*** random sample, however, may not provide a true picture of forest cover since the urban forest is usually not distributed across the landscape randomly.



Simple random sample in (N=200). The green areas represent trees while dots are measurement plots.

A ***stratified*** random sample offers an alternative statistical representation with plots randomly allocated according to land use. A stratified random sample decreases the amount of plots wasted on sites with little or no trees (e.g., large commercial parking lots and agriculture fields). However, because such sites are important characteristics of any populated place, some plots will still be located there.



Stratified random sample (N=200). The green areas represent trees. There are more points located in areas with tree cover than in the simple random sample.

Stem-Up Community Tree Inventory Instructions

Research has found that 200 tenth-acre plots in a given area provides enough information for statistical inference and benefit mapping while also maintaining an acceptable level of costs associated with data collection (Nowak et al. 2008). Fewer points may be appropriate for a small area, but a greater number of points decrease error in the sample. A statistical sample mitigates the effects of data collection error and landscape variation. The project facilitator will add five to ten percent more plots as "extra plots" in case of some of the original 200 are inaccessible. Once the community determines the scope, the project facilitator will locate the plots on a map using Geographic Information System technology. Plot center geo-coordinates and the map will then be distributed to volunteers.
Finally, a ***full inventory*** (also called a 100 percent inventory) is often used to measure street trees, parks, and other public areas. This project scope measures each tree in the designated area. A full inventory is usually not a practical alternative for assessing the urban forest. Because a full inventory is unlikely to be implemented across and the entire community, it does not usually provide a true representation of the urban forest. However, a full inventory is beneficial for managing specific trees, such as those along a major thoroughfare.

What is i-Tree?

Several urban forest inventory software packages are available. Some are freeware (licensed to use free of charge), while others can be fairly expensive. Inventory software should have some basic data entry fields such as Global Positioning Systems (GPS) coordinates and tree species. Preferably, additional entry fields would include tree height, diameter, crown width, crown missing, dieback, and land use and ground cover attributes. Canopy measurements are needed to assess canopy attributes.

One of the most commonly employed programs is the USDA Forest Service's i-Tree, available online at www.itreetools.org (this is not an endorsement by the authors or the University of Georgia for this product). i-Tree is a software suite produced with the collaboration of private and public partners. Currently, there are six core applications: Eco, Hydro, Canopy, Design, Landscape, and MyTree. Each application focuses on specific objectives. For example, Eco provides a broad spectrum of data fields that, when combined with air pollution and meteorological data, quantifies community forest structure, environmental effects, and applies a monetary value to tree benefits. By contrast, Hydro simulates the effects of changes in tree and impervious cover characteristics on stream flow and water quality.
The i-Tree software suite is peer-reviewed, public domain (freeware), easy-to-use software that allows for scalable analysis. In other words, results can be generalized from individual trees to neighborhood to city levels based on a sample inventory. From this information, users can make management recommendations such as species selection, address invasive species, and perform storm damage assessment. The remainder of this article focuses on the data entry variables found within i-Tree Eco.

How is the data recorded?

Example data sheets and respective "cheat sheets" for the plot inventory (Appendices 1 and 2) and the full inventory (Appendices 3 and 4) can be found in the appendix to this document. The advantage of paper data input sheets is there is no risk of technological failure, although they may get wet while in the field. However, paper data sheets are somewhat cumbersome to use. Due to the number of variables, the data sheet must be printed on 8.5 by 11-inch paper (at least). In addition, paper requires an additional step – inputting the data into an electronic database – after measurements are taken. To address these deficiencies, and to make data processing faster, i-Tree offers a web-based mobile app. In short, the user sets up the project on the desktop computer, then can send the project data collection fields as a link to be used on a mobile device or chose to print an equivalent paper datasheet. Mobile devices provide many shortcuts, and tree inventory apps are getting better all the time, but not all inventory personnel have signal in all locations, and some do not have smartphones; therefore, alternative solutions should be known.

i-Tree offers several user-identified input categories. For example, in addition to groundcover, stem, and canopy measurements, it is often a good idea to include at least a basic (Yes/No) hazard observation measure. If desired, a positive response to this measure on the data sheet indicates the need to complete the hazard identification sheet (Appendix 5). Each of the measurements found on these data sheets will be explained in the following sections.

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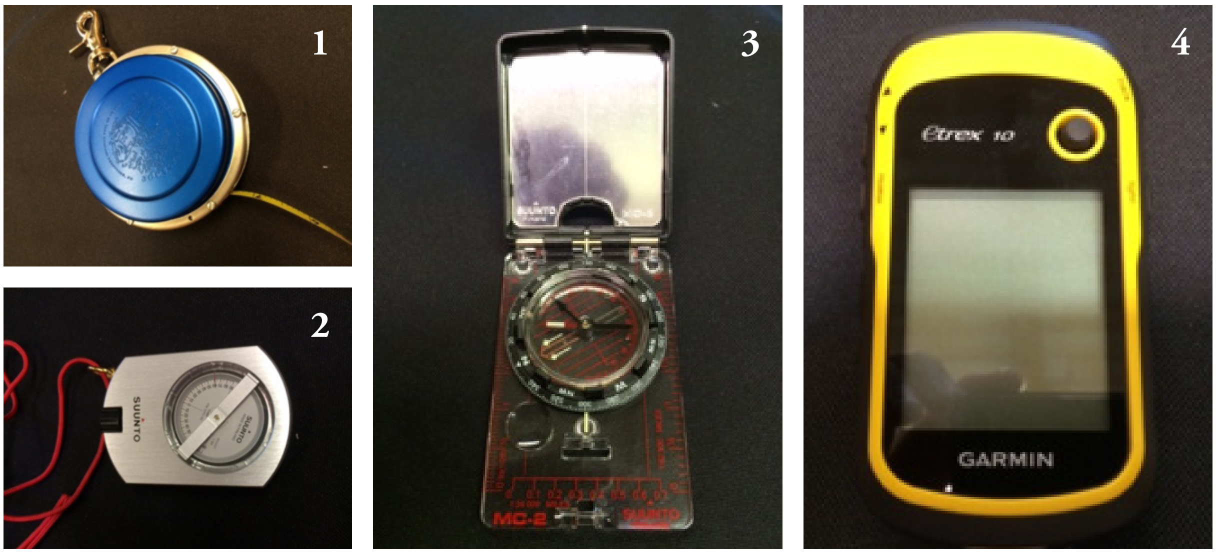
Stem-Up Community Tree Inventory Instructions

What equipment is needed?

We recommend four basic pieces of equipment (see illustrations below) to conduct a basic volunteer inventory: 1) diameter tape, 2) compass, 3) clinometer, and 4) GPS unit. While additional equipment or more expensive equipment could be used, we find this equipment is appropriate for limited budgets and for use with volunteers who borrow the equipment. If available, smart phone apps may be used instead of the handheld compass and GPS.



PROCEDURES

Note: We suggest urban forest inventory facilitators create an on-line public folder (e.g., Dropbox/Google Drive, etc.) where volunteers can access maps, documents, PowerPoint presentations, literature, and additional information on procedures.

Plot Information

The first measurements describe the plot, or the sample area where the tree(s) is found in a sample-based inventory (Appendix 1 and Appendix 2, page 1). Plots are typically one tenth of an acre, or 37.2 feet in radius, although project managers can decrease this area if needed (keep in mind that decreasing plot area should correspond with increasing sample size if statistical confidence is to be maintained) (Nowak et al. 2008). Once plot center is found using a GPS unit, the data collectors measure a radius of 37.2 feet from plot center using a diameter tape. Every tree with at least half the stem falling inside the radius is considered within the plot and should be measured. The following is replicated from the Sample Plot Cheat Sheet (Appendix 1). If a plot is located on private property, access must be granted by the owner (Appendices 6 and 7), otherwise the collector notes that only a portion of the plot was measured.

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Stem-Up Community Tree Inventory Instructions

Plot ID: Enter plot ID

As mentioned above, plots are randomly created within the border of a given area. The plot ID is assigned by i-Tree when the project is created. Describing location is beneficial for returning to the tree during a future inventory (successive inventories monitor change) because GPS contains error. The facilitator describes the location of the plot using roads and other geographic landmarks. A copy of a large scale photo helps the volunteers get reasonably close to the plot. Then, GPS is used to get within 30 feet (about the amount of error in mobile device and handheld GPS units) of the plot center.

Recording data onto the data sheet. Always use a pencil.

Plot WP: Enter GPS waypoint of the plot center (not trees) (Appendix 8). The data collector attempts to arrive as close as possible to the coordinates indicated by the GPS. At this point, the volunteer marks a "Center Point" of the plot using a landscaping flag, stick, rock, or some other identifiable object. The plot is then measured using a radius of 37.2 feet (37 feet and 13/32 inches), or 1/10th acre. Again, trees are considered within the plot if at least half the stem at 4.5 ft. (known as diameter at breast height or DBH) lies within the radius measure.

Making a waypoint using GPS.

DATE: Enter date of work.

CREW: Enter crew ID. A unique crew ID is assigned by the facilitator.

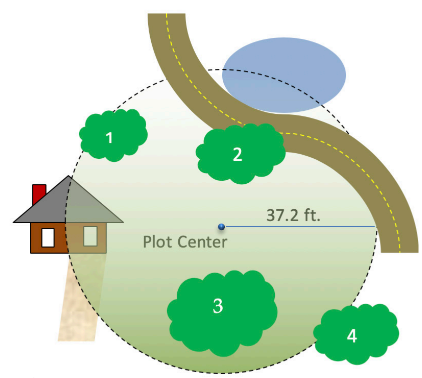
GPS UNIT: Enter GPS Unit ID. Crew ID and GPS Unit ID are used to trace the data back to volunteer collectors as part of quality control. If using the smart phone app, Not Applicable (NA) can be entered here.

PLOT ADDRESS: If the plot (or any portion) is located on private property, enter the plot address, including street number, street, and zip code.

PLOT PHONE: If the plot (or any portion) is located on private property, enter the telephone number. The telephone number will be available after the property owner has consented to the procedure (Appendices 6 and 7). In some cases, special permission will need to be granted to access public property. In such cases, the same permission documentation should be used with access granted by the supervising authority.

OWNER NAME: Record the name of the owner of property (if public, note government entity).

NOTES: Record anything noteworthy here. Record lack of access (e.g., property owner refusal or environmental conditions).



This 1/10th acre plot has 3 trees. Tree #4 is more than halfway out of the plot, while Tree #1 has more than half the stem inside the plot boundary.

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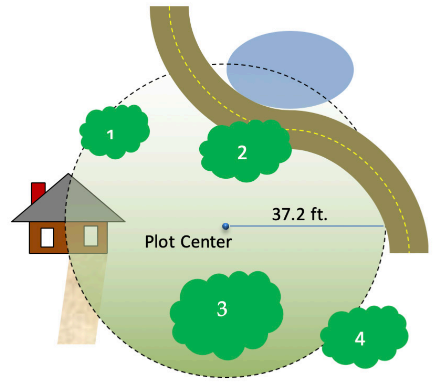
Stem-Up Community Tree Inventory Instructions

ACTUAL LAND USE AND PERCENT IN: The letter from the list below is recorded along with percent of each land use that falls within the plot. Proportions are recorded in increments of one to five percent, then every five percentage points. As with other qualitative estimates in the inventory, land use should be discussed and agreed upon by team members. Up to four land uses can be recorded. Below are the land uses recognized by i-Tree.

Residential (R)
Multi-family residential (M)
Commercial/Industrial (C)
Park (P)
Cemetery (E)
Golf Course (G)
Agriculture (A)
Vacant (V)
Institutional (I)
Utility (U)
Water/wetland (W)
Transportation (T)
Other (O)



This plot has approximately: 4% T, 1% W, 95% R.

PLOT TREE COVER: Record the estimated percent of tree canopy over the plot. This is another qualitative estimate that should be discussed among team members.

SHRUB COVER: Record the estimated percent of shrub cover in the plot. The facilitator will inform the volunteers on what is classified as shrub cover.

GROUND COVER: Pervious versus impervious surface as well as soil area is important in assessing tree vigor and ecosystem services. Record the percent ground cover in plot, which must total 100 percent. The crew notes the percentage of the plot ground area that is covered by the materials below. Estimation may be facilitated by dividing the plot in halves or quarters, then summing the proportions of each section.

This 1/10th acre plot has 3 trees. Tree #4 is more than halfway out of the plot, while Tree #1 has more than half the stem inside the plot boundary.

Building (B)
Concrete (C)
Tar (T): Blacktop/asphalt
Rock (R): Pervious rock surfaces such as gravel, brick, or flagstone walkways or patios (without mortar). This category includes sand in playgrounds or added as topping to existing soil. Large solid rock outcrops should be listed as concrete.
Bare soil (S)
Duff/mulch (D)
Herbs (H): Herbaceous ground cover, other than grass, including agricultural crops
Maintained grass (MG)
Unmaintained grass (UG)
Water (W)

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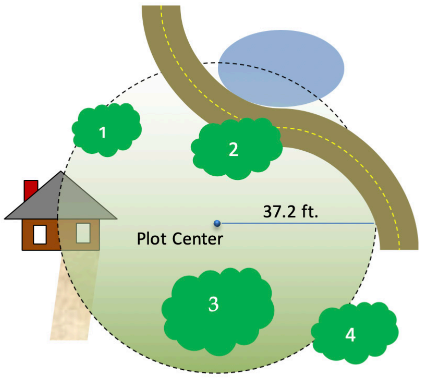
Stem-Up Community Tree Inventory Instructions



This plot has approximately: 40% tree cover, 0% shrub cover, 2% T, 1% C, 1% W, 1% B, 95% MG.

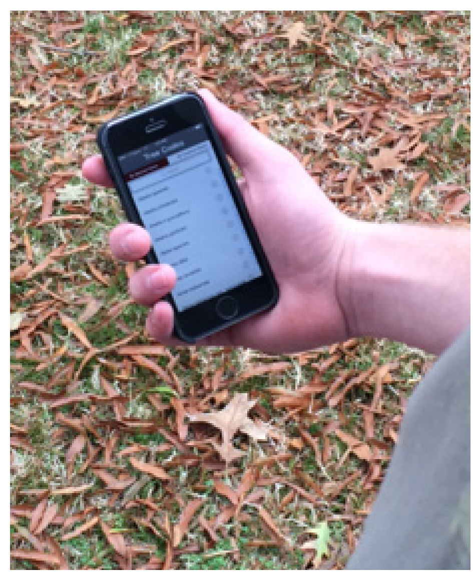
Groundcovers in this plot include: Tar, Maintained Grass, and some mulch around the tree. The land use is Institutional.

The following metrics are for individual trees within the plot (Appendix 1 and Appendix 2, page 2). Data collection for living and dead trees starts with the tree closest to due north and proceeds in a clockwise direction.

Plot ID: Enter the plot ID from page 1 (Plot Information) so that the individual tree information can be linked to the correct plot.

PLOT WP: Enter the GPS waypoint for the plot from page 1.

TREE ID: Record the tree species (U if unknown and take a photo and send to the facilitator) using the UFORE abbreviations (https://www.itreetools.org/support/resources-overview/i-tree-methods-and-files/i-tree-eco-v6-data-collection-sheets-and-species-list, last accessed August 1, 2019). i-Tree protocol recommends a relevant tree must be greater than or equal to 1 inch at 4.5 feet, although the project manager can change this protocol if needed.



Using the tree code app to record the tree ID UFORE abbreviation.

STATUS: The crew should discuss and come to consensus about whether the tree was:
P: Planted—the tree was planted intentionally (often characterized by orderly patterns, e.g., rows, and landscaping);
I: Ingrowth—the tree self-seeded;
U: Unknown—planted vs. ingrowth cannot be determined.
Record dead trees as -1 and skip to the “Site” variable.

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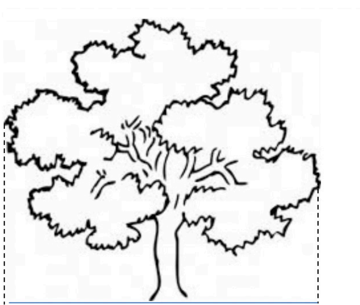
Stem-Up Community Tree Inventory Instructions

DR: Record the direction of the tree from the center of plot using azimuth in degrees. DR and DS are used as geographic references in addition to the plot center waypoint. Again, geographic references are important for future inventory updates.

DS: Record the distance of the tree from plot center to the edge of the trunk.

LAND USE: The previous land use metric indicated land use within the entire plot; whereas, this metric records land use under individual tree canopies in the plot. Record the land use to drip line of the tree crown. The drip line is the very edge of the crown. Most of the time, this will be the same as the land use recorded for the plot. The following land uses may be recorded.

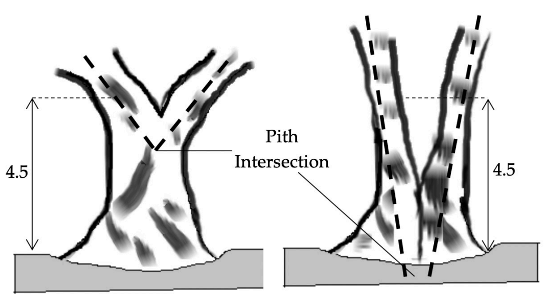
A smartphone app makes recording direction easy.



Dripline

Residential (R)
Multi-family residential (M)
Commercial/Industrial (C)
Park (P)
Cemetery (E)
Golf Course (G)
Agriculture (A)
Vacant (V)
Institutional (I)
Utility (U)
Water/wetland (W)
Transportation (T)
Other (O)

DBH: Record the tree's DBH (a relevant tree must be greater than or equal to 1 inch at 4.5 feet) on the uphill side of the tree to the nearest 0.1 inch/cm. Record up to 6 stems (≥1 in) if the pith union is below ground. If more than 6 stems, lower the measurement height to 1 foot above ground and record the DBH of the 6 largest stems. See Appendix 9 for DBH measuring procedures. On trees with swelling or other irregularities at DBH, measure the diameter immediately above the irregularity and note the height where DBH was taken.



Measuring DBH in multistemmed trees.

Using the diameter tape to measure DBH. Follow the correct procedure to hold the tape (Appendix 9).

[Tree-DBH1]

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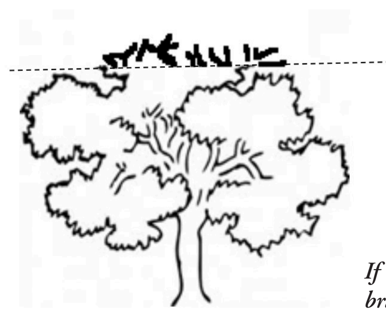
Stem-Up Community Tree Inventory Instructions

TREE HEIGHT: i-Tree requires three height measurements (Appendix 10).

Total tree height: Measure the height of the tree to the highest visible branch (alive or dead).

Measuring tree height using a clinometer. Follow the correct procedure to hold the clinometer (Appendix 10).

Height to live top: Measure the height to the highest visible live branch. This height will be the same as total tree height unless the tree is alive but the top of the crown is dead.



If the tree does not have any dead branches at the top, the height to live top is the same as total height. In the case of this tree, height to live top is shorter than total height.

Height to crown base: Measure the tree height to the base (the lowest live foliage) of the crown. If the base is not reachable using the measuring tape, the clinometer must be used and measured using the same procedure as measuring total height.

Measuring height to crown base using a diameter tape.

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Stem-Up Community Tree Inventory Instructions

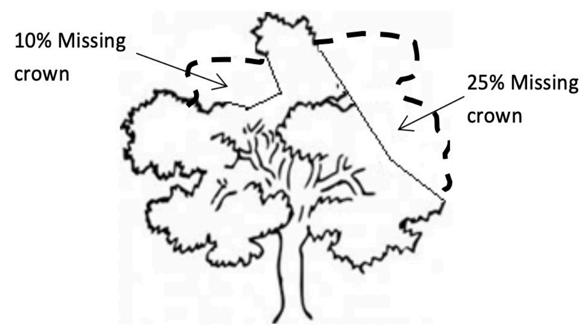
CROWN

Crown width: Measure the width of each tree's crown (to nearest foot). Two volunteers are needed to measure the crown width. Making sure the diameter tape touches the tree stem to approximate the diameter of a circle encompassing the crown, hold each end of the tape to the drip line and record the measurement. This procedure should be repeated in two perpendicular directions: north-south and east-west to account for energy savings.

Measuring crown width East and West.

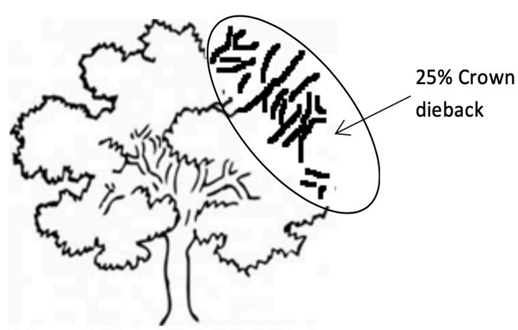
Measuring crown width North and South.

Percent canopy missing: This metric estimates the percent of branches and foliage that is absent due to pruning, defoliation, uneven crown (i.e., irregular due to damage or some other negative abiotic or biotic impact), or dwarf or sparse leaves.



This tree has approximately 35% of its crown missing.

Crown dieback (DB): Record percent branch dieback on each side and top of crown area. Dieback is a condition in which a tree or shrub begins to die from the tip of its leaves or shoots backward resulting from disease or an unfavorable environment.



Approximately 25% crown dieback.

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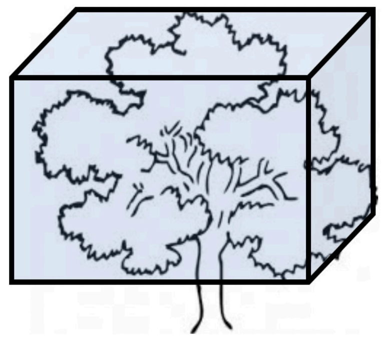
Stem-Up Community Tree Inventory Instructions

Crown light exposure (CLE): Record the number of sides of the tree receiving sunlight. There is a maximum of five (four sides and top). As a rule of thumb, include each side that receives at least 50% sunlight.



Imagine a box covering the crown to measure CLE. A tree can have up to five sides exposed to sunlight.

IMPERVIOUS SURFACE: Estimate the percent of the area beneath the dripline of the tree that is impervious to water. Often, this will reflect the single tree metric for land use (above). An impervious surface is one that does not allow water to penetrate into the soil. Greater areas of imperious surface result in increased runoff into drainages.

TREES NEAR BLDGS: Identify trees (≥20 ft. tall) that are located within 60 ft. of space-conditioned residential or commercial buildings that are three stories or fewer in height (e.g., two stories and an attic). Record the direction (D = azimuth in degrees) from the tree to the closest part of the building and the distance (S = if >60 ft., just note >60 ft.). These metrics are needed for calculating energy savings.

SITE: Indicate whether the tree is a street tree (Yes = Y) or not a street tree (No = N). A street tree is any tree or part of tree, including the canopy and root systems, that lies on or has grown onto or over public property, or in public right of way owned by a public entity.

Measuring distance to the closest building using a diameter tape.

HAZARD: In some cases, project managers might want to include some rough measure of likelihood of failure. For example, data collectors could mark (Yes = Y) or (No = N) if the overall tree, foliage, branches/bole show indications of pest, disease, or if tree/branches could be a hazard necessitating a visit by a professional. A hazard is any tree/part of tree that may cause harm to people or property (e.g., car). It is important to understand that only a Certified Arborist should conduct a complete tree risk assessment due to liability concerns. However, because they are observing many trees, volunteers are invaluable for identifying obvious, major problems. If a tree is a hazard, well-trained collectors may complete the additional hazard identification form (Appendix 5). If a hazard is indicated, arborists will return to the tree to assess it.

Stem-Up Community Tree Inventory Instructions

ADDITIONAL READING

David J. Nowak, Jeffrey T. Walton, Jack C. Stevens, Daniel E. Crane, and Robert E. Hoehn (2008) Effect of Plot and Sample Size on Timing and Precision of Urban Forest Assessments. Arboriculture & Urban Forestry, 34(6):386–390.

David J. Nowak, Daniel E. Crane, Jack C. Stevens, Robert E. Hoehn, Jeffrey T. Walton, Jerry Bond (2008) A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services. Arboriculture and Urban Forestry, 34(6):347–358.

Jason Gordon. Community Forestry: Another Way of Thinking about Forest Management, IS1958. MSU Extension Service.

Jason Gordon. Conducting a Community Tree Inventory, P2811. MSU Extension Service.

US Forest Service. (n.d.) i-Tree Streets User's Manual v5.x.. Retrieved January 19, 2015, from www.itreetools.org/eco

UFORE Methods (n.d.) Retrieved January 19, 2015, from http://www.itreetools.org/eco/

Appendix I.9:
ACC Community Tree Study Door Hangars

Athens-Clarke County
Community Tree Study

Sorry we missed you!

Athens-Clarke County (ACCGov), in partnership with the University of Georgia, is conducting a Community Tree Study.

The Community Tree Study will help ACCGov better understand the structure, function, and benefits of trees in Athens-Clarke County.

This property was randomly selected as one of 228 small sample plots throughout the county to participate in the study. We would greatly appreciate your assistance in this effort.

We would like to access your

☐ **Front Yard** ☐ **Back Yard**

to take some quick measurements of trees

To participate in this study:

- visit accgov.com/communitytreestudy
- scan this QR code with a smartphone
- call 706-613-3561

You can provide general permission or specify a date and time before August 1, 2021.

Questions about the Community Tree Study?

Rodney Walters
ACCGov Community Forester
rodney.walters@accgov.com
762-400-7519

Thank you for your participation in the Athens-Clarke County Community Tree Study

Our Community Tree Study student data teams from the University of Georgia Warnell School of Forestry have conducted the measurements of the trees in a sample plot on this property.

This study will provide a better understanding of the composition, structure, and benefits of public and private trees in Athens-Clarke County community forests on a countywide scale.

Once the Community Tree Study is completed by fall 2021, a report of the findings will be available at accgov.com/communitytreestudy.

Questions about the Community Tree Study?

Rodney Walters
ACCGov Community Forester
rodney.walters@accgov.com
762-400-7519

Appendix I.10: ACC Community Forester Letter (Tree Study Information and Property Access Request)

Recipient 4/5/2021
Street and Number
Athens, GA (Zip Code)

Dear Athens Clarke County resident:

Do you like trees? So do we! You may not know this but Athens-Clarke County has the highest documented tree canopy cover percentage of any other community of 100,000 people or more in the United States! Yet, there are many things we don't know about our trees. To help understand our trees better, Athens-Clarke County is conducting a community tree study this summer beginning in May 2021.

The purpose of this letter is to ask for your permission to collect data about one or more trees on this property.

In order to draw statistically-based conclusions about the community trees, we have generated over 200 sample plots randomly across Athens-Clarke County. Each plot is one tenth of an acre, may extend over multiple properties, and may contain large trees, small trees, or no trees. One or more of these sample plots is located on this property. Two-person teams composed of UGA Warnell School of Forestry and Natural Resources students under the supervision of Dr. Jason Gordon will gather tree data. The only thing the data collection teams will measure for the study are the trees. These measurements will not harm the trees or the property in any way. The data collection is expected to take approximately 60 minutes

Since only 200 small sample plots are part of this study throughout the whole community, we would greatly appreciate your assistance in this effort. If you would like to participate in this study and allow team members to collect this data, **please scan the QR Code and complete the online permission form -or- visit Athens Community Tree Study Webpage** (www.accgov.com/communitytreestudy) **to complete the online permission form**

-or- complete the enclosed permission form and return it in the self-addressed postage paid envelope. If we do not receive a response by May 21, 2021, I may contact you to request permission for our team members to access the property. Please contact me at (762) 400-7519 with any questions or concerns you may have about this project. Please retain this letter for your records.

Thank you for your support on this valuable community effort. This is a great opportunity to have your trees represented in the Athens Clarke County community tree to benefit many future generations of residents. We hope that you will participate!

Sincerely,

Rodney Walters
Athens Clarke County Community Forestry Coordinator
(762) 400-7519, rodney.walters@accgov.com