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Providence's Urban Forest, 2021

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Abstract

A survey of the urban forest was conducted in Providence, Rhode Island from 2015 to 2021. Across the 13.1 thousand acres encompassing the city, there are an estimated 495.2 thousand live trees. More than half of tree stems are small diameter (under 5.0 inches in diameter). The most dominant species based on the number of trees and leaf area are Norway maple, black oak, northern red oak, American elm, and northern white-cedar. Trees on public lands account for 30.0 percent of the total live tree population. Trees on private lands account for 70.0 percent. A majority of trees on private land are found on commercial/industrial land (42.6 percent of total live trees). The trees across the city are subject to a wide range of pests, pathogens, and damage agents—with significant proportions of each species affected by one or more damage agents. Furthermore, 6.3 percent of stems are standing dead trees. Invasive tree and plant species are common in the city, being found on 47.9 percent of the sample plots. Trees in Providence provide many ecosystem services, including air pollution removal, carbon sequestration, reduction in stormwater runoff, and effects on residential building energy use and carbon emissions. The compensatory value of the urban forest is estimated at $405.9 million with the urban forest producing over $6.2 million in annual benefits. This report presents information about the current state of the Providence urban forest and the benefits it provides to residents of the city.

Keywords: i-Tree; My City's Trees; tree volume and biomass; carbon sequestration and storage; UFIA; Urban Forest Inventory and Analysis; Urban FIA; urban forest structure and health; urban forest values and ecosystem services

Cover photo: The Rhode Island State House. Courtesy photo by AJ Elton of City of Providence, Rhode Island, Forestry Division.

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Providence’s Urban Forest, 2021

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EXECUTIVE SUMMARY

A Forest Service employee reviews invasive species information in Providence. USDA Forest Service photo by Sjana Schanning.

The City of Providence was sampled in 2021 to assess the magnitude, composition, and value of its urban forest resource. The sampled area of the city (representing a total of 13,159 acres), is estimated to contain 495,168 live trees, 58.4 percent of which are less than 5.0 inches in **diameter**[1]. The most common tree species[2] at least 1.0 inch in diameter are Norway maple, black oak, northern white-cedar, white mulberry, and American elm. The most common large-diameter tree species (11.0+ inches in diameter) are Norway maple, black oak, red maple, northern red oak, and American beech. The most dominant species based on the number of trees and leaf area are Norway maple, black oak, northern red oak, American elm, and northern white-cedar.

The greatest proportion of trees are found on commercial/industrial land (42.6 percent; 210,971 trees). Overall, 34.7 percent of trees are classified as growing in maintained areas. Trees on public lands total 148,410 and account for 30.0 percent of the total live tree population. Trees on private lands total 346,759 and account for 70.0 percent of the population.

[1] See glossary for definition of bolded terms.

[2] Common and scientific names for tree species observed in the 2021 Urban FIA inventory of Providence are reported in Appendix 2.

Urban forest ecosystem services are evaluated in terms of air pollution removal, carbon sequestration, reduction in stormwater runoff, and effects on residential building energy use and carbon emissions. The compensatory value of the urban forest (roughly equivalent to the replacement value of all trees in the urban forest) is estimated at $405.9 million with the urban forest producing over $6.2 million in annual benefits (Table 1).

The tree species with the greatest estimated average percent dieback is northern red oak (17.6 percent dieback) and the species with the greatest rot is white mulberry (5.0 percent rot). Northern red oak also has 37.3 percent of its population classified as standing dead. The most common urban specific damages affecting all tree species in the sampling area are topping/pruning (5.5 percent of trees) and conflict with crown (5.3 percent of trees). Tree species with the greatest proportion of their population affected by urban damages are northern white-cedar (20.5 percent of trees affected by topping/pruning) and red maple (16.1 percent of trees affected by conflict with crown).

Invasive plant species also threaten to alter forest composition and are found on 47.9 percent of the sampled plots; Norway maple is estimated to cover the largest area (342 acres) of any invasive plant species in the city.

These natural and anthropogenic threats may affect the health and composition of Providence's urban forest. Through better understanding of the benefits conferred by and potential threats to the urban forest, resource managers, arborists, and city planners can improve forest management, leading to healthier urban forests and more livable communities.

Table 1.—Summary of urban forest estimates, City of Providence, 2021

Feature	Estimate
Number of trees[a]	
Total live trees	495,168 (129,072)[b]
Live saplings (1.0 to 4.9 inches in diameter)	289,000 (117,000)[b]
Live trees (at least 5.0 inches in diameter)	206,000 (28,311)[b]
Standing dead saplings (1.0 to 4.9 inches in diameter)	23,000 (16,000)[b]
Standing dead trees (at least 5.0 inches in diameter)	10,000 (3,700)[b]
Most abundant species	
By number of live trees	Norway maple
By leaf area	Norway maple
Ecosystem Impacts and Services	
VOC emissions	85 tons/year
Pollution removal	81 tons/year ($3.1 million/year)
Reduction in acute respiratory symptoms	283 cases/year ($25,000/year)
Avoided runoff	6.7 million cubic feet ($445,000/year)
Carbon storage[c]	84,000 tons ($14.4 million)
Carbon sequestration	2,300 tons/year ($389,000/year)
Net aboveground volume	3.8 million cubic feet
Reduced building energy use[c,d]	86,000 GJ/year ($2.0 million/year)
Reduced carbon emissions[c,d]	1,600 tons/year ($273,000/year)
Compensatory value	405.9 million

Estimates are rounded.

VOC = volatile organic compound (a negative ecosystem impact).

Ton = short ton (U.S.) (2,000 lbs.).

To convert carbon estimates to carbon dioxide, multiply carbon value by 3.667.

GJ = gigajoule (one billion [10^9] joules).

[a] Diameter measurements were taken at breast height (d.b.h.).

[b] Numbers in parentheses are standard error.

[c] Estimates are for the live and dead tree population. All other estimates are based on the live tree population only, except where noted.

[d] Estimates are calculated using trees greater than or equal to 5.0 inches in diameter.

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BACKGROUND

Downtown Providence. Courtesy photo by AJ Elton of City of Providence, Forestry Division.

Urban forests offer a wide range of environmental, social, and public health benefits, such as wildlife habitat, aesthetic appeal, social cohesion, enhanced recreational opportunities, reduced air temperatures, improved water quality, mitigated air and noise pollution, and benefits to mental health and well-being. Since 1930, the U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) program has provided information on the amount, status, and character of **forest land**[3] across the country. The 2014 U.S. Farm Bill (The Agriculture Act of 2014) directed FIA to explore possibilities to expand the scope of the FIA inventory to include forest monitoring in U.S. urban areas. This effort led to the development of the current FIA Strategic Plan (USDA Forest Service 2016a) that includes a special focus on the nation's most populous cities.

In this report, the term "urban forest" describes all trees located in the city across both public and private ownerships, including planted trees along streets and boulevards, trees in parks and residential yards, remnant forest along railroads and riparian areas, small woodlots, and larger forested areas. FIA has partnered with the Forest Service i-Tree team, which has a long tradition of conducting urban forest inventories and delivering data about urban forests and their associated ecosystem services. This combined national urban forest inventory effort leverages the strengths of both groups, drawing on the urban data processing and reporting strengths of the i-Tree program and FIA's strengths in quality, consistency, and comprehensiveness of data collection.

[3] See glossary for definition of bolded terms.

The area where Providence, Rhode Island currently sits is part of the traditional homeland of the Narragansett people. The modern city was founded in 1636 by Roger Williams as the seat of the newly established colony of Providence Plantations. The first city forester position was created in 1907, making it one of the oldest urban forestry programs in the state (and among the first in the country). The initial goal of the forester focused primarily on the aesthetics of the landscaped city. From the early onset of the program the forester used trees to mitigate the soot accumulation associated with commercial production within the city. The first in-depth tree inventory was completed in 2006 and consisted of city-owned street trees, including trees located within sidewalks and adjacent to streets and roads (Cicilline et al. 2008).

Methods

To evaluate the extent, composition, and benefits of Providence's urban forest and establish a baseline for future monitoring, a sample-based inventory was conducted following Urban FIA monitoring methods and reporting tools described in the Urban FIA Northern Research Station (NRS) Field Guide Version 7.1 (USDA Forest Service 2017) and the online supplement to this report (Baer et al. 2025), along with i-Tree Eco modeling software (www.itreetools.org, Nowak 2024). This process established survey plots across Providence and aims to revisit those plots every 7 years. Future reports can build on these data and consistently provide information on urban forest extent, diversity, health condition, and benefits. This report summarizes data collected from the first complete cycle, from 2015 to 2021. The sampling area was defined by the U.S. Census Bureau Designated Places boundary for Providence (highlighted in red in Fig. 1a). In total, the Urban FIA sample surveyed 192 plots across the city's 13,159 acres within the designated sampling area in Providence (Fig. 1).

New methods were implemented in the inventory of Providence's urban forest to allow for flexibility in the estimation of tree characteristics for forked trees. In this inventory, all stems of forked trees are quantified and characterized as part of the same tree. All extrapolated estimates for forked trees are based on this approach except for estimates of tree merchantability and volume estimation. Refer to Baer et al. (2025) for more detailed information. Throughout this report, except where explicitly noted, trees refer to woody plant species listed in Appendix 3 and 3B of the NRS Field Guide Version 7.1 (USDA Forest Service 2017) with **diameters** of at least 1.0 inch, and results are given for live trees.

The collected data were analyzed using FIA methodology and i-Tree Eco modeling software outlined in Baer et al. 2025. Additional analyses were conducted using R Statistical software version 4.2.1 (R Core Development Team 2022) and Microsoft Excel; figures presented in this report were generated using the base, dplyr (Wickham et al. 2022), and ggplot2 (Wickham 2016) packages within the R Statistical Software platform, and Microsoft Excel. Maps throughout this document were created using ArcGIS® software by Esri (ArcGIS Pro version 2.9; Esri 2021). ArcGIS® is the intellectual property of Esri and is used herein under license.

This report summarizes the findings of these analyses and includes information on forest structure, ecosystem services, and associated monetary values. Structure describes various physical attributes of the urban forest, including tree species composition, number of trees, tree density, tree health, leaf area, biomass, and species diversity. Ecosystem services discussed in this report were evaluated based on forest structure in conjunction with local environmental variables and include such attributes as air pollution removal and carbon storage and sequestration. Monetary values are an economic estimate of various ecosystem services or structural attributes.

In addition to this report, information from this analysis is accessible via My City's Trees, an online interactive tool that allows users to explore results and print data queries. Data tables are also available for download from FIA's Urban DataMart.

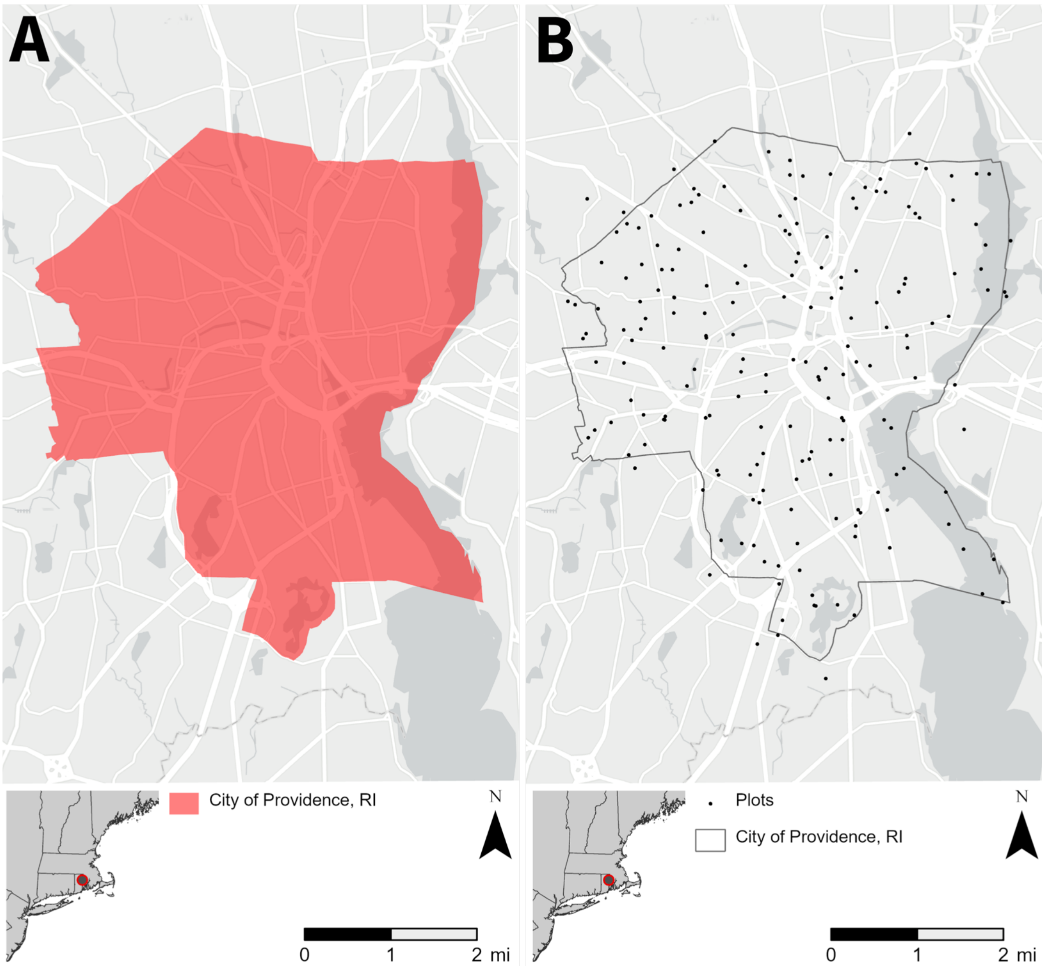

Figure 1.—Study area (A) and approximate plot locations (B) for the Urban Forest Inventory and Analysis (FIA) inventory, City of Providence, 2021. The Light Gray Canvas basemap layer was provided by Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community.

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AREA AND COVER CHARACTERISTICS

View of Providence from Neutaconkanut Hill. Courtesy photo by AJ Elton of City of Providence, Forestry Division.

In 2010, Rhode Island had 256,000 acres of urban land that covered 38.7 percent of the state area, and this urban area is projected to increase to 73.5 percent by the year 2060 (Nowak and Greenfield 2018). Providence is the largest city in Rhode Island by population (178,000 residents with a population density of 9,676 per square mile in 2010; U.S. Census Bureau 2018). U.S. Census data from 2010 was used for this report and updated census data will be included in future reports.

Land Cover

National land cover data were used to analyze variability of the urban forest across the city by land cover class (Homer et al. 2015, MRLC 2018). Plots were categorized into general land cover class groups (Table 2).

Land cover definitions are based on the 2011 National Land Cover Database (NLCD) (Homer et al. 2015) and are described in Appendix 1. The most prevalent land cover classification is developed-high, followed by developed-medium, water, and developed-low (Table 3). Figure 2 shows the distribution of land cover class groups across the city. Areas of dev-low land cover are estimated to contain the greatest proportion of trees in the sampling area of any land cover (38.4 percent), followed by dev-med, dev-open/veg, and dev-high land covers (34.8 percent, 15.5, and 9.4 percent of the trees in the sampling area, respectively).

Table 2.—National Land Cover Database (NLCD) land cover class groups inventoried, City of Providence, 2021

NLCD land cover class group	NLCD land cover classes
Developed-open/veg	Developed, Open Space and Deciduous Forest and Mixed Forest and Evergreen Forest and Shrub/Scrub and Woody Wetlands and Emergent Herbaceous Wetlands and Grassland/Herbaceous and Pasture/Hay and Cultivated Crops
Developed-low	Developed, Low Intensity
Developed-medium	Developed, Medium Intensity
Developed-high	Developed, High Intensity and Barren Land
Water	Open Water

Source: Homer et al. 2015.

See Appendix 1 for descriptions of the NLCD land cover classes.

Table 3.—Sample area and plot counts within National Land Cover Database (NLCD) land cover class groups, City of Providence, 2021

NLCD land cover class group	Area (acres)	Land (percent)	Plots (number)
Developed-high	5,429	41	84
Developed-medium	4,470	34	62
Water	1,247	9	15
Developed-low	1,095	8	18
Dev-open/veg	917	7	13
Total	**13,159**	**100**	**192**

Due to rounding, not all values will add up exactly.

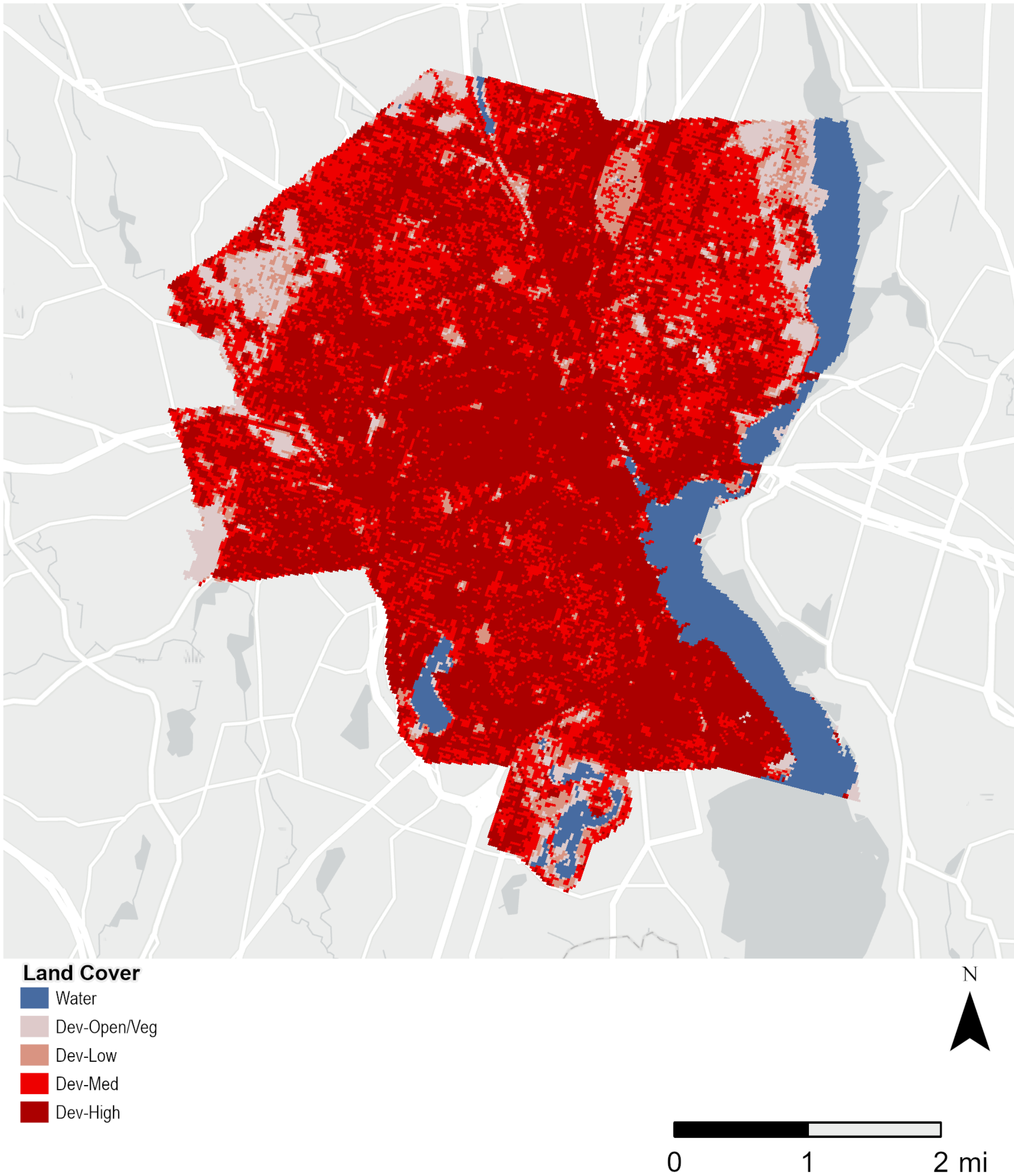

Figure 2.—Distribution of National Land Cover Database (NLCD; Homer et al. 2015) land cover class groups, City of Providence, 2021. The Light Gray Canvas basemap layer was provided by Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community.

FIA Land Use

In addition to categorization according to NLCD land cover class groups, plots were also classified in the field based on FIA land use classes (Table 4). There are often multiple land uses on a single plot. When this occurs, the area of each land use is mapped and a percent of the total plot area is assigned an FIA land use class. These categories provide a specific look at how the land is being used by the local population in Providence.

Commercial/industrial is the most prevalent land use class in Providence, covering 27.8 percent of the city area (containing 42.6 percent of the city's trees), followed by **rights-of-way** (24.9 percent of the city area), residential (20.7 percent), water (11.2 percent), and multi-family residential (6.8 percent) (Table 5).

Table 4.—Forest Inventory and Analysis (FIA) land use classes and subclasses inventoried, City of Providence, 2021

FIA land use class	FIA land use subclasses
Agriculture	Agriculture, Christmas tree plantation, cropland, idle farmland, maintained wildlife openings, nursery, orchard, pasture, shelterbelt, windbreak
Commercial/Industrial	Commercial, cultural, developed, industrial, institutional, mining, wasteland
Forest	None
Multi-family residential	None
Natural lands	Beach, nonvegetated land, other, wetland
Rangeland/Chapparal	None
Recreation/Cemetery	Cemetery, golf course, park, recreation
Residential	None
Rights-of-way	Rights-of-way, transportation, utility
Water	None

Source: USDA Forest Service 2017.

Table 5.—Sample area and plot counts within Forest Inventory and Analysis (FIA) land use classes, City of Providence, 2021

FIA land use class	Area (acres)	Standard error (acres)	Land (percent)	Plots (number)
Forest land	463	143	3.5	6.7
Commercial/Industrial	3,659	390	27.8	55
Multi-family residential	890	206	6.8	12.9
Residential	2,718	335	20.7	40.2
Recreation/Cemetery	672	202	5.1	9.6
Rights-of-way	3,280	296	24.9	49.1
Water	1,477	116	11.2	18.6
Total	**13,159**	**225**	**100.0**	**192.0**

Due to rounding, not all values will add up exactly.

Tree, Shrub, and Ground Cover

Tree cover in Providence is estimated at 16.5 percent and shrub cover at 5.5 percent based on field crew assessments. Field plot estimates are used to evaluate tree cover and can have a relatively high degree of uncertainty due to the nature of tree cover data collection in the field and effects of sample size. Generally, better tree cover estimates can be derived from photointerpretation or high-resolution tree cover maps derived from remotely-sensed data.

Overall, tree cover ranges from 0.2 percent to 100 percent on plots where trees are present (Fig. 3a). Shrub cover on plots ranges from 0.03 percent to 85 percent on plots where shrubs are present (Fig. 3b). Average tree cover is highest on forest land (84.7 percent tree cover), recreation/cemetery (61.7 percent), and multi-family residential land uses (22.0 percent) (Table 6). Shrub cover is highest on forest land (39.6 percent shrub cover), recreation/cemetery (8.9 percent), and residential land uses (7.8 percent). Impervious cover is highest on rights-of-way (85.3 percent impervious cover), commercial/industrial (44.2 percent), and multi-family residential land uses (40.3 percent) (Table 6).

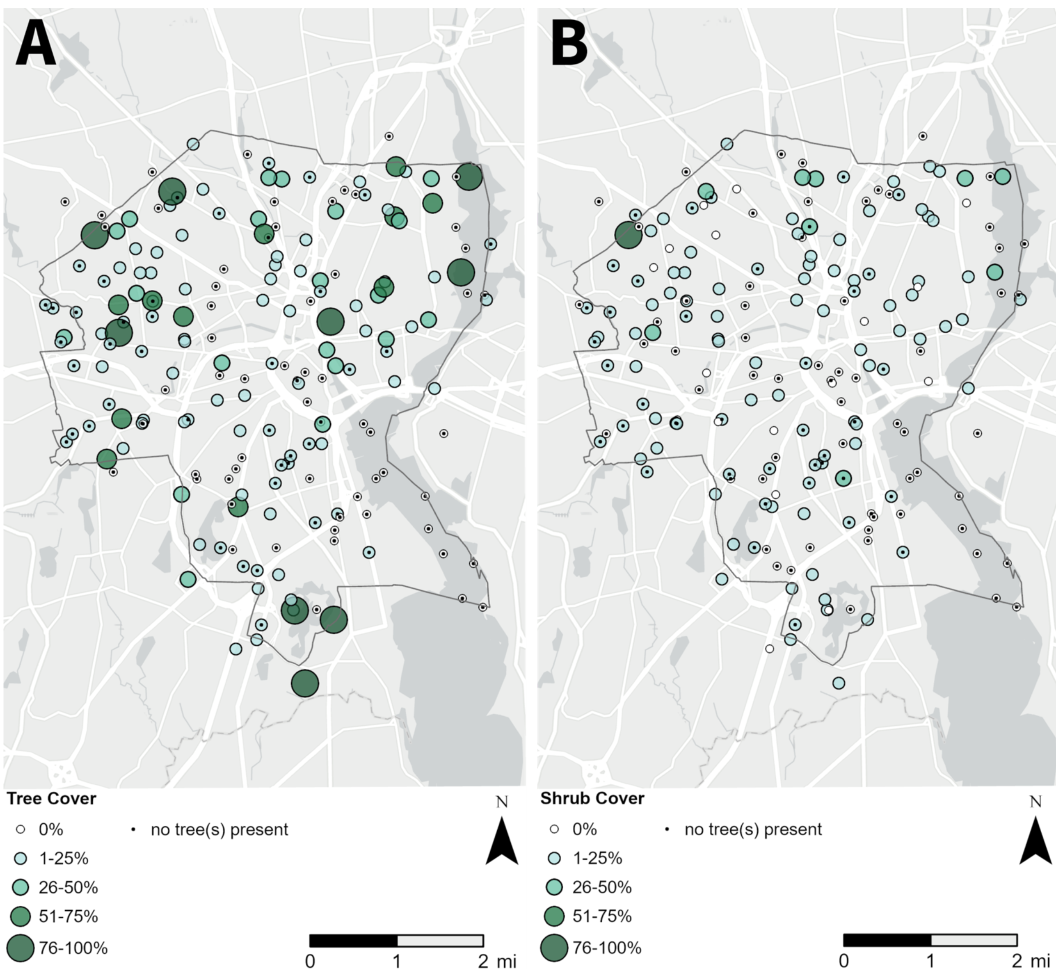

Figure 3.—Tree (A) and shrub (B) cover estimates for each Forest Inventory and Analysis (FIA) plot using approximate plot locations, City of Providence, 2021. The Light Gray Canvas basemap layer was provided by Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community.

Table 6.—Average percent tree, shrub, and impervious cover by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021

FIA land use class	Tree (percent)	Shrub (percent)	Impervious (percent)
Forest land	84.7	39.6	0.0
Commercial/Industrial	9.8	4.5	44.2
Multi-family residential	22.0	4.2	40.3
Residential	15.6	7.8	23.0
Recreation/Cemetery	61.7	8.9	13.0
Rights-of-way	11.3	1.5	85.3
Water	1.2	0.7	0.0
Total	**16.5**	**5.5**	**41.7**
Total standard error	**9.1**	**0.7**	**1.9**

Due to rounding, not all values will add up exactly.

Field crews categorized ground surface cover on each field plot according to five classes: (i) building, (ii) low vegetation (woody plants under 1 foot tall and all herbaceous plants), (iii) permeable (soil, leaf litter, mulch, gravel, etc.), (iv) impervious (non-building), or (v) water. Permeable and low vegetation ground covers account for 31.2 percent of all ground covers, while building and other impervious cover account for 57.6 percent (Figs. 4 and 5). An additional 11.2 percent of the city is classified as water.

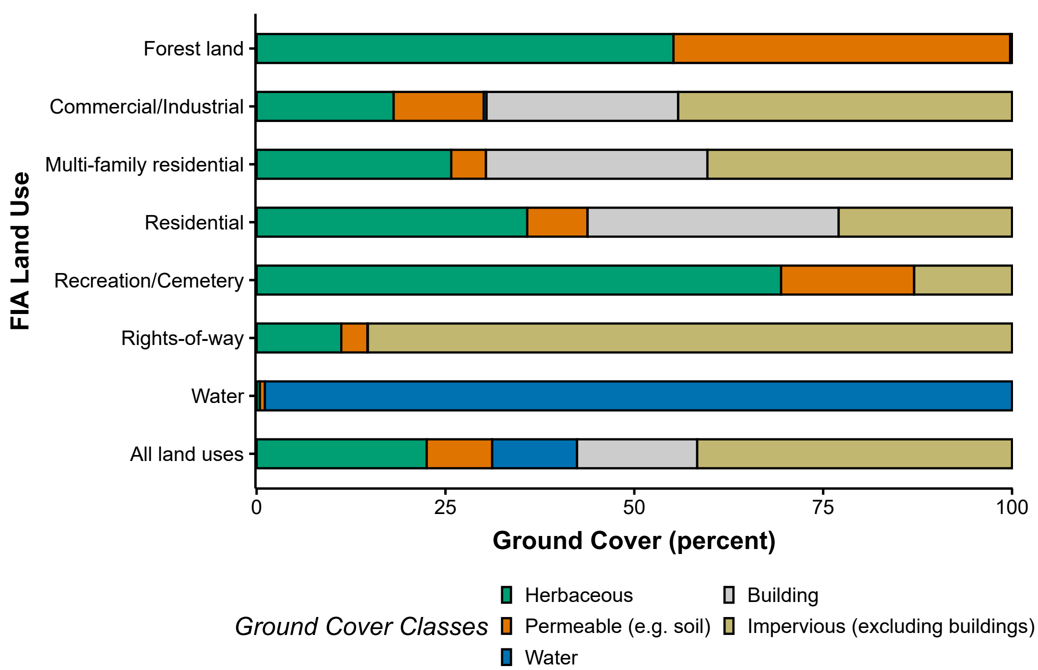

Figure 4.—Average ground cover by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021.

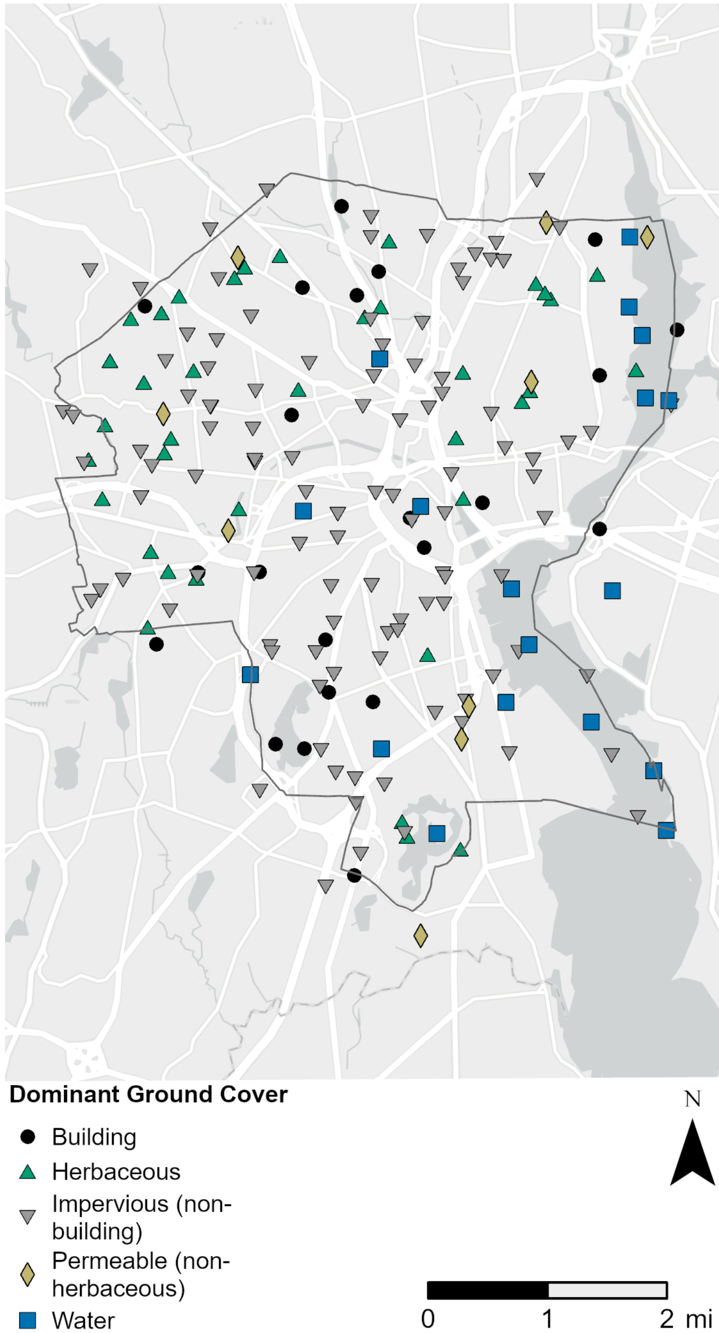

Figure 5.—Dominant ground cover for each Forest Inventory and Analysis (FIA) plot using approximate plot locations, City of Providence, 2021. The Light Gray Canvas basemap layer was provided by Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community. Note: plot locations are approximate; therefore herbaceous, impervious, and other terrestrial cover types may appear to intersect bodies of water on the base map.

Ownership

Plot ownership was divided into private, State and local government, Federal government, and unknown (water) classes. The most dominant ownership in Providence is private (54.7 percent), followed by State and local (33.7 percent), unknown (water) (11.2 percent) and Federal (0.4 percent) (Table 7). Percent tree cover is greatest in Federal (100.0 percent), followed by State and local (18.9 percent), and private (17.6 percent). In Providence, there are a total of 346,759 trees (70 percent of the live tree population) on private lands, 140,751 trees (28.4 percent) on State and local land, and 5,970 trees (1.2 percent) on Federal lands (Table 7). Providence's sapling (trees 1.0–4.9 inches in diameter) population is mostly found on private lands (76.0 percent), followed by State and local lands (24.0 percent) (Table 7).

Table 7.—Number of live trees by ownership and diameter class, City of Providence, 2021

Ownership class	1.0–4.9 in. diameter trees (number)	5.0–10.9 in. diameter trees (number)	11.0+ in. diameter trees (number)	Total (number)	Area (acres)
Private	220,000	74,000	53,000	347,000	7,200
State and Local	70,000	40,000	32,000	141,000	4,400
Unknown (water)	0	1,300	400	1,700	1,500
Federal	0	500	5,500	6,000	55
Total	**289,000**	**115,000**	**91,000**	**495,000**	**13,000**

Due to rounding, not all values will add up exactly.

FOREST STRUCTURE

Norway maple trees, one of the most common tree species in the city of Providence, lining a residential street. USDA Forest Service photo by Jesse Caputo.

Number of Trees

Providence's urban forest has an estimated 495,000 live trees and 33,000 standing dead trees. The number of trees varies by land use and diameter class. The greatest proportion of the trees in Providence are located on commercial/industrial land (42.6 percent, 210,971 trees) (Table 8). Overall, 58.4 percent of Providence's trees are saplings, while the remaining 23.2 percent and 18.4 percent are medium trees (5.0–10.9 inches in diameter) and large trees (≥11.0 inches in diameter), respectively.

The greatest proportion of trees (38.4 percent) are found within the dev-low land cover class group. The highest tree density (173.6 trees per acre) is found on the dev-low cover class group (Table 9).

Table 8.—Number of live trees by Forest Inventory and Analysis (FIA) land use class and diameter class, City of Providence, 2021

FIA land use class	1.0–4.9 in. diameter trees (number)	5.0–10.9 in. diameter trees (number)	11.0+ in. diameter trees (number)	Total (number)	Total standard error (number)	Density (no./ac)
Forest land	61,000	27,000	20,000	109,000	50,000	234
Commercial/ Industrial	175,000	23,000	13,000	211,000	119,000	58
Multi-family residential	5,300	4,600	7,300	17,000	8,500	19
Residential	18,000	34,000	16,000	68,000	23,000	25
Recreation/ Cemetery	0	16,000	20,000	36,000	14,000	54
Rights-of-way	30,000	9,600	13,000	53,000	35,000	16
Water	0	1,300	400	1,700	1,400	1
Total	**289,000**	**115,000**	**91,000**	**495,000**	**–**	**38**
Total standard error	**117,000**	**21,000**	**12,000**	**129,000**	**–**	**–**

Due to rounding, not all values will add up exactly.

– = no value for cell

Table 9.—Number of live trees by National Land Cover Database (NLCD) land cover class group and diameter class, City of Providence, 2021

NLCD land cover class group	1.0–4.9 in. diameter trees (number)	5.0–10.9 in. diameter trees (number)	11.0+ in. diameter trees (number)	Total (number)	Total standard error (number)	Density (no./ac)
Dev-open/veg	27,000	23,000	27,000	77,000	21,000	84
Developed-low	158,000	16,000	16,000	190,000	116,000	174
Developed-medium	89,000	53,000	31,000	172,000	51,000	39
Developed-high	16,000	15,000	15,000	47,000	12,000	9
Water	0	7,500	2,000	9,500	8,800	8
Total	**289,000**	**115,000**	**91,000**	**495,000**	**–**	**38**
Total standard error	**117,000**	**21,000**	**12,000**	**129,000**	**–**	**–**

Due to rounding, not all values will add up exactly.

– = no value for cell

Species Composition

The 10 most common tree species[4] by number account for 65.3 percent of all recorded live trees and are Norway maple, black oak, northern white-cedar, white mulberry, American elm, black cherry, apple spp., northern red oak, red maple, and black locust (Table 10, Fig. 6). A breakdown of the estimated number of each recorded tree species by diameter classes is presented in Appendix 2. The relative abundance of the most common trees by species and diameter class are presented in Table 11 and Figures 7 and 8. Small diameter trees (saplings) are generally the most abundant of the three tree size classes for the 10 most common tree species, comprising 66.8 percent of the total, while large diameter trees comprise only 13.9 percent of the total (Table 11, Fig. 7). When broken down into 2-inch diameter classes, the top five most common species by number showed an abundance distribution similarly skewed toward smaller diameter trees (Fig. 8).

Table 10.—Urban forest tree species composition, City of Providence, 2021

Common name	Trees (number)	Percent
Norway maple	98,000	19.7
black oak	48,000	9.7
northern white-cedar	41,000	8.2
white mulberry	28,000	5.7
American elm	27,000	5.5
black cherry	20,000	4.1
apple spp.	19,000	3.9
northern red oak	15,000	3.1
red maple	14,000	2.8
black locust	13,000	2.7
English yew	13,000	2.7
pin cherry	13,000	2.6
Japanese flowering cherry	11,000	2.3
American beech	11,000	2.2
red mulberry	11,000	2.2
sugar maple	9,400	1.9
flowering dogwood	7,700	1.5
white ash	6,800	1.4
Japanese yew	6,300	1.3
green ash	6,300	1.3
scarlet oak	5,500	1.1
Japanese maple	4,900	1.0
eastern white pine	4,100	0.8
honeylocust	3,500	0.7
Callery pear	3,500	0.7
red pine	3,500	0.7
sycamore maple	3,500	0.7
eastern redcedar	3,400	0.7
sweet birch	2,900	0.6
pignut hickory	2,600	0.5
Austrian pine	2,500	0.5
Japanese zelkova	2,400	0.5
European beech	2,300	0.5
white oak	2,200	0.4
boxelder	2,100	0.4
silver maple	2,100	0.4
northern catalpa	2,000	0.4
London planetree	1,900	0.4
pin oak	1,800	0.4
Atlantic white-cedar	1,600	0.3
katsura tree	1,500	0.3
sweet cherry	1,300	0.3
eastern cottonwood	1,300	0.3
tree of heaven	1,300	0.3
Siberian elm	1,200	0.2
littleleaf linden	1,200	0.2
American basswood	1,200	0.2
yellow-poplar	995	0.2
mockernut hickory	866	0.2
black walnut	866	0.2
Chinese elm	832	0.2
Norway spruce	498	0.1
blue spruce	498	0.1
river birch	498	0.1
hawthorn spp.	498	0.1
sweet crab apple	498	0.1
silver poplar	498	0.1
Freeman maple	498	0.1
cedar of Lebanon	498	0.1
pear spp.	498	0.1
sawara-cypress	433	0.1
sweetgum	416	0.1
eastern hemlock	396	0.1
Total	**495,000**	**100.0**

Due to rounding, not all numbers will add up exactly.

For a breakdown of tree species composition by diameter class, refer to Appendix 2.

[4] Common and scientific names for all tree species observed in the 2021 Urban FIA inventory of Providence are reported in Appendix 2.

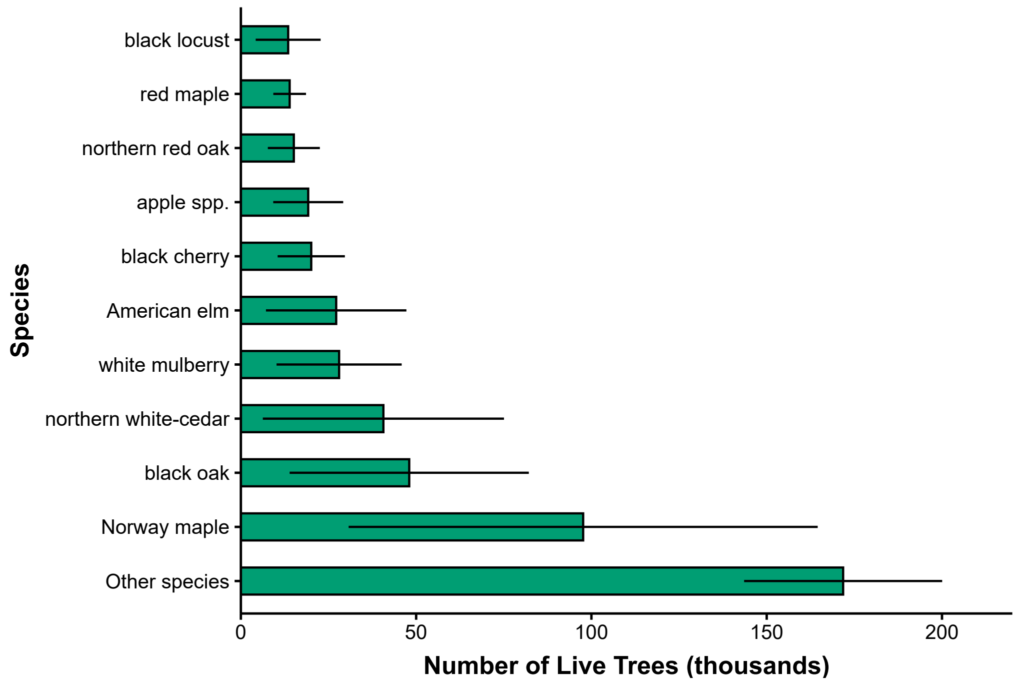

Figure 6.—The 10 most common tree species by number of trees, City of Providence, 2021. Other species is the total for all other tree species in the inventory. Error bars represent 68 percent confidence intervals around the estimated means.

Table 11.—Number of live trees by size class for the 10 most common tree species, City of Providence, 2021

Common name	1.0–4.9 in. diameter trees (number)	5.0–10.9 in. diameter trees (number)	11.0+ in. diameter trees (number)	Total (number)
Norway maple	66,000	17,000	15,000	98,000
black oak	35,000	4,100	9,400	48,000
northern white-cedar	32,000	8,500	500	41,000
white mulberry	21,000	3,800	3,100	28,000
American elm	15,000	9,500	2,900	27,000
black cherry	15,000	3,500	1,300	20,000
apple spp.	17,000	2,200	500	19,000
northern red oak	4,900	4,500	5,700	15,000
red maple	0	7,500	6,400	14,000
black locust	12,000	1,800	0	13,000
Total	**216,000**	**62,000**	**45,000**	**323,000**

Due to rounding, not all values will add up exactly.

Standard errors for each estimate are reported in Appendix 2.

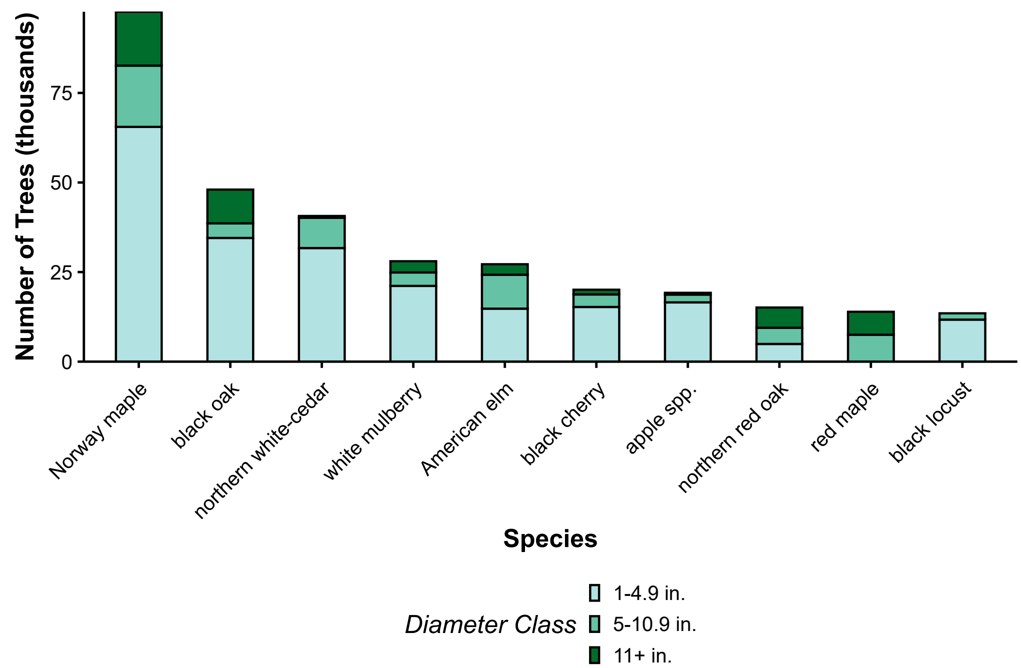

Figure 7.—The number of trees in each size class for the 10 most common tree species, City of Providence, 2021.

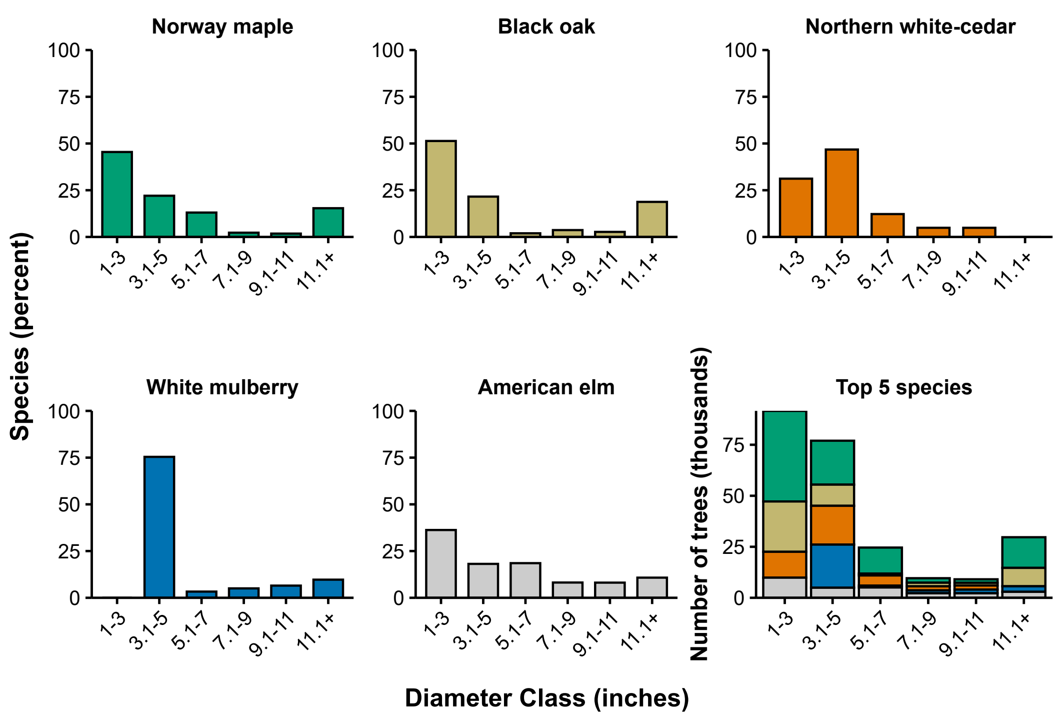

Figure 8.—Percentage of species population by diameter class for the five most common tree species, City of Providence, 2021.

The preceding table and figures highlight the most prominent species by number for all trees 1.0 inch in diameter and larger. As smaller diameter trees are generally more abundant per unit area, the overall species composition may be more reflective of the smaller diameter species when analyzing estimates based on number of trees. For this reason, it is also helpful to rank species according to other metrics such as the number of trees within various size classes, leaf area, importance value, volume, or biomass. The three most common species in terms of stem numbers in the smallest-diameter size classes (less than 5.0 inches in diameter) are Norway maple, black oak, and northern white-cedar, together representing less than half (45.5 percent) of all live trees less than 5.0 inches in diameter (Table 12, Appendix 2). Norway maple, American elm, and northern white-cedar are the most common species in intermediate diameter size classes, representing 30.5 percent of all live trees between 5.0 and 10.9 inches in diameter. Dominant species in the largest diameter classes, often the most recognizable component of the urban forest canopy, are Norway maple, black oak, and red maple, comprising 33.9 percent of live trees at least 11.0 inches in diameter (Table 12, Appendix 2).

Table 12.—The most common tree species by diameter class, City of Providence, 2021

Diameter class (inches)	Common name	Trees (number)
1.0–4.9	Norway maple	66,000
	black oak	35,000
	northern white-cedar	32,000
	white mulberry	21,000
	apple spp.	17,000
5.0–10.9	Norway maple	17,000
	American elm	9,500
	northern white-cedar	8,500
	red maple	7,500
	Japanese yew	6,300
11.0+	Norway maple	15,000
	black oak	9,400
	red maple	6,400
	northern red oak	5,700
	American beech	3,900

Estimates are rounded.

Standard errors for each estimate are reported in Appendix 2.

In Providence, tree species composition on private land is dominated by Norway maple (26.9 percent), northern white-cedar (10.0 percent), and apple spp. (5.5 percent) (Table 13). The most common tree species on public lands are black oak (23.3 percent), American elm (13.9 percent), and white mulberry (10.0 percent) (Table 14). A total of 45 tree species are recorded on private lands, resulting in a **Shannon-Wiener diversity index** value of 3.0. The 43 species of trees recorded on public lands results in a Shannon-Wiener diversity index value of 2.9. As calculated, this diversity index takes into account tree species richness (total number of species) and species evenness (relative abundances among species) and ranges from approximately 2.0 to 3.5 within cities measured using Urban FIA protocol. On private land, the top three genera with the greatest number of trees are maple (*Acer*), cherry (*Prunus*), and white-cedar (*Thuja*). On public land they are oak (*Quercus*), elm (*Ulmus*), and mulberry (*Morus*) (Fig. 9). Species composition within NLCD land cover group class is detailed in Appendix 3.

Table 13.—Species composition on private lands, City of Providence, 2021

Common name	Trees (percent)
Norway maple	26.9
northern white-cedar	10.0
apple spp.	5.5
black locust	3.9
black oak	3.9
white mulberry	3.8
English yew	3.8
black cherry	3.7
pin cherry	3.7
northern red oak	3.2
American beech	3.2
Japanese flowering cherry	2.9
red maple	2.2
flowering dogwood	2.2
sugar maple	2.1
American elm	1.9
white ash	1.8
Japanese yew	1.8
green ash	1.6
red mulberry	1.5
Japanese maple	1.4
sycamore maple	1.0
eastern redcedar	1.0
scarlet oak	0.7
Callery pear	0.6
boxelder	0.6
silver maple	0.6
Atlantic white-cedar	0.5
northern catalpa	0.5
pin oak	0.4
sweet cherry	0.4
tree of heaven	0.4
white oak	0.4
European beech	0.3
eastern white pine	0.3
sweet birch	0.2
blue spruce	0.1
eastern cottonwood	0.1
Freeman maple	0.1
pear spp.	0.1
American basswood	0.1
sawara-cypress	0.1
honeylocust	0.1
Japanese zelkova	0.1
eastern hemlock	0.1

Estimates are rounded.

Table 14.—Species composition on public lands, City of Providence, 2021

Common name	Trees (percent)	Common name	Trees (percent)
black oak	23.3	Siberian elm	0.8
American elm	13.9	littleleaf linden	0.8
white mulberry	10.0	yellow-poplar	0.7
black cherry	4.8	Japanese flowering cherry	0.7
red maple	4.2	white oak	0.6
northern white-cedar	4.0	green ash	0.6
red mulberry	3.6	mockernut hickory	0.6
Norway maple	3.0	black walnut	0.6
northern red oak	2.7	Chinese elm	0.6
red pine	2.3	eastern cottonwood	0.5
eastern white pine	2.1	American basswood	0.5
honeylocust	2.1	Norway spruce	0.3
scarlet oak	2.0	river birch	0.3
pignut hickory	1.8	hawthorn spp.	0.3
Austrian pine	1.7	sweet crab apple	0.3
sugar maple	1.4	silver poplar	0.3
sweet birch	1.3	cedar of Lebanon	0.3
Japanese zelkova	1.3	white ash	0.3
London planetree	1.3	sweetgum	0.3
katsura tree	1.0	northern catalpa	0.3
Callery pear	1.0	pin oak	0.3
European beech	0.9		

Estimates are rounded

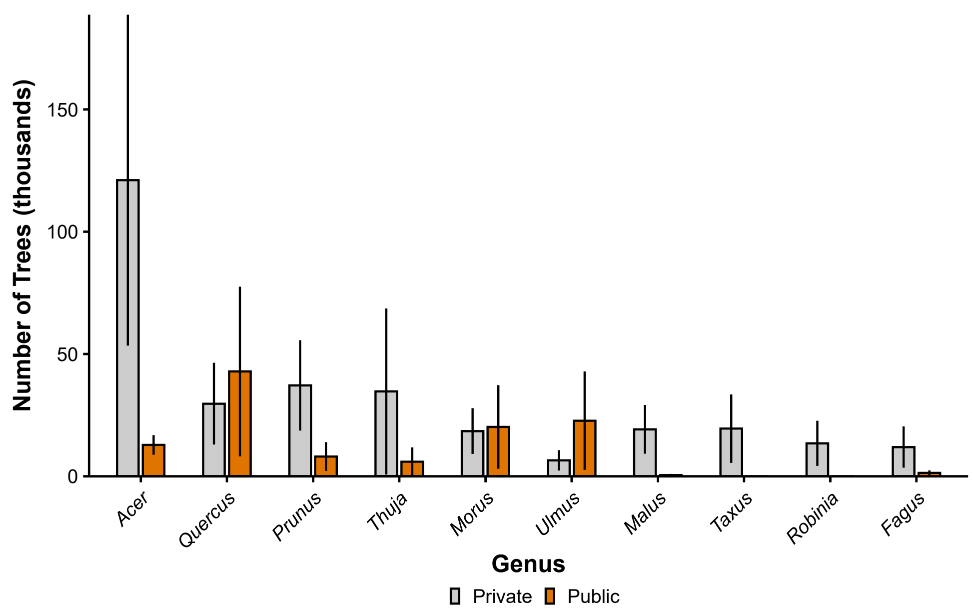

Figure 9.—The 10 most common genera within ownership classes, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

Maintained Area Trees

Overall, 34.7 percent of trees in Providence are found in maintained areas. Maintained areas are those which are regularly impacted by mowing, weeding, cutting, brush clearing, herbicide applications, etc. Examples of maintained areas include, but are not limited to, lawns, shrub and flower beds, rights-of-way, and manicured parks. However, a tree found in a maintained area has not necessarily received care. In Providence, the most common tree species in maintained areas are northern white-cedar (20.2 percent of all trees in maintained areas), Norway maple (8.2 percent), and English yew (7.7 percent) (Table 15). Appendix 4 lists the composition of tree species in maintained areas for Providence.

Table 15.—The 10 most common tree species in maintained areas, City of Providence, 2021

Common name	Trees (number)	Percent of all trees in maintained areas
northern white-cedar	35,000	20.2
Norway maple	14,000	8.2
English yew	13,000	7.7
sugar maple	9,400	5.5
white mulberry	9,400	5.4
apple spp.	7,900	4.6
Japanese yew	6,300	3.7
Japanese flowering cherry	6,300	3.6
red mulberry	5,300	3.1
Japanese maple	4,900	2.9

Estimates are rounded.

Leaf Area

Leaf area is correlated with many ecosystem services provided by the urban forest. It is estimated as the surface area (on one side) of the leaves on a given tree or in an area. The proportion of total leaf area in the urban forest is greatest for trees 29.1+ inches in diameter (17.3 percent), followed by 5.1–7.0 inches in diameter (8.1 percent), and 3.1–5.0 inches in diameter (7.9 percent) (Fig. 10). In Providence, leaf area is greatest in forest land uses (23.7 percent of total leaf area), followed by commercial/industrial (21.9 percent), and recreation/cemetery land uses (21.1 percent) (Fig. 11).

Leaf area index (LAI) refers to a standardized measure of leaf surface area per unit of tree cover and is calculated as the total leaf area divided by the total ground area covered by tree canopies. Higher LAI values indicate a greater depth or layering of leaves in the tree canopy. As each land use class has a different amount of area covered by trees, LAI allows for standardized comparison of leaves per unit canopy area among land use classes (acres of leaves per acre of tree cover). The leaf area index in land uses with trees ranges from 14.1 in forest land use to 3.3 in water (Fig. 11).

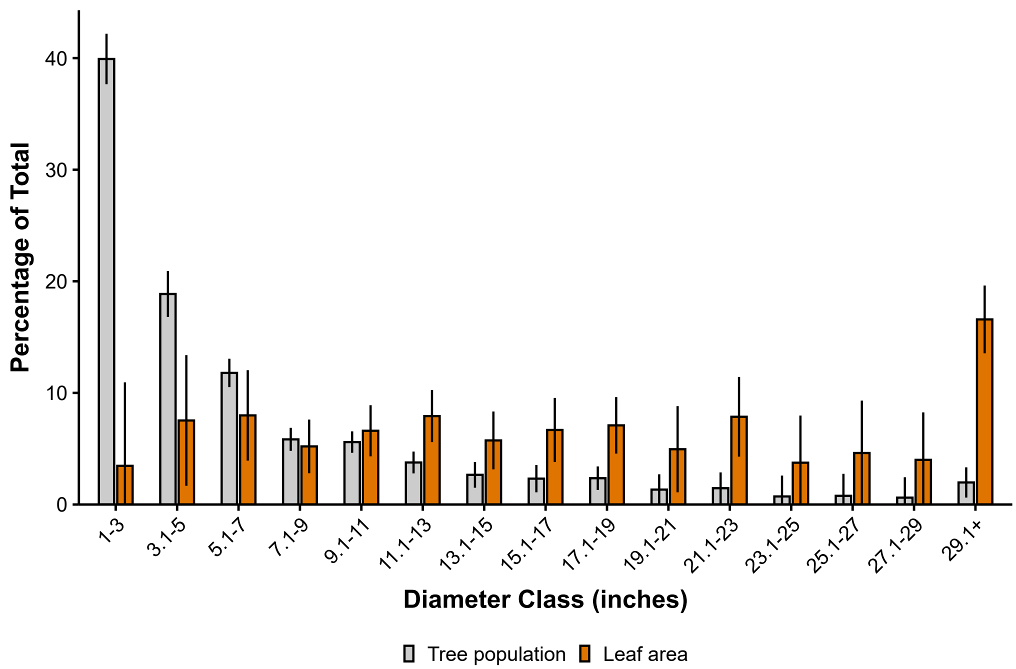

Figure 10.—Percent of tree population and leaf area by 2-inch diameter class, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

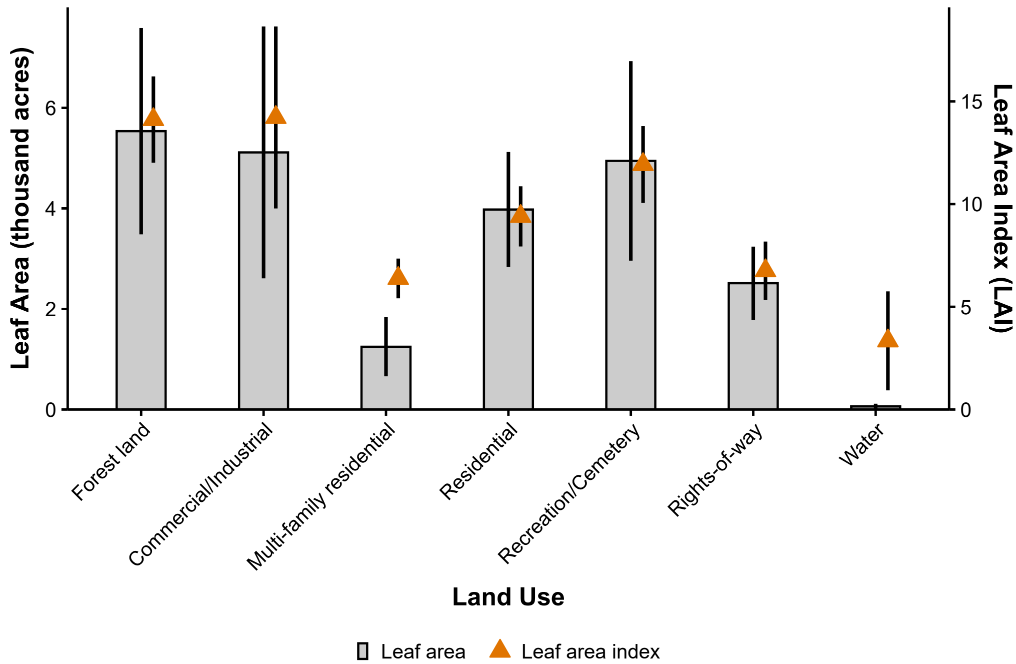

Figure 11.—Leaf area and leaf area index (LAI) by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

Species Importance

Importance values (IVs) establish the relative contribution of the observed species to the overall species composition of the urban forest and are calculated by summing the values of its relative leaf area and relative abundance. High importance values do not mean that these trees should be encouraged in the future, but rather that they currently dominate the urban forest structure in terms of their population size and leaf area. The species in Providence's urban forest with the greatest IVs are Norway maple (41.4), black oak (16.2), and northern red oak (10.2) (Table 16).

Table 16.—Percent of total tree population represented by tree species with the highest importance value (IV), City of Providence, 2021

Common name	Population (percent)	Leaf area (percent)	Importance value
Norway maple	19.7	21.7	41.4
black oak	9.7	6.5	16.2
northern red oak	3.1	7.2	10.2
American elm	5.5	4.2	9.7
northern white-cedar	8.2	1.3	9.5
white mulberry	5.7	2.8	8.4
red maple	2.8	5.5	8.3
American beech	2.2	4.7	6.9
sugar maple	1.9	4.0	5.9
black cherry	4.1	1.3	5.4

Estimates are rounded.

Importance value = population (%) + leaf area (%).

VOLUME AND BIOMASS

London planetrees lining a city neighborhood street in Providence. Courtesy photo by AJ Elton of City of Providence, Forestry Division.

Wood Volume and Value

Wood volume is a measure of the solid content of the tree stem and is used to estimate wood quantity. A detailed description of methods used to compute wood volume in terms of net cubic foot volume and **sawtimber volume** for this report is presented in Baer et al. (2025). Understanding the net volume of wood provided by a community's trees can serve a variety of purposes. From a management perspective, a thorough knowledge of wood volume can help predict potential storm damage and support planning for post-disaster recovery, including debris removal and cost. Volume data can also inform urban wood markets, which add value to traditional wood waste derived from tree removal, storm damage, and general tree maintenance. Such data can incentivize repurposing wood waste into traditional wood products such as lumber, handcrafted furniture, nature-based landscape supplies, and biofuel (e.g., Nowak et al. 2019).

In Providence, live trees at least 5.0 inches in diameter are estimated to contain 3.8 million cubic feet of net volume, of which 9.6 million board feet is sawtimber volume. To put this value in perspective, the median size of American homes constructed in 2019 was 2,301 square feet (U.S. Census Bureau 2020), which would require approximately 14,500 board feet to construct. Thus, the net sawtimber volume of Providence's urban forest is roughly equivalent to the amount of wood that would be needed to construct 663 median-sized homes. Norway maple contributes the greatest net cubic-foot volume at 12.8 percent of the city's total (Table 17). Northern red oak contributes 17.2 percent of the total net **board-foot** sawtimber volume (Table 18). By diameter class, the greatest net cubic-foot volume is provided by trees 29.1 inches or greater in diameter (Fig. 12).

Table 17.—Net cubic-foot volume for tree species with greatest net volume, City of Providence, 2021

Common name	Net volume (cubic feet)	Standard error (cubic feet)	Net volume (percent)
Norway maple	486,000	138,000	12.8
northern red oak	363,000	214,000	9.5
black oak	334,000	156,000	8.8
European beech	309,000	168,000	8.1
eastern white pine	305,000	283,000	8.0
sugar maple	214,000	156,000	5.6
scarlet oak	191,000	87,000	5.0
American beech	165,000	116,000	4.3
red maple	161,000	70,000	4.2
eastern cottonwood	118,000	95,000	3.1
Other species	1,160,000	182,000	30.5
Total	**3,810,000**	**523,000**	**100.0**

Due to rounding, not all values will add up exactly.

Other species is the total for all other tree species in the inventory.

Table 18.—Net board-foot sawtimber volume for tree species with greatest net volume, City of Providence, 2021

Common name	Net volume (board feet)	Standard error (board feet)	Net volume (percent)
northern red oak	1,650,000	1,170,000	17.2
eastern white pine	1,650,000	1,610,000	17.2
black oak	1,280,000	681,000	13.3
eastern cottonwood	859,000	711,000	8.9
Norway maple	822,000	406,000	8.6
American beech	680,000	524,000	7.1
sugar maple	535,000	409,000	5.6
scarlet oak	506,000	257,000	5.3
pignut hickory	230,000	234,000	2.4
American elm	195,000	140,000	2.0
Other species	1,210,000	376,000	12.6
Total	**9,610,000**	**2,330,000**	**100.0**

Due to rounding, not all values will add up exactly.

Other species is the total for all other tree species in the inventory.

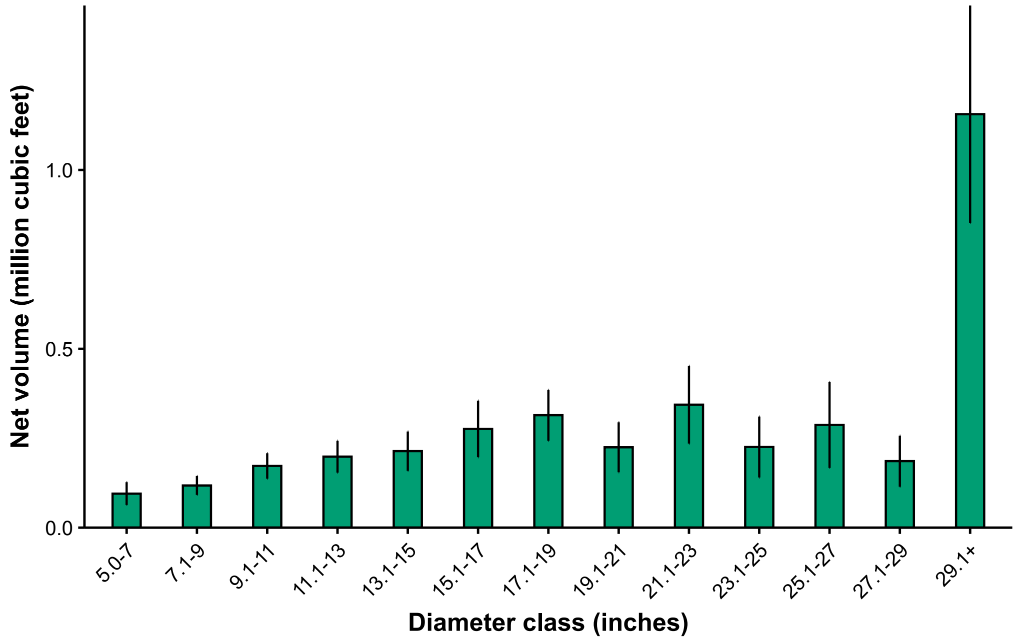

Figure 12.—Net cubic-foot volume by tree diameter class, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

While **sawtimber** could potentially be derived from urban forests to provide economic value, the broader social-ecological value of this forest is derived from healthy trees. Healthy urban forests provide benefits that support environmental and human health and well-being and are valued at over $18 billion per year nationally (Nowak and Greenfield 2018). Harvesting healthy urban trees will reduce local annual benefits. Utilizing urban wood waste, however, does not affect the healthy tree canopy and augments the value of the urban forest. Urban wood waste could produce between $89–786 million per year nationally depending upon the product derived (e.g., wood chips to lumber) (Nowak et al. 2019).

Increasing public interest in environmentally responsible and sustainable products presents opportunities for urban wood utilization programs. In urban settings, trees generally only become a source for wood products after removal for development purposes or because of safety factors including age, pest and disease damage, or storm events. Many of these urban trees are unsuitable for traditional sawtimber products but may still have economic and cultural value. Methods to evaluate the quality of urban wood for potential products are not well defined since wood markets and products are quite varied across different geographic areas. Further research would allow for the development of metrics to evaluate the amount of urban wood waste available for specialty products. For example, many consumers of urban wood are interested in wood with grain character. Character wood that contains knots, insect damage and distorted grain is often highly desirable for specialty products, but these are the same wood qualities that make for less desirable traditional lumber. Urban wood waste utilization programs and markets may be better informed by drawing upon available FIA information about net growth, removals, and mortality.

Biomass

Like wood volume, tree biomass information is important in estimating both wood production and carbon storage. The overall aboveground biomass of all live trees in Providence is estimated at 264,000 green tons, which includes the weight of its moisture content (Table 19). The amount of biomass stored by live trees in Providence varies by species. The tree species with the greatest total above-ground biomass are northern red oak (12.5 percent), Norway maple (11.0 percent), and European beech (10.6 percent) (Table 19).

Table 19.—Aboveground biomass for tree species with the greatest biomass, City of Providence, 2021

Common name	Biomass (green tons)	Standard error (green tons)	Biomass (percent)
northern red oak	33,000	18,000	12.5
Norway maple	29,000	7,900	11.0
European beech	28,000	15,000	10.6
black oak	26,000	11,000	9.7
scarlet oak	16,000	8,300	6.0
sugar maple	15,000	11,000	5.8
red maple	12,000	5,800	4.4
eastern white pine	11,000	9,900	4.1
silver maple	10,000	7,300	3.8
American beech	8,000	5,600	3.0
Other species	76,000	12,000	28.9
Total	**264,000**	**34,000**	**100.0**

Due to rounding, not all values will add up exactly.

Other species is the total for all other tree species in the inventory.

URBAN FOREST VALUES

Mature trees lining a city neighborhood street in Providence. Courtesy photo by AJ Elton of City of Providence, Forestry Division.

Urban forest values can be quantified as functional or structural. Social and biophysical functional values, either positive (e.g., decreased energy use) or negative (e.g., increased energy use) are based on the annual functions the trees perform, including sequestering carbon, removing air pollutants, and influencing surrounding microclimates which affects the amount of energy used to heat or cool buildings. The forest may provide many other functional values that are not quantified in this report (e.g., reduction in ultraviolet radiation, wildlife habitat, enhanced recreational opportunities, fostering social cohesion, and community health and well-being). Thus, the functional estimates provided in this report represent only a portion of the total forest functional values. Structural values include the amount of carbon stored by a tree and the tree's compensatory value, which can be thought of as the replacement value of the tree. Structural and functional values tend to increase with increased number and size of healthy trees and are usually on the order of several million dollars per year at a city scale.

Forest management activities can increase the values and services provided by the urban forest. However, these values and benefits can also decrease if the amount of healthy tree cover declines. Various costs associated with urban forest management, such as tree pruning, inspection, removal and disposal are not accounted for in this assessment and may offset some of the estimated monetary benefits described here (McPherson et al. 2005).

Urban forest ecosystem services associated with air pollution removal, avoided runoff, carbon sequestration, and compensatory value exclude dead trees, as these benefits are mainly based on existing leaf area, leaf biomass, or live tree conditions. However, standing dead trees do contribute to carbon storage and energy effects and are included in estimates for these values.

Air Pollution

Poor air quality is a common problem in urban areas. Air pollution can adversely affect human health through increased rates of pulmonary, cardiac, vascular, and neurological diseases and mortality (Pope et al. 2002), along with negatively impacting ecosystem processes and reducing visibility. Urban forests can improve air quality by directly removing pollutants from the air and reducing energy consumption by buildings, which consequently reduces air pollution emissions from power plants and other energy sources. While trees emit volatile organic compounds (VOCs) that can contribute to ozone (O_3) formation (Fehsenfeld et al. 1992, Karlik and Pittenger 2012), integrative studies have revealed that an increase in tree cover tends to reduce O_3 formation, although the extent to which this is the case depends upon species composition (Calfapietra et al. 2013; Manes et al. 2012; Nowak et al. 2000, 2006).

Pollution removal by the urban forest in Providence is greatest for O_3 (58.9 tons per year), followed by nitrogen dioxide (NO_2; 13.6 tons per year), carbon monoxide (CO; 4.0 tons per year), particulate matter less than 2.5 microns ($PM_{2.5}$; 3.7 tons per year), and sulfur dioxide (SO_2; 0.4 tons per year) (Fig. 13). The economic value of this pollution removed is estimated using i-Tree methodology in one of two ways, depending on the pollutant. For NO_2, SO_2, O_3, and $PM_{2.5}$, estimates are based on avoided health effects due to lower pollution concentrations. For CO, the estimated value is based on the avoided externality costs of air pollution to society (Nowak 2024). The estimated value associated with pollution removal is greatest for $PM_{2.5}$ ($2.3 million), followed by O_3 ($758,000), NO_2 ($21,000), CO ($5,300), and SO_2 ($300) (Table 20). It is estimated that trees in Providence remove a total of 81 tons of air pollution per year with an associated value of $3.1 million. More information about value calculations can be found in Baer et al. (2025).

Decreases in the concentration of various air pollutants due to removal by trees is expected to have a positive effect on human health in Providence (Nowak et al. 2014, U.S. EPA 2012). Using measured field data and pollution data from 2015, air quality improvements from trees produce numerous health benefits including an estimated 283 fewer cases of acute respiratory symptoms per year with an associated value of over $25,000 (Table 20).

Trees in Providence emit an estimated 85 tons of VOCs (27 tons of isoprene and 58 tons of monoterpenes) per year. Emissions vary among species based on species characteristics (e.g., some genera such as oaks are high isoprene emitters) and leaf biomass. The genera *Quercus* and *Acer* contribute 78.9 percent of VOC emissions (Fig. 14). These VOCs are precursor chemicals to ozone formation.

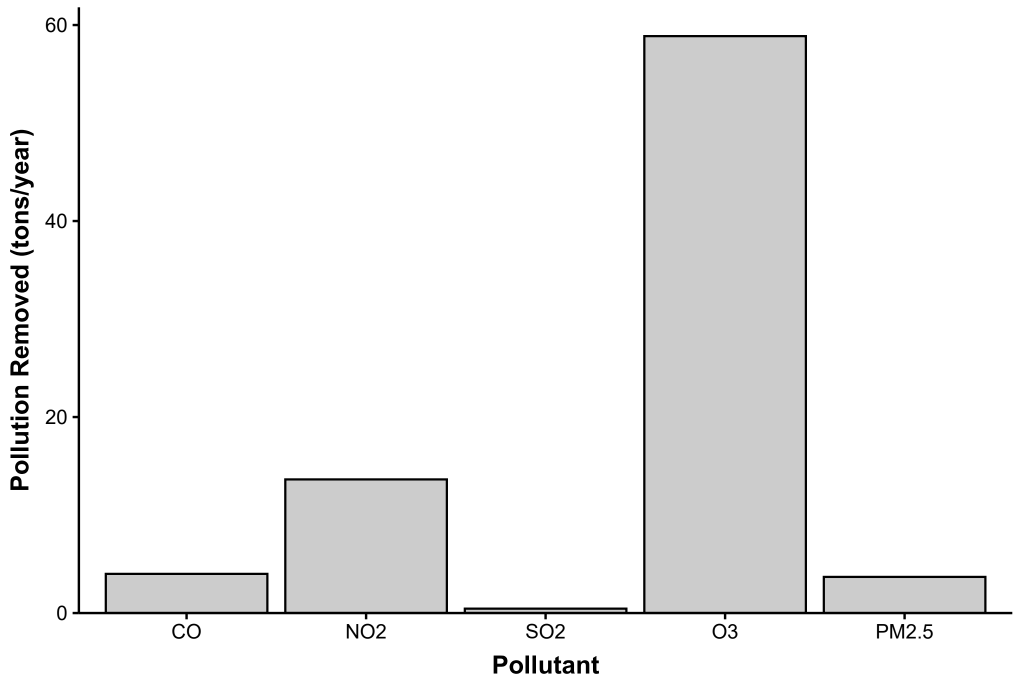

Figure 13.—Air pollution removal by trees, City of Providence, 2021.

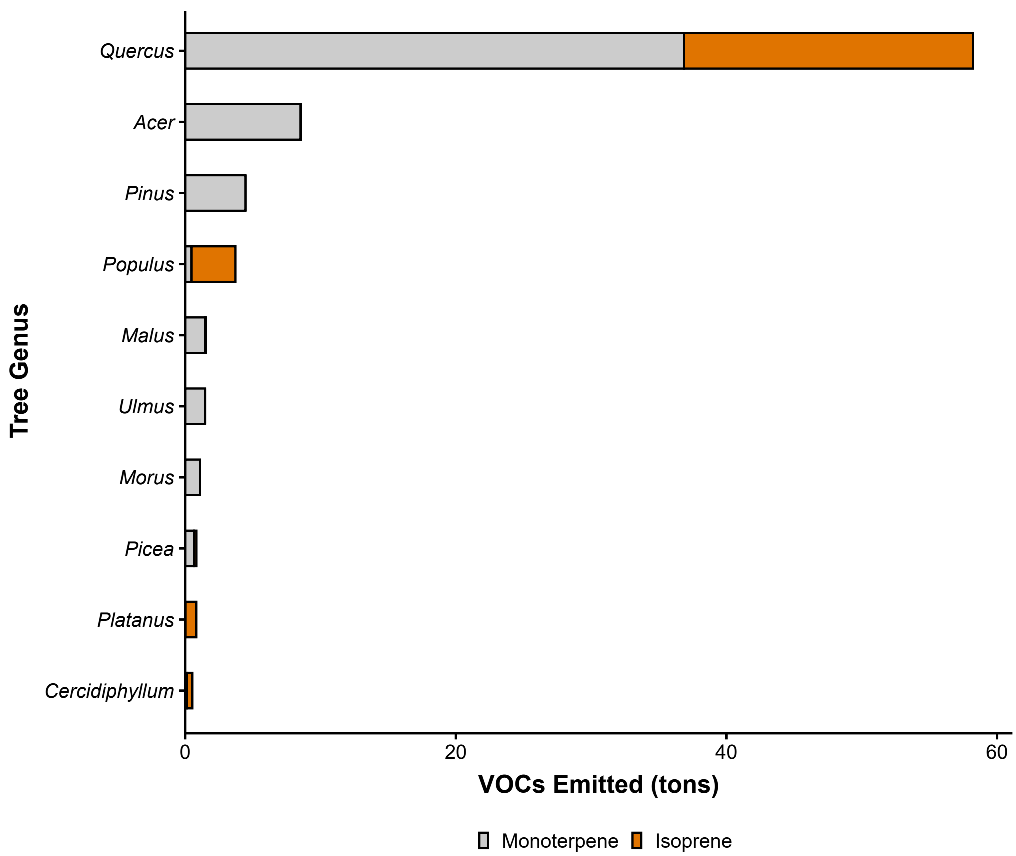

Figure 14.—Volatile organic compound (VOC) emissions by genus, City of Providence, 2021.

Table 20.—Incidence and associated value of avoided health effects from changes in pollution concentrations due to pollution removal by trees, City of Providence, 2021

	Nitrogen dioxide (NO_2)		Sulfur dioxide (SO_2)		Ozone (O_3)		Particulate matter ($PM_{2.5}$)	
Health effect	**Incidence (cases/year)**	**Associated value ($/year)**	**Incidence (cases/year)**	**Associated value ($/year)**	**Incidence (cases/year)**	**Associated value ($/year)**	**Incidence (cases/year)**	**Associated value ($/year)**
Acute Bronchitis	–	–	–	–	–	–	0.2	15.7
Acute Myocardial Infarction	–	–	–	–	–	–	0.1	5,600
Acute Respiratory Symptoms	9.2	290	0.1	3.8	170	14,000	110	10,000
Asthma Exacerbation	140	12,000	1.1	83.8	–	–	80.7	6,600
Chronic Bronchitis	–	–	–	–	–	–	0.1	20,000
Emergency Room Visits	0.1	52.7	<0.1	2.1	0.1	35.4	0.1	51.2
Hospital Admissions	0.3	8,200	<0.1	170	0.2	5,100	–	–
Hospital Admissions, Cardiovascular	–	–	–	–	–	–	<0.1	1,100
Hospital Admissions, Respiratory	–	–	–	–	–	–	<0.1	680
Lower Respiratory Symptoms	–	–	–	–	–	–	2	100
Mortality	–	–	–	–	0.1	733,000	0.3	2,290,000
School Loss Days	–	–	–	–	62.8	6,200	–	–
Upper Respiratory Symptoms	–	–	–	–	–	–	1.7	77.5
Work Loss Days	–	–	–	–	–	–	18.1	2,800
Total	**150**	**21,000**	**1.2**	**260**	**230**	**758,000**	**210**	**2,330,000**

Due to rounding, not all values will add up exactly.

Dashes indicates that the value is not estimated for that pollutant and health effect. The same health effects were not analyzed for each pollutant.

$PM_{2.5}$ = particulate matter less than 2.5 microns.

Avoided Runoff

Surface water runoff (commonly referred to as surface runoff or stormwater runoff) can contribute pollution to streams, wetlands, rivers, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation, while the remainder reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil or end up in surface depression storage becomes surface runoff (Hirabayashi 2013). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees can reduce surface runoff. Tree canopies intercept precipitation, while root systems promote infiltration and water storage in the soil. The amount of avoided runoff is less than the total amount intercepted because soils also absorb precipitation and thus reduce runoff in the absence of trees. The trees in Providence are estimated to reduce runoff by 7 million cubic feet per year (50 million gallons annually), with an estimated value of $445,052 per year based on a national average cost of stormwater control and treatment of $ 0.008936 per gallon (Nowak 2024). Tree species with the greatest overall impact on runoff are Norway maple, northern red oak, and black oak due to their large leaf surface area (Fig. 15).

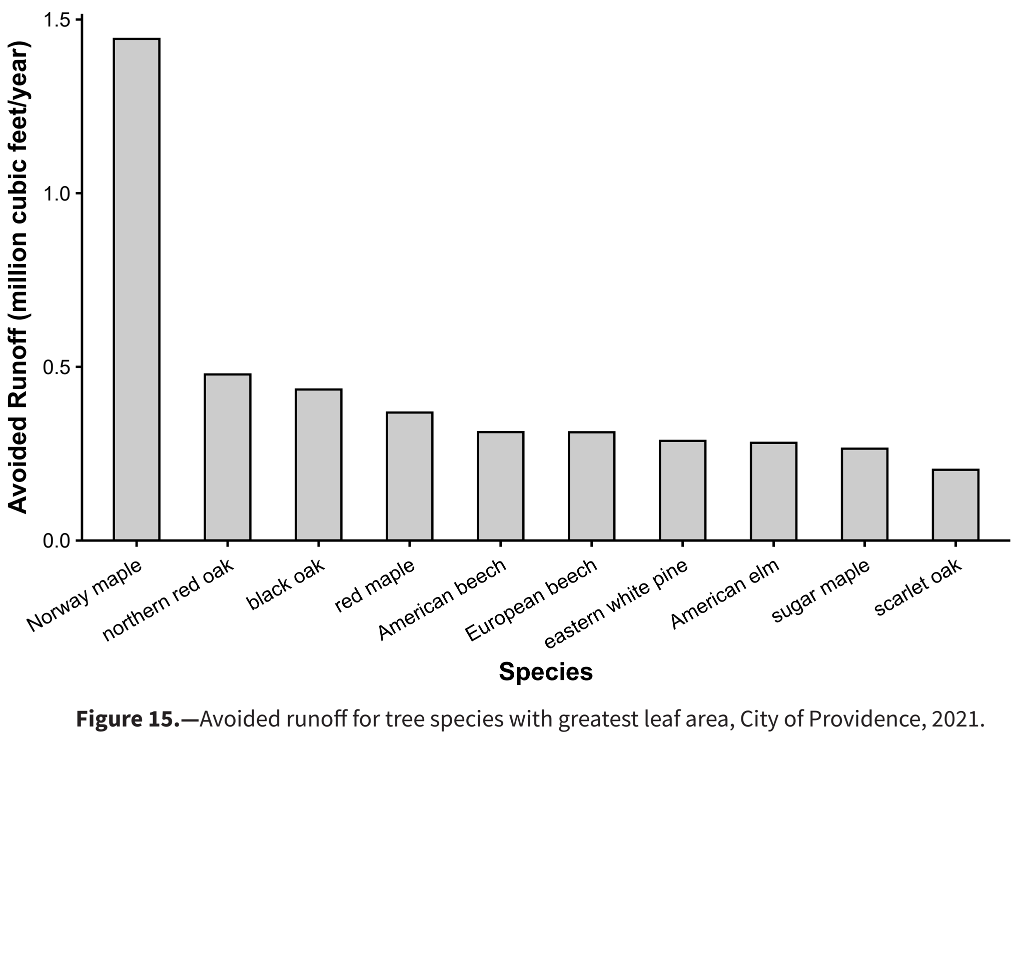

Figure 15.—Avoided runoff for tree species with greatest leaf area, City of Providence, 2021.

Energy Conservation

Trees can affect building energy use by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months (cooling season) and can either increase or decrease building energy use in the winter months (heating season), depending on the location of the trees around the building (Heisler 1986, Nowak et al. 2017). Estimates of tree effects on energy use are based on field measurements of the tree distance and directions to space-conditioned residential buildings (McPherson and Simpson 1999; Nowak et al. 2008a; Nowak 2024; U.S. EIA 2012a, b; U.S. EIA 2014a, b, c).

In Providence, interactions between buildings and trees 5.0 inches in diameter and greater are projected to annually decrease energy requirements by 86,000 gigajoules (GJ) during the heating and cooling seasons (an energy equivalent of 544,380 gallons of home heating fuel oil) (Table 21), with an annual savings in energy costs of $2 million (Table 22). Savings in residential energy costs were calculated based on state average 2012 costs for natural gas (U.S. EIA 2014b), 2012/2013 heating season fuel oil costs (U.S. EIA 2012a, b), and 2012 costs of wood (U.S. EIA 2014a). Trees in the urban forest also are estimated to reduce carbon dioxide (CO_2) emissions from fossil-fuel-based power sources by 5,200 tons annually (1,400 tons of carbon; $273,000), equivalent to the burning of over 3.6 million pounds of coal or roughly 10,968 barrels of oil (Hong and Slatick 1994, U.S. EPA 2020).

Table 21.—Annual energy savings due to live and dead trees 5.0+ inches in diameter near residential buildings during heating and cooling seasons, City of Providence, 2021

Reduced energy use and emissions	Cooling	Heating	Total
Carbon avoided (tons)	240	1,200	1,400
Energy effects (GJ)	12,000	74,000	86,000

Estimates are rounded.

To convert carbon estimates to carbon dioxide, multiply carbon value by 3.667.

GJ = gigajoule (one billion [10^9] joules).

Table 22.—Annual monetary savings due to live and dead trees 5.0+ inches in diameter near residential buildings during heating and cooling seasons, City of Providence, 2021

Reduced energy use and emissions	Cooling ($)	Heating ($)	Total ($)
Carbon avoided	46,000	227,000	273,000
Energy effects	769,000	1,210,000	1,970,000

Due to rounding, not all values will add up exactly.

Based on 2012 statewide energy costs (U.S. Energy Information Administration 2012a, 2012b, 2014b, 2014c) and 2015 social cost of carbon (Interagency Working Group 2013, U.S. Environmental Protection Agency 2015).

Carbon Storage and Sequestration

Climate change is an issue of global concern that threatens vulnerable species and ecosystems (e.g., coral reefs, polar and coastal areas) along with food production, water resources, and human health (Intergovernmental Panel on Climate Change 2014). Reductions in the amount of energy required to heat or cool residential buildings described in the energy conservation section of this report lead to reduced CO_2 emissions from fossil-fuel based power sources (Abdollahi et al. 2000). Trees can also help mitigate climate change by annually sequestering atmospheric carbon (in the form of CO_2) and storing carbon in their accumulated tissue (i.e., biomass). Although FIA volume and biomass models use species specific calculations, it is generally accepted that approximately half of the biomass in a tree is carbon (Westfall et al. 2024).

Carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose or are consumed in a fire event. Although tree maintenance practices (e.g., pruning) can contribute to carbon emissions, maintaining healthy trees helps to retain carbon stored in trees (Nowak et al. 2002b). Using removed trees for wood products is one way to help forestall carbon emissions related to wood decomposition. Wood from removed trees can also be used to produce energy (e.g., heat or cool buildings), helping to reduce fossil-fuel based carbon emissions. Trees in Providence store an estimated 84,244 tons of carbon (308,893 tons of CO_2) valued at $14.4 million (Table 23). Tree carbon values are based on the 2015 estimated social costs of carbon ($170.60 per ton of carbon; Interagency Working Group on Social Cost of Carbon 2013, Intergovernmental Panel on Climate Change 2014). The social cost of carbon is a monetary value that encompasses the economic impact of increased carbon emissions on factors such as agricultural productivity, human health, and property damage. Carbon storage varies across the city (Fig. 16), among land uses, and by species. The species that store the most carbon are northern red oak, Norway maple, and European beech (Fig. 17).

Table 23.—Aboveground and belowground carbon in live and standing dead trees by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021

FIA land use class	Aboveground in live trees (tons C)	Belowground in live trees (tons C)	Total in standing dead trees (tons C)	Total (tons C)	Standard error (tons C)
Recreation/Cemetery	19,000	2,900	28	22,000	8,900
Forest land	17,000	2,900	240	20,000	7,200
Commercial/Industrial	13,000	1,900	450	15,000	5,900
Residential	11,000	1,700	160	13,000	4,000
Rights-of-way	6,300	900	89	7,200	2,100
Multi-family residential	5,700	700	20	6,400	3,000
Water	140	17	0	160	150
Total	**72,000**	**11,000**	**990**	**84,000**	**–**
Standard Error	**9,200**	**1,500**	**460**	**11,000**	**–**

Due to rounding, not all values will add up exactly.

– = no value for cell.

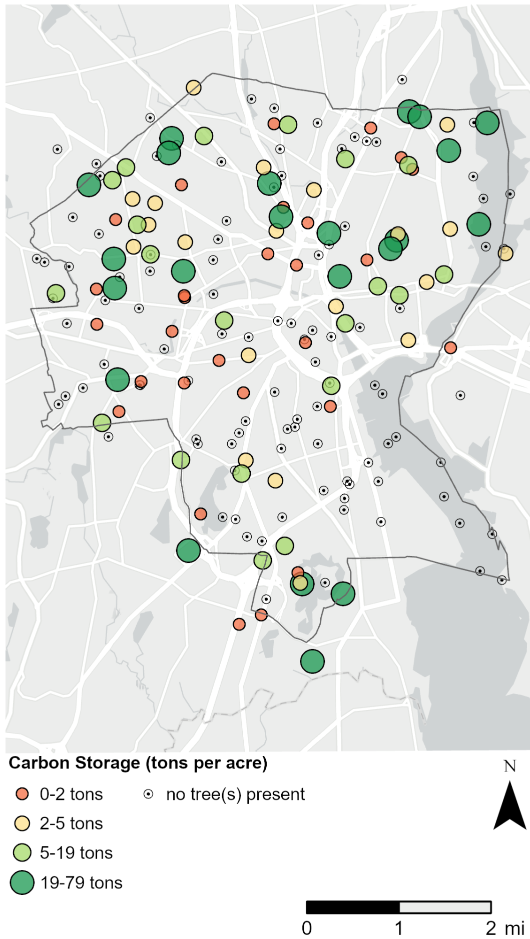

Figure 16.—Carbon storage per acre is shown for each Forest Inventory and Analysis (FIA) plot using approximate plot locations, City of Providence, 2021. The Light Gray Canvas basemap layer was provided by Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community.

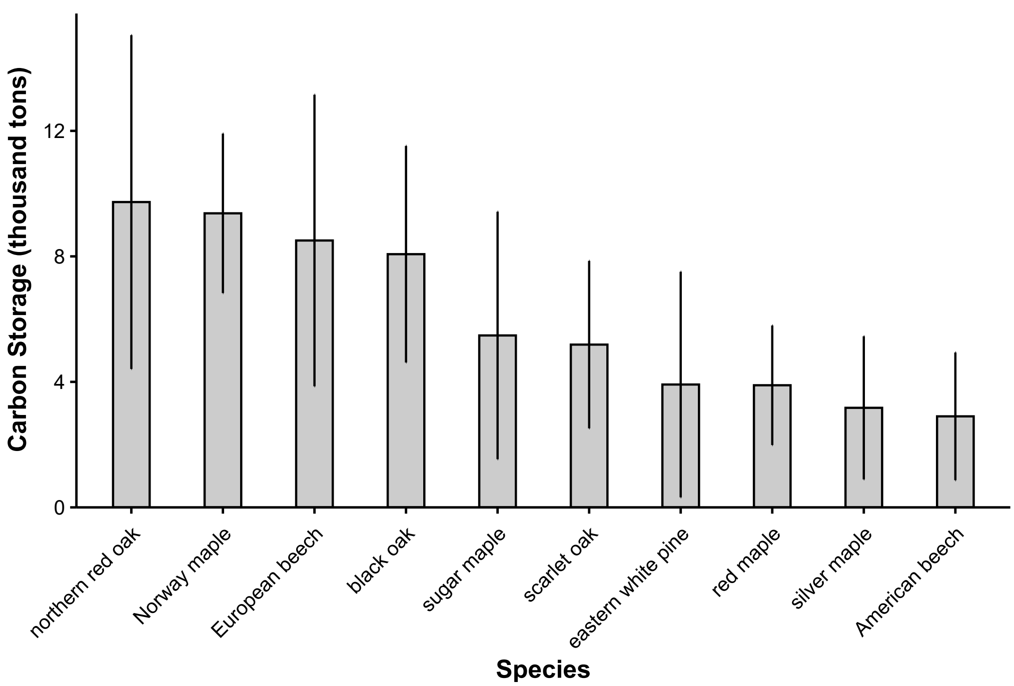

Figure 17.—Live and dead carbon storage for 10 tree species with the greatest carbon storage, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

Figures 18 and 19 show the distribution of carbon storage and sequestration in trees by diameter class both as a proportion of the total amount of carbon stored and on a per tree basis.

In addition to carbon storage, which accounts for past carbon sequestration, healthy trees continue to annually sequester carbon in new tissue growth. Gross sequestration by urban trees in Providence is about 2,300 tons of carbon per year (8,400 tons per year of CO_2) with an associated value of $388,703 per year, which is roughly equivalent to the annual emissions associated with 1,600 passenger vehicles or energy usage by 900 homes (U.S. EPA 2020). Norway maple is estimated to sequester the most carbon of all species in the urban forest (14.7 percent of all sequestered carbon) (Fig. 20).

Estimates of carbon storage and sequestration in developed and undeveloped land uses, along with evaluations of tree growth, removals, and mortality by ownership, can aid in assessing impacts of proposed land use changes and in developing climate change strategies and targets.

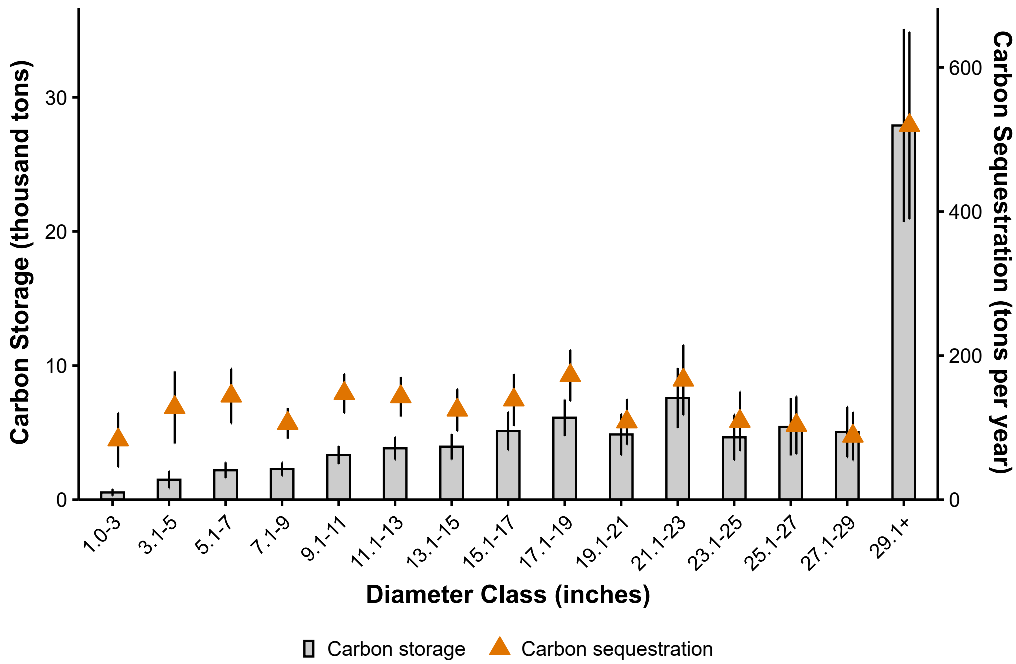

Figure 18.—Total live and dead carbon storage and sequestration by diameter class, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

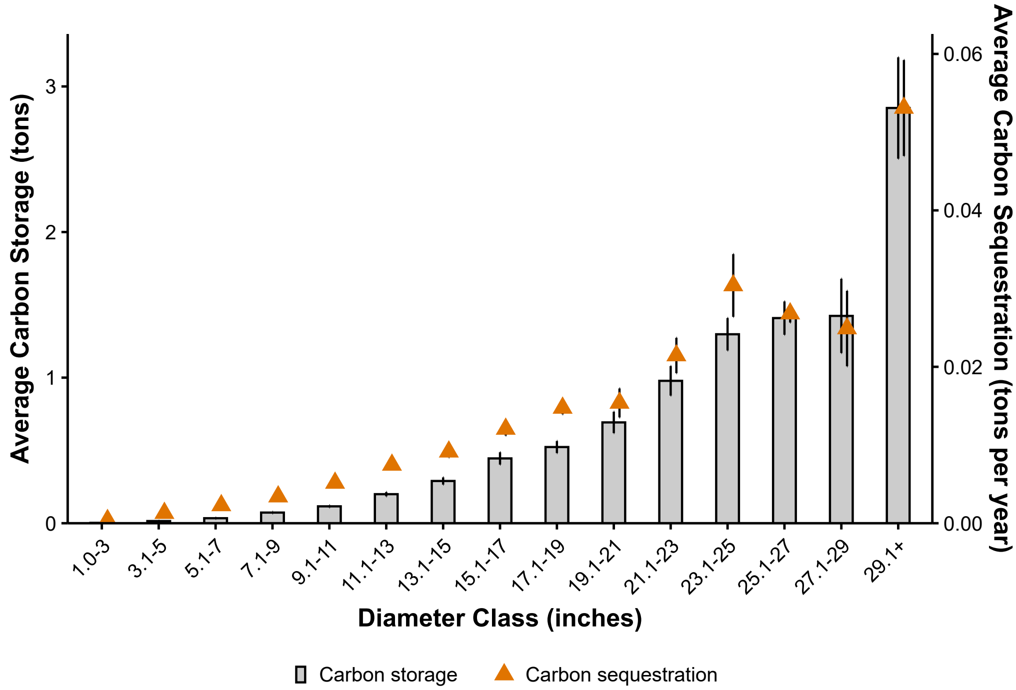

Figure 19.—Average per tree live and dead carbon storage and sequestration by diameter class, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

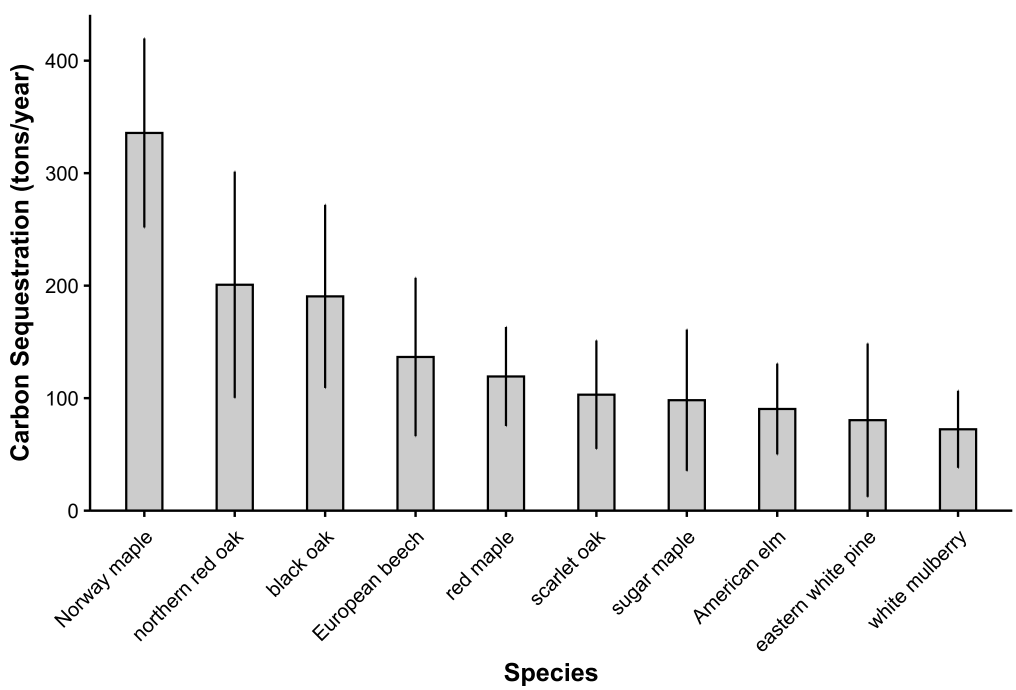

Figure 20.—Carbon sequestration for 10 tree species with the greatest annual carbon sequestration, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

Structural Values

The city's forest has a structural value that includes the compensatory value and carbon storage value of each tree. The compensatory value is an estimate of the value of the tree as a structural asset (e.g., how much should one be compensated for the loss of the physical structure of the tree), which tends to increase with the size and health of the tree. For small trees, a replacement cost can be used; for larger trees, appraisal procedures are used (Council of Tree and Landscape Appraisers 2000, Nowak et al. 2002a). This appraisal is an estimate based on tree species, diameter, condition and location, and does not include many personal, social, functional or future values that may be ascribed to a tree (Nowak and Aevermann 2019). Note that invasive tree species have compensatory values because the methods used to estimate compensatory value do not account for whether the species is native, non-native, or invasive. Additionally, invasive species can still contribute some ecosystem services. The compensatory value of the trees in Providence is estimated to be about $405.9 million. This compensatory value is a function of the number, health, diameter, and species of all trees measured, as well as the land use in which they were encountered. The species with the largest compensatory values in Providence are Norway maple, northern red oak, and European beech (Fig. 21). The mean compensatory value per acre for all surveyed plots in Providence is $28,499; for the 46.4 percent of these plots that contain trees, the mean compensatory value per acre is $61,500 (Fig. 22). However, compensatory value per acre is estimated to exceed $77,000 for 23 plots in which the average tree diameter is 12.8 inches. The structural value of urban trees in Providence is a combination of their compensatory value (estimated at $405.9 million) and the value associated with carbon storage by the trees (estimated at $14.4 million).

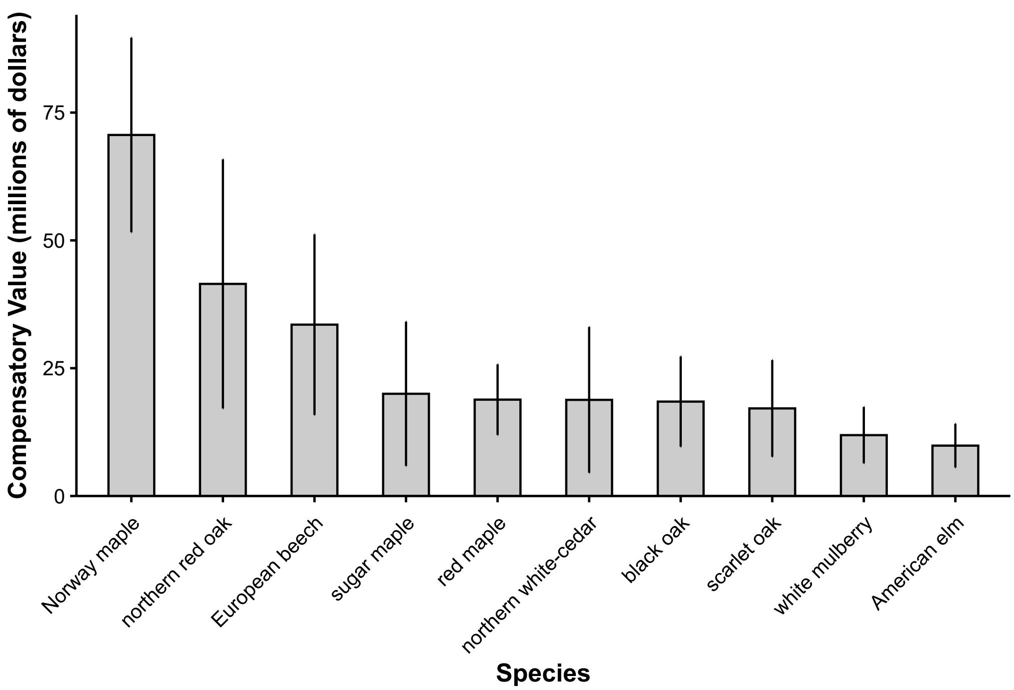

Figure 21.—The compensatory value for 10 of the highest value tree species, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

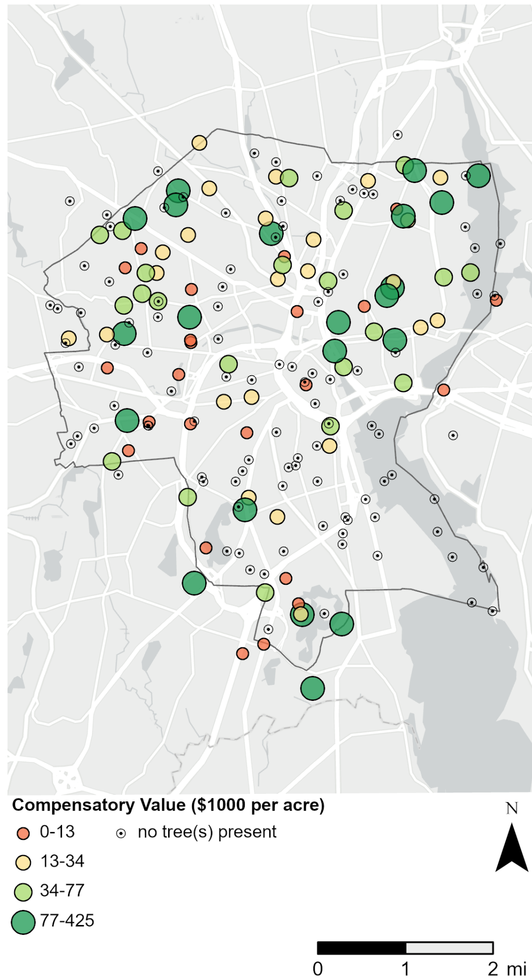

Figure 22.—Compensatory value per acre is shown for each Forest Inventory and Analysis (FIA) plot using approximate plot locations, City of Providence, 2021. The Light Gray Canvas basemap layer was provided by Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community.

URBAN FOREST HEALTH

Tree damage and rot on a red maple, a common tree in Providence. USDA Forest Service photo by Jesse Caputo.

A healthy urban forest provides greater benefits to society than an unhealthy one. This section highlights crown dieback, tree damages and rot, the number of standing dead trees, and the presence and prevalence of invasive plant species as indicators of urban forest health in Providence. Detailed methods of invasive species as indicators of urban forest health metrics are presented in the Urban FIA NRS Field Guide Version 7.1 (USDA Forest Service 2017) .

Crown Dieback and Bole Rot

Tree crown condition can be used as an indicator of tree health. Large, dense crowns are often indicative of vigorously growing trees, while small, sparsely foliated crowns signal trees with little or no growth. Crown dieback is one of the initial indications that a tree may be in a state of decline. Crown dieback is measured as a percentage of the crown volume with recent mortality of small fine branches and twigs in the upper and outer portion of the tree's crown. Trees with more than 25 percent crown dieback may be in decline (Steinman 2000). High levels of dieback may indicate an insect, disease, or environmental problem associated with a particular tree, tree species, or group of trees. Of the tree species that have a minimum sample size of 10 trees and show evidence of dieback, northern red oak has the highest average dieback (17.6 percent) (Table 24). Approximately 32.6 percent of northern red oak displays greater than 25 percent crown dieback, indicating that this species may be threatened by insect, disease, or environmental stressors in Providence.

Table 24.—Tree species with greatest average dieback, City of Providence, 2021

Common name	Average dieback (percent)	Standard error (percent)	Trees with more than 25% dieback (percent)
northern red oak	17.6	12.2	15.7
black oak	8.0	0.6	2.0
black cherry	6.2	4.0	0.0
American beech	4.4	1.6	0.0
scarlet oak	4.1	1.9	2.0
red maple	2.7	1.0	0.8
white mulberry	1.4	1.4	0.5
Norway maple	0.8	0.4	0.3
northern white-cedar	0.6	0.0	0.0
American elm	0.3	0.3	0.0

Estimates are rounded.

Only species with minimum sample size of 10 live trees are included in this analysis to minimize effect of small sample size on percentage estimates.

In addition to crown dieback, the amount of rot present in the trunk of a tree may indicate tree health issues and serve as a predictor of potential hazardous trees in urban areas. The percent of the main stem that is **rotten or cull** between 1 foot above the ground and approximately 4.0-inch top diameter outside of bark was recorded for all trees at least 5.0 inches in diameter. Of species with a minimum sample size of 10 trees, the species with the highest average rotten/cull amounts are white mulberry and red maple (Table 25).

Table 25.—Tree species with the greatest average rot, City of Providence, 2021

Common name	Average rot (percent)	Standard error (percent)	Trees with more than 15% rot (percent)
white mulberry	5.0	2.2	1.1
red maple	4.6	1.9	2.7
black cherry	3.9	3.3	0.7
Norway maple	3.3	1.1	0.5
northern red oak	1.3	1.5	0.9
black oak	1.0	0.6	0.0
northern white-cedar	0.9	0.8	0.0
American elm	0.9	0.5	0.0
scarlet oak	0.7	0.5	0.0
American beech	0.5	0.2	0.0

Estimates are rounded.

Only species with minimum sample size of 10 live trees are included in this analysis to minimize effect of small sample size on percentage estimates.

Rot is only measured on trees 5.0+ inches in diameter.

Tree Damage and Potential Infrastructure Issues

Urban trees are susceptible to a wide range of insect, disease, and abiotic (e.g., soil compaction) damage agents that may affect tree survival, growth, and wood quality. Many damage agents are host specific and their impacts may vary by regional and local growing conditions. Live trees greater than 1.0 inch in diameter were examined for indications of several damage agents. Up to three damage agents were recorded per tree; each recorded agent was required to meet a minimum severity threshold (e.g., 20 percent of the foliage affected). If more than three damage agents were observed on a tree, the top three were prioritized according to their ability to: (1) prevent the tree from surviving more than 1–2 years, (2) reduce the tree's growth in the near term, and (3) negatively affect a tree's marketable wood products. The full list of potential damage agents is presented in the Urban FIA NRS Field Guide Version 7.1 (USDA Forest Service 2017). Stem decay and spongy moth (*Lymantria dispar*) are the most common causes of damage, affecting 11.5 and 8.2 percent of trees, respectively (Table 26).

Table 26.—Percentage of trees with observed damage, City of Providence, 2021

Damage type	Trees (percent)
boring Insects	0.2
Cankers	1.0
Decline Complexes/Dieback/Wilts	0.1
Defoliators	0.1
Foliage diseases	0.1
General Insects	0.3
Human Activities	5.2
Stem Decay	11.5
Wild Animals	0.5
beech bark disease	2.2
spongy moth	8.2
hemlock woolly adelgid	0.1
imbedded objects	2.7
shoot borer	0.2
vine damage	4.4
wind	0.1
Other Damages and Symptoms	
Other damages and symptoms	0.5
Broken top	0.4
Dead top	2.1
Dieback	5.3

Estimates are rounded.

In addition to damage agents, each live tree greater than 1.0 inch in diameter was evaluated for the presence of the following infrastructure issues that affect urban trees:

- Root/stem girdling
- Conflict with roots (sidewalk-root conflict/infrastructure damage)
- Topping/pruning
- Conflict with crown (branches within 5 feet of overhead wires)
- Bark inclusion
- Improper planting
- Excessive mulch

Topping/pruning is the most common issue, occurring in 5.5 percent of trees. Conflict with crown and bark inclusion are the second and third most common urban specific infrastructure issues, occurring in 5.3 and 2.7 percent of trees, respectively (Fig. 23).

Differences exist in the prevalence of these issues among the FIA-designated land uses and may further inform forest health and management priorities. In Providence, severe topping or poor pruning occurs in 35.9 percent of trees on multi-family residential land, conflict with crown in 24.4 percent of trees on rights-of-way land, and conflict with roots in 17.8 percent of trees on rights-of-way land.

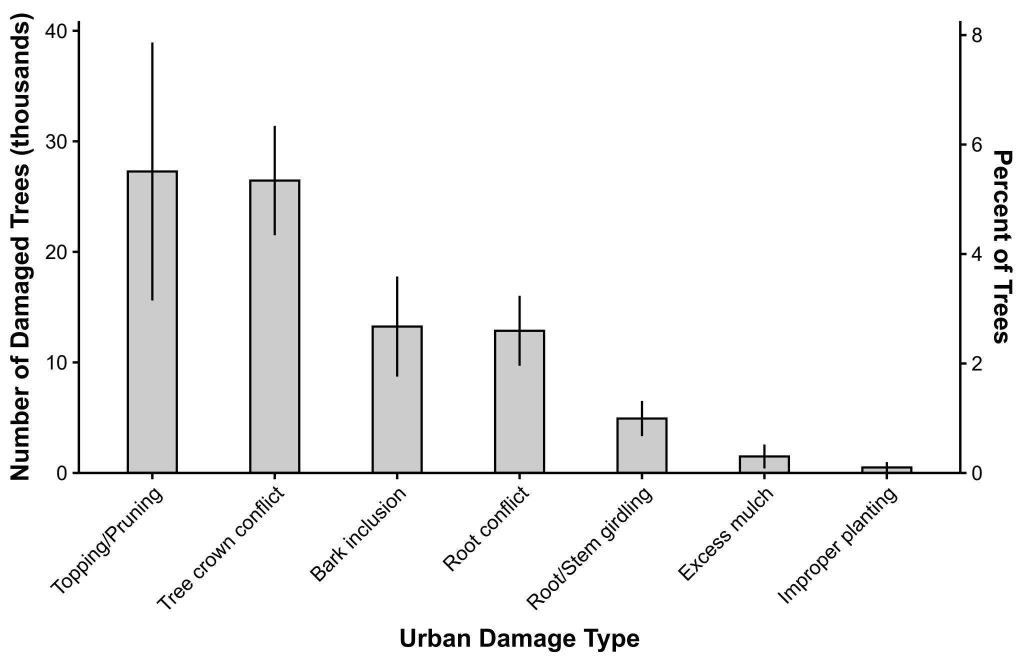

Figure 23.—Number and percent of trees by urban infrastructure issue category, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

Of species with a minimum sample size of 10 trees, the species with the greatest proportion of their population affected by urban-specific damages are northern white-cedar (20.5 percent affected by topping/pruning) and red maple (16.1 percent affected by conflict with crown) (Table 27).

Table 27.—Percent of live trees identified with damage, maintenance, and site issues, City of Providence, 2021

Common name	Number of trees	Standard error	Bark inclusion (percent)	Crown conflict (percent)	Excess mulch (percent)	Improper planting (percent)	Root conflict (percent)	Root/stem girdling (percent)	Topping/ pruning (percent)
American basswood	1,000	1,000	0.0	0.0	0.0	0.0	64.6	0.0	0.0
American beech	11,000	8,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
American elm	27,000	20,000	7.3	4.9	0.0	0.0	0.0	0.0	0.0
apple spp.	19,000	10,000	2.6	6.5	0.0	0.0	0.0	2.6	27.4
Atlantic white-cedar	2,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Austrian pine	2,000	2,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
black cherry	20,000	10,000	2.2	2.0	0.0	0.0	0.0	0.0	0.0
black locust	13,000	9,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
black oak	48,000	34,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
black walnut	1,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
blue spruce	0	0	0.0	100.0	100.0	0.0	0.0	0.0	100.0
boxelder	2,000	2,000	0.0	0.0	0.0	0.0	40.4	0.0	0.0
Callery pear	3,000	2,000	40.4	59.6	0.0	0.0	23.8	0.0	47.7
cedar of Lebanon	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chinese elm	1,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
eastern cottonwood	1,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
eastern hemlock	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
eastern redcedar	3,000	2,000	0.0	60.4	0.0	0.0	0.0	0.0	0.0
eastern white pine	4,000	2,000	10.6	10.2	0.0	0.0	0.0	0.0	10.2
English yew	13,000	12,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
European beech	2,000	1,000	18.7	0.0	0.0	0.0	0.0	0.0	17.1
flowering dogwood	8,000	6,000	0.0	0.0	0.0	0.0	0.0	5.4	11.9
Freeman maple	0	0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
green ash	6,000	6,000	0.0	7.9	0.0	0.0	7.9	0.0	0.0
hawthorn spp.	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
honeylocust	4,000	2,000	0.0	49.4	0.0	0.0	77.0	0.0	0.0
Japanese flowering cherry	11,000	8,000	0.0	8.9	0.0	0.0	4.4	0.0	0.0
Japanese maple	5,000	5,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japanese yew	6,000	6,000	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Japanese zelkova	2,000	2,000	38.0	41.4	0.0	0.0	0.0	0.0	0.0
katsura tree	1,000	1,000	100.0	0.0	0.0	0.0	0.0	0.0	0.0
littleleaf linden	1,000	1,000	0.0	67.8	0.0	0.0	67.8	0.0	33.9
London planetree	2,000	2,000	0.0	21.0	0.0	0.0	0.0	0.0	21.0
mockernut hickory	1,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
northern catalpa	2,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Continued on next page

Table 27. (continued)—Percent of live trees identified with damage, maintenance, and site issues, City of Providence, 2021

Common name	Number of trees	Standard error	Bark inclusion (percent)	Crown conflict (percent)	Excess mulch (percent)	Improper planting (percent)	Root conflict (percent)	Root/stem girdling (percent)	Topping/ pruning (percent)
northern red oak	15,000	7,000	0.0	7.9	0.0	0.0	0.0	0.0	2.6
northern white-cedar	41,000	34,000	0.0	0.0	0.0	0.0	0.0	0.0	20.5
Norway maple	98,000	67,000	0.5	4.6	0.0	0.0	2.4	2.8	1.0
Norway spruce	0	0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
pear spp.	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pignut hickory	3,000	3,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pin cherry	13,000	12,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pin oak	2,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
red maple	14,000	5,000	3.0	16.1	0.0	0.0	16.0	6.4	3.0
red mulberry	11,000	8,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
red pine	3,000	3,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
river birch	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
sawara-cypress	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
scarlet oak	6,000	2,000	0.0	9.0	0.0	0.0	0.0	0.0	0.0
Siberian elm	1,000	1,000	33.9	33.9	0.0	0.0	33.9	0.0	0.0
silver maple	2,000	1,000	19.2	60.6	0.0	0.0	0.0	0.0	0.0
silver poplar	0	0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
sugar maple	9,000	7,000	0.0	9.7	0.0	0.0	0.0	0.0	0.0
sweet birch	3,000	2,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
sweet cherry	1,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	31.3
sweet crab apple	0	0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
sweetgum	0	0	0.0	100.0	0.0	0.0	100.0	0.0	0.0
sycamore maple	3,000	3,000	14.3	0.0	0.0	0.0	14.3	0.0	0.0
tree of heaven	1,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
white ash	7,000	6,000	0.0	7.3	0.0	0.0	0.0	0.0	0.0
white mulberry	28,000	18,000	10.4	0.0	0.0	0.0	0.0	1.5	1.5
white oak	2,000	1,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0
yellow-poplar	1,000	1,000	0.0	0.0	100.0	0.0	0.0	0.0	0.0

Estimates are rounded.

Only species with minimum sample size of 10 live trees are included in this analysis to minimize effect of small sample size on percentage estimates.

Standing Dead

The number of standing dead trees serves as another measure of urban forest health and can be useful data for management planning. The extent to which a standing dead tree poses a threat to humans, infrastructure, or both depends on the location of the tree. Standing dead trees in maintained areas where human activity is likely high, such as residential and institutional land uses or transportation corridors, will generally be considered hazardous trees and prioritized for removal. Conversely, standing dead trees in patches of forest away from heavy human use are of minimal risk but beneficial for wildlife habitat and their removal may be deemed undesirable. Because of the variability of removal rates among land use classes, caution is advised when interpreting forest health issues based on numbers of standing dead trees.

Standing dead trees are found on 11 plots (of 192) in Providence. Of the total live and dead tree population, 6.3 percent are estimated to be standing dead trees. The tree species with the highest percentage of standing dead trees are sassafras (*Sassafras albidum*)[5], eastern hemlock, and northern red oak (Table 28). The species that comprises the largest proportion of the dead tree population is northern red oak (Table 29). Land uses with the highest estimated number of standing dead trees are forest land, recreation/cemetery, and commercial/industrial (Fig. 24). The majority of standing dead trees are observed on unmaintained land in forest land uses.

Table 28.—Number of trees classified as standing dead by species, City of Providence, 2021

Common name	Standing dead trees (number)	Standard error (number)	Percent of species
sassafras	430	440	100.0
eastern hemlock	2,600	2,600	86.8
northern red oak	12,000	12,000	45.2
white ash	5,400	5,500	44.3
red mulberry	5,400	5,500	33.6
sweet birch	1,300	950	31.2
white oak	400	430	15.5
sycamore maple	500	490	12.5
black cherry	1,300	1,300	6.1
sugar maple	500	490	5.0
American elm	1,400	1,000	4.9
red maple	430	440	3.0
white mulberry	500	490	1.7
black oak	830	620	1.7
Total	**33,000**	**18,000**	**6.3**

Due to rounding, not all values will add up exactly.

[5] No live sassafras trees were inventoried during the 2021 Urban FIA inventory of Providence.

Table 29.—Proportion of the total population of trees that are dead by species, City of Providence, 2021

Common name	Standing dead trees (percent)
northern red oak	37.3
white ash	16.1
red mulberry	16.1
eastern hemlock	7.8
American elm	4.2
sweet birch	3.9
black cherry	3.9
black oak	2.5
sugar maple	1.5
white mulberry	1.5
sycamore maple	1.5
red maple	1.3
sassafras	1.3
white oak	1.2
Total	**100.0**

Due to rounding, not all values will add up exactly.

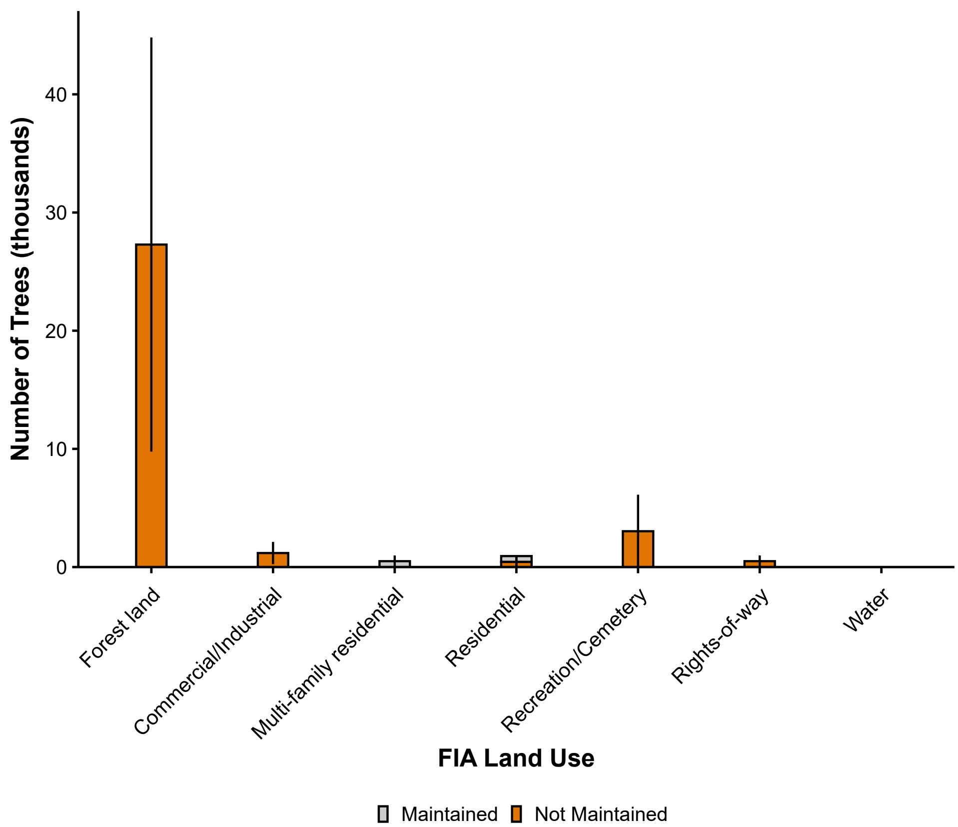

Figure 24.—Proportion of standing dead trees by Forest Inventory and Analysis (FIA) land use class and maintenance status, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

Invasive Plant Species

Invasive plant species are often noted for their vigor, ability to adapt to novel environments, high reproduction capacity, and lack of natural enemies. These factors may enable them to displace native plants and threaten natural areas (Davis 2009, Simberloff 2013). Important considerations for invasive plant control efforts include weighing short- and long-term trade-offs in terms of ecosystem services provided or disrupted by invasive species. The removal of invasive species and loss of ecosystem services they provide may lead to a subsequent need to increase the abundance of desirable species to offset these losses. Field crews in Providence examined each plot for the presence of select invasive species based on the species list shown in Appendix 5 (includes the common and scientific name for each species). Of the 192 plots examined, invasive species were identified on 47.9 percent (92 plots).

Invasive species found in Providence are presented in Figure 25. Beyond noting simple presence or absence, crews noted the percentage of the plot area covered by the invasive species, allowing for the estimation of total area covered by each species within the city (Bechtold and Scott 2005). These estimated areas may offer insights into which species are having the greatest impact in the city. Of the invasive species recorded, Norway maple (342 acres; 2.6 percent of the sampling area), Oriental bittersweet (152 acres; 1.2 percent of the sampling area), and Japanese knotweed (149 acres; 1.1 percent of the sampling area) cover the largest area. Of particular concern is the potential for these and other invasive species to spread beyond their current distribution into the surrounding landscape, potentially displacing native species and altering local ecosystems (Pimentel et al. 2000).

Additional measurements are recorded in the field for most tree species. As some of the species on the invasive plants list for Providence are classified as trees, data on individual trees were collected in addition to descriptions of species cover on the plot. In Providence, tree data were collected for Norway maple, Siberian elm, black locust, and tree of heaven. Taken together, these invasive trees are estimated to account for 22.9 percent of all live trees surveyed (estimated total trees: 113,218), and 23.5 percent of the total leaf area.

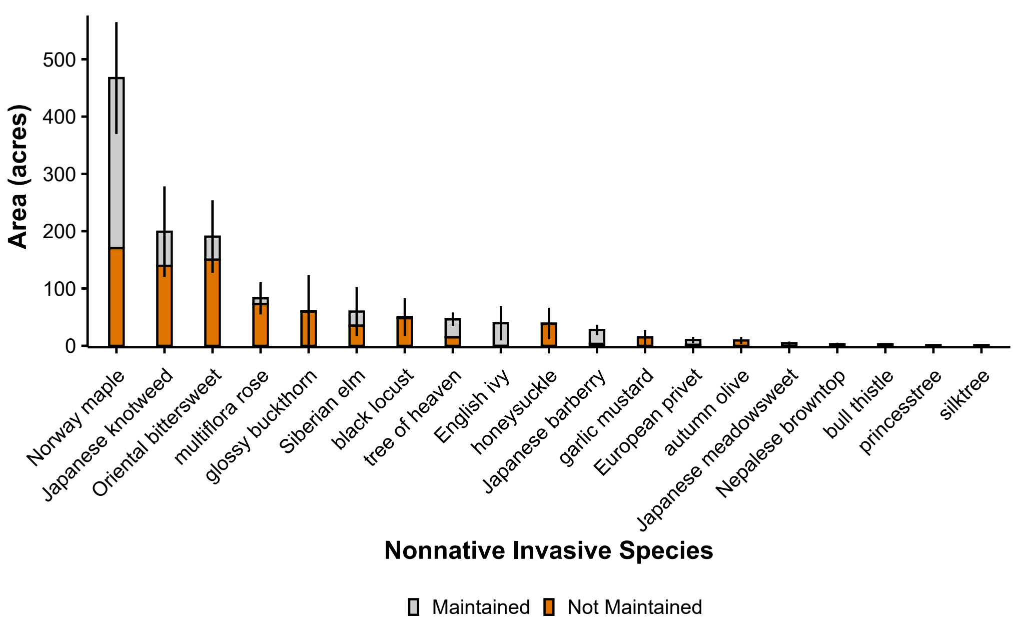

Figure 25.—Area of non-native invasive species cover by species on maintained and unmaintained land, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

Pests and Pathogens

Pathogens and insect pests can affect the health, sustainability, and benefits of urban forests. Identifying pathogens and pests of concern and their potential host-specific impacts allows managers to prioritize specific insects and diseases for monitoring and control measures. We evaluated 53 insects and diseases[6], along with their tree hosts in Providence, to quantify their potential impact on the urban forest (Table 30). The number of trees at risk (Fig. 26) reflects all the known host tree species that could experience damage or mortality either directly or indirectly due to the pest or pathogen and does not necessarily include only trees that are known to be directly at risk of attack, infection, or both. As FIA crews did not attribute tree damage or mortality to specific pests or pathogens, it was not possible to identify what portion of each host tree's population was directly at risk from or affected by the focal pests and pathogens. Pest range maps (Nowak 2024, USDA Forest Service 2023) were used to determine the proximity of each pest to the area. For Providence, proximity was classified for insects and diseases in Providence County; within 250 miles of the county; between 250 and 750 miles of the county; or greater than 750 miles away. Since there are no pest range maps for Dutch elm disease and chestnut blight, the ranges of these pests were based on known occurrence and the known host range, respectively (Nowak 2024). Proximity data for insects and diseases, along with the numbers of trees potentially affected and their compensatory values, are illustrated in Table 30.

Based on the host tree species for each pest and the current range of the pest, it is possible to estimate the risk faced by each tree species sampled in the urban forest to attack by each of these insects or diseases and assign each tree species a relative risk weight. In Appendix 6, each pest that could pose a risk to a tree species is scored as 4 points if it occurs within Providence County, 3 points if occurs within 250 miles of the county, 2 points if it occurs within 750 miles of the county, and 1 point if it is not present within 750 miles of the county. These values are summed across each row to determine the relative risk weight for each tree species recorded in the city.

Tree species that were sampled in Providence, but not listed in Appendix 6, are not known to be hosts to any of the 53 insects and diseases evaluated. Appendix 6 also excludes the pests and diseases that were not a threat to any of the tree species sampled.

[6] Common and scientific names for pests and pathogens evaluated during the 2021 inventory of Providence are in Table 30.

Table 30.—The number of host trees potentially at risk from various insects and diseases, City of Providence, 2021

Proximity (miles)	Abbreviation	Common name	Scientific name	Trees at risk (number)	Proportion of all trees (percent)	Compensatory value ($)
within county	WM	Winter Moth	*Operophtera brumata*	280,119	56.6	240,615,365
	FTC	Forest Tent Caterpillar	*Malacosoma disstria*	187,647	37.9	160,994,832
	SM	Spongy Moth	*Lymantria dispar*	115,834	23.4	116,833,930
	LAT	Large Aspen Tortrix	*Choristoneura conflictana*	50,431	10.2	14,981,272
	DED	Dutch Elm Disease	*Ophiostoma novo-ulmi*	29,252	5.9	12,448,843
	BBD	Beech Bark Disease	*Neonectria faginata*	13,347	2.7	42,962,335
	EAB	Emerald Ash Borer	*Agrilus planipennis*	13,101	2.6	7,037,502
	SPB	Southern Pine Beetle	*Dendroctonus frontalis*	11,436	2.3	18,664,737
	DA	Dogwood Anthracnose	*Discula destructiva*	7,672	1.5	3,070,980
	WPBR	White Pine Blister Rust	*Cronartium ribicola*	4,075	0.8	8,829,193
	RPS	Red Pine Scale	*Matsucoccus resinosae*	3,483	0.7	3,673,255
	BC	Butternut Canker	*Sirococcus clavigignenti juglandacearum*	866	0.2	551,237
	HWA	Hemlock Woolly Adelgid	*Adelges tsugae*	396	0.1	991,489
within 250 miles	SLF	Spotted Lanternfly	*Lycorma delicatula*	425,272	85.9	323,352,774
	BM	Browntail Moth	*Euproctis chrysorrhoea*	304,776	61.5	242,115,891
	ALB	Asian Longhorned Beetle	*Anoplophora glabripennis*	287,690	58.1	200,439,712
	OW	Oak Wilt	*Bretziella fagacearum*	72,567	14.7	80,363,081
	BLD	Beech Leaf Disease	*Litylenchus crenatae mccannii*	13,347	2.7	42,962,335
	HRD	Heterobasidion Root Disease	*Heterobasidion irregulare/occidentale*	11,499	2.3	15,508,786
	PSB	Pine Shoot Beetle	*Tomicus piniperda*	11,040	2.2	17,673,248
	SW	Sirex Wood Wasp	*Sirex noctilio*	10,543	2.1	15,749,358
	JPBW	Jack Pine Budworm	*Choristoneura pinus*	7,557	1.5	12,502,448
	SBW	Spruce Budworm	*Choristoneura fumiferana*	1,391	0.3	3,330,760
	SB	Spruce Beetle	*Dendroctonus rufipennis*	995	0.2	2,339,272
	TCD	Thousand Canker Disease	*Geosmithia morbida*	866	0.2	551,237
	BWA	Balsam Woolly Adelgid	*Adelges piceae*	498	0.1	415,382
within 750 miles	FR	Fusiform Rust	*Cronartium quercuum* f. sp. *Fusiforme*	72,567	14.7	80,363,081
	AL	Aspen Leafminer	*Phyllocnistis populiella*	45,278	9.1	11,304,511

Continued on next page

Table 30. (Continued)—The number of host trees potentially at risk from various insects and diseases, City of Providence, 2021

Proximity (miles)	Abbreviation	Common name	Scientific name	Trees at risk (number)	Proportion of all trees (percent)	Compensatory value ($)
farther than 750 miles	MOB	Mediterranean Oak Borer	*Xyleborus monographus*	210,199	42.4	245,298,194
	PSHB	Polyphagous Shot Hole Borer	*Euwallacea* nov. sp.	123,155	24.9	162,365,336
	POCRD	Port-Orford-Cedar Root Disease	*Phytophthora lateralis*	40,658	8.2	18,806,440
	SOD	Sudden Oak Death	*Phytophthora ramorum*	35,854	7.2	82,472,936
	WBBU	Western Blackheaded Budworm	*Acleris gloverana*	995	0.2	2,339,272
	WSB	Western Spruce Budworm	*Choristoneura occidentalis*	995	0.2	2,339,272
	MPB	Mountain Pine Beetle	*Dendroctonus ponderosae*	498	0.1	415,382
within county	ARD	Armillaria Root Disease	*Armillaria* spp.	0	–	–
	CB	Chestnut Blight	*Cryphonectria parasitica*	0	–	–
within 750 miles	LWD	Laurel Wilt	*Raffaelea lauricola*	0	–	–
farther than 750 miles	ARCA	Aspen Running Canker	*Neodothiora populina*	0	–	–
	BSRD	Black Stain Root Disease	*Leptographium wageneri*	0	–	–
	BOB	Bur Oak Blight	*Tubakia iowensis*	0	–	–
	DFB	Douglas-Fir Beetle	*Dendroctonus pseudotsugae*	0	–	–
	DBSR	Douglas-fir Black Stain Root Disease	*Leptographium wageneri* var. *pseudotsugae*	0	–	–
	FE	Fir Engraver	*Scolytus ventralis*	0	–	–
	GSOB	Goldspotted Oak Borer	*Agrilus auroguttatus*	0	–	–
	HS	Hemlock Sawfly	*Neodiprion tsugae*	0	–	–
	JPB	Jeffrey Pine Beetle	*Dendroctonus jeffreyi*	0	–	–
	NSE	Northern Spruce Engraver	*Ips perturbatus*	0	–	–
	PBSR	Pine Black Stain Root Disease	*Leptographium wageneri* var. *ponderosum*	0	–	–
	WBB	Western Balsam Bark Beetle	*Dryocoetes confusus*	0	–	–
	SFM	Subalpine Fir Mortality	NA - multiple pests	0	–	–
	WFNPM	Western Five-Needle Pine Mortality	NA - multiple pests	0	–	–
	WPB	Western Pine Beetle	*Dendroctonus brevicomis*	0	–	–

Estimates are rounded.

– = no value for cell.

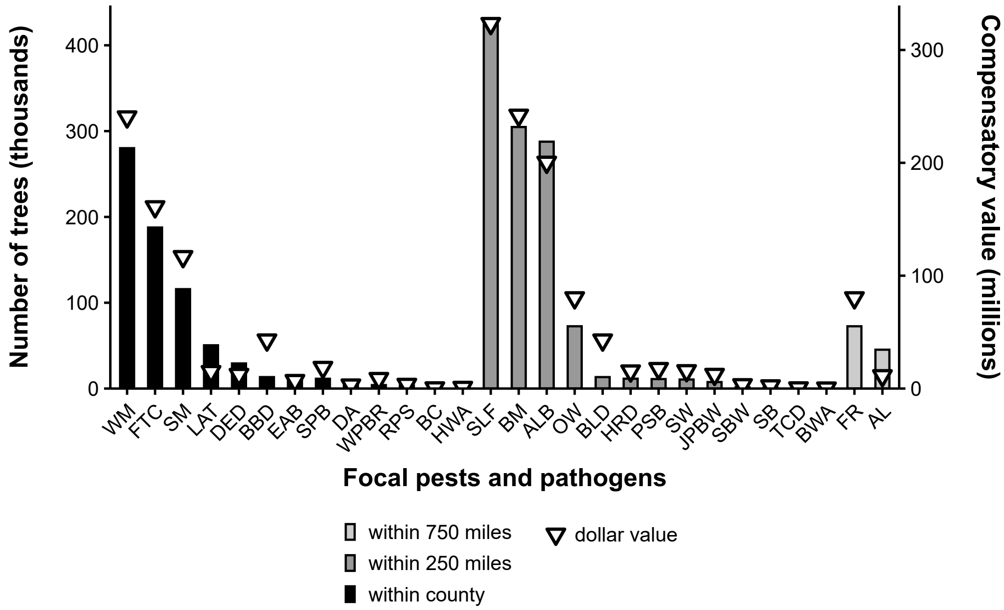

Figure 26.—Number of trees in City of Providence at risk due to pests and pathogens and their associated compensatory values. Black bars denote pests and pathogens that have been recorded within a county, gray bars denote pests and pathogens recorded within 250 miles of a county, and light gray bars denote pests and pathogens recorded within 750 miles of a county. Pest abbreviations are presented in Table 30.

MANAGEMENT IMPLICATIONS

Oriental bittersweet, a common non-native invasive species in Providence. USDA Forest Service photo by Jesse Caputo.

The primary goal of Urban FIA is to provide an accurate estimate of the composition, distribution, health, and values of urban forests to aid in sustainable urban forest management and planning. This report presents information about the current state of the Providence urban forest and the benefits it provides to residents of the city. A close inspection of these data can help planners understand where improvements can be made and develop tree planting and conservation goals for the future. The data will also serve as a baseline against which the future results from continued monitoring can be compared. These comparisons will allow managers to assess rates of tree growth and mortality, as well as changes in species composition, the distribution of size classes, and the corresponding changes in benefits associated with the urban forest. Effective monitoring allows for the development of data-driven management strategies to maximize the benefits of Providence's urban forest while minimizing the cost associated with its maintenance.

The trees of Providence provide many ecosystem services and benefits—carbon storage and sequestration, pollution remediation, avoided runoff, energy conservation and others. These benefits are worth an estimated $6.2 billion annually, more than twice what Cicilline et al. (2008) estimated for street trees. This shows that—despite the emphasis in urban forestry on street trees—the trees in parks, on rights-of-ways, in residential yards, and on commercial developments provide a substantial amount of value to urban residents. In order to produce the fullest suite of potential benefits, urban trees (whether street trees or not) must first be healthy trees. A number of factors reducing tree health are at play in the urban forest of Providence. An estimated 6.3 percent of trees in the city are standing dead. Of those that are alive, many are being adversely affected by pests, pathogens, or damage agents. Stem decay and damage from spongy moths are two of the most prevalent damage agents in the city, impacting 11.6 percent and 8.2 percent of all trees. Many damage agents disproportionately impact trees of certain species (or, in some cases, are even specific to those species). For example, 32.6 percent of Northern red oak stems have crown dieback greater than 25 percent (and thus may be considered to be in decline), a greater percentage than other tree species. This tree is one of the most important in the city in terms of biomass, leaf area, and sawtimber; its loss could have serious negative ramifications for multiple ecosystem services. Some risk factors in the urban forest are products of human management. For example, 20.5 percent of tree stems show signs of severe topping or poor pruning, 35.9 percent of trees on multi-family residential lots. Not all risk factors were surveyed. For example, Cicilline et al. (2008) found that 16.2 percent of street trees were in conflict with surrounding infrastructure, usually pavement, and thus were not free-to-grow. Addressing these health considerations, treating or replacing ailing trees, encouraging hardier species, etc. may increase the overall sustainability and resilience of the urban forest, and in doing so protect the ecosystem services and benefits it provides.

Species diversity is another factor considered paramount to the sustainability and resilience of the urban forest. An urban forest with many species is likely to be less affected by a disease or pathogen outbreak, and likely to recover more quickly and thoroughly afterwards (Sanders 1981). A classic example is provided by the incidence and spread of Dutch elm disease in the 20th-century; communities that relied disproportionately on elm trees lost a greater percentage of their trees (and the associated services and benefits) than communities with more diverse tree cover (Bassuk 1990). Providence is host to an estimated 45 tree species on private land, resulting in a Shannon-Wiener index value of 3.0. This is in the middle of the range for U.S. cities (the number is slightly lower on public lands). The Shannon-Wiener index incorporates species evenness as well as species richness. Even so, 26.9 percent of trees on private land belong to a single species, Norway maple. This represents a potential risk. Should the city see an outbreak of a pathogen or pest to which maple is susceptible (such as, for example, the nearby Asian longhorn beetle; Table 30 and Appendix 6), a significant proportion of the city's trees could be at risk. Cicilline et al. (2008) also identify this concern, estimating that 31.9 percent of street trees are maples. Efforts to increase tree species diversity in Providence could increase the sustainability and resilience of the urban forest, as well as provide a wider range of potential benefits.

It is difficult to discuss species diversity in an urban context without also discussing the role of invasive and non-native species. Urban environments are often more locally diverse than adjacent non-urban environments largely because of non-native species (e.g., McKinney 2006). These non-native species, some of which may be invasive, contribute to overall species richness, as well as provide ecosystem services and benefits in their own right—services such as carbon storage, pollution remediation, and avoided runoff. As such, they contribute to the value provided by the urban forest. On the other hand, non-native invasive species can have negative ecological impacts on native species as well as provide ecosystem disservices to people (Gaertner et al. 2017). Additionally, by outcompeting, out-growing, and/or hybridizing with native species, non-native species can increase species richness at the expense of species evenness, ultimately resulting in a lower Shannon-Wiener index. The complex interactions among these considerations can make it difficult to determine whether invasive and non-native species are "net negative" or "net positive" (Pejchar and Mooney 2009, Tassin and Kull 2015, Vaz et al. 2017). However, by thoughtfully and carefully reducing the prevalence of non-native species (especially invasive non-natives) and replacing them with multiple, functionally-equivalent native species, species richness can be maintained (or even increased), evenness can be increased, and overall service provision may be improved. Non-native and invasive species are common in Providence, being found on 47.9 percent of survey plots. The most numerous and most important tree species in the city, Norway maple, is also a non-native invasive species. This may serve as an important consideration in decisions made about the future of this species there, whether efforts should be made to reduce or replace it, and what species might be considered to take its place.

The survey summarized in this report has focused primarily on biophysical attributes of Providence's forests—attributes such as numbers of trees, forest structure, biomass, and species diversity. The ecosystem services highlighted here are generally supporting and regulating services (e.g., Díaz et al. 2015). Many of the most important services that trees provide to people are cultural services. However, these cannot be measured by field crews on sample plots. Furthermore, a majority of the city area is in private ownership (>55 percent). To fully understand the history, current condition, and likely future trajectory of these acres, it is useful to understand the motivations, needs, and actions of private landowners. The Urban National Landowner Survey (UNLS) is a component of the FIA program, an effort to survey private owners of residential properties in cities and urban areas, to better understand who owns the urban forest and how these landowners use, value, and manage their urban trees and greenspaces. The UNLS was initialized in Baltimore, Maryland in 2018 (Butler et al. 2025, Locke et al. 2025) and expanded to an additional five cities in 2019 (e.g., Locke et al., in press). Providence was not one of the cities in this initial cohort, but we can infer from the results of the UNLS that urban landowners in general derive multiple benefits from the trees on their land (including cultural services). At the same time, they also have a number of concerns about potential disservices from the same trees—disservices such as damage from falling trees and branches, pests, maintenance requirements, and allergies. Although landowners are active in terms of the management and use of their greenspace, they generally express low familiarity with formal policies/programs as well as the expertise and information provided by tree care professionals and experts (Locke et al. 2025; Locke et al., in press). When the UNLS is expanded to include Providence, the FIA program will be able to provide the city's decisionmakers and landowners with a more complete picture of the ecological and social conditions that drive management of the urban forest.

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CONCLUSIONS

Large trees provide shade for a street in Providence. Courtesy photo by AJ Elton of City of Providence, Forestry Division.

Providence's urban forest contributes to the city's environmental, economic, and societal well-being. Throughout the city, an estimated 495,000 trees, representing 64 species, provide an estimated tree canopy cover of 16.5 percent. These trees provide a wide range of important environmental benefits including air pollution removal, reduced carbon emissions, carbon storage and sequestration, reduced energy use for buildings, stormwater capture, and many others.

There are several forces that may impact Providence's forest structure, health, and the environmental benefits provided to the city's residents in the future. These include insect and disease infestations, aging and loss of larger trees, the expansion of invasive species, changes in the management and use of the forest, and growth of the human population.

This analysis provides a baseline for future monitoring. While data from this report capture attributes of the current urban forest resource and associated ecosystem services and values, future monitoring will identify how the forest is changing over time. The plots measured in Providence will be re-measured on a 7-year cycle as part of the continuing Urban FIA program. Future analyses of the city's forest can be used to determine the role that natural and human forces play in shaping forest structure and composition.

For now, managers can use the data in this report to inform long-term management plans and policies to sustain a healthy urban tree population and ecosystem services for future generations. Planning and management of the urban forest resource can help sustain vital ecosystem services and values for current and future generations in Providence. In the future, change analyses can be used to evaluate the success of urban forest management programs.

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GLOSSARY OF TERMS

Definitions

Board-foot: A unit of measure indicating the amount of wood contained in an unfinished board 1.0 foot wide, 1.0 foot long, and 1.0 inch thick.

Diameter: For timber species, diameter is measured at breast height (d.b.h.), which is usually measured at 4.5 feet above the ground line on the uphill side of the tree. For woodland species, if the tree has multiple stems, the diameter of each is taken and combined to establish total diameter for the tree. Woodland diameters are measured at the ground line or at the stem(s) root collar (d.r.c.), whichever is higher. Timber tree species are listed in Appendix 2 (USDA Forest Service 2017). There were no woodland tree species sampled in the Providence 2021 inventory.

Forest/forest land/forested area: Land that has at least 10 percent crown cover by live trees or land formerly having such tree cover, and is not currently developed for a nonforest use. The minimum area for classification as forest land is 1 acre and 120 feet in width. Unimproved roads and trails, streams and other bodies of water, or natural clearings in forested areas shall be included within surrounding forest conditions, if <120 feet in width and 1.0 acre in size (<30 feet wide for streams and rivers). Forest land is divided into timberland, reserved forest land, and other forest land (such as woodland) (USDA Forest Service 2016b).

Invasive species: A non-native species whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112 1999). A list of invasive plant species used in this inventory protocol is presented in Appendix 5.

Rights-of-way: Developed lands including improved and/or maintained roads, railways, power or gas line clearings, and maintained canals (USDA Forest Service 2017).

Rotten or cull: Missing or rotten main stem or large branch volume caused by agents including cankers, punky knots, hollow sounding stems, or embedded metal in the wood (USDA Forest Service 2016b, 2017).

Sawtimber: A live tree of commercial species containing at least a 12-foot sawlog or two noncontiguous sawlogs 8.0 feet or longer and meeting regional specifications for freedom from defect. Softwoods must be at least 9.0 inches d.b.h. Hardwoods must be at least 11.0 inches d.b.h. (USDA Forest Service 2016b).

Sawtimber volume: Net volume of the sawlog portion of live sawtimber in board feet, International 1/4-inch Rule (unless specified otherwise), from stump to a minimum 7.0 inches top diameter outside bark for softwoods and a minimum 9.0 inches top diameter outside bark for hardwoods (USDA Forest Service 2016b).

Shannon-Wiener diversity index: An index of species diversity (also known as the Shannon diversity index) which takes into account both species richness (total number of species in a community) and species evenness (relative abundances among species in a community). Shannon diversity (*H'*) is calculated as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln(p_i)$$

where: S = the total number of species in the community (species richness) and p_i = proportion of the total assemblage of individuals represented by individuals of species i (Shannon 1948, Spellerberg and Fedor 2003).

Woodland: A subset of FIA-designated forest land that is dominated by woodland species (Dooley 2019).

Woodland species: FIA classifies all tree species into either woodland or timber categories. Woodland species are typically small, slow-growing trees characterized by a multi-stemmed growth form; timber species generally grow from a single central stem (USDA Forest Service 2017). This difference in typical form induces some differences in data collection and calculation, such as how diameters are determined (see Diameter definition). There were no woodland tree species sampled in the Providence 2021 inventory.

APPENDIX 1 – LAND COVER DESCRIPTIONS

Table 31.—National Land Cover Database (NLCD) land cover class descriptions, City of Providence, 2021

NLCD land cover class	NLCD code	Land cover description
Open water	11	Areas of open water generally with less than 25 percent of vegetation or soil.
Perennial ice/snow	12	Areas characterized by a perennial cover of ice and/or snow, generally greater than 25 percent of total cover.
Developed-open space	21	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed-low intensity	22	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20 percent to 49 percent of total cover. These areas most commonly include single-family housing units.
Developed-medium intensity	23	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 percent to 79 percent of the total cover. These areas most commonly include single-family housing units.
Developed-high intensity	24	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80 percent to 100 percent of the total cover.
Barren land (rock/sand/clay)	31	Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.
Deciduous forest	41	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen forest	42	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed forest	43	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
Dwarf scrub	51	Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20 percent of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
Shrub/Scrub	52	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Grassland/Herbaceous	71	Areas dominated by graminoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Sedge/Herbaceous	72	Alaska only areas dominated by sedges and forbs, generally greater than 80 percent of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
Lichens	73	Alaska only areas dominated by fruticose or foliose lichens generally greater than 80 percent of total vegetation.
Moss	74	Alaska only areas dominated by mosses, generally greater than 80 percent of total vegetation.
Pasture/Hay	81	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
Cultivated crops	82	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
Woody wetlands	90	Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Emergent herbaceous wetlands	95	Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Source: Homer et al. 2015

APPENDIX 2 – TREE SPECIES COMPOSITION

Table 32.—List of all live tree species and their characteristics, City of Providence, 2021

Genus	Species	Common name	1.0–4.9 in. diameter trees (number)	5.0–10.9 in. diameter trees (number)	11.0+ in. diameter trees (number)	Total (number)	Total (percent)	Total standard error (number)	Average diameter (in.)
Acer	*negundo*	boxelder	0	832	1,200	2,100	0.4	1,800	14.0
Acer	*palmatum*	Japanese maple	0	4,900	0	4,900	1.0	5,400	5.7
Acer	*platanoides*	Norway maple[a]	66,000	17,000	15,000	98,000	19.7	67,000	5.6
Acer	*pseudoplatanus*	sycamore maple	0	995	2,500	3,500	0.7	3,000	12.7
Acer	*rubrum*	red maple	0	7,500	6,400	14,000	2.8	4,700	11.7
Acer	*saccharinum*	silver maple	0	0	2,100	2,100	0.4	1,400	25.2
Acer	*saccharum*	sugar maple	6,300	416	2,600	9,400	1.9	7,000	9.9
Acer	*x freemanii*	Freeman maple	0	0	498	498	0.1	488	11.8
Ailanthus	*altissima*	tree of heaven[a]	0	866	416	1,300	0.3	982	7.9
Betula	*lenta*	sweet birch	0	1,900	934	2,900	0.6	2,000	10.9
Betula	*nigra*	river birch	0	498	0	498	0.1	488	5.9
Carya	*alba*	mockernut hickory	0	433	433	866	0.2	883	13.8
Carya	*glabra*	pignut hickory	0	2,200	433	2,600	0.5	2,600	9.0
Catalpa	*speciosa*	northern catalpa	0	1,600	396	2,000	0.4	1,400	10.4
Cedrus	*libani*	cedar of Lebanon	0	0	498	498	0.1	488	30.1
Cercidiphyllum	*japonicum*	katsura tree	0	0	1,500	1,500	0.3	1,500	16.4
Chamaecyparis	*pisifera*	sawara-cypress	0	0	433	433	0.1	441	20.9
Chamaecyparis	*thyoides*	Atlantic white-cedar	0	792	849	1,600	0.3	1,100	14.4
Cornus	*florida*	flowering dogwood	4,900	2,300	416	7,700	1.5	5,500	4.7
Crataegus	spp.	hawthorn spp.	0	498	0	498	0.1	488	9.2
Fagus	*grandifolia*	American beech	5,400	1,700	3,900	11,000	2.2	8,500	7.4
Fagus	*sylvatica*	European beech	0	0	2,300	2,300	0.5	1,200	42.1
Fraxinus	*americana*	white ash	4,900	433	1,400	6,800	1.4	5,500	5.3
Fraxinus	*pennsylvanica*	green ash	5,400	0	914	6,300	1.3	5,500	5.3
Gleditsia	*triacanthos*	honeylocust	0	1,700	1,800	3,500	0.7	1,600	13.9
Juglans	*nigra*	black walnut	0	433	433	866	0.2	883	13.5

Due to rounding, not all values will add up exactly.

Continued on next page

Diameter measurements were taken at breast height (d.b.h.).

[a] Tree species included on the list of invasive plants monitored during the inventory of Providence, 2021 (see Appendix 5).

Table 32. (continued)—List of all live tree species and their characteristics, City of Providence, 2021

Genus	Species	Common name	1.0–4.9 in. diameter trees (number)	5.0–10.9 in. diameter trees (number)	11.0+ in. diameter trees (number)	Total (number)	Total (percent)	Total standard error (number)	Average diameter (in.)
Juniperus	*virginiana*	eastern redcedar	0	3,000	433	3,400	0.7	2,400	7.1
Liquidambar	*styraciflua*	sweetgum	0	0	416	416	0.1	430	16.4
Liriodendron	*tulipifera*	yellow-poplar	0	995	0	995	0.2	975	7.2
Malus	*coronaria*	sweet crab apple	0	498	0	498	0.1	488	7.0
Malus	spp.	apple spp.	17,000	2,200	498	19,000	3.9	10,000	3.5
Morus	*alba*	white mulberry	21,000	3,800	3,100	28,000	5.7	18,000	5.9
Morus	*rubra*	red mulberry	11,000	0	0	11,000	2.2	7,700	2.6
Picea	*abies*	Norway spruce	0	498	0	498	0.1	488	7.4
Picea	*pungens*	blue spruce	0	0	498	498	0.1	488	22.4
Pinus	*nigra*	Austrian pine	0	0	2,500	2,500	0.5	2,400	12.5
Pinus	*resinosa*	red pine	0	3,000	498	3,500	0.7	3,400	9.7
Pinus	*strobus*	eastern white pine	0	995	3,100	4,100	0.8	2,500	21.3
Platanus	*hybrida*	London planetree	0	0	1,900	1,900	0.4	1,500	20.8
Populus	*alba*	silver poplar	0	0	498	498	0.1	488	24.7
Populus	*deltoides*	eastern cottonwood	0	0	1,300	1,300	0.3	993	26.2
Prunus	*avium*	sweet cherry	0	498	832	1,300	0.3	989	14.2
Prunus	*pensylvanica*	pin cherry	13,000	0	0	13,000	2.6	12,000	1.6
Prunus	*serotina*	black cherry	15,000	3,500	1,300	20,000	4.1	9,600	4.3
Prunus	*serrulata*	Japanese flowering cherry	10,000	995	0	11,000	2.3	7,700	2.7
Pyrus	*calleryana*	Callery pear	0	2,700	832	3,500	0.7	2,100	9.3
Pyrus	spp.	pear spp.	0	498	0	498	0.1	488	5.6
Quercus	*alba*	white oak	0	1,300	896	2,200	0.4	1,100	10.9
Quercus	*coccinea*	scarlet oak	0	2,500	3,100	5,500	1.1	2,100	16.7
Quercus	*palustris*	pin oak	0	1,800	0	1,800	0.4	1,100	7.5
Quercus	*rubra*	northern red oak	4,900	4,500	5,700	15,000	3.1	7,400	11.9
Quercus	*velutina*	black oak	35,000	4,100	9,400	48,000	9.7	34,000	5.7
Robinia	*pseudoacacia*	black locust[a]	12,000	1,800	0	13,000	2.7	9,300	2.3
Taxus	*baccata*	English yew	13,000	0	498	13,000	2.7	12,000	1.4
Taxus	*cuspidata*	Japanese yew	0	6,300	0	6,300	1.3	6,200	5.9
Thuja	*occidentalis*	northern white-cedar	32,000	8,500	498	41,000	8.2	34,000	4.2

Due to rounding, not all values will add up exactly.

Continued on next page

Diameter measurements were taken at breast height (d.b.h.).

[a] Tree species included on the list of invasive plants monitored during the inventory of Providence, 2021 (see Appendix 5).

Table 32. (continued)—List of all live tree species and their characteristics, City of Providence, 2021

Genus	Species	Common name	1.0–4.9 in. diameter trees (number)	5.0–10.9 in. diameter trees (number)	11.0+ in. diameter trees (number)	Total (number)	Total (percent)	Total standard error (number)	Average diameter (in.)
Tilia	*americana*	American basswood	0	433	792	1,200	0.2	971	22.7
Tilia	*cordata*	littleleaf linden	0	832	396	1,200	0.2	962	11.8
Tsuga	*canadensis*	eastern hemlock	0	0	396	396	0.1	432	18.9
Ulmus	*americana*	American elm	15,000	9,500	2,900	27,000	5.5	20,000	5.8
Ulmus	*parvifolia*	Chinese elm	0	832	0	832	0.2	860	8.8
Ulmus	*pumila*	Siberian elm[a]	0	0	1,200	1,200	0.2	743	21.7
Zelkova	*serrata*	Japanese zelkova	0	2,400	0	2,400	0.5	1,600	7.9
Total			**289,000**	**115,000**	**91,000**	**495,000**	**100.0**	**129,000**	**6.7**

Due to rounding, not all values will add up exactly.

Diameter measurements were taken at breast height (d.b.h.).

[a] Tree species included on the list of invasive plants monitored during the inventory of Providence, 2021 (see Appendix 5).

APPENDIX 3 – TREE CHARACTERISTICS WITHIN NLCD LAND COVER CLASS GROUP AND FIA LAND USE

Table 33.—Estimates of total number of trees, basal area, and average diameter by National Land Cover Database (NLCD) land cover class group, City of Providence, 2021

NLCD land cover class group	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Developed-Low	American basswood	792	3.8	31.0
	American elm	19,151	2.8	4.3
	apple spp.	4,932	0.2	2.5
	Atlantic white-cedar	792	0.2	6.8
	black cherry	10,656	0.7	2.5
	black locust	396	< 0.1	5.5
	black oak	37,295	6.6	3.6
	boxelder	396	0.5	15.4
	eastern cottonwood	792	3.1	28.1
	eastern hemlock	396	0.7	18.9
	European beech	396	3.1	39.9
	flowering dogwood	4,932	0.2	2.5
	honeylocust	792	1.2	16.4
	Japanese flowering cherry	4,932	< 0.1	1.0
	Japanese maple	4,932	0.8	5.7
	littleleaf linden	396	0.7	18.7
	London planetree	396	1.0	22.9
	northern catalpa	1,584	1.3	11.4
	northern red oak	6,120	1.0	5.4
	Norway maple	65,122	12.5	3.6
	pin oak	396	< 0.1	7.0
	red maple	396	0.2	11.1
	scarlet oak	1,980	1.2	10.2
	Siberian elm	396	2.3	33.8
	silver maple	396	3.3	40.6
	sugar maple	396	0.9	21.9
	white ash	4,932	< 0.1	1.0
	white mulberry	15,192	1.7	4.6
	white oak	792	0.6	12.2
Developed-Medium	American elm	4,975	0.5	8.5
	apple spp.	7,335	0.2	3.9
	Austrian pine	2,488	0.5	12.5
	black cherry	995	0.5	18.9
	black locust	6,838	< 0.1	2.4
	blue spruce	498	0.3	22.4

Estimates are rounded.

Continued on next page

[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

Table 33. (continued)—Estimates of total number of trees, basal area, and average diameter by National Land Cover Database (NLCD) land cover class group, City of Providence, 2021

NLCD land cover class group	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Developed-Medium (cont.)	Callery pear	995	< 0.1	7.7
	cedar of Lebanon	498	0.6	30.1
	eastern cottonwood	498	0.3	23.1
	eastern redcedar	498	< 0.1	7.9
	eastern white pine	1,493	0.3	12.7
	English yew	13,178	< 0.1	1.4
	European beech	1,493	2.3	35.8
	flowering dogwood	1,493	0.1	7.4
	Freeman maple	498	< 0.1	11.8
	green ash	498	0.2	15.8
	hawthorn spp.	498	< 0.1	9.2
	honeylocust	1,493	0.4	13.6
	Japanese flowering cherry	995	< 0.1	7.2
	Japanese yew	6,340	0.3	5.9
	Japanese zelkova	1,990	0.1	7.7
	katsura tree	1,493	0.5	16.4
	London planetree	1,493	0.7	20.2
	northern red oak	1,493	0.9	16.9
	northern white-cedar	40,658	1.1	4.2
	Norway maple	23,754	3.5	9.1
	Norway spruce	498	< 0.1	7.4
	pear spp.	498	< 0.1	5.6
	pin cherry	12,681	< 0.1	1.6
	pin oak	498	< 0.1	8.7
	red maple	4,975	1.0	12.2
	red pine	3,483	0.4	9.7
	river birch	498	< 0.1	5.9
	scarlet oak	498	1.1	43.0
	silver poplar	498	0.4	24.7
	sugar maple	6,838	0.6	4.3
	sweet cherry	498	< 0.1	7.0
	sweet crab apple	498	< 0.1	7.0
	sycamore maple	3,483	0.7	12.7
	white ash	995	0.6	21.3
	white mulberry	10,321	0.7	6.4
	yellow-poplar	995	< 0.1	7.2

Estimates are rounded.

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[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

Table 33. (continued)—Estimates of total number of trees, basal area, and average diameter by National Land Cover Database (NLCD) land cover class group, City of Providence, 2021

NLCD land cover class group	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Developed-High	American elm	832	0.2	13.8
	apple spp.	6,512	0.1	3.5
	Atlantic white-cedar	416	< 0.1	15.3
	boxelder	1,664	0.4	13.7
	Callery pear	2,496	0.3	10.0
	Chinese elm	832	< 0.1	8.8
	eastern redcedar	2,080	< 0.1	5.9
	eastern white pine	416	< 0.1	13.8
	flowering dogwood	1,248	0.1	10.3
	green ash	416	0.1	15.6
	honeylocust	1,248	0.2	12.6
	Japanese flowering cherry	5,264	< 0.1	3.4
	Japanese zelkova	416	< 0.1	8.8
	littleleaf linden	832	< 0.1	8.4
	Norway maple	7,904	1.1	11.4
	red maple	2,080	0.4	12.4
	red mulberry	5,264	< 0.1	2.4
	Siberian elm	832	0.2	16.0
	silver maple	1,664	0.8	21.6
	sugar maple	416	< 0.1	7.4
	sweet cherry	832	0.3	18.6
	sweetgum	416	0.1	16.4
	tree of heaven	416	< 0.1	13.4
	white mulberry	2,080	0.4	12.6
Developed-Open/ Vegetation	American basswood	433	0.1	7.4
	American beech	11,025	7.1	7.4
	American elm	1,733	0.9	8.8
	apple spp.	433	< 0.1	6.1
	Atlantic white-cedar	433	1.9	27.4
	black cherry	8,426	2.1	4.9
	black locust	6,261	0.2	1.9
	black oak	8,230	10.8	14.1
	black walnut	866	1.0	13.5
	eastern redcedar	866	0.5	9.6
	eastern white pine	2,166	10.9	28.8
	European beech	433	11.2	65.9
	green ash	5,394	0.4	3.5

Estimates are rounded.

Continued on next page

[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

Table 33. (continued)—Estimates of total number of trees, basal area, and average diameter by National Land Cover Database (NLCD) land cover class group, City of Providence, 2021

NLCD land cover class group	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Developed-Open/ Vegetation (cont.)	mockernut hickory	866	1.0	13.8
	northern catalpa	433	0.1	6.9
	northern red oak	6,498	16.0	17.6
	Norway maple	866	0.8	11.8
	pignut hickory	2,599	1.9	9.0
	pin oak	866	0.3	7.1
	red maple	3,465	5.6	13.8
	red mulberry	5,394	0.3	2.8
	sawara-cypress	433	1.1	20.9
	scarlet oak	3,032	5.8	16.6
	sugar maple	1,733	9.5	30.0
	sweet birch	866	1.5	15.8
	tree of heaven	866	0.1	5.2
	white ash	866	0.8	11.5
	white mulberry	433	< 0.1	5.3
	white oak	866	0.4	9.0
Water	American elm	500	0.2	10.4
	black oak	2,502	1.4	10.1
	northern red oak	1,001	0.2	6.8
	red maple	3,003	0.8	7.8
	sweet birch	2,002	0.7	8.8
	white oak	500	0.3	12.1

Estimates are rounded.

[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

Table 34.—Estimates of total number of trees, basal area, and average diameter by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021

FIA land use class	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Forest land	American basswood	433	0.3	7.4
	American beech	7,993	7.0	5.4
	American elm	20,197	8.1	4.6
	black cherry	12,492	2.3	3.2
	black locust	6,261	0.5	1.9
	black oak	10,262	24.6	13.2
	black walnut	866	2.0	13.5
	eastern cottonwood	792	7.4	28.1
	eastern white pine	2,166	21.6	28.8
	green ash	5,394	0.8	3.5
	mockernut hickory	866	2.0	13.8
	northern catalpa	433	0.2	6.9
	northern red oak	2,300	2.1	8.6
	Norway maple	866	1.6	11.8
	pignut hickory	2,599	3.7	9.0
	pin oak	1,262	0.7	7.1
	red maple	5,101	12.1	11.7
	red mulberry	5,394	0.5	2.8
	scarlet oak	2,166	4.7	12.9
	Siberian elm	396	5.3	33.8
	sweet birch	2,435	4.4	11.1
	tree of heaven	866	0.3	5.2
	white ash	866	1.5	11.5
	white mulberry	14,796	3.5	4.4
	white oak	1,367	1.7	10.1
Commercial/Industrial	American elm	5,168	0.4	7.2
	apple spp.	11,272	0.1	2.7
	black cherry	5,825	0.2	3.1
	black locust	7,234	< 0.1	2.6
	black oak	6,516	0.8	5.8
	boxelder	396	0.1	15.4
	Callery pear	2,080	0.3	9.7
	eastern cottonwood	498	0.4	23.1
	eastern white pine	416	0.1	13.8
	English yew	12,681	< 0.1	1.0
	European beech	931	3.8	49.9
	flowering dogwood	5,348	0.1	3.1
	Freeman maple	498	0.1	11.8
	green ash	416	0.2	15.6
	honeylocust	396	< 0.1	10.3
	Japanese flowering cherry	10,196	< 0.1	2.2

Estimates are rounded.

Continued on next page

[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

Table 34. (continued)—Estimates of total number of trees, basal area, and average diameter by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021

FIA land use class	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Commercial/Industrial (cont.)	Japanese zelkova	416	< 0.1	8.8
	northern catalpa	1,188	0.1	7.7
	northern red oak	4,932	0.2	4.9
	northern white-cedar	34,687	0.7	3.5
	Norway maple	71,178	2.6	3.4
	pin cherry	12,681	< 0.1	1.6
	pin oak	498	< 0.1	8.7
	red maple	4,233	0.8	10.8
	scarlet oak	792	0.3	14.5
	silver maple	396	1.0	40.6
	sweet cherry	498	< 0.1	7.0
	white ash	4,932	< 0.1	1.0
	white mulberry	3,879	0.7	10.3
	white oak	792	0.2	12.2
Multi-family residential	American elm	498	1.3	20.6
	apple spp.	5,264	0.3	2.8
	black cherry	498	2.3	27.5
	boxelder	1,664	2.3	13.7
	eastern white pine	498	0.3	9.8
	flowering dogwood	995	0.5	8.4
	northern red oak	498	4.0	36.3
	Norway maple	995	1.4	13.0
	silver maple	1,248	4.6	24.3
	sycamore maple	2,985	2.5	11.6
	white mulberry	2,080	2.2	12.6
Residential	American elm	416	< 0.1	9.2
	apple spp.	2,676	0.4	8.0
	Atlantic white-cedar	1,208	0.3	9.8
	black cherry	396	< 0.1	10.3
	black oak	866	0.5	16.6
	blue spruce	498	0.5	22.4
	eastern hemlock	396	0.3	18.9
	eastern redcedar	3,444	0.4	7.1
	English yew	498	0.1	11.1
	flowering dogwood	1,330	0.2	8.7
	Japanese maple	4,932	0.3	5.7
	Japanese yew	6,340	0.4	5.9
	Norway maple	20,577	6.9	10.7
	pear spp.	498	< 0.1	5.6
	red maple	416	0.1	11.4
	red mulberry	5,264	< 0.1	2.4

Estimates are rounded.

Continued on next page

[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

Table 34. (continued)—Estimates of total number of trees, basal area, and average diameter by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021

FIA land use class	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Residential (cont.)	scarlet oak	498	1.8	43.0
	silver maple	416	0.1	13.3
	sugar maple	7,234	1.3	5.2
	sweet cherry	832	0.6	18.6
	sycamore maple	498	0.4	19.3
	tree of heaven	416	0.1	13.4
	white ash	995	1.0	21.3
	white mulberry	7,271	0.4	4.5
Recreation/Cemetery	American beech	3,032	4.8	12.7
	Atlantic white-cedar	433	2.6	27.4
	Austrian pine	2,488	3.2	12.5
	black cherry	866	1.4	13.5
	cedar of Lebanon	498	3.7	30.1
	eastern white pine	995	1.8	14.1
	European beech	1,391	15.5	36.9
	hawthorn spp.	498	0.3	9.2
	katsura tree	1,493	3.4	16.4
	London planetree	1,493	5.0	20.2
	northern red oak	6,193	21.2	17.5
	northern white-cedar	5,970	3.3	8.1
	Norway spruce	498	0.2	7.4
	red maple	1,861	2.3	12.0
	red pine	3,483	2.7	9.7
	river birch	498	0.1	5.9
	sawara-cypress	433	1.5	20.9
	scarlet oak	866	4.7	25.8
	sugar maple	1,733	13.0	30.0
	sweet birch	433	0.3	9.9
	yellow-poplar	995	0.4	7.2
Rights-of-way	American basswood	792	1.3	31.0
	American elm	914	0.3	13.7
	black oak	30,383	0.9	2.9
	Callery pear	1,411	0.2	8.8
	Chinese elm	832	0.1	8.8
	green ash	498	0.2	15.8
	honeylocust	3,137	1.2	14.3
	Japanese flowering cherry	995	< 0.1	7.2
	Japanese zelkova	1,990	0.2	7.7
	littleleaf linden	1,228	0.3	11.8
	London planetree	396	0.3	22.9
	northern catalpa	396	0.3	22.4

Estimates are rounded.

Continued on next page

[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

Table 34. (continued)—Estimates of total number of trees, basal area, and average diameter by Forest Inventory and Analysis (FIA) land use class, City of Providence, 2021

FIA land use class	Common name	Trees (number)	Basal area[a] (sq ft per ac)	Average diameter[b] (inches)
Rights-of-way (cont.)	Norway maple	4,030	1.8	16.2
	red maple	1,807	0.7	14.4
	scarlet oak	1,188	0.1	7.3
	Siberian elm	832	0.4	16.0
	silver poplar	498	0.5	24.7
	sugar maple	416	< 0.1	7.4
	sweet crab apple	498	< 0.1	7.0
	sweetgum	416	0.2	16.4
Water	northern red oak	1,188	0.3	7.7
	red maple	500	0.1	8.0

Estimates are rounded.

[a] Basal area is the cross-sectional area of the tree stems measured at the diameter.

[b] Diameter measurements were taken at breast height (d.b.h.).

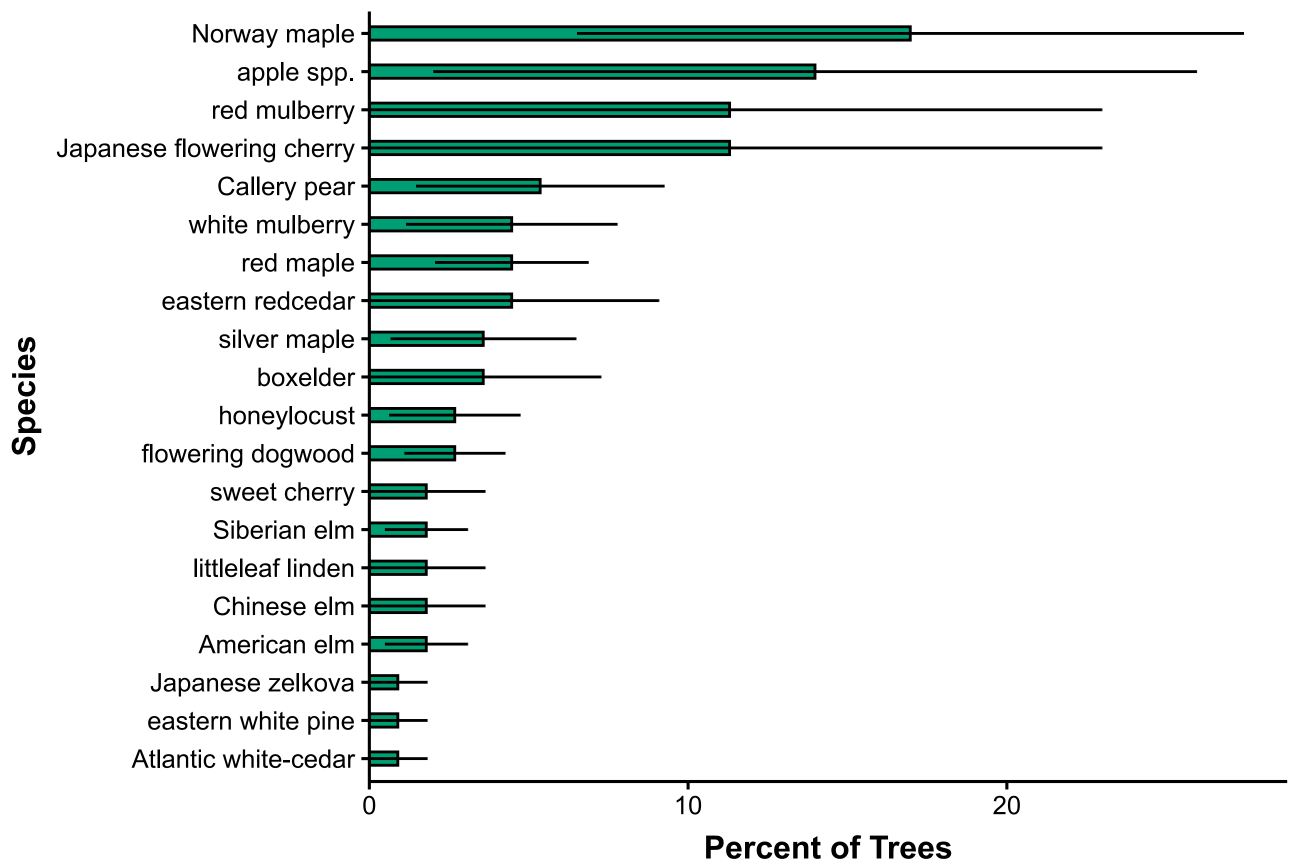

Figure 27.—Percent of the total tree population for up to 20 of the most common tree species observed in the developed-high National Land Cover Database (NLCD) land cover class group, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

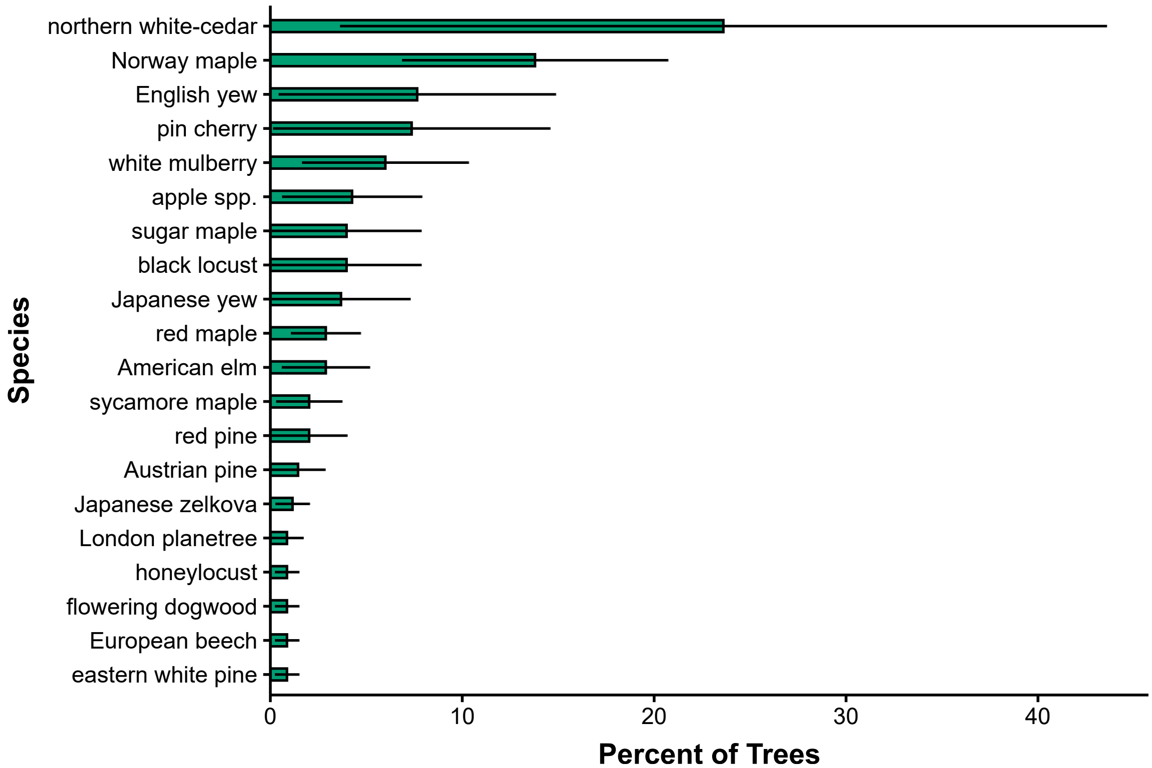

Figure 28.—Percent of the total tree population for up to 20 of the most common tree species observed in the developed-medium National Land Cover Database (NLCD) land cover class group, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

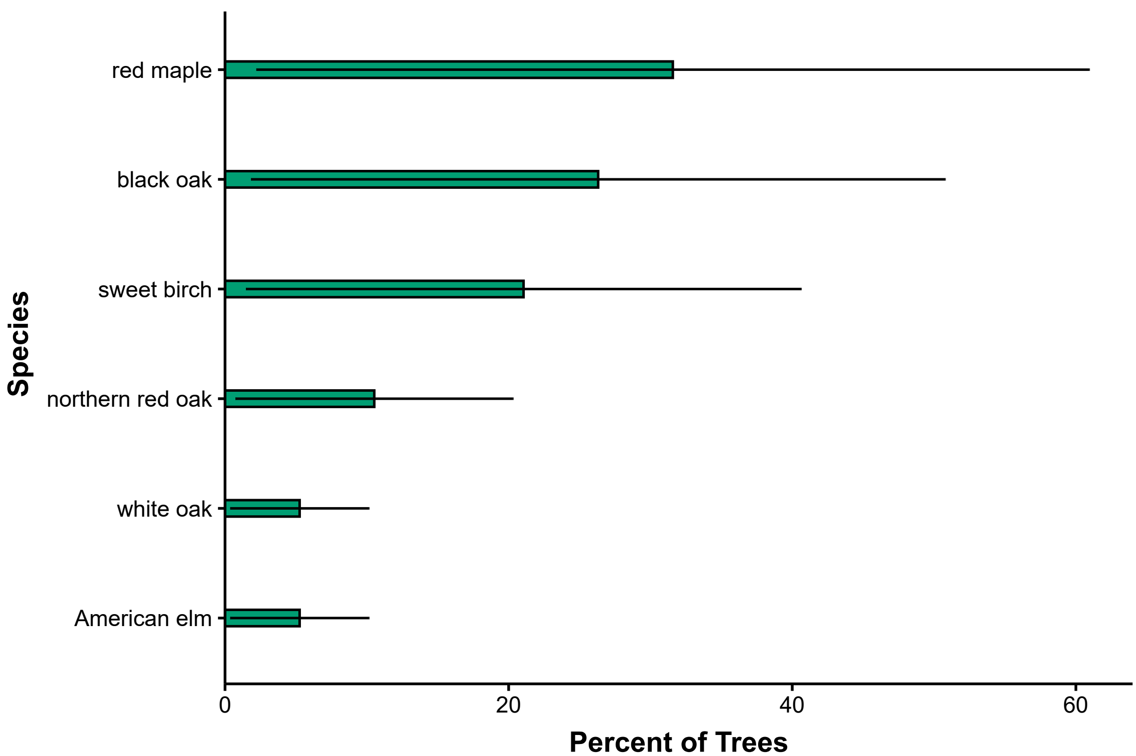

Figure 29.—Percent of the total tree population for up to 20 of the most common tree species observed in the water National Land Cover Database (NLCD) land cover class group, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

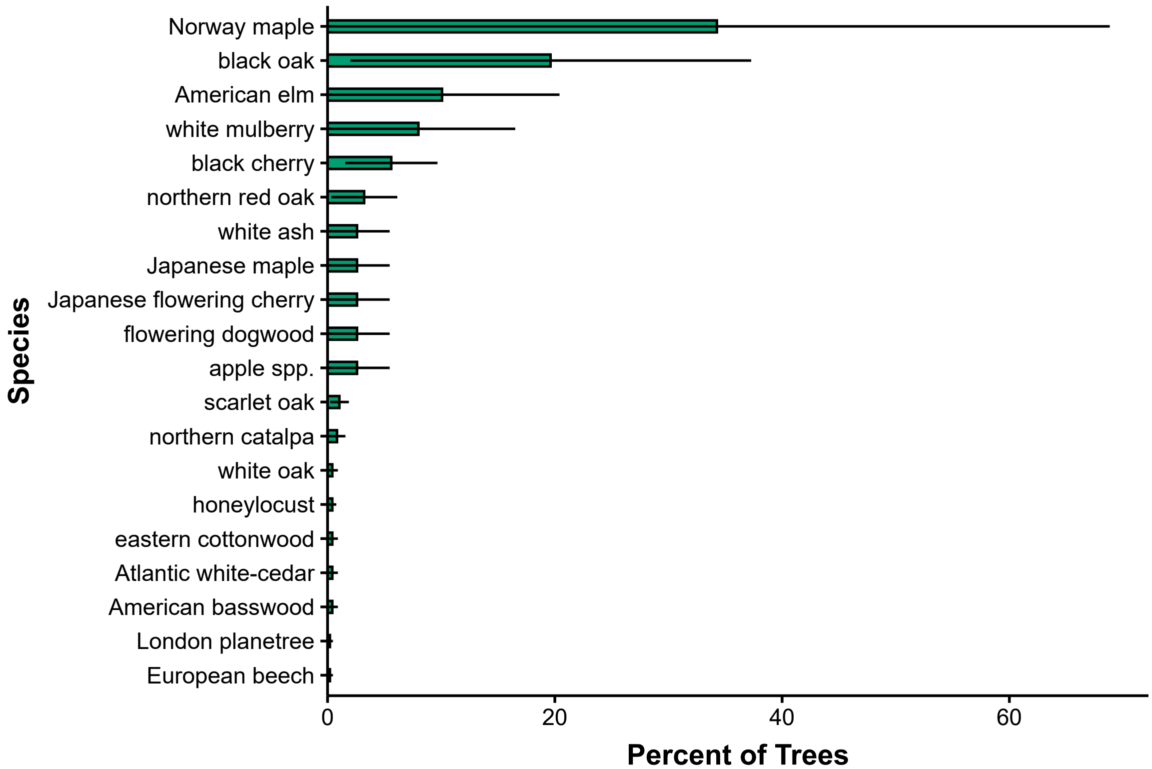

Figure 30.—Percent of the total tree population for up to 20 of the most common tree species observed in the developed-low National Land Cover Database (NLCD) land cover class group, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

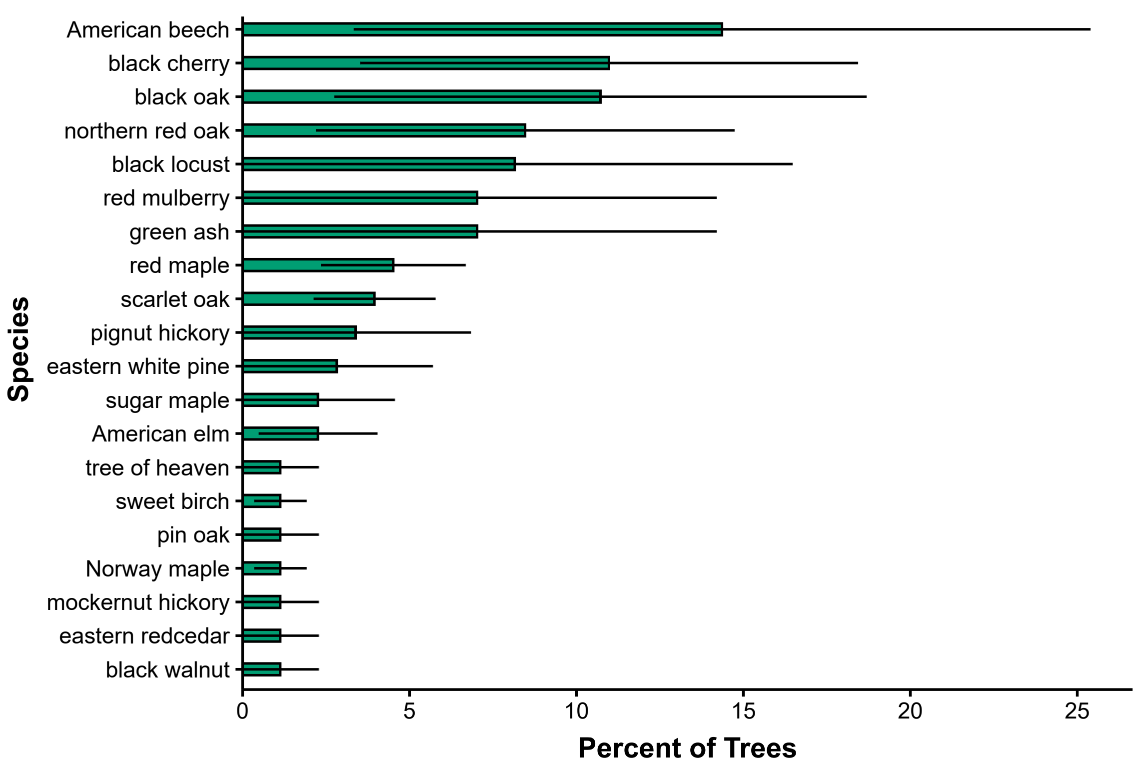

Figure 31.—Percent of the total tree population for up to 20 of the most common tree species observed in the developed-open National Land Cover Database (NLCD) land cover class group, City of Providence, 2021. Error bars represent 68 percent confidence intervals around the estimated means.

APPENDIX 4 – SPECIES COMPOSITION IN MAINTAINED AREAS

Table 35.—Tree species composition in maintained areas, City of Providence, 2021

Common name	Number of trees
northern white-cedar	35,000
Norway maple	14,000
English yew	13,000
sugar maple	9,400
white mulberry	9,400
apple spp.	7,900
Japanese yew	6,300
Japanese flowering cherry	6,300
red mulberry	5,300
Japanese maple	4,900
red maple	4,500
honeylocust	3,500
Callery pear	3,500
red pine	3,500
sycamore maple	3,500
eastern redcedar	2,900
flowering dogwood	2,700
Austrian pine	2,500
Japanese zelkova	2,400
European beech	2,300
eastern white pine	1,900
London planetree	1,900
black cherry	1,800
boxelder	1,700
silver maple	1,700
Atlantic white-cedar	1,600
katsura tree	1,500
northern red oak	1,400
scarlet oak	1,400
American elm	1,300
littleleaf linden	1,200
white ash	1000
yellow-poplar	1000
green ash	910
sweet cherry	830
Siberian elm	830
Chinese elm	830
American basswood	790
Norway spruce	500
blue spruce	500
river birch	500
hawthorn spp.	500
sweet crab apple	500
silver poplar	500
cedar of Lebanon	500
pear spp.	500
sawara-cypress	430
tree of heaven	420
sweetgum	420
eastern hemlock	400

Estimates are rounded.

APPENDIX 5 – LIST OF INVASIVE PLANT SPECIES

Table 36.—Invasive plant species list used in the inventory protocol for City of Providence, 2021

Scientific name	Common name
Acer platanoides	Norway maple
Ailanthus altissima	tree of heaven
Albizia julibrissin	mimosa, silktree
Alliaria petiolata	garlic mustard
Berberis thunbergii	Japanese barberry
Berberis vulgaris	common barberry
Celastrus orbiculatus	Oriental bittersweet
Centaurea stoebe ssp. *micranthos*	spotted knapweed
Cirsium arvense	Canada thistle
Cirsium vulgare	bull thistle
Cynanchum louiseae	Louise's swallow-wort
Cynanchum rossicum	European swallow-wort
Elaeagnus angustifolia	Russian olive
Elaeagnus umbellata	autumn olive
Euphorbia esula	leafy spurge
Frangula alnus	glossy buckthorn
Hedera helix	English ivy
Hesperis matronalis	dames rocket
Ligustrum vulgare	European privet
Lonicera spp.	honeysuckle
Lonicera x bella	showy fly honeysuckle
Lonicera japonica	Japanese honeysuckle
Lonicera morrowii	Morrow's honeysuckle
Lonicera tatarica	Tatarian honeysuckle
Lysimachia nummularia	creeping jenny
Lythrum salicaria	purple loosestrife
Melia azedarach	Chinaberrytree
Melaleuca quinquenervia	melaleuca
Microstegium vimineum	Nepalese browntop
Phalaris arundinacea	reed canarygrass
Phragmites australis	common reed
Polygonum cuspidatum	Japanese knotweed
Polygonum sachalinense	giant knotweed
Rhamnus cathartica	common buckthorn
Rosa multiflora	multiflora rose
Robinia pseudoacacia	black locust
Spiraea japonica	Japanese meadowsweet
Tamarix ramosissima	saltcedar
Triadica sebifera	Chinese tallow
Ulmus pumila	Siberian elm
Viburnum opulus	European cranberrybush
Lonicera maackii	Amur honeysuckle
Paulownia tomentosa	paulownia, empress-tree
Polygonum x bohemicum	Bohemian knotweed

APPENDIX 6 – TREE SPECIES' PEST RISK SCORE

Table 37.—Tree species' pest risk score from various insects and diseases, City of Providence, 2021

Common name	Cumulative pest risk score	WM	FTC	SM	LAT	DED	BBD	EAB	SPB	DA	WPBR	RPS	BC	HWA	SLF	BM	ALB	OW	BLD	HRD	PSB	SW	JPBW	SBW	SB	TCD	BWA	FR	AL	MOB	PSHB	POCRD	SOD	WBBU	WSB	MPB
eastern white pine	27		4						4		4				3					3	3	3	3													
northern red oak	26	4	4	4											3	3		3										2		1	1		1			
pin oak	26	4	4	4											3	3		3										2		1	1		1			
Norway spruce	25								4											3	3	3		3	3		3							1	1	1
scarlet oak	25	4	4	4											3	3		3										2		1	1					
white oak	25	4	4	4											3	3		3										2		1	1					
black oak	24	4	4	4											3	3		3										2		1						
red pine	24		4						4			4								3	3	3	3													
sweet cherry	24	4	4		4										3	3	3												2	1						
black cherry	23	4	4		4										3	3	3												2							
American elm	22	4	4			4									3	3	3														1					
Chinese elm	22		4	4		4									3	3	3														1					
river birch	22	4	4	4	4										3		3																			
Siberian elm	21	4	4			4									3	3	3																			
Japanese flowering cherry	20		4		4										3	3	3												2		1					
pin cherry	20	4	4		4											3	3												2							
American basswood	19	4	4	4											3		3														1					
boxelder	19	4		4											3	3	3													1	1					
eastern cottonwood	19	4	4	4	4												3																			
silver poplar	19	4	4	4	4										3																					
sweet birch	18	4	4		4										3		3																			
green ash	18	4	4					4							3		3																			
sugar maple	18	4	4												3	3	3													1						
sweet crab apple	17	4		4											3	3	3																			
blue spruce	15								4												3			3	3									1	1	
white ash	15	4	4					4							3																					
American beech	14			4			4								3				3																	
Austrian pine	14		4						4												3	3														
Callery pear	14			4											3	3	3														1					
Norway maple	14	4													3	3	3													1						
red maple	14	4													3	3	3													1						
silver maple	14	4													3	3	3													1						
apple spp.	13			4											3	3	3																			
pear spp.	13			4											3	3	3																			
black walnut	11												4		3											3					1					
eastern hemlock	11								4					4										3												
Freeman maple	11														3	3	3													1	1					
Japanese maple	11														3	3	3													1	1					
littleleaf linden	11		4	4													3																			
sycamore maple	11														3	3	3													1			1			
European beech	10						4												3											1	1		1			
sweetgum	9		4	4																											1					
flowering dogwood	7									4					3																					
London planetree	7														3		3														1					
white mulberry	7														3		3														1					
eastern redcedar	4																			3											1					
hawthorn spp.	4			4																																
Japanese zelkova	4														3																1					
northern white-cedar	4														3																	1				
tree of heaven	4														3																1					
yellow-poplar	4														3																1					
black locust	3														3																					
katsura tree	3																3																			
pignut hickory	3														3																					
red mulberry	3																3																			
English yew	1																																1			
honeylocust	1																														1					
northern catalpa	1																														1					

See Table 30 for a key to the pest and pathogen abbreviations used in this table.

Northern Research Station
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