City of Tampa Tree Canopy and Urban Forest Analysis

2016

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Final Report to the City of Tampa
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Executive Summary

Background

This report summarizes the third urban forest inventory and ecological analysis conducted for the City of Tampa. The City of Tampa tree ordinance (Ord. No. 2006-74, § 9, 3-23-06) requires that the urban forest be assessed every five years. In an effort to reduce concerns over bias, this work has been conducted by a collaborative team from the University of South Florida and the University of Florida following an established USDA Forest Service field protocol. This report provides detailed information about the current size, composition, health, and distribution of Tampa's urban forest. It also provides a means for determining how the forest and associated benefits have changed over the last five-year monitoring interval and since the initial inventory in 2006.

The intended audience for this report includes policymakers, agency managers, businesses, neighborhood associations and the City's residents. This project is part of the City of Tampa's Urban Forest Program. This report is intended to help Tampa enact tangible solutions to protect the City's natural environment for future generations.

Key Findings –Urban Forest Composition

- Tampa's municipal forest consists of 9.3 million trees and contains 112 tree species and 145 shrub species.
- Of the 112 tree species identified, 51 (46%) are listed in the Urban Forest Management Plan's Tree Matrix as desirable species suitable for planting.
- 55% of the tree species are rated as having a high to medium-high wind resistance; and 36% having a medium-low to low wind resistance. There is no reliable wind resistance information on the remaining 9%.
- Native species account for 70% of the trees found in Tampa. Brazilian pepper now represents 8% of the total population (11% if mangroves are excluded).
- Eight species of trees and palms account for 62% of the City's trees.
- One out of every four trees in Tampa is a mangrove species. However, mangrove ecosystems account for only 1.6% of Tampa's land area and 2.5% of the leaf area.
- The high density of these mangrove ecosystems partially explains why tree size is skewed to smaller diameter trees — with 70% between 1" and 6" in diameter.
- While some areas of the City are densely forested, Tampa has an average of 125 trees per acre — a third of what is typical of native forests.
- With regard to forest health, 55% of trees are rated as being in excellent condition; 28% are in good condition, 6% are in fair condition, and 11% are in poor condition or dead.

Key Findings – Urban Forest Canopy Cover

- Tampa has 27,641 acres of tree canopy, 20,839 acres of grass/shrub land cover, and about 23,926 acres of impervious surfaces (e.g., buildings, roads, and other paved surfaces).
- Estimated citywide canopy coverage increased from 31.7% in 2006 to 34.4% in 2011, but then decreased to 32.3% in 2016. These differences were not statistically significant.

- From 2006 to 2011, there was a slight increase in tree canopy in all Planning Districts, and a significant increase in South Tampa. Between 2011 and 2016 there was essentially no change within most Districts, except a slight increase in Central Tampa.
- With regard to the Neighborhood Associations, tree canopy ranged from a low of 4% in the Channel District to a high of 73% in Tampa Palms.
- Most of the City's tree canopy (13,956 acres or 50%) is located on residential properties.
- Nearly 25% of all tree canopy (6,522 acres) is located on properties designated as Major Environmentally Sensitive Areas in the Land Use Element of the Tampa Comprehensive Plan.
- Compared to other Future Land Use categories, the public Right-of-Way has the third largest acreage of tree canopy (2,797 acres) and an even larger area of grass/shrub (3,316 acres) where some additional tree planting could conceivably be done.

Key Findings – Urban Forest Economic Benefits and Ecosystem Services

Each year, Tampa's urban forest:

- Reduces 808 tons of air pollutants that cause respiratory problems — eliminating an estimated $4.5 million in health care costs
- Reduces residential building air conditioning (shading) and heating (wind break) costs by $7 million
- Reduces 50 million cubic feet of stormwater runoff (valued at $3.4 million)
- Stores 865 million tons of carbon in trees and woody shrubs (valued at $112 million)
- Sequesters 62,000 tons/year of atmospheric carbon by trees and shrubs (valued at $8 million)

In addition to the $134.9 million dollars in ecosystem services listed above, an investigation into home prices and tree cover conducted as part of this assessment found:

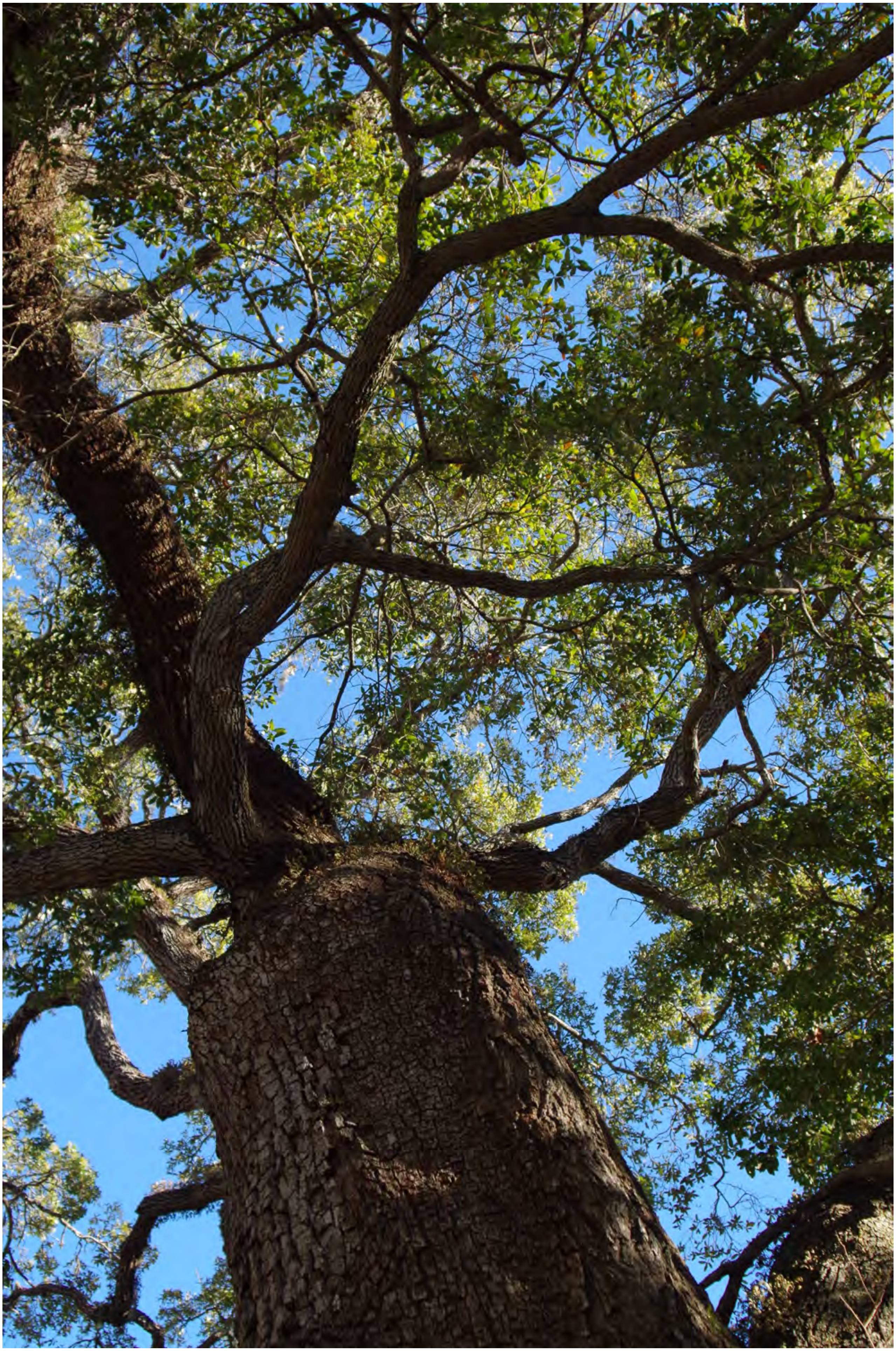
- The sale price of single-family homes increased between $155 to $164 for every 1% increase in tree canopy within the 500-foot neighborhood surrounding the house lot.
- With 32% canopy coverage citywide, Tampa's urban forest increases home values by $5,248 on average.

Total estimated structural (or replacement) value of the urban forest is $2.01 billion.

Purpose of the Urban Forest Analysis

The City of Tampa's Urban Forest Management Plan (UFMP) was adopted by the Tampa City Council in 2013 and enacted by an executive order in 2014. Defined objectives and measurable performance criteria within the UFMP guide its implementation and ongoing evaluation. The 2016 Tampa Tree Canopy and Urban Forest Analysis describes the state of the urban forest and estimates some of its economic, social, and environmental values as a part of the evaluation process. The data collected and summarized here allow the City to measure its progress, identify confounding issues, and make operational and policy adjustments, as it strives to meet the plan's intended outcomes.

The 5-year cycle of inventory and analysis deliberately coincides with the 5-year revision cycle for the UFMP. This report will be reviewed by the City through its Internal Technical Working Group and Natural Resources Advisory Committee. These two appointed committees will make recommendations (as needed) to Tampa's planning department and executive branch on ways to improve the efficiency and effectiveness of urban forestry operations and policy.



City of Tampa's Urban Forest Management Plan

The City of Tampa's UFMP outlines numerous management and urban forest resource objectives, establishes a timeframe for the implementation of management efforts, and identifies the agency or partnership responsible for completing the work. Performance criteria are used to judge the effectiveness of these efforts and their impact on the environmental, economic, social, and cultural function of Tampa's urban forest (Table 1). These criteria are intended to reflect public values, as well as the vision and goals initially set by the Steering Committee on Urban Forest Sustainability.

Each criterion provides a range of performance indicators that are used to gauge the current state of Tampa's urban forest management and facilitate decision-making in the City's urban forest policy processes (Table 1). This allows the City to assess and improve urban forest management practices over time through an adaptive management process.

Specific criteria and performance indicators associated with the City's urban forest vegetation resource are monitored every five years though the Urban Forest Analysis (i.e., this report). Each analysis provides new data for policy makers, resource managers, and concerned citizens to assess the current condition of Tampa's urban forest. It also allows for the tracking of long-term trends in urban forest composition and condition given past and ongoing management efforts.

Monitoring these specific criteria and performance indicators allows the City of Tampa to use an adaptive management approach to urban forestry, and promote flexible decision-making. Careful monitoring of the indicators will help the administration adjust policies or operations as part of an iterative learning process leading to more effective decisions and enhanced benefits while reducing tensions among stakeholders.

Table 1. Performance criteria related to Tampa's urban forest vegetation resource.

Cells outlined in black indicate the condition of the urban forest given the results of the 2016 Urban Forest Analysis and the performance indicators provided. (11) indicates criteria rating in 2011, as listed in the City of Tampa Urban Forest Management Plan. November 2013.

Criteria	Vegetation Resource – Performance Indicators				Key Objective
	Low	Moderate	Good	Optimal	
1 Species suitability for Tampa's climate zones	Less than 50% of trees are of species considered suitable for Tampa.	**50%–75% of trees are of species considered suitable for Tampa.** (11)	More than 75% of trees are of species considered suitable for Tampa.	At least 90% of the trees are of species suitable for Tampa.	Establish a tree population suitable for Tampa's urban environment and adapted to the regional environment.
2 Canopy cover relative to goals by municipal planning district	The existing canopy cover equals 0%–25% of the goal.	The existing canopy cover equals 25%–50% of the goal.	The existing canopy cover equals 50%–75% of the goal.	**The existing canopy cover equals 75%–100% of the goal.** (11)	Relative canopy cover to goal for each municipal planning district category.
3 Tree species diversity	Fewer than five species dominate the entire tree population citywide.	No species represents more than 20% of the entire tree population citywide.	**No species represents more than 15% of the entire tree population citywide.**	No species represent more than 10% of the entire tree population citywide. (11)	Establish a diverse tree population citywide.
4 Diameter (DBH) distribution of trees in the city	Any relative DBH (RDBH) class[i] (0%-25% RDBH, 26%-50% RDBH, etc.) represents more than 75% of the tree population.	**Any RDBH class represents between 50% and 75% of the tree population.**	No RDBH class represents more than 50% of the tree population.	25% of the tree population is in each of four RDBH classes.	Provide for uneven aged distribution[ii] citywide.
5 Tree health condition by municipal planning district.	Less than 30% of trees rated as excellent health condition.	**31–60% of trees rated as excellent health condition.** (11)	61–85% of trees rated as excellent health condition.	Greater than 85% of trees rated as excellent health condition in all municipal planning districts.	Healthy trees live longer, produce greater no. of benefits and reduce costs associated with maintenance.
6 Wind resistance of tree species[iii] citywide	Majority of trees are rated in lowest category of wind resistance.	**Majority of trees are rated in medium and high categories of wind resistance.** (11)	Majority of trees are rated in high category of wind resistance.	Greater than 80% of trees are rated in highest category of wind resistance.	Reduce disruption of social and economic services; reduce cost of cleanup and protect private property and human well-being.
7 Tree species longevity	Less than 25% of trees are of species considered long-lived for Tampa.	**25% to 49% of trees are of species considered long-lived for Tampa.**	50%–75% of trees are of species considered long-lived for Tampa. (11)	More than 75% of trees are of species considered long-lived for Tampa.	Establish a long-lived[iv] tree population that maximizes benefits vs. costs
Current State - Summary	**0**	**5**	**1**	**1**	

[i] RDBH – Relative Diameter at Breast Height: the ratio between the measured diameter at breast height and the maximum diameter for the species.

[ii] Uneven Aged Distribution: The population of all trees is comprised of a diversity of ages. Uneven-aged forest stands (urban forests) usually possess a reverse J-shaped diameter distribution, with large numbers of small trees and relatively few large-diameter trees. In reality, each species of tree within the forest stand (urban forest) will have its own diameter distribution, and the overall age distribution is a composite of these (after Nyland, 1996).

[iii] Wind Resistance of Trees: Duryea et al. (2007). Hurricanes and the urban forest: effects on southeastern coastal plain trees. *Arboriculture and Urban Forestry*, 33(2): 83-97. And Duryea et al. (2007). Hurricanes and the urban forest: effects on tropical and sub-tropical trees. *Arboriculture and Urban Forestry*, 33(2): 98-112.

[iv] Long-lived: refers to species of trees that exhibit the ability to tolerate harsh urban conditions for time frames that approximate their natural lifespan.

The Benefits of Trees

Aesthetic

Trees bring a sense of place and maturity to new developments, while larger species help to create a more human scale to old and existing townscapes.

Shade and Cooling

Trees cool the air by providing shade and through evapotranspiration from their leaves. Larger canopy species are particularly effective.

Property Value

Tree-lined streets have been proven to increase house prices by as much as 15%. Most people chose to live around trees where possible.

Assists Recovery

Helps improve recovery times from illness, reduces stress, plus improves mental health and well-being.

Energy Saving

Trees located alongside buildings can act as a secondary insulating layer, regulating temperatures around buildings. If well placed, trees can help keep buildings cooler in the summer and warmer in the winter.

Focal Point

Improves social cohesion. Reduces crime.

Storing Carbon

As trees grow they accumulate carbon in their woody tissues, reducing the amount of this greenhouse gas in the atmosphere.

Urban Forest Food

Trees provide fruit and nuts for wildlife and humans. They also provide an important source of nectar for bees and other insects.

Biodiversity and Habitat

An increase in tree diversity will benefit a host of insects, birds and mammals in our towns and cities.

Improving Air Quality

Trees filter fine particles from the air, reducing pollution and improving health.

Stormwater Attenuation

Trees help to reduce localized flooding by intercepting rainfall and maintaining soil permeability.

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Project Methods

Study Area

The City of Tampa, Florida (28°N, 82°W) is located on the west coast of Florida and sits close to the mid-point of the peninsula. The City's political jurisdiction as of 2016, including the shoreline of Tampa Bay, was used to define the project study area (Figure 1). The total study area is 118 square miles (75,288 acres). According to the United States Census Bureau (www.census.gov), total population within the City of Tampa was 335,709 in the year 2010 and was estimated at 377,165 for the year 2016.

Tampa is located in a transitional zone between subtropical south Florida and temperate north Florida. The City is also split into two different USDA Plant Hardiness Zones with the northern inland parts of the City in zone 9b and the southern coastal parts in zone 10a. Tree species found in this unique transitional climate are generally specific to either subtropical or temperate climates. Therefore, this coexistence of tree species at their northern and southern limits provides for a unique and diverse urban forest composition.

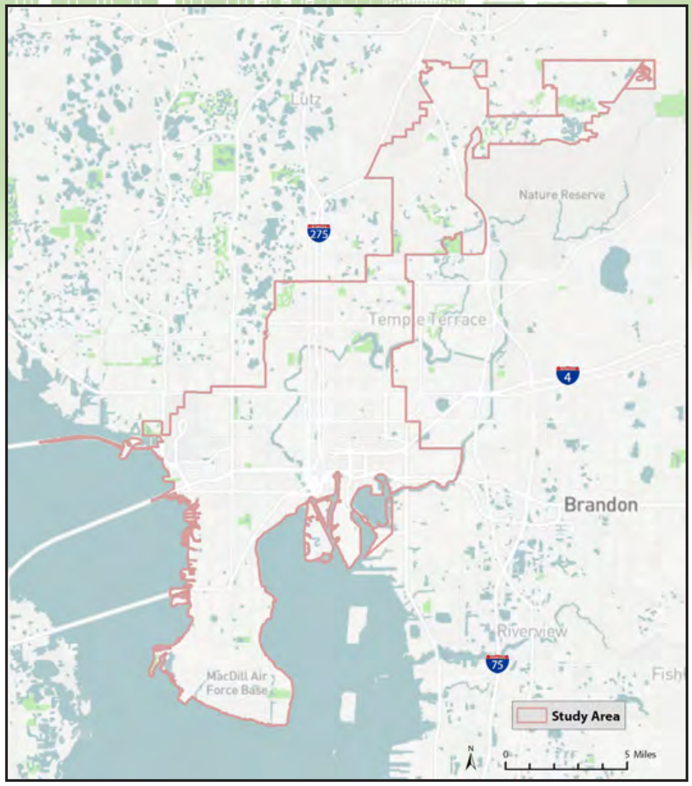

Figure 1. Project study area.

Field Methods

The City of Tampa's initial urban forest assessment took place in 2006-2007. In creating the sampling design, a hexagonal grid (Figure 2) was transposed onto the City, with each hexagon unit representing 437 acres and containing one randomly generated sample point. Two hundred and one permanent inventory plots were created within Tampa's political boundary. The latitude and longitude coordinates for each sample point were used to define plot centers. In the field, plot centers were located by GPS and confirmed by measuring proximity to fixed reference objects (e.g., buildings, intersections, etc.). A fixed radius $^{1}/_{10}$ acre (r=37.2 ft) sample area from plot center was used to establish the plot boundaries.

In compliance with the City of Tampa tree ordinance Ord. No. 2006-74, § 9, 3-23-06, follow-up assessments were conducted every five years after the initial inventory

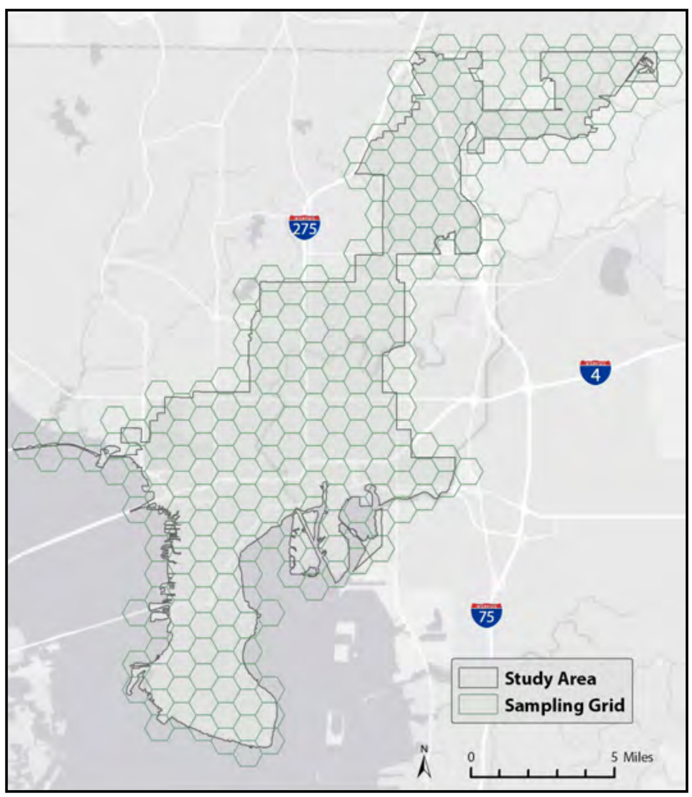

Figure 2. Study area with field sampling grid.

Measuring a tree's diameter at breast height (DBH).

was completed. All two hundred and one plots were re-inventoried in 2011-2012 and 2016-2017. The 2016 follow-up assessment collected data at 193 of the original 201 plots. Eight new locations (not sampled in 2011) were added to the project to replace plots that researchers were unable to access in 2016.

For this study, data were collected on trees, shrubs (i.e., understory), and ground cover. Only trees 1 inch in diameter at breast height (DBH, measured 4.5 feet from the ground) were recorded. Woody plants taller than 1 foot but with stems less than 1 inch at DBH were considered shrubs. Woody or herbaceous vegetation less than 1 foot tall were considered ground cover.

Data were collected following the plot sampling protocol referenced in the 2017 i-Tree User's Manual (v6), Phase III found at www.itreetools.org. Though not required by the protocol, palm tree and palm shrub cover were defined separately from woody tree and woody shrub cover to account for differences in their growth habit and biology. These data were aggregated prior to ecosystem service modeling.

Data collected also included the following: Percent cover of tree and shrub stratum (with and without palm species); Percent ground cover; Identification of tree and shrub species; Tree DBH; Tree height; Tree crown measurements; Crown condition assessments; Proximity of trees to buildings; Tree crown light exposure index.

Data were analyzed by the i-Tree Eco software tool (v6), formerly known as UFORE (Urban Forest Effects Model) (Nowak et al. 2002), which was created by the U.S. Forest Service. Models within i-Tree Eco quantify the structure and following values of the urban forest: Structural value; Residential heating and cooling savings; Avoided air pollution abatement value; Public health savings; Carbon sequestration value; Carbon storage value; Avoided stormwater costs.

Field Plot Stratification and Reporting

Field data collected at the 201 field sampling plots were extrapolated to estimate urban forest composition, structure (e.g., tree size, density) and benefits for the entire City of Tampa. This extrapolation was conducted for each land use (e.g., residential, commercial, etc.), and projected over the total area for each land use within the City. These total areas were determined using a parcel-based land use map combined with maps of open-water and mangrove habitats. The land use designations assigned represent how land was actually being used at the time of the 2016 field sampling and tree canopy mapping. They do not necessarily correspond to regulatory designations such as zoning or future land use.

The correct classification of land use is a fundamental factor that affects the amount of estimation error (i.e., uncertainty) associated with the extrapolated i-Tree model results. With a decade of experience, the research team conducting the Urban Forest Analysis has a much greater understanding of the importance of correct land use classification when making citywide projections of species composition, structure, and ecosystem benefits. This understanding has led to several major improvements/changes (compared to previous years) to how we classified land use. For example, two previous catch-all categories of "Public / Quasi-Public Institutional" and "Recreational / Open Space / Natural" have been split into: Public Institutional, Private Institutional, Parks/Recreation, and Natural/Conservation Lands. Mangrove forests have been separated into a distinct category in order to provide information about this important resource, as well as to remove these protected areas from the tree count/species estimates for other land use categories. Residential has been split into Single-Family and Multi-Family. Open-water has been more thoroughly represented, while leaving wetlands within the land use where they are located.

Table 2. Land use categories, associated acreage, and # of field plots.

Current Use of Land	Area (acres)	City Area	Field Plots
Agriculture	1,679	2.2%	1
Commercial	6,933	9.2%	18
Industrial	2,968	3.9%	9
Mangrove	1,218	1.6%	6
Natural / Conservation Lands	4,657	6.2%	14
Parks / Recreation	2,553	3.4%	12
Private Institutional	2,343	3.1%	7
Public Communications/Utilities	343	0.5%	4
Public Institutional	13,043	17.3%	24
Residential Multi-Family	3,374	4.5%	11
Residential Single-Family	20,749	27.6%	58
Right-of-Way / Transportation	13,022	17.3%	30
Water	2,406	3.2%	7
Total	**75,288**	**100%**	**201**

The land use designations are shown in Table 2. The total acreage and percent of the City's area are based on Tampa's jurisdictional boundaries excluding the open water of Tampa Bay. Also included in the table is the number of field plots that represent each land use. All field plot land use assignments were based on location within a geographic information system, and field verified to ensure the designation made was appropriate.

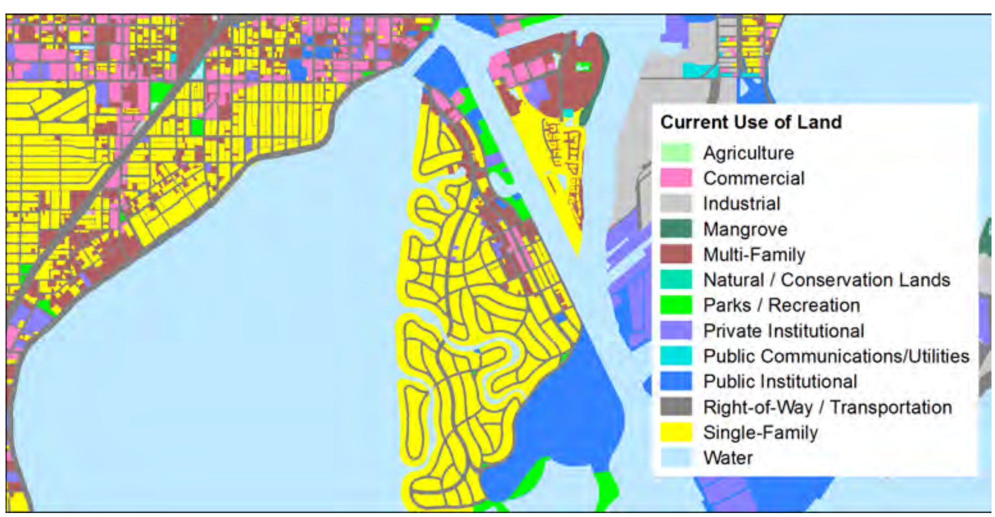

Figure 3. Map snippet showing mosaic of Current Use of Land in the City of Tampa.

Tree Canopy Methods

Tree Canopy is the mass of leaves, branches and stems of trees that cover the ground when viewed from above. In addition to the sample-based field inventory used to estimate urban forest composition, structure, health and associated functional benefits, remote sensing techniques were used to measure 2016 tree canopy cover, as well as change in canopy coverage within the City of Tampa since the first and second urban forest analyses.

Tree Canopy Mapping

Tree canopy mapping provides information about the distribution of tree cover, as well as grass/shrub and other land coverage within the City of Tampa. The method used to map 2016 tree canopy was a slight improvement compared to the method used for the 2011 Urban Forest Analysis. Tree canopy mapping for 2016 was conducted using advanced object-based image analysis techniques in collaboration with Jarlath O'Neil-Dunne from the University of Vermont (O'Neil-Dunne et al. 2014). Object-based methods have been shown to be more accurate for mapping tree cover in the Tampa area than other land cover classification methods.

The tree canopy map was based on six-inch resolution (i.e. imagery capturing objects as small as 6 inches), multi-spectral (blue, green, red, near-infrared) aerial imagery from early spring 2016 obtained from the Hillsborough County Property Appraiser. Aerial LiDAR (LASER rangefinding) data from the Southwest Florida Water Management District was converted to relative height above ground and used to differentiate between trees and grass or buildings and other impervious surfaces. These data sources, as well as ancillary data like road centerlines and water/wetland boundaries were used as part of a set of land cover classification rules. Extensive manual corrections were then made of the initial maps by visual examination of all sections of the study area.

The final map included six land cover classes: tree canopy (>8 ft tall); grass/shrub (<8 ft tall); buildings; other impervious surfaces (e.g., roads, sidewalks, driveways, parking lots); bare earth; and water. Accuracy of the tree canopy cover dataset was assessed by visually comparing the classified land cover at 4,199 randomly distributed points. Overall accuracy of the final tree canopy cover was 92.2%.

Tree canopy and other land cover classes were summarized for different geographic areas of the City using geographic information systems data acquired with the assistance of staff from City of Tampa Planning & Development. Boundary layers for tree cover and change summaries included: Zoning categories, Future Land Use categories, Neighborhood Associations, and the i-Tree land use classifications described above.

Figure 4. Aerial images, LiDAR, and ancillary map data are used to create detailed land cover maps.

Tree Canopy Change

A long-term assessment of changes in tree canopy cover was conducted as part of the second City of Tampa Urban Forest Analysis (2011) using Landsat satellite images taken in 1975, 1986, 1996, 2006 and 2011. Canopy cover decreased substantially between 1975 and 1986, and then gradually increased in 1996, and 2006. By 2011, the amount of tree canopy cover had returned to 1975 levels (Landry et al. 2013). Although this method provided a useful and efficient measure of change since the 1970s, it consistently underestimated total tree cover. In lieu of using Landsat image analysis for 2016, this report used the more robust, accurate, and labor-intensive dot-based analysis to track tree canopy change (Pu et al. 2011) for the years 2006 to 2016 (a timeframe that coincides with the three urban forest analyses conducted by the City of Tampa).

The dot-based method, developed by researchers from the U.S. Forest Service, uses geographic information systems software to create randomly distributed point locations throughout the City (Nowak et al. 1996). At each point, a trained technician examines an aerial image and determines whether or not the point falls on a tree canopy. While labor intensive, an advantage of the dot-based method is that the accuracy of the tree cover estimates is not sensitive to differences in the resolution of the aerial images used for the analysis. Figure 5 illustrates why tree canopy maps generated from aerial images are typically not appropriate for measuring change over time. Notice how the lines on the football field are difficult to see on the images on the left. Computer algorithms that generate tree canopy maps are very sensitive to image resolution. Small trees that were mapped in 2016 using the image on the right (0.5 ft pixel) may not have been mapped in 2006 using the image on the left (3.28 ft pixel). Thus, a change analysis based on tree canopy maps would show an increase in trees solely due to the higher resolution. The dot-based method overcomes this problem and therefore it is a more accurate change analysis technique.

Figure 5. Image resolution for tree canopy analysis.
Left to right: 2006 (3.28 ft./pixel), 2011 (1 ft./pixel), 2016 (0.5 ft./pixel).

This project used aerial images to estimate tree canopy in 2006, 2011 and 2016 (Figure 5). Citywide tree canopy coverage for each year was determined by two trained technicians independently evaluating over 4,000 points. Tree canopy change results within Tampa's Planning Districts and City Council Districts were determined based on the assessment of over 9,000 points by a single trained technician. The results produce estimates of overall tree canopy as well as the uncertainty associated with the estimate. The statistical significance of changes from one year to the next were based on overlap of 95% confidence levels.

The Value of Trees for Single-Family Home Sales

The impact of tree canopy and trees on the sales price of single-family homes was estimated using the hedonic pricing method (Donovan and Butry 2010), a statistical technique that looks at the contribution of internal (e.g. number of bedrooms) and external (e.g. school district) factors that contribute to the price of a good or service. This method is often used to estimate the value of environmental amenities that are hard to value using traditional appraisal methods. The hedonic analysis used for this Tampa study estimates the contribution that tree canopy adds to the sales price of homes by considering all of the other important variables that influence sales price. An overview of the methods are included within the results section and the detailed methods are provided in Appendix B.

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Results and Discussion

Urban Forest Composition

Tree Population

There are an estimated 9.3 million trees in the City of Tampa, representing 112 species. The ten most common tree species, representing 66% of the total population, are white mangrove (*Laguncularia racemosa*), baldcypress/pondcypress (*Taxodium* spp.), Brazilian pepper (*Schinus terebinthifolius*), laurel oak (*Quercus laurifolia*), black mangrove (*Avicennia germinans*), wax myrtle (*Morella cerifera*), cabbage palm (*Sabal palmetto*), swamp tupelo (*Nyssa sylvatica* var. *biflora*), live oak (*Quercus virginiana*), and buttonbush (*Cephalanthus occidentalis*) (Figure 6). Brazilian pepper, an exotic invasive tree, is the only species represented in the top ten that is not native to Florida.

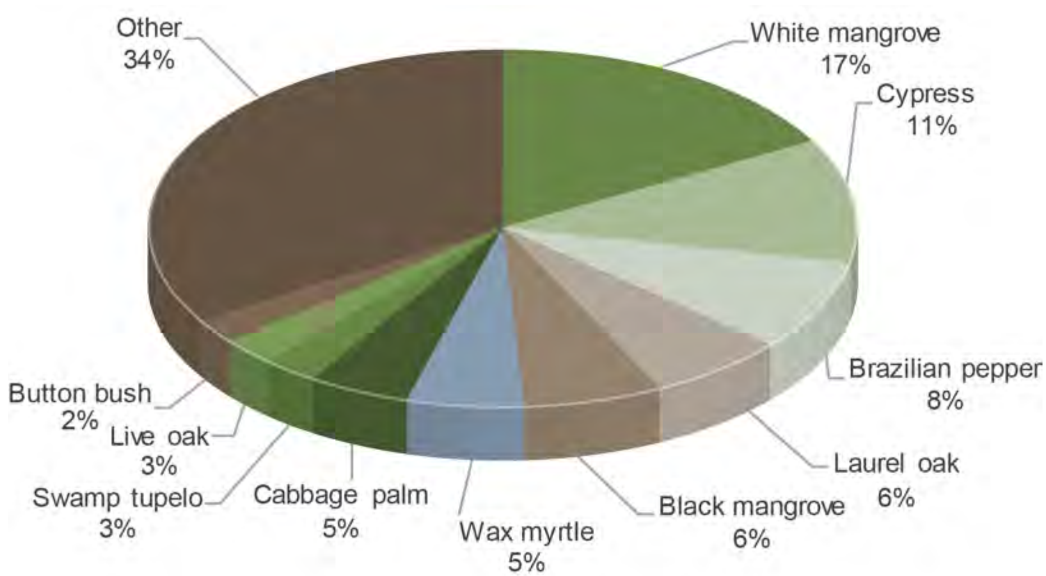


Figure 6. Top ten tree species and their associated percentages by estimated tree numbers in 2016.

Figure 7. Top ten tree species in the City of Tampa.

Diversity

Diversity, or species richness, is the number of species present in a given area. Species diversity can be an important indicator of an urban forest's vulnerability or resilience to natural disturbances such as insect and disease outbreaks (Alvey 2006, Duryea et al. 2007, Escobedo et al. 2009, Raupp et al. 2006). Areas with low species diversity can be highly vulnerable if and when these disturbances occur. One hundred and eighty (180) plant species were identified in the City. Of these, 112 species (Appendix A) were trees (woody stems ≥1" DBH), and 145 species were shrubs (woody plants ≥ 1ft height, <1" DBH).

When looking at the total number of tree species per land use category, Residential Single-Family areas had the greatest diversity (79 species), containing over 70% of the total tree species identified in this study. This comes as little surprise as homeowners typically plant a broader range of tree species in their home landscapes or as part of their gardening activities. By comparison, Natural/Conservation Lands had less than half the number of species seen in Residential Single-Family areas (32 species) (Figure 8).

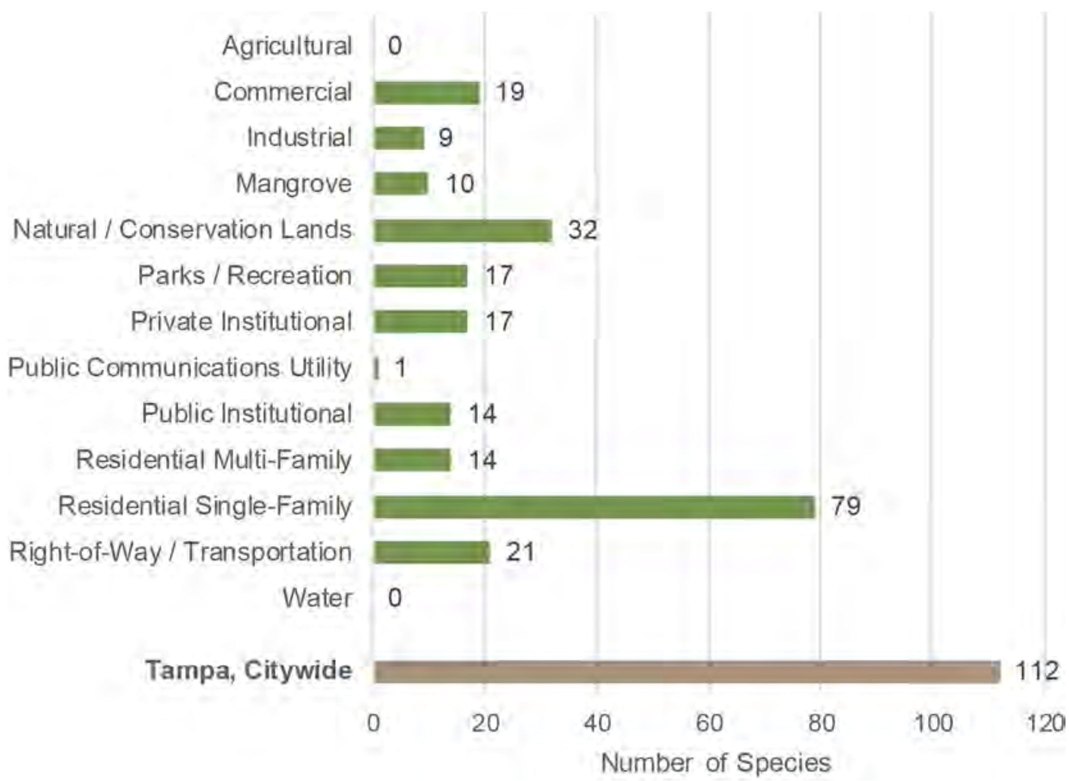


Figure 8. Comparison of the number of tree species by land use in 2016.
Note: Agricultural category is represented by only one sample plot.

Wax Myrtle
Morella cerifera

Cabbage palm
Sabal palmetto

Swamp tupelo
Nyssa sylvatica var. *biflora*

Live oak
Quercus virginiana

Buttonbush
Cephalanthus occidentalis

Native and Non-Native Tree Species

Species that were found in Florida prior to European colonization in the 16th century are considered native to the state. Non-native species are those that were introduced beyond their native range by humans. Of the 112 tree species identified in the City of Tampa, approximately 70% are native to Florida. Invasive species are non-native species that spread into and dominate a new area due to a lack of natural diseases and/or predators. The presence of invasive species can negatively impact the abundance and distribution of native plants and animals.

Eighteen of the species found in the 2016 Urban Forest Analysis are listed by the Florida Exotic Pest Plant Council (FLEPPC 2017) as known invasives. Nine of the eighteen species are listed as Category I invasive species by FLEPPC, indicating these species are known to cause severe ecological damage in Florida. Brazilian pepper is one of the 18 FLEPPC Category I listed species and one of the top-ten dominant species in the City, representing around 8% of the total tree population. This species is one of great concern for the City as it readily spreads into disturbed areas, creating dense thickets that are costly and time-consuming to eradicate.

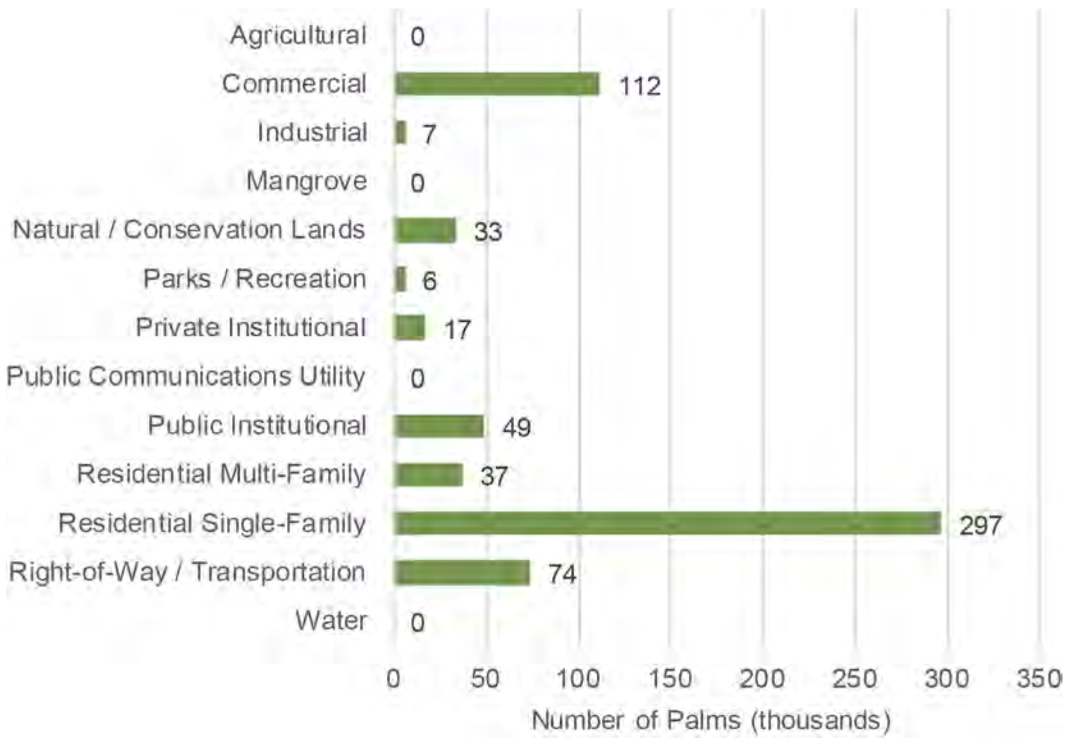
White lead tree, Leucaena leucocephala*, is a Category I invasive species.*

Palms

Palms represent a unique structural element of the City's landscape and are often distinct features in the City's skyline. Palm species are commonly planted on residential sites and public rights-of-way to accent the City's sub-tropical climate. Palms (monocots) technically have more in common biologically with grasses than hardwood trees. Their physical structure and metabolic systems differ widely from flowering and coniferous trees. However, palms do represent a significant portion of Tampa's urban forest (7%) and provide important ecological and economic values that should be considered when evaluating the urban forest.

Ten different palm species were identified in Tampa's urban forest in 2016, with an estimated total number of 631,104 trees. The Residential Single-Family and Commercial land use categories had the greatest number of palms in 2016 (Figure 9). While only three species of palms were found in Commercial land use areas, the Residential Single-Family and Right-of-Way/Transportation land use areas had the greatest diversity (eight and five species respectively). Florida's state tree, the cabbage palm, is one of the top ten dominant species in the urban forest canopy (5% of all trees) and the most common of the palms (Figure 10). Four of the ten palm species documented in 2016 are listed as FLEPPC Category II invasive, indicating these species have increased in abundance or frequency but have not yet altered plant communities to extent of FLEPPC Category I species (FLEPPC 2017). The four Category II invasive palms identified in the City's urban forest are Senegal date palm (*Phoenix reclinata*), Alexander palm (*Ptychosperma elegans*), queen palm (*Syagrus romanzoffiana*), and Mexican fan palm (*Washingtonia robusta*).

Figure 9. Number of palms by land use in 2016.
Note: Agricultural category is represented by only one sample plot.



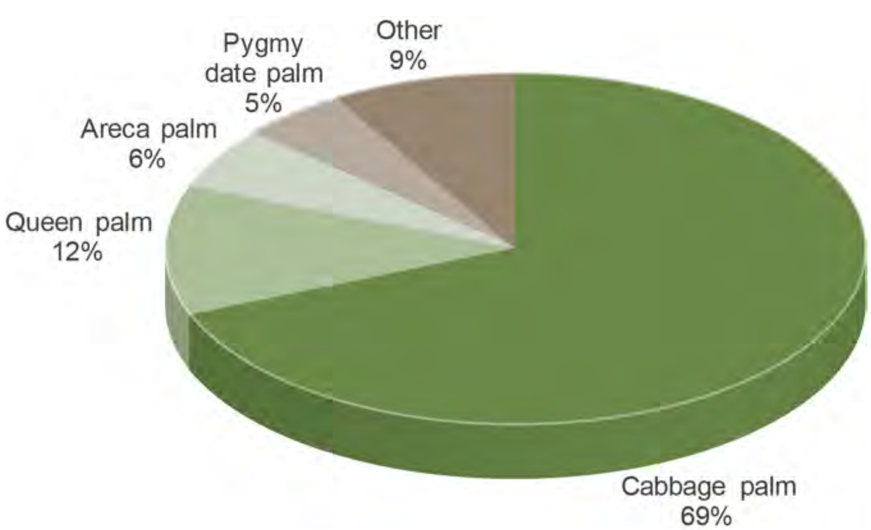
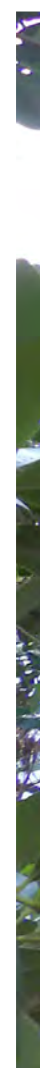


Figure 10. Relative number of the top five palm species based on the estimated number of trees in 2016.



Mangroves

The natural range of mangrove forests in the United States is mainly limited to Southeastern coastal areas due to their sensitivity to sub-freezing temperatures. They are found on the coasts of North and South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas (Odum and McIvorm 1990). The mangrove forest is valued for its ability to stabilize sediments, protect shorelines from erosion, and filter out pollution from the water (Rey and Connelly 2015). In addition, mangrove forests are an integral part of the Tampa Bay estuary since they serve as important nursery, feeding, and nesting areas for a variety of fish, shellfish, birds, and other wildlife. Many of Florida's threatened and endangered plant and animal species live in these forests.

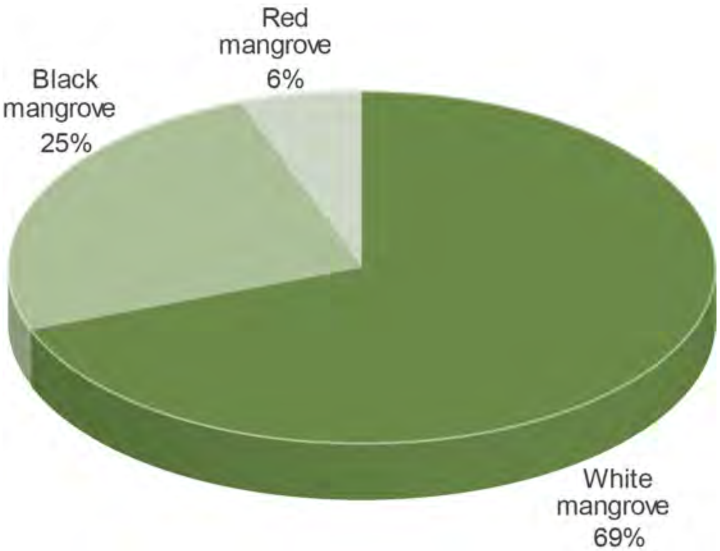


Figure 11. Proportion of mangrove species in 2016.

There are three species of mangroves found in Florida: the red mangrove (*Rhizophora mangle*), the black mangrove (*Avicennia germinans*), and the white mangrove (*Laguncularia racemosa*).These three species represent over a quarter (estimated 2.3 million trees) of the total number of trees in Tampa's urban forest. Mangroves are typically small diameter trees that grow in dense thickets and are confined to overlapping ecological zones along the coastline. While these species represent a sizable portion of the urban forest by stem count, they occupy only a small area compared to other species with similar tree numbers. Within the mangrove forest itself, white mangroves represent 69% of trees, black mangrove 25%, and red mangroves 6% (Figure 11).

Mangrove forest is found on the undeveloped portions of the Tampa Bay coastline.

Inland Forest

The inland forest is defined as the portion of Tampa's urban forest that excludes mangrove species (red, black, white). Although mangrove species play a critical role in the City's urban forest, the regulation of these species is controlled by state law and does not fall under City jurisdiction. An estimated 7 million trees represented by 109 tree species occupy this inland region of Tampa's urban forest. The top ten tree species represent 63% of total number of trees within the inland forest (Figure 12). Brazilian pepper (11%) is the only non-native invasive tree represented in the top ten list.

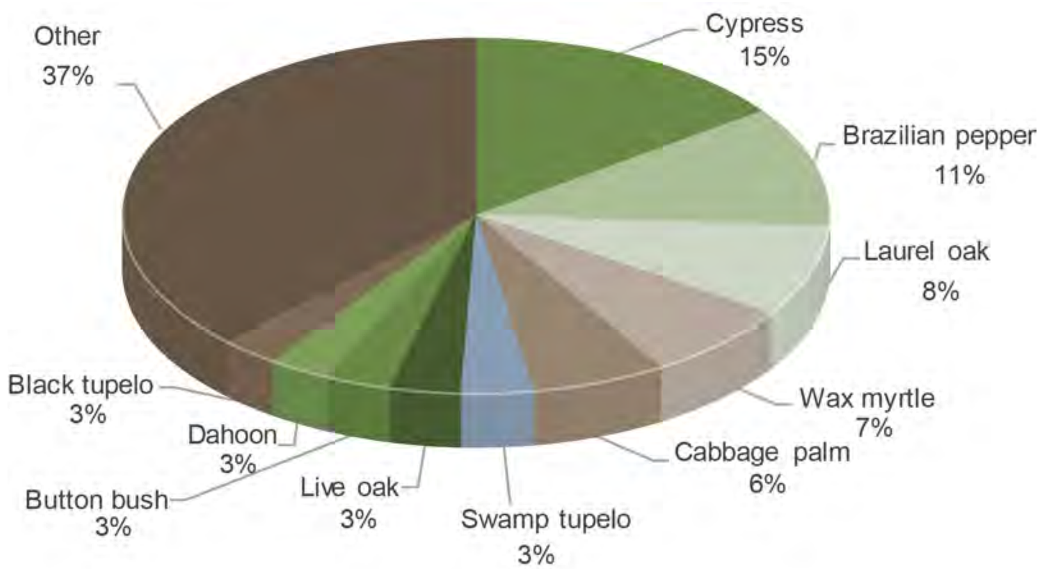


Figure 12. Top ten species of the inland forest (without mangroves) in 2016.

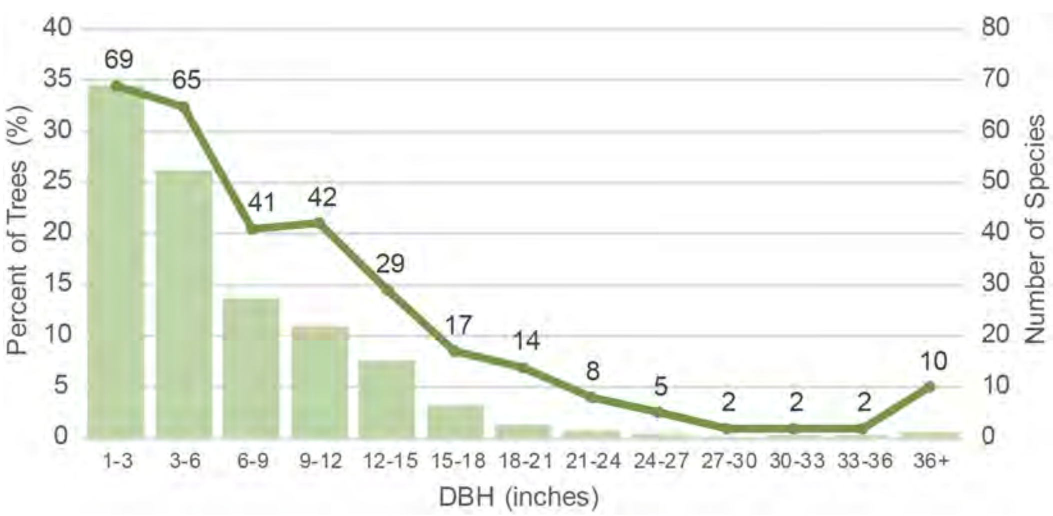


Figure 13. Diameter (DBH) distribution of trees (without mangroves) with number of species present in each DBH class.

Urban Forest Management Plan Performance Criteria – 2016

Species suitability for Tampa's climate zones

The species suitability for Tampa's climate zones criterion was designed to measure the suitability of Tampa's trees to the present urban and regional environment. Health, growth, and longevity of trees are dependent upon species-specific needs for water, sunlight, and appropriate temperature range. Tree suitability is calculated using research from University of Florida and U.S. Department of Agriculture – Forest Service. Results indicate that 49% of the tree species, comprising 76.5% of the leaf area, are well suited to Tampa's environment. Therefore, a "moderate" rating is assigned to this vegetation resource performance criterion, unchanged since 2011.

Table 3. Performance criteria related to species suitability.

Criteria	Vegetation Resource – Performance Indicators				Key Objective
	Low	Moderate	Good	Optimal	
Species suitability for Tampa's climate zones	Less than 50% of trees are of species considered suitable for Tampa.	**50%-75% of trees are of species considered suitable for Tampa.**	More than 75% of trees are of species considered suitable for Tampa.	At least 90% of the trees are of species suitable for Tampa.	Establish a tree population suitable for Tampa's urban environment and adapted to the regional environment.

Tree species diversity

Performance indicators for the tree species diversity criterion measure the variation in tree species found within Tampa's urban forest. A diverse urban forest, including genetic diversity, helps to protect against potentially catastrophic impacts associated with insect and disease infestation. Tree species diversity is calculated from collected field data and compared to general recommendations from the urban forestry profession. Results indicate that no one species of tree represented more than 11% of the total population of trees, while 4 species did contain leaf areas of 10% to 14%. Therefore, a "good" rating is assigned to this vegetation resource performance criterion, a decrease from the optimal rating in 2011.

Table 4. Performance criteria related to tree species diversity.

Criteria	Vegetation Resource – Performance Indicators				Key Objective
	Low	Moderate	Good	Optimal	
Tree species diversity	Fewer than five species dominate the entire tree population citywide.	No species represents more than 20% of the entire tree population citywide.	**No species represents more than 15% of the entire tree population citywide.**	No species represent more than 10% of the entire tree population citywide.	Establish a diverse tree population citywide.

Wind resistance of tree species citywide

The wind resistance for tree species citywide criterion was developed to measure the ability of the urban forest to withstand the strong winds associated with hurricanes and thunderstorms that frequent the region. Damage or loss during these storms increases costs and reduces the benefits to citizens. Wind resistance is calculated using research results from the University of Florida suggesting tree species resistance to wind damage (Duryea et al. 2007). Results indicate that 55% of the tree species are rated as having a high to medium-high wind resistance; and 36% having a medium-low to low wind resistance. These is no reliable wind resistance information on the remaining 9%.Therefore, a "moderate" rating is assigned to this vegetation resource performance criterion, unchanged since 2011.

Table 5. Performance criteria related to wind resistance.

Criteria	Vegetation Resource – Performance Indicators				Key Objective
	Low	Moderate	Good	Optimal	
Wind resistance of tree species citywide.	Majority of trees are rated in lowest category of wind resistance.	**Majority of trees are rated in medium and high categories of wind resistance.**	Majority of trees are rated in high category of wind resistance.	Greater than 80% of trees are rated in highest category of wind resistance.	Reduce disruption of social and economic services; reduce cost of cleanup and protect private property and human well being.

Tree species longevity

Performance indicators for the tree species longevity criterion measure the percentage of tree species found within Tampa's urban forest considered to be long-lived. Trees that are long-lived help to reduce the high initial costs associated with planting and establishment, while often living out the latter part of their lives as relatively larger trees producing high levels of benefits for the community. For the purpose of this evaluation, trees considered long-lived have average life spans of greater than 125 years (Loehle 1987). They are expected to outlive the generation that plants them. Results indicate that 28% of the total population of trees, comprising 47% of the leaf area, are considered long-lived. Therefore, a "moderate" rating is assigned to this vegetation resource performance criterion, a decrease in rating since 2011.

Table 6. Performance criteria related to tree species longevity.

Criteria	Vegetation Resource – Performance Indicators				Key Objective
	Low	Moderate	Good	Optimal	
Tree species longevity	Less than 25% of trees are of species considered long-lived for Tampa.	**25% to 49% of trees are of species considered long-lived for Tampa.**	50%-75% of trees are of species considered long-lived for Tampa.	More than 75% of trees are of species considered long-lived for Tampa.	Establish a long-lived tree population that maximizes benefits vs. costs

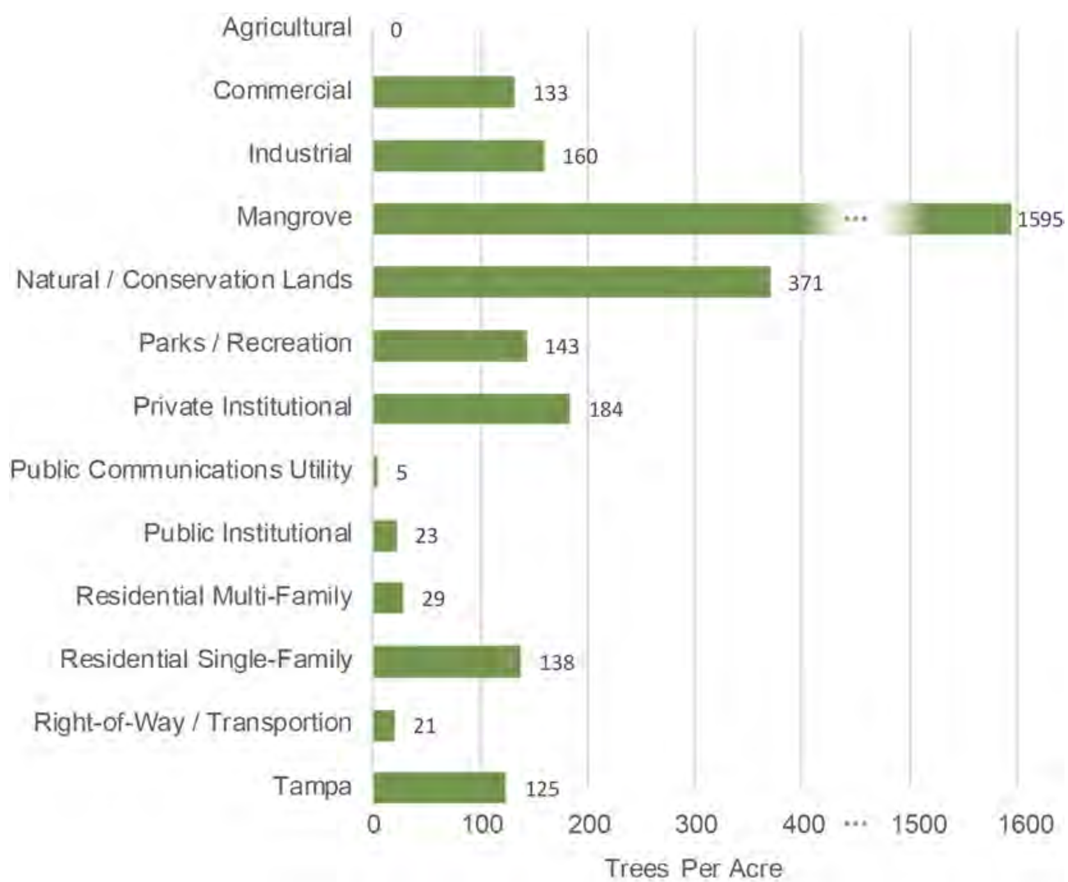
Urban Forest Structure

Forest structure is the horizontal and vertical distribution of vegetation layers (trees, shrubs, and ground cover) in the forest. The City of Tampa's urban forest structure was determined by measuring and calculating various physical forest attributes such as: tree density, diameter distribution, vegetation cover, leaf area, and tree canopy health. Assessing the structure of a forest is critical for evaluating its ability to provide ecosystems services and perform ecological functions. In addition, these forest structure metrics provide important data that can be used to help drive urban forest management policies and laws.

Tree Density

Tree density is measured in number of trees per acre, which is a useful metric for characterizing tree abundance throughout the different land uses in this study. The citywide tree density average for Tampa was 125 trees/acre, which is comparable to the 112 trees/acre found in the similarly sized city of Atlanta, GA (estimated 9.4 million trees, 134 sq. miles). The Mangrove land area had the highest tree density in the City's urban forest with almost 1600 trees/acre (Figure 14). However, this is not surprising since mangroves form dense thickets of numerous small-diameter stems and are mainly limited to tidally influenced areas that occupy a small percentage (1.6%) of total City area. The Natural/ Conservation Lands had the second highest tree density value of 371 trees/acre and represent the naturally forested areas of the City that have not been greatly impacted from urbanization. In comparison, the Residential Single-Family land, which covers the most acreage (27.6%) and has the most tree species (79), has only 138 trees/acre. The lowest tree density values are found in the Public Communications and Agricultural lands with 5 and zero trees/acre respectively.

Figure 14. Average trees per acre for each land use in the City of Tampa.
Note: Agricultural category is represented by only one sample plot.



Tree Diameter Distribution

Tree diameter distribution is an important metric used by foresters to help estimate the relative age distribution of trees in the forest. As urban trees grow and increase in diameter, so do the ecosystem services they provide. Moreover, most of the net benefits (ecosystem services) received from an individual tree are not fully accounted until it reaches a mature size. However, this does not imply that forest managers want a tree population dominated by large diameter trees as this would have implications on the sustainability of the forest over time as these larger trees decline and die. Instead, a common goal most cities and foresters aim for is an uneven-aged distribution (i.e., a mix of young, mature, and older trees) in the tree population.

The diameter distribution of Tampa's urban forest is skewed towards the smaller diameter classes (1 to 6 inches), accounting for 70% off the total tree population (Figure 15). Small diameter trees represent both understory or shrub-like species and the future of Tampa's urban forest (i.e., young trees). In the 1- to 3-inch diameter class, 17% of the population is made up of Brazilian pepper, a species which maintains small diameter throughout its life. Native, small-stemmed species like wax myrtle and buttonbush round out the top three species in the 1- to 3-inch diameter class with 17% and 7% of the population respectively. In the 3- to 6-inch diameter class, Florida natives like cypress species (*Taxodium* spp.) contribute 15%, and laurel oak 9%, while the invasive Brazilian pepper makes up 14% of the population. Trees in the largest diameter class (36+ inches) represent less than half a percent (0.4%) of the total estimated tree population. Native oak species (live oak, laurel oak, and sand live oak), which have the potential to reach large trunk diameters, account for more than 80% of the trees in the 36+ inch size class. Earpod tree (*Enterolobium contortisiliquum*) and cypress species contributed 9% and 8% of the remaining 20%, respectively.

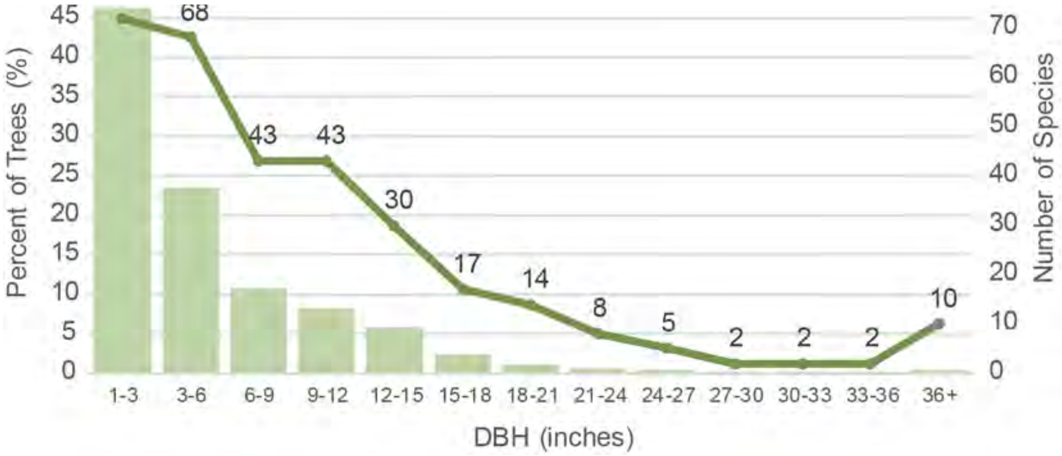
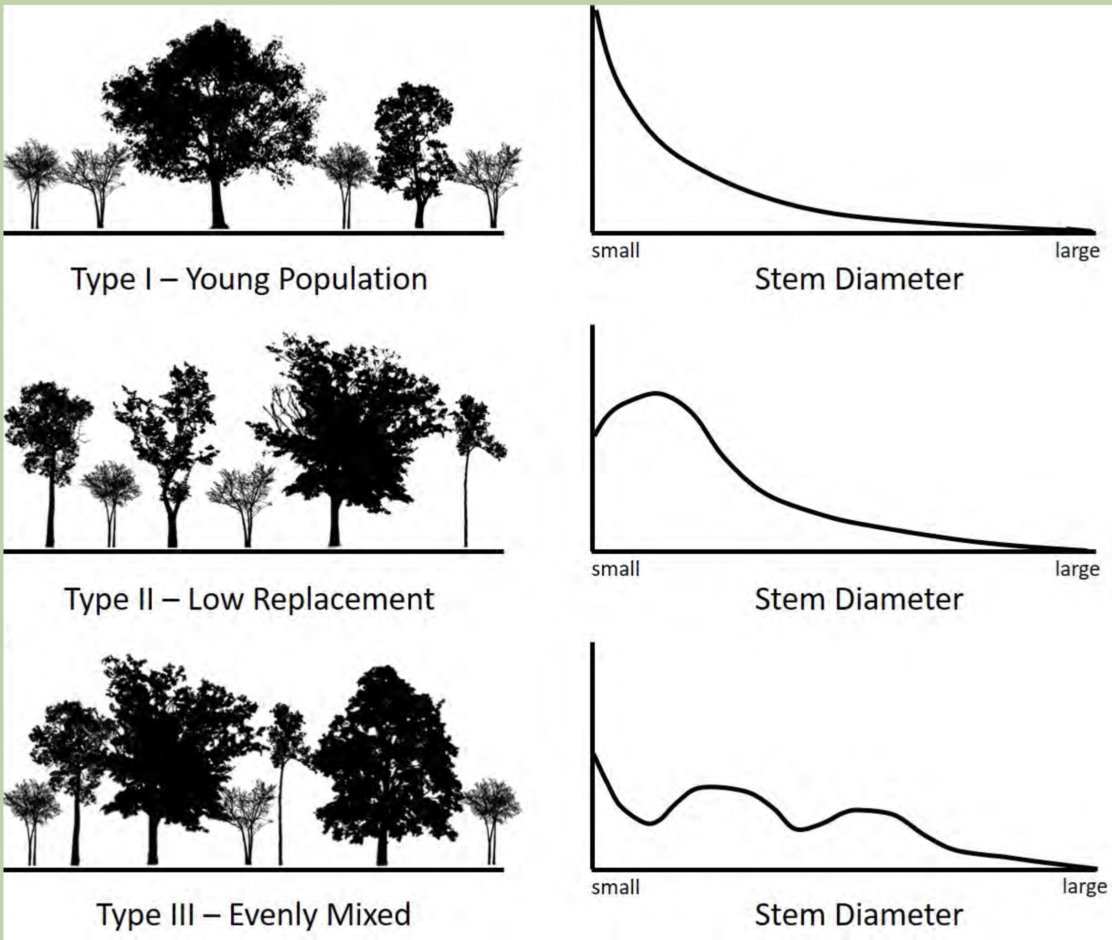


Figure 15. Tree diameter (DBH) distribution by diameter class (columns) with the number of species present in each class (line). Data include mangroves.

Explanation for Tree Diameter Distribution

Coniferous and broadleaf trees need to grow continuously to survive. As such, their stem diameters can be used to approximate tree age. Urban forest managers often look at the distribution of these diameters to make inferences regarding the age of their vegetative resource and the management implications associated with this information. In looking at Figure 15 and Figure 16, we can see Tampa has a forest that most closely resembles Type – 1 Young Population. This is an indication that there are many small trees present in the City (even when mangroves are excluded), with noticeably lower numbers of medium-to-large trees. Heightened planting efforts, the presences of dense thickets of invasive, small-diameter trees (e.g. Brazilian pepper), the relative newness of many developments, and removals related to tree safety and development likely all attribute to this pattern in stem diameters.

Figure 16. Forest types.



Leaf Area and Importance Values

Leaf area is the measure of the total green leaf surface area on a tree. This tree measurement is used in the i-Tree Eco model to estimate some of the ecosystems services (e.g., air pollution removal and avoided runoff) that the urban forest provides. The i-Tree Eco model calculates leaf area of individual tree species using regression equations for urban tree species and accounts for certain tree conditions (e.g., tree health and crown light exposure) that may impact this calculated metric (Nowak, 1996).

When determining the relative importance of a species, context is important. Live oak (14%), laurel oak (13%), and cabbage palm (11%) represent the top three species for leaf area, accounting for 38% of total leaf area in the City, despite being only 13% of the total estimated tree population (Figure 17). In contrast, white mangrove and Brazilian pepper represent 25% of the total estimated tree population (17% and 8% respectively) yet only contribute 5% to the total leaf area. For ecosystem services like avoided runoff, species with a higher relative proportion of leaf area are the species contributing the most.

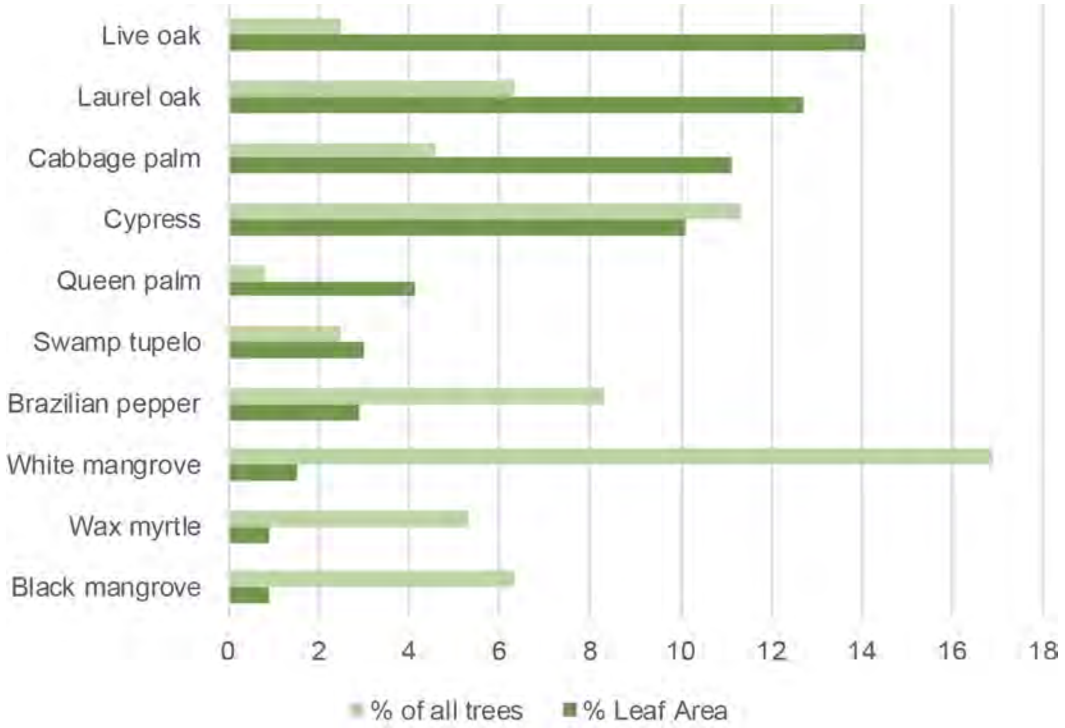


Figure 17. Percent leaf area and population percentage by species.

Forest Health

The overall health of a forest is critical to understanding its functionality and ability to produce various ecosystem services. In this study, forest health was estimated by individual tree canopy condition ratings. In particular, tree canopy conditions were evaluated by rating the percentage of leaf dieback. These ratings are used to adjust estimates of carbon storage/sequestration and energy conservation (Nowak et al. 2008). Forest health was evaluated by land use category and for each of the City of Tampa's planning districts.

Citywide, 55% of the trees are considered to be in excellent health, 28% are in good health, 6% are in fair health, and the remaining 11% are considered to be in poor health condition or standing dead (Figure 18). More than 70% of the trees in the Multi-Family Residential, Public Institutional, Public Communications Utility, Parks/Recreation, and Right-of-Way/Transportation land use categories are considered to be in excellent health. The Single Family Residential (55%), Natural/Conservation Lands (49%), Mangroves (48%), and Industrial (60%) land use categories have similar percentages of healthy trees (defined as excellent health condition) to the citywide average of 55%. Natural/Conservation Lands (10%), Industrial (21%), and Mangrove (16%) land use areas have the highest amount of trees considered to be in poor to dead condition.

Forest Health was also evaluated by the City of Tampa's five planning districts (Figure 19). The South Tampa planning district has the highest percentage of healthy trees (excellent category) with 73%. In comparison, the New Tampa district represented the district with the lowest percentage of healthy trees with 45%. The Westshore TIA planning district had the highest percentage of poor to dead trees at 21%. Between 48 to 60% of the trees in the remaining three districts (Central Tampa, USF Institutional, and Westshore TIA) were considered to be healthy.

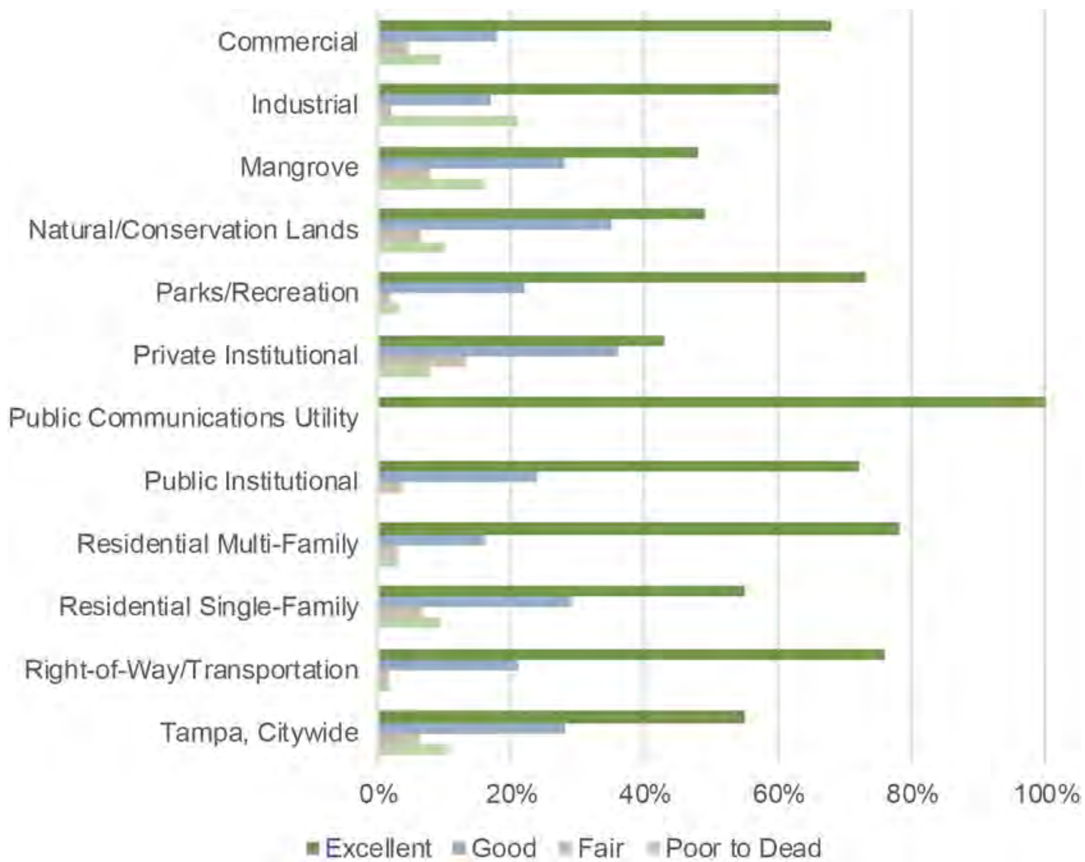


Figure 18. Tree health condition by land use.

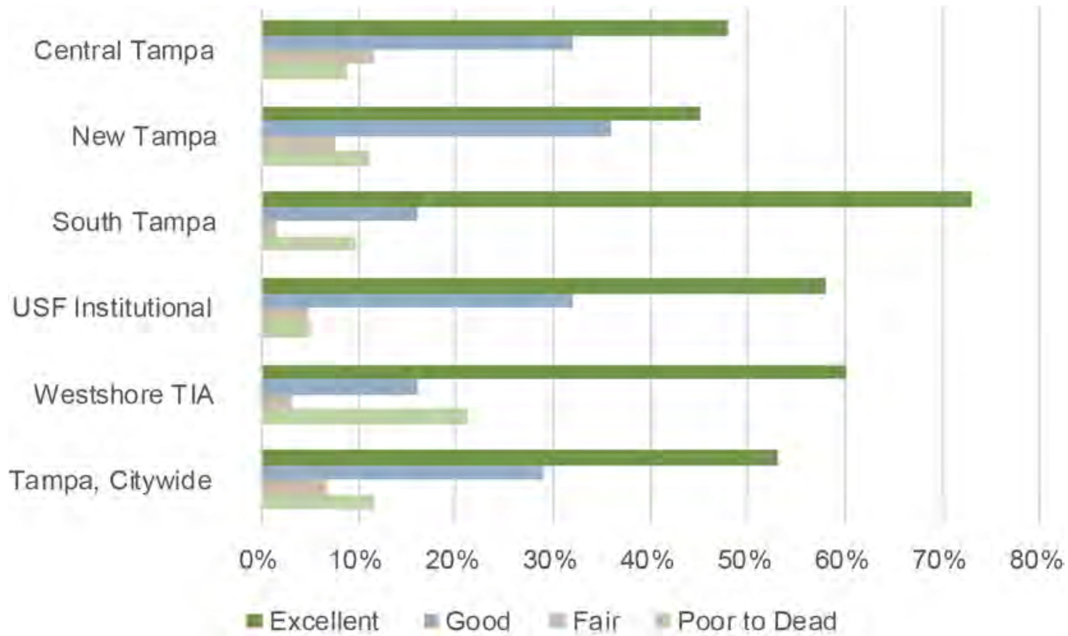


Figure 19. Tree health condition by City Planning District.

Shrub Cover

Percent shrub cover is an estimate of area that is covered by woody plants at least one foot in height and with less than one inch stem diameter. This is often an overlooked component of the urban forest, but shrubs do add to the overall species diversity and ecosystem services provided by the urban forest. For example, the additional leaf area provided by shrubs in areas where trees do not already exist can help increase pollution removal rates and decrease stormwater runoff amounts by intercepting more rainfall. That said, areas where trees are present over shrubs are simply designated as tree cover (their impacts are not additive).

In Tampa, the estimated shrub coverage throughout the City is approximately 10% (Figure 20) and is comprised of 145 different species (Figure 21). The highest shrub cover is found in the Mangrove areas with 38% coverage distributed over 11 different species. By comparison, the Residential Single-Family areas (which are among the most treed) had only 14% shrub coverage. However, this area had over 100 different shrub species. The Natural/Conservation Land areas, which represent more of the natural forested areas of the City, have 36% shrub coverage, comprised of 32 shrub species.

Ixora (Ixora coccinea) *is an exotic shrub frequently used in landscapes.*

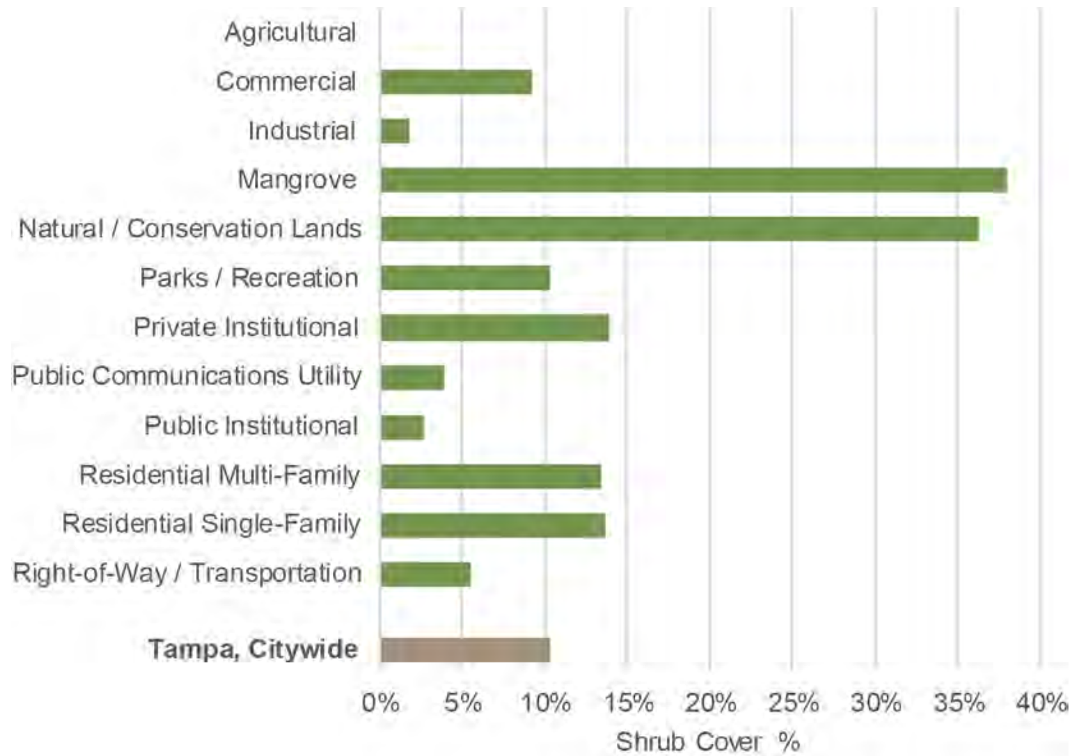


Figure 20. Percent shrub cover by land use.
Note: Agricultural category is represented by only one sample plot.

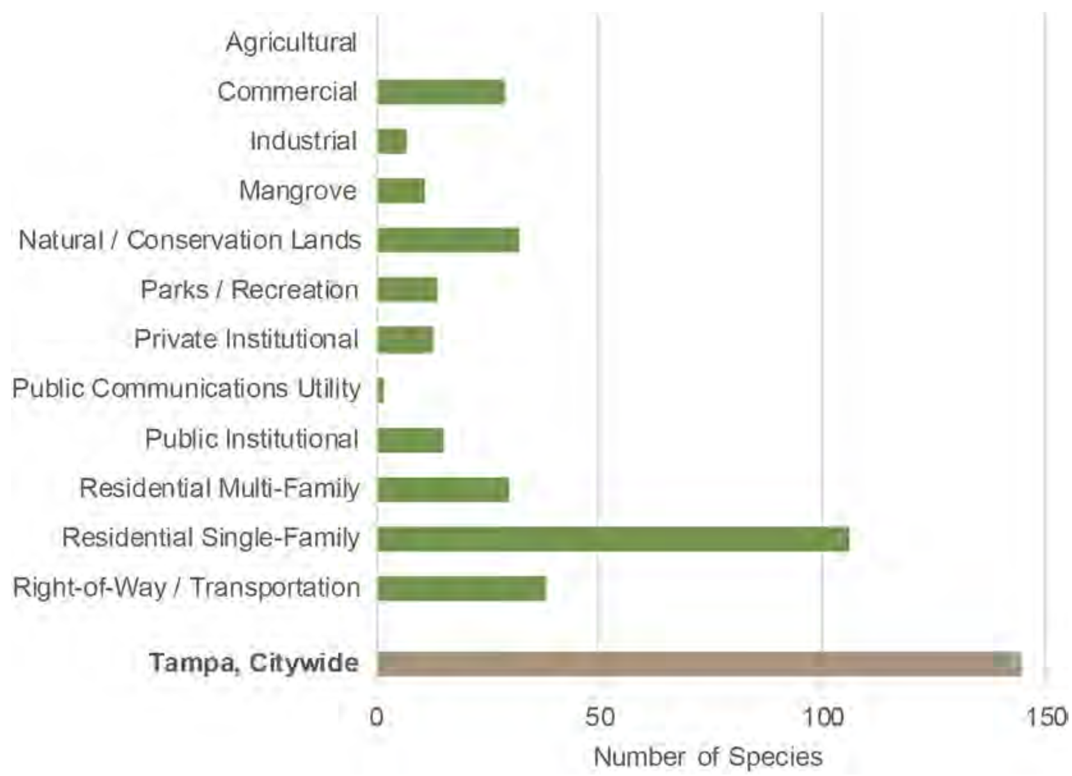


Figure 21. Number of shrub species present in each land use category.
Note: Agricultural category is represented by only one sample plot.

Ground Cover

The ground cover stratum consists of a variety of surface types covering the ground including woody and herbaceous vegetation less than one foot tall. For this study, ground cover is divided into two broad categories: impervious (asphalt, cement, and buildings) and pervious (bare soil, leaf litter, herbaceous vegetation, maintained grass, rock, wild grass, and water) surfaces. In general, impervious surfaces result in rainwater being diverted as storm water runoff while pervious areas allow for rainwater infiltration into the soil. Urbanization of lands typically results in a greater percentage of impervious surface areas which have been documented to have numerous effects on natural hydrological processes (Shuster et al. 2005).

Thirty-five percent of the ground cover in the City of Tampa is classified as impervious surfaces (Figure 22). However, three land use types had more than 50% impervious area each (Figure 23): Multi-Family Residential (54%), Public Communications Utility (52%), and Right-of-Way/Transportation (53%). In comparison, the Agricultural, Mangrove, and Natural/Conservation Lands land use areas all contained 0% impervious surfaces.

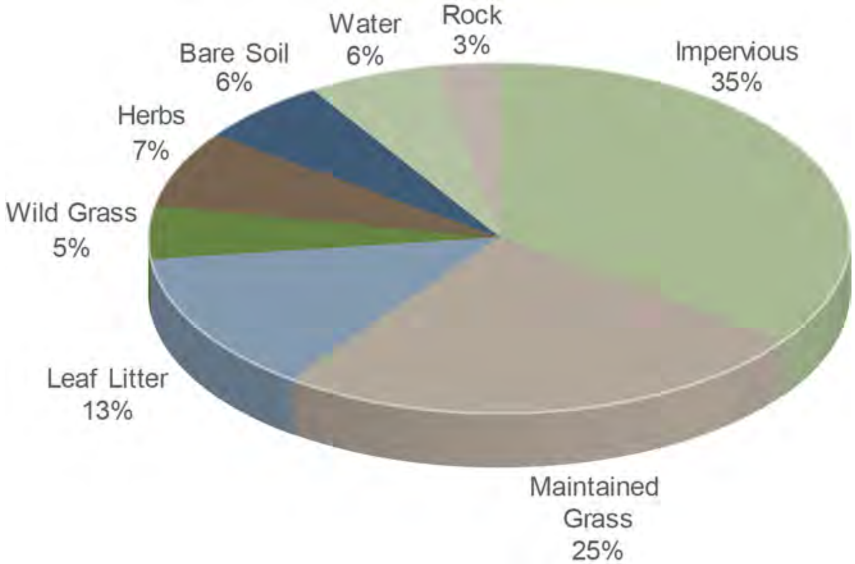


Figure 22. Distribution of ground cover types by percent in the City of Tampa.

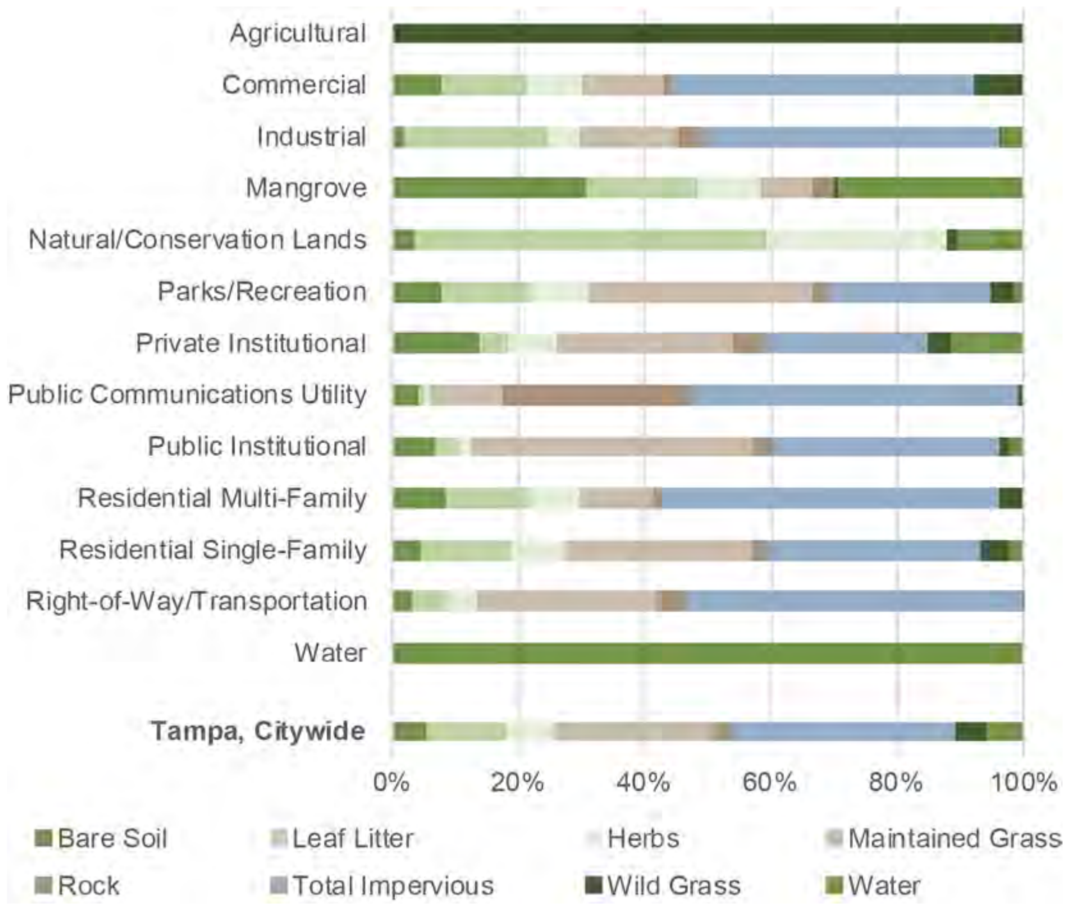


Figure 23. Proportional distribution of ground cover types by land use in the City of Tampa.
Note: Agricultural category is represented by only one sample plot.

Urban Forest Management Plan Performance Criteria – 2016

Diameter (DBH) distribution of trees in the city

While it is not always possible to determine the exact age of trees, tree diameter often serves as proxy for guiding management decisions. With regard to sustainability, mix of tree sizes/ages is desired to stagger losses associated with old age and decline. When assessing the diameter distribution in Tampa, relative diameter (RDBH) classes were calculated to account for differences in growth potential for small- and large-stature trees. Results produced an inverse J-shaped curve, indicating a relatively young population of trees. The smallest relative diameter class equals 60% of the trees measured. Therefore, a 'moderate' rating is assigned to the diameter distribution of all trees in the city indicator.

Tree health condition by municipal planning district

The tree health condition criteria was developed on the premise that healthy trees live longer, produce greater number of benefits, and reduce cost associated with maintenance. Healthy trees were defined as trees receiving an excellent canopy condition rating. Results indicate that all planning districts have at least 45% healthy trees in them with a city-wide average of 53% healthy trees. Therefore, a "moderate" rating is assigned to this vegetation resource performance criteria in 2016, the same rating as 2011.

Table 7. Performance criteria related to urban forest structure.

Criteria	Vegetation Resource – Performance Indicators				Key Objective
	Low	Moderate	Good	Optimal	
Diameter (DBH) distribution of trees in the city	Any relative DBH (RDBH)i class (0%–25% RDBH, 26%–50% RDBH, etc.) represents more than 75% of the tree population.	**Any RDBH class represents between 50% and 75% of the tree population.**	No RDBH class represents more than 50% of the tree population.	25% of the tree population is in each of four RDBH classes.	Provide for uneven aged distribution citywide.
Tree health condition by municipal planning district.	Less than 30% of trees rated as excellent health condition.	**31%–60% of trees rated as excellent health condition.**	61%–85% of trees rated as excellent health condition.	Greater than 85% of trees rated as excellent health condition in all municipal planning districts.	Healthy trees live longer, produce greater no. of benefits and reduce costs associated with maintenance.

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Tree Canopy Change Analysis

Long-Term Trends

As part of the *City of Tampa 2011 Urban Forest Analysis*, the long-term change in tree canopy cover was mapped using Landsat satellite images from 1975 to 2011. The trend showed that canopy cover decreased between 1975 and 1986 and then gradually increased until 2011 tree canopy had returned to 1975 levels. This report used the more robust and accurate dot-based analysis to track tree canopy change for the years 2006 to 2016.

Tree Canopy Change 2006–2016

One indicator of whether the City of Tampa Urban Forest Management Plan and land development policies are having the desired effect is to accurately measure how tree canopy cover has changed over recent years. Tree canopy change was estimated using the dot-based method described in the project methods section. Aerial images from 2006, 2011 and 2016 were used to estimate tree canopy (and the statistical uncertainty associated with the estimates) for each of those years. The uncertainty is calculated as the 95% confidence interval and tells us if the amount of canopy between two years is statistically different.

Citywide

To estimate citywide tree canopy cover change, two separate technicians independently reviewed aerial images from 2006, 2011 and 2016 using the dot-based method. To eliminate potential error introduced by a single technician, the only points included in these results were the ones where both technicians agreed on the interpretation. Tree Canopy was calculated using 4,199 points for 2016, 1,890 points for 2011, and 1,864 points for 2006. More points were used for the 2016 estimate to reduce the measurement uncertainty (i.e., 95% confidence interval).

Results indicate that the average citywide tree cover increased from 31.7% in 2006 to 34.4% in 2011, but then decreased to 32.3% in 2016. However, it is very important to consider the confidence intervals. In statistical terms, the estimated 32.3% tree canopy for 2016 has a 95% probability of actually being as low as 30.9% or as high as 33.7%. Because of the slight overlap of the confidence interval in 2011 and 2016, we cannot say with certainty that the change from 34.4% in 2011 to 32.3% in 2016 was a real decrease. However, the trend seems to be a slight decline in tree canopy cover.

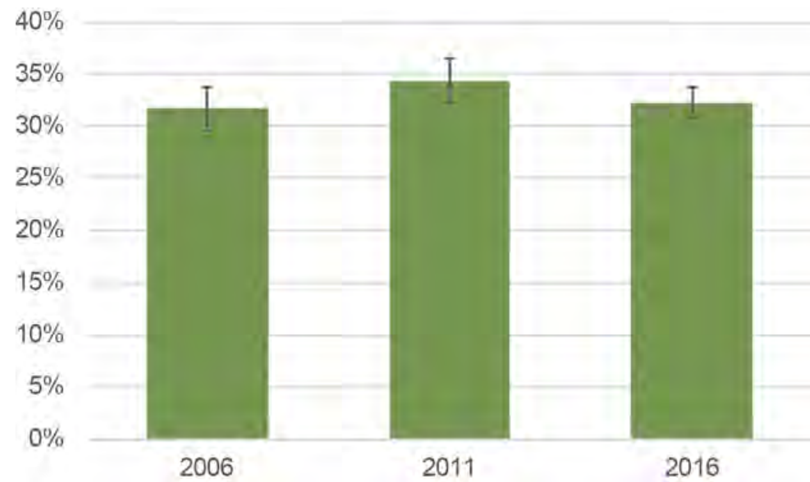


Figure 24. Citywide tree cover 2006-2016.

Table 8. Citywide tree cover 2006-2016.

Year	Tree Canopy	95% Confidence Interval
2006	31.7%	CI = 29.6 - 33.8 %
2011	34.4%	CI = 32.2 - 36.5 %
2016	32.3%	CI = 30.9 - 33.7 %

TREE CANOPY IN OTHER U.S. CITIES

Tree canopy cover results for other US cities were assembled to provide a comparison with the City of Tampa.

City	Year	Tree Canopy
Atlanta, GA[1]	2008	48%
Austin, TX[2]	2010	37%
Baltimore. MD[2]	2007	27%
Charlotte, NC[3]	2012	37%
Detroit, MI[2]	2010	23%
Gainesville, FL[4]	2015	54%
Houston, TX[5]	2009	27%
Jacksonville, FL[6]	2015	41%
Miami, FL[4]	2009	22%
New York City, NY[2]	2010	21%
Philadelphia, PA[2]	2008	20%
Pittsburgh, PA[2]	2010	42%
Portland, OR[2]	2007	30%
Savannah, GA[7]	2013	44%
Tampa, FL	2016	32%
Virginia Beach, VA[3]	2008	38%
Washington, DC[2]	2011	36%

Sources: [1]Georgia Tech. (2014). Assessing Urban Tree Canopy in the City of Atlanta; A Baseline Canopy Study (geospatial.gatech.edu/Greenspace). [2]Various sources, from the article Nine Cities That Love Their Trees (www.nationalgeographic.com/news-features/urban-tree-canopy). [3]UVM Spatial Analysis Lab. Urban Tree Canopy Assessments (gis.w3.uvm.edu/utc/). [4]Andreu, M. G., Fox, D., Landry, S., Northrop, R., and Hament, C. (2017). Urban Forest Ecological Analysis. City of Gainesville, March 2017; Appendix C. City of Gainesville, FL. [5]Nowak, D. J., & Greenfield, E. J. (2012). Tree and impervious cover change in U.S. cities. Urban Forestry & Urban Greening, 11(1), 21-30. [6]Plan-it Geo. (2015). An Assessment of Urban Tree Canopy in the City of Jacksonville, Florida (www.planitgeo.com). [7]Plan-It Geo. (2015). An Assessment of Urban Tree Canopy in Chatham County, Georgia (www.planitgeo.com).

Planning District

The dot-based method was also used to estimate change in tree canopy for the five Planning Districts within the City of Tampa. Since the uncertainty of the analysis is based largely on the number of points within each Planning District, additional random points were evaluated by a trained technician. A total of 9,294 random points were evaluated for each of the three aerial images: 2006, 2011 and 2016.

The graph shows the average tree canopy cover for 2006, 2011 and 2016 for each of the five Planning Districts. The error bars on the graph and the table show the 95% confidence interval of the estimates. Due to the level of uncertainty in the change analysis, as indicated by the confidence intervals, we cannot say with certainty that there was a significant increase or decrease from 2006-2011 or from 2011-2016. There appear to have been slight increases in tree canopy from 2006 to 2011 in all Planning Districts followed essentially no change from 2011-2016 in most Districts, except in Central Tampa where there was a slight decrease. In South Tampa, there was a statistically significant increase in tree canopy cover between 2006 and 2011 that remained at the higher level in 2016.

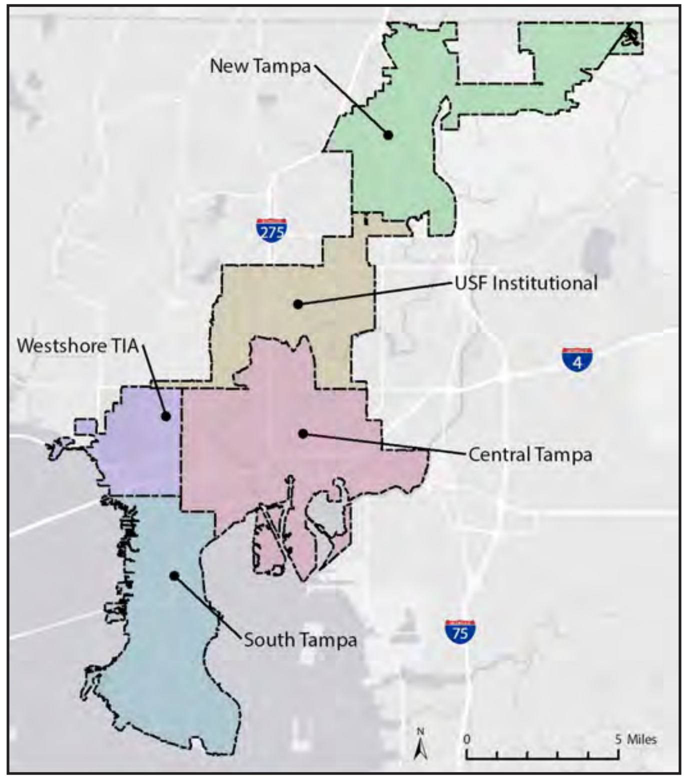
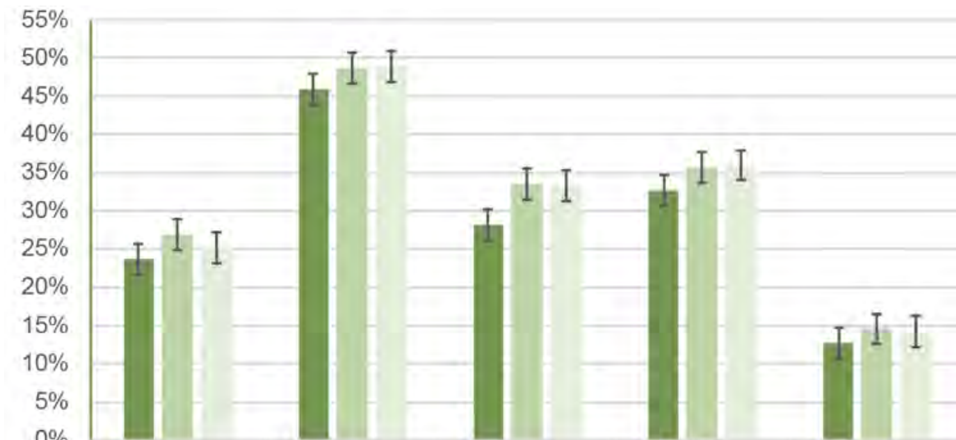


Figure 25. City of Tampa Planning Districts



	Central Tampa	New Tampa	South Tampa	USF Institutional	Westshore TIA
2006	23.7%	46.0%	28.2%	32.6%	12.7%
2011	26.9%	48.7%	33.5%	35.7%	14.6%
2016	25.2%	49.0%	33.3%	36.0%	14.2%

Figure 26. Planning District tree cover change 2006–2016.

Table 9. Canopy cover estimates by Planning District using dot-based method.
Values represent the 95% confidence interval of each estimate.

Central Tampa	1,780	21.7 – 25.7%	24.8 – 29.0%	23.2 – 27.2%
New Tampa	2,220	43.9 – 48.1%	46.6 – 50.8%	46.9 – 51.0%
South Tampa	2,000	26.2 – 30.2%	31.4 – 35.5%	31.2 – 35.3%
USF Institutional	2,044	30.6 – 34.7%	33.6 – 37.8%	33.9 – 38.0%
Westshore TIA	1,250	10.9 – 14.6%	12.6 – 16.5%	12.3 – 16.2%

City Council District

The dot-based method was also used to estimate change in tree canopy for each of the City Council Districts within the City of Tampa. The same random points evaluated for the Planning Districts were assigned to the appropriate City Council District based on geographic location. The results from the citywide canopy change were used for the three At-Large Districts (i.e., Districts 1-3), since the boundaries were identical. In District 4, tree canopy increased from 2006 to 2011 and remained nearly the same in 2016. In District 5, tree canopy increased from 2006 to 2011, but then shows a slight decrease between 2011 and 2016. Tree cover in District 6 fluctuated slightly, but remained statistically unchanged. In District 7, the tree canopy cover increased slightly each year and there was a statistically significantly increase from 2006 to 2016. Finally, the tree canopy change in the At-Large Districts was the same as citywide change: a slight increase from 2006 to 2011 followed by slight decrease in 2016.

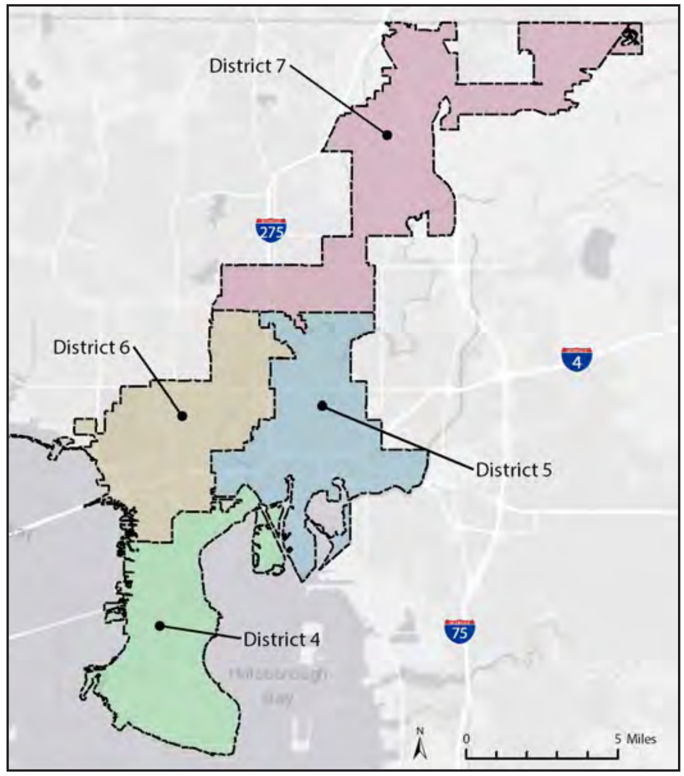


Figure 27. Map of City Council Districts.

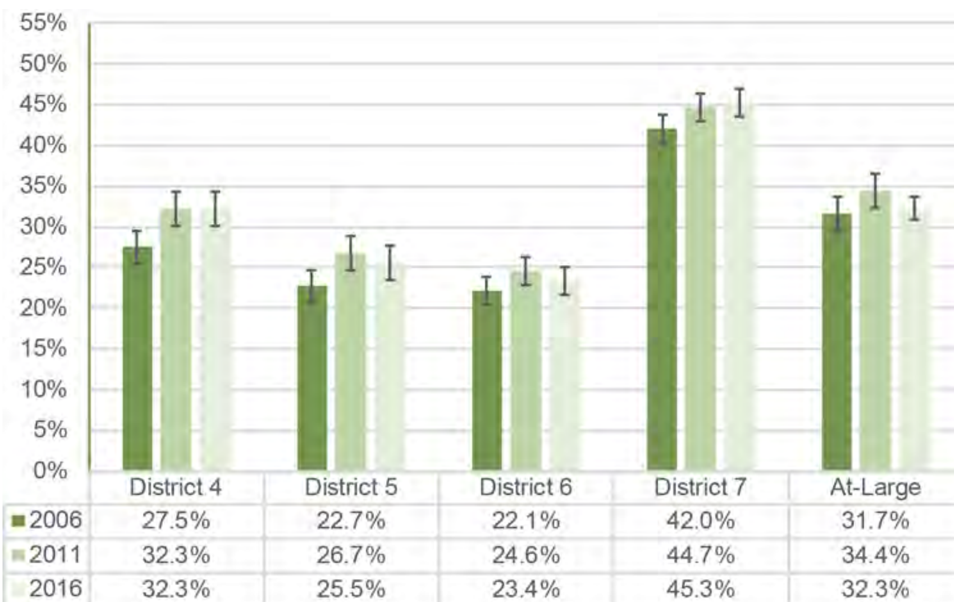


Figure 28. City Council District tree cover change 2006–2016.

Table 10. Canopy cover estimates by City Council District using dot-based method.
Value represents the 95% confidence interval of each estimate.

City Council District	2006	2011	2016
District 4	25.6% - 29.5%	30.2% - 34.3%	30.2% - 34.3%
District 5	20.7% - 24.7%	24.6% - 28.9%	23.4% - 27.6%
District 6	20.4% - 23.8%	22.8% - 26.3%	21.7% - 25.1%
District 7	40.4% - 43.7%	43.1% - 46.4%	43.7% - 47.0%
At-Large Districts (1, 2, 3)	29.6% - 33.8%	32.2% - 36.5%	30.9% - 33.7%

Urban Forest Management Plan Performance Criteria – 2016

Canopy cover relative to goals by municipal planning district

The City of Tampa Urban Forest Management Plan recommends “No net loss of canopy cover by municipal planning district” as a performance criteria for the vegetation resource. Results indicate that none of the Planning Districts experienced a statistically significant change in tree canopy cover between 2011 and 2016. Therefore, an optimal rating is assigned to the Canopy cover performance criterion, unchanged since 2001.

Table 11. Performance criteria related to canopy cover goals.

Criteria	Vegetation Resource – Performance Indicators				Key Objective
	Low	Moderate	Good	Optimal	
Canopy cover relative to goals by municipal planning district	The existing canopy cover equals 0%-25% of the goal.	The existing canopy cover equals 25%-50% of the goal.	The existing canopy cover equals 50%-75% of the goal.	**The existing canopy cover equals 75%-100% of the goal.**	Relative canopy cover to goal for each municipal planning district category. The goal is defined as no net loss in a Planning District.

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Tree Canopy Mapping

Tree canopy mapping was conducted using advanced remote sensing techniques and six-inch resolution aerial imagery from 2016. Six categories of land cover were mapped, including: tree canopy, grass/shrub (i.e., other vegetation), bare earth, building, other impervious surfaces (e.g., roads, sidewalks, driveways, parking lots), and water. All results are based on the jurisdictional area within the City of Tampa that excludes the open-water of Tampa Bay, a total of 75,288 acres. The final canopy maps were determined to be 92.2% accurate based on a detailed assessment. In contrast to the tree canopy change analysis, urban tree canopy mapping shows us how existing tree canopy is distributed for each property parcel, categories of future land use and zoning, and within each neighborhood association. Given the methods used, canopy coverage can be broken down in nearly any imaginable way, allowing Tampa to conduct additional assessments not detailed in this report should the need arise.

Citywide Land Cover

The 2016 land cover mapping results indicate approximately 27,641 acres of this area is tree canopy. As a citywide percentage, this value was not statistically different from the dot-based estimates detailed in the canopy change section (though it is slightly higher). In addition to tree canopy, there were 7,697 acres covered by buildings, 16,229 acres covered by roads and other impervious surfaces, and 2,882 acres covered by water or bare earth/sand. The City of Tampa also has approximately 20,839 acres of grass/shrub cover. This represents a substantial area of land outside of buildings and other impervious surfaces that could be used to increase tree canopy (Possible Urban Tree Canopy – see box).

While the change analysis is limited to its initially-defined boundary (e.g., citywide or a particular planning district), the land cover maps generated using the remote sensing techniques used here can be scaled to assess the spatial distribution of tree canopy within any desired area within the City.

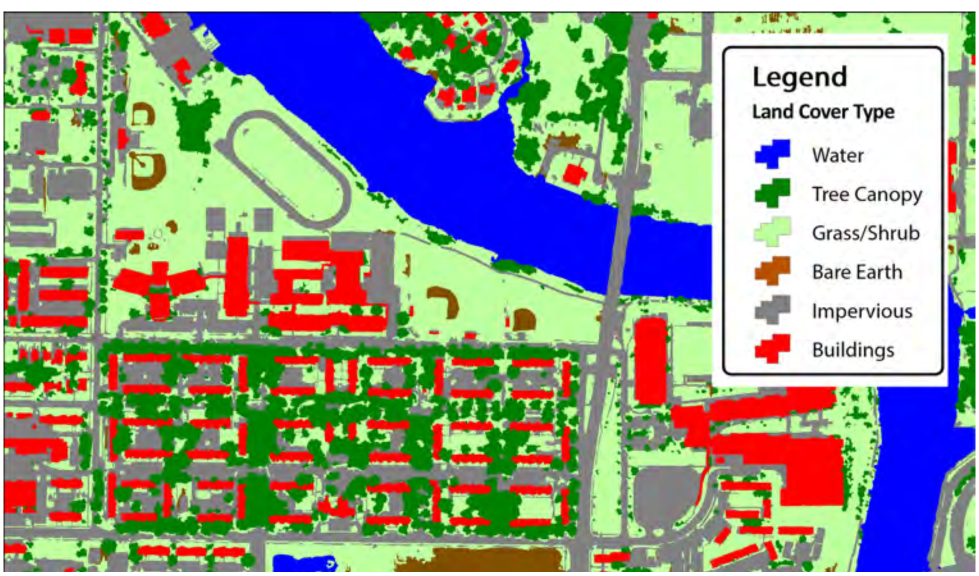


Figure 29. Example land cover map.

POSSIBLE URBAN TREE CANOPY

In addition to knowing where trees are located, it also can be useful to identify where there is room to plant trees. The US Forest Service, as part of their analysis of tree canopy in New York City (Grove et al. 2006, Locke et al. 2010), introduced the term Possible Urban Tree Canopy (UTC) to refer to non-road, non-building and non-water land, where it is biophysically feasible to plant trees. Within this City of Tampa report, the amount and location of the "other vegetation" land cover category meets the US Forest Service definition of Possible UTC. In other words, the vegetation category can be used to indicate the amount of tree canopy that could be achieved if trees were planted in these areas. However, the US Forest Service also has been careful to suggest that it is not necessarily socially desirable or economically feasible to plant trees in all of these areas.

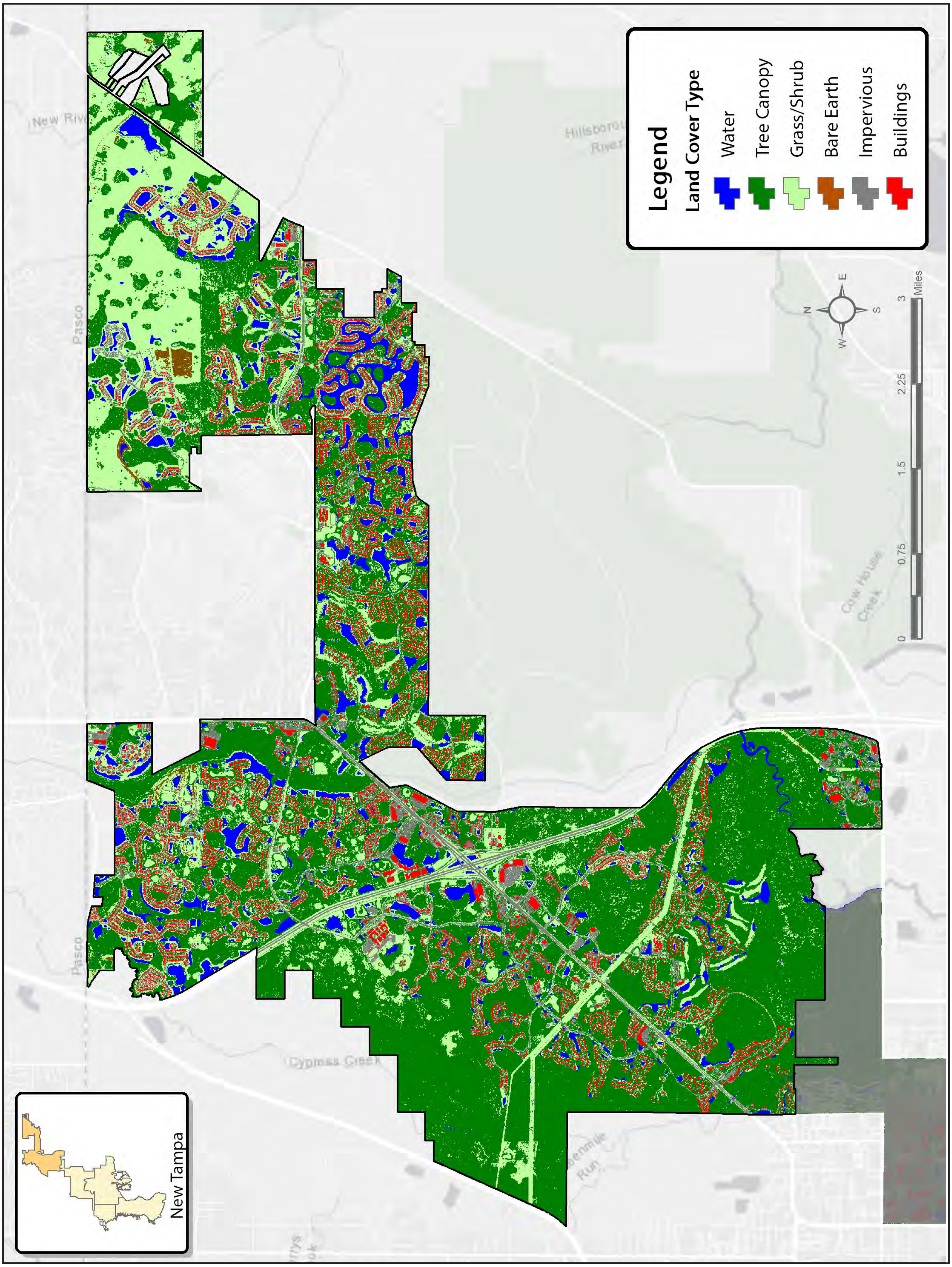


Figure 30. Map of land ccver in the New Tampa area.

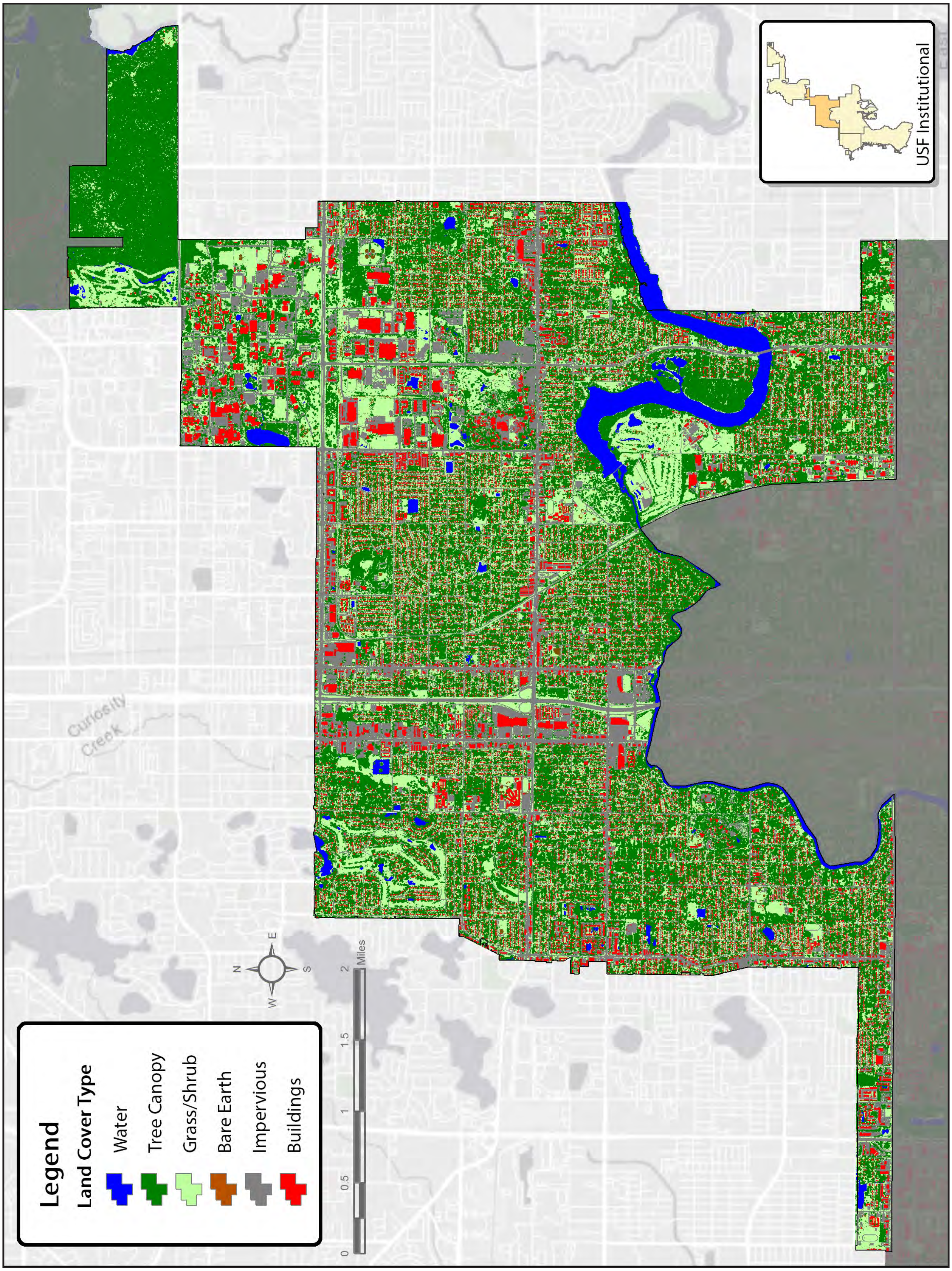


Figure 31. Map of land cover in the USF Institutional area.

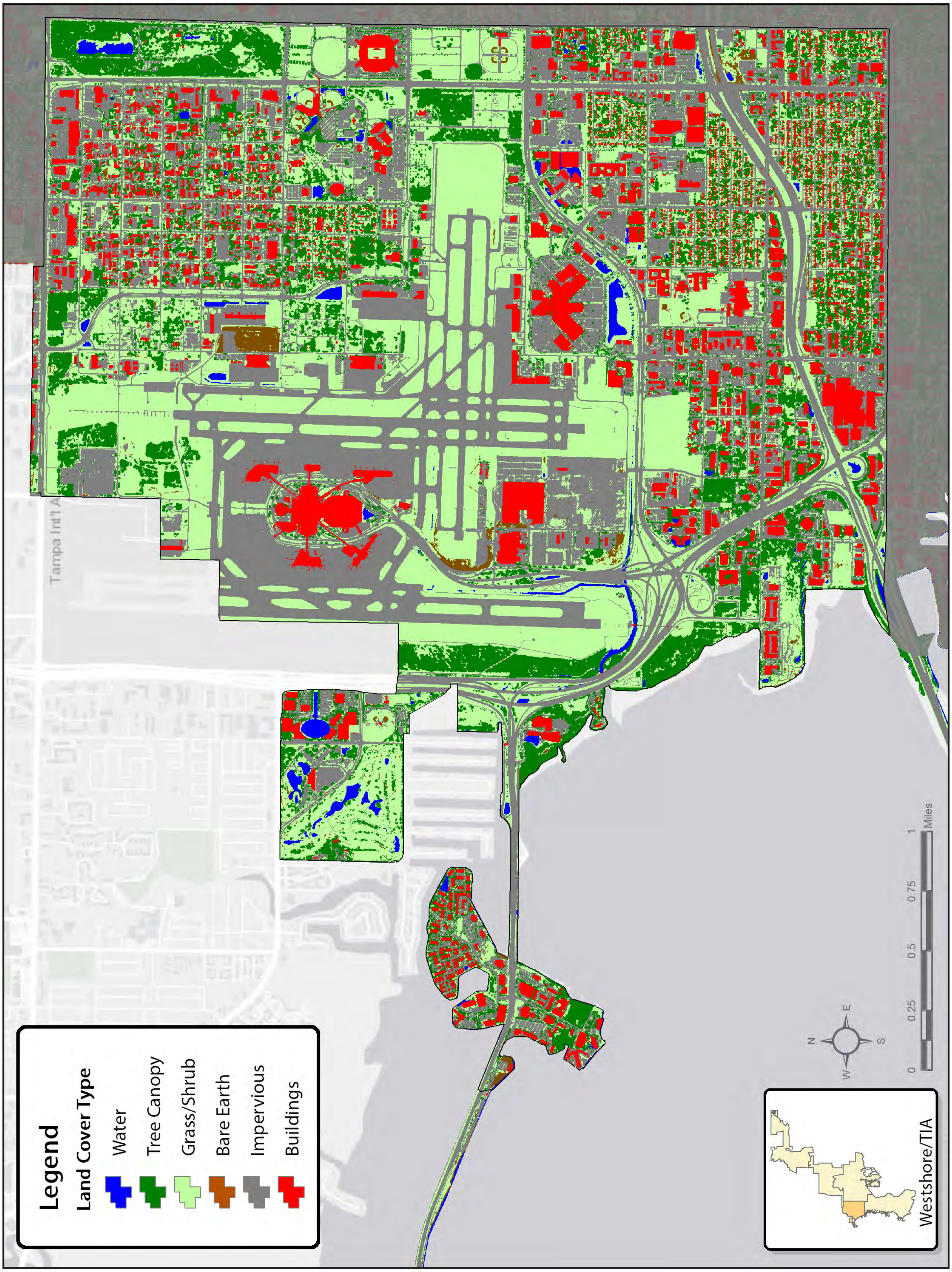


Figure 32. Map of land cover in the Westshore/Tampa International Airport area.

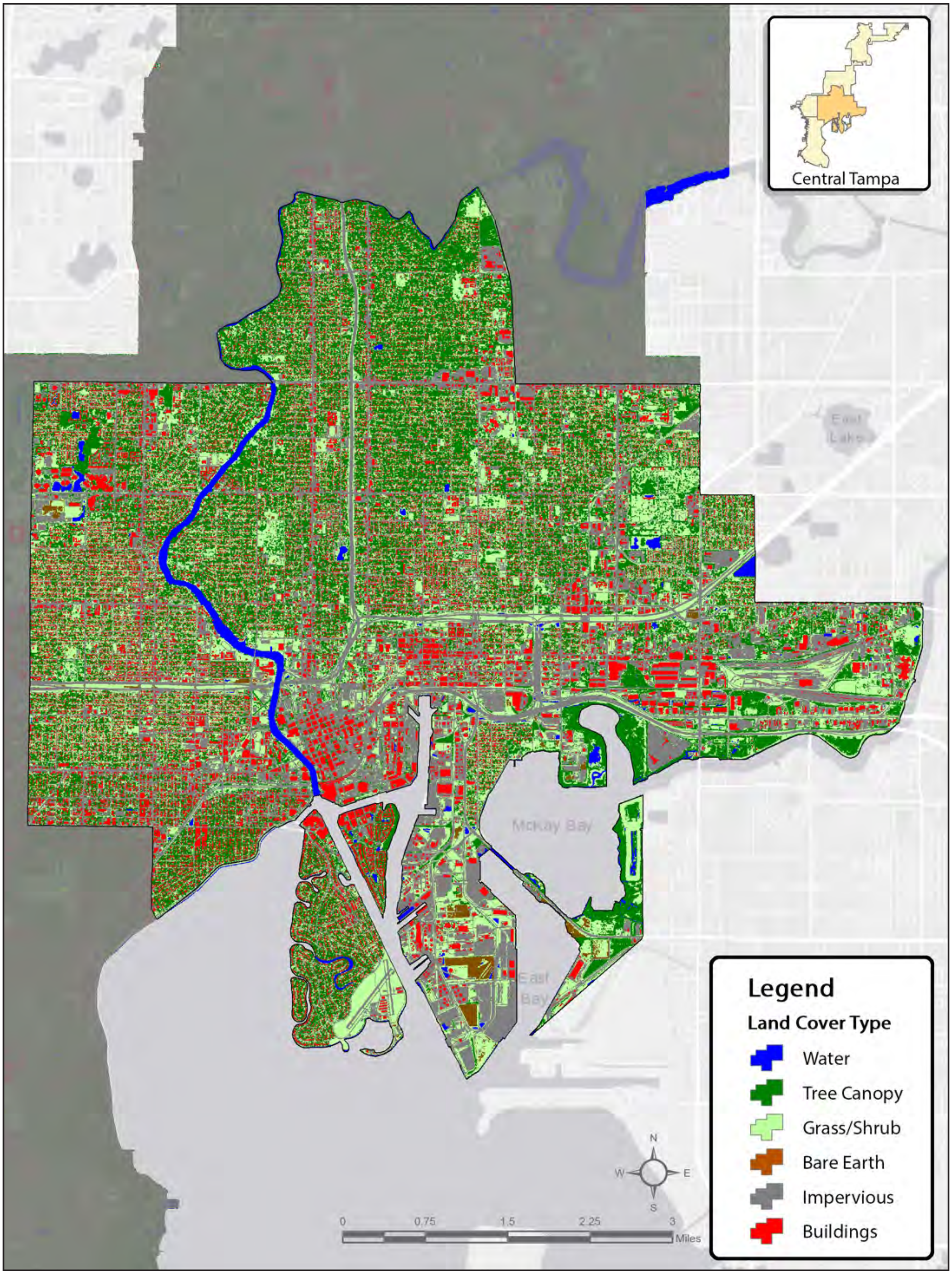


Figure 33. Map of land cover in the Central Tampa area.

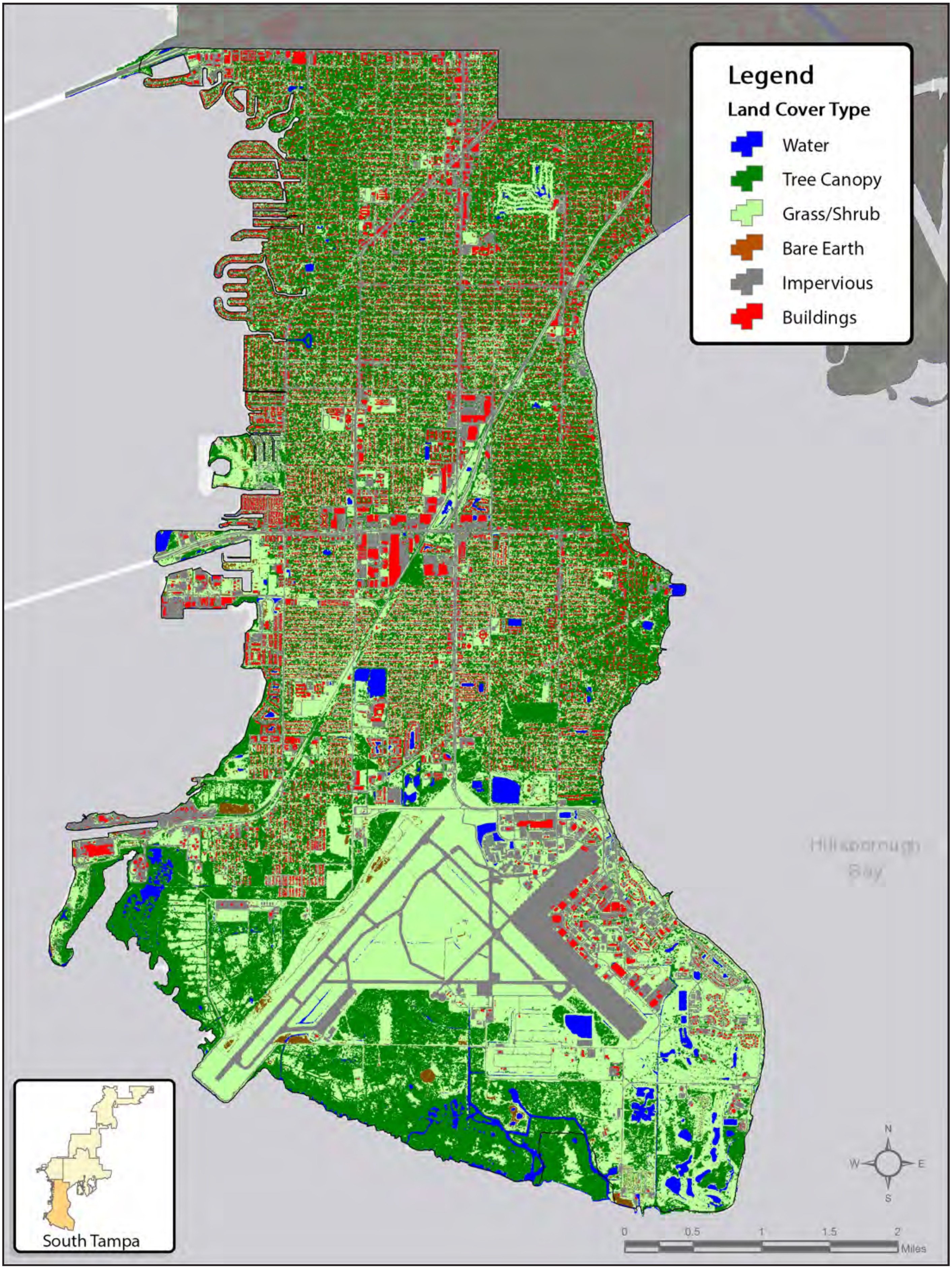


Figure 34. Map of land cover in the South Tampa area.

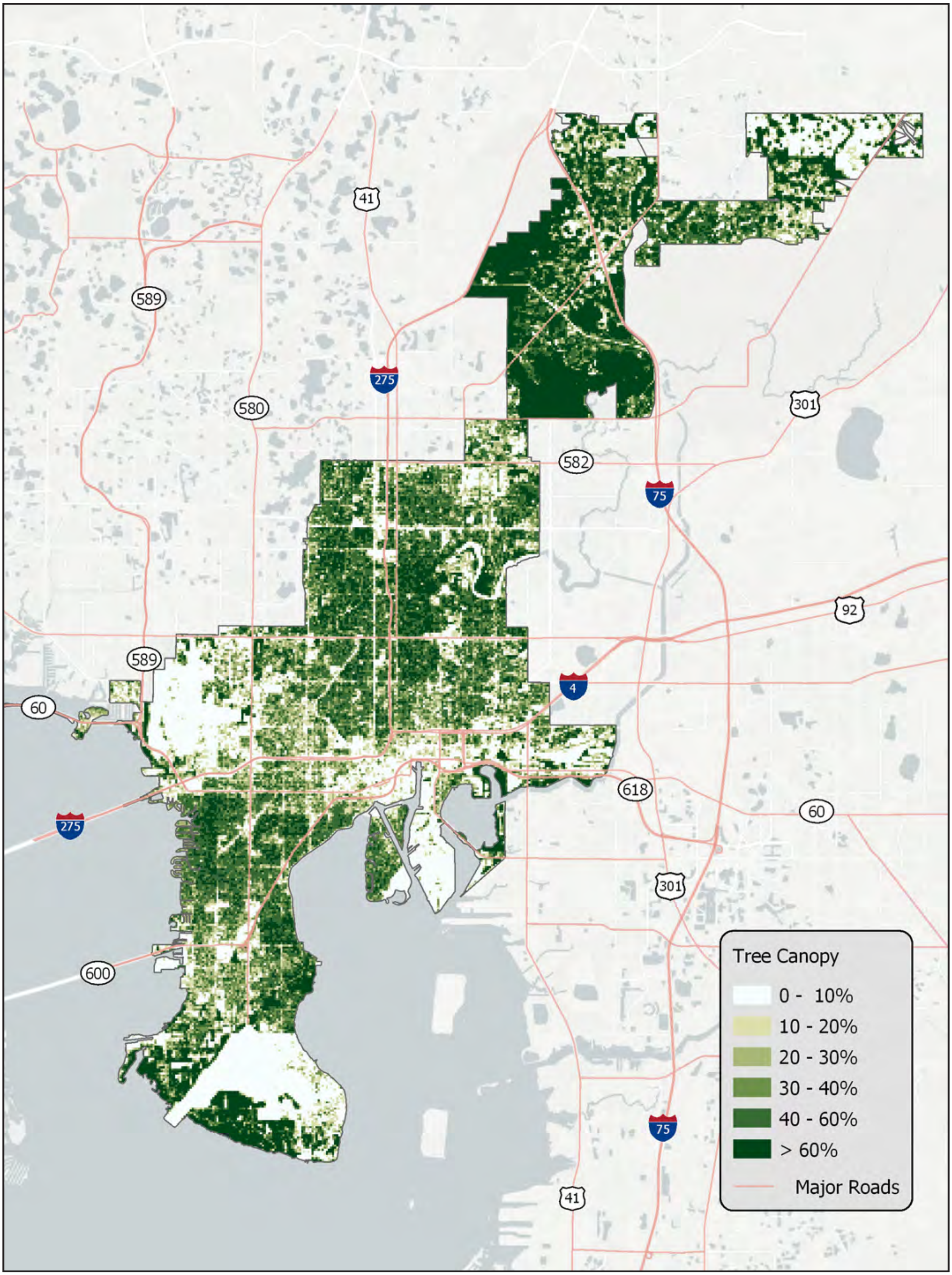


Figure 35. Map of tree canopy in the City of Tampa.

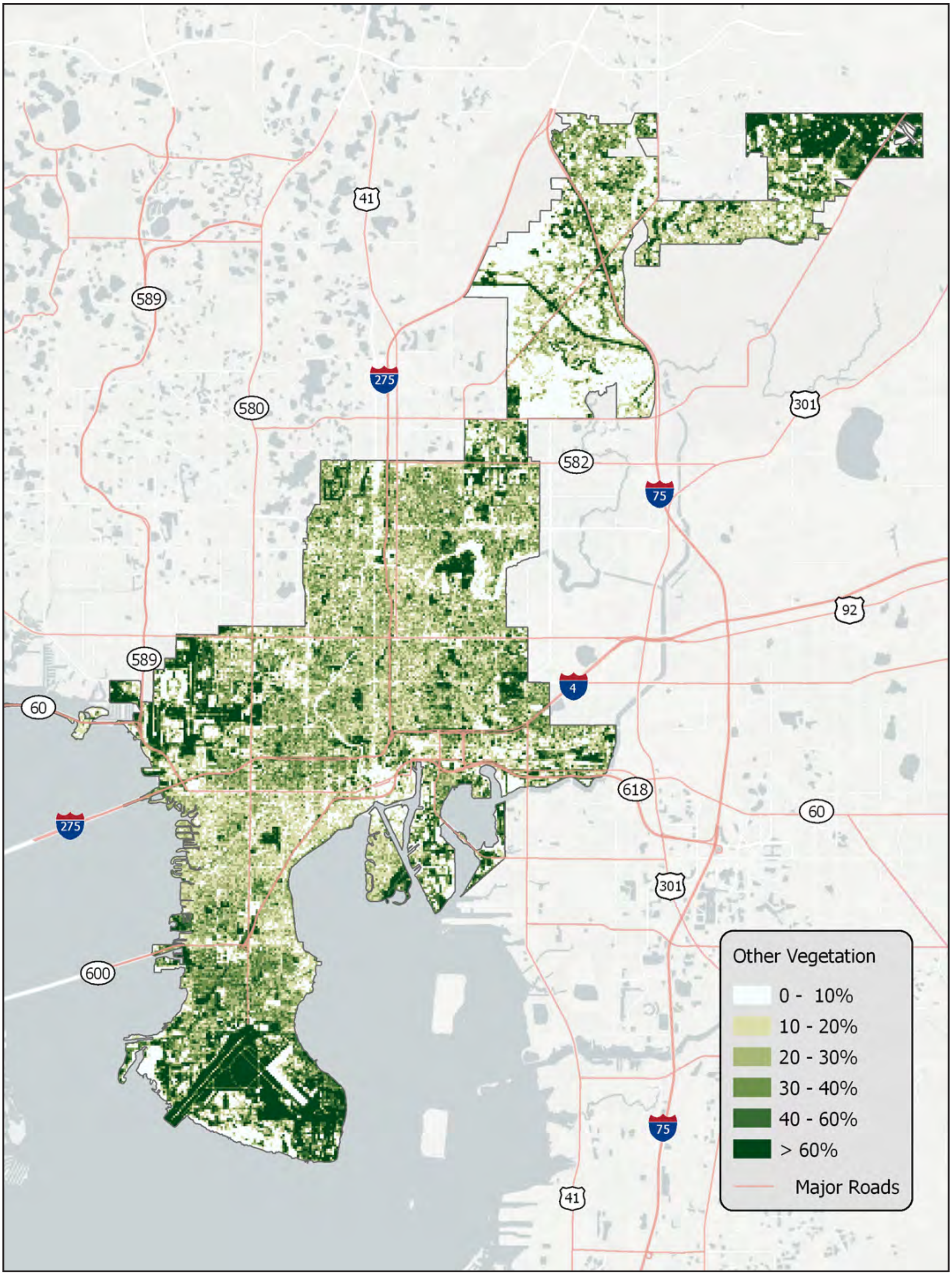


Figure 36. Map of grass/shrub cover in the City of Tampa.

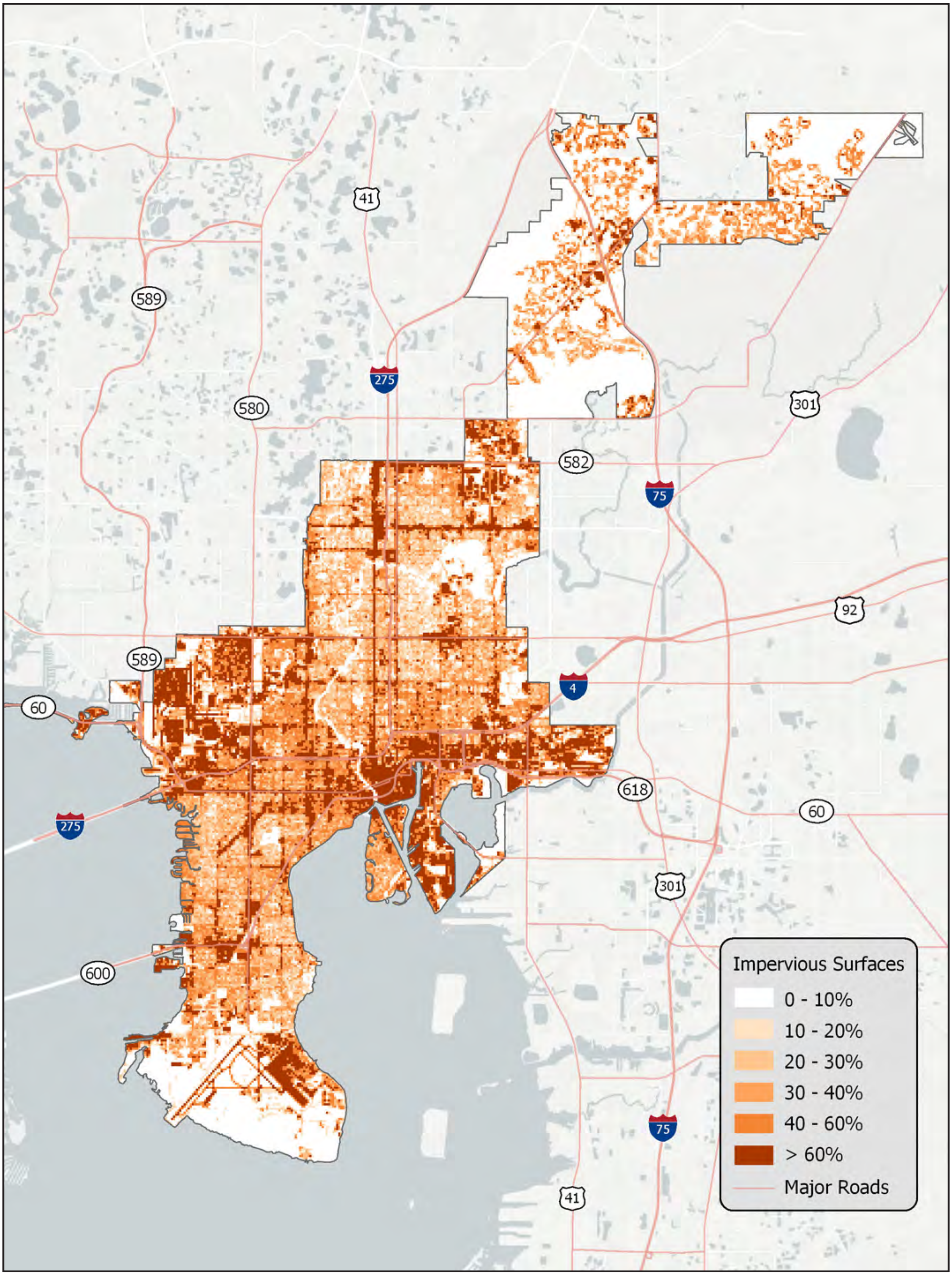


Figure 37. Map of impervious surface in the City of Tampa.

Land Cover by Current Use of Land

As described in the project methods, a customized stratification system was used to maximize the accuracy of extrapolated results from the field sampling of urban forest plots. Land use, for this section, represents how land was actually being used as of 2016 based on field sampling and tree mapping. The terms used should not be confused with regulatory designations such as zoning or future land use.

The percentage of land area covered by tree canopy is greatest within the Natural/Conservation Lands (89%) and Mangrove (84%) land areas, followed by Residential Single-Family (51%), Parks/Recreation (42%), and Multi-Family Residential (38%). In terms of total acreage within the City, there is more tree canopy within the Residential Single-Family (10,680 acres), than there is total vegetation in all other categories. Lands that are under public ownership or predominantly publicly managed or protected include Public Institutional, Public Communications/Utilities, Parks/Recreation, Mangroves, Natural/Conservation Lands and Right-Of-Way/Transportation. These "public" lands include 12,341 acres of tree canopy and another 11,435 acres of grass/shrub.

Table 12. Breakdown of cover type within the Current Use of Land categories.

Current Use of Land	Total Acres	Tree Canopy	Grass/ Shrub	Bare Earth	Impervious	Water
Agriculture	1,679	25%	73%	1%	0%	1%
Commercial	6,933	24%	18%	1%	57%	0%
Industrial	2,968	17%	23%	1%	58%	1%
Mangrove	1,218	84%	15%	0%	0%	1%
Natural / Conservation Lands	4,657	89%	10%	0%	0%	0%
Parks / Recreation	2,553	42%	48%	1%	7%	1%
Private Institutional	2,343	23%	30%	1%	45%	1%
Public Institutional	13,043	23%	44%	2%	30%	1%
Public Communications/Utilities	343	17%	51%	1%	31%	0%
Residential Multi-Family	3,374	38%	18%	0%	43%	1%
Residential Single-Family	20,749	51%	23%	0%	25%	0%
Right-of-Way / Transportation	13,022	23%	28%	0%	48%	0%
Water	2,406	7%	10%	0%	1%	82%

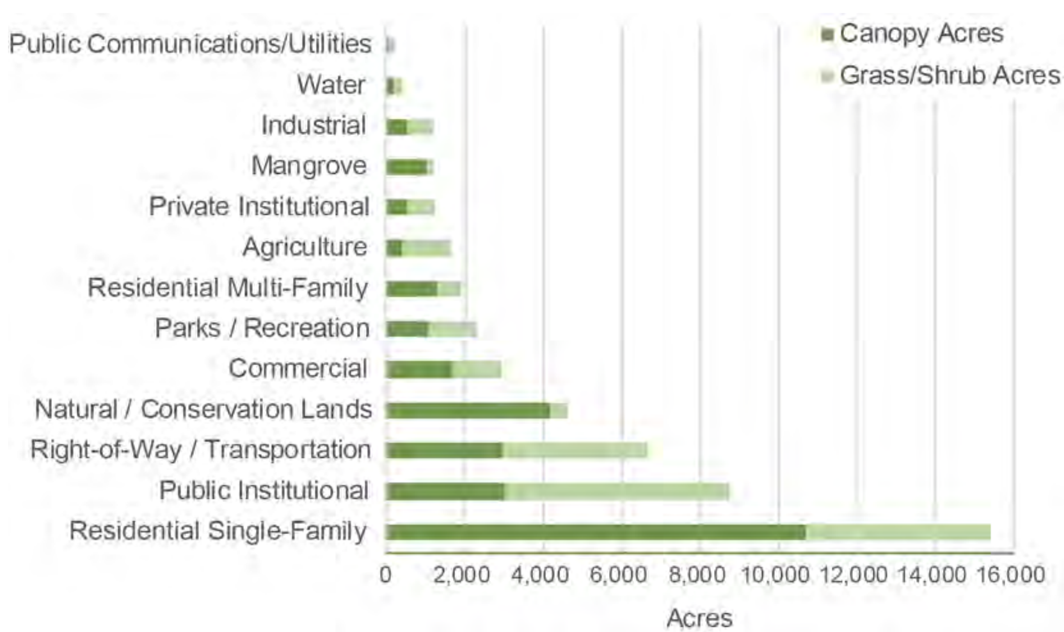


Figure 38. Acres of tree canopy and grass/shrub cover within the Current Use of Land categories.

Future Land Use

Trees and shrubs are found in many of Tampa's undeveloped areas. Whether or not these trees will remain in the years to come depends, in part, on Future Land Use (FLU). FLU is regulated through the Tampa Comprehensive Plan and is mapped on the Future Land Use Map. The goals, objectives, and policies established through this process are summarized and visualized as the FLU map. Future Land Use along with the Zoning & Land Development Code determine applicable land use and development regulations. It should be noted that the area of MacDill Air Force Base is excluded from the FLU map and therefore not included in these tree canopy estimates. The table below summarizes tree canopy and other land cover classes within each FLU category. The buildings and other impervious classes are combined into a single impervious class. As a simple proportion of the FLU category, tree canopy cover is highest in Environmentally Sensitive Areas (84% tree cover), followed by residential 6 units/acre (51%) and residential 10 units/acre (51%). The percentage of tree canopy is lowest in the Central Business District, General Mixed Use, Regional Mixed Use, and Heavy Industrial categories. However, even in these categories it might be possible to more than double canopy cover with tree planting in grass/shrub areas.

Table 13. Total acres and cover type for each Future Land Use category.

Future Land Use Category (# is units/acre)	Total Acres	Tree Canopy	Grass/ Shrub	Impervious	Bare Earth	Water
Central Business District	280	7%	11%	75%	1%	6%
Community Commercial - 35	2,460	21%	17%	60%	0%	2%
Community Mixed Use - 35	2,336	22%	20%	54%	1%	3%
Major Environmentally Sensitive Areas	7,737	84%	11%	1%	1%	3%
General Mixed Use - 24	83	12%	16%	72%	0%	0%
Heavy Industrial - 1.5	3,484	13%	27%	55%	3%	3%
Light Industrial - 1.5	1,816	27%	21%	43%	1%	8%
Municipal Airport Compatibility Plan	339	26%	21%	52%	0%	1%
Neighborhood Mixed Use - 35	108	19%	30%	44%	1%	7%
Public/Semi-Public	5,361	16%	42%	40%	1%	2%
Recreation and Open Space	2,114	39%	41%	9%	2%	9%
Right-of-Way	11,802	24%	28%	48%	0%	0%
Residential - 3	1,551	36%	26%	27%	0%	11%
Residential - 6	1,865	50%	18%	30%	0%	2%
Residential - 10	12,789	50%	23%	24%	0%	3%
Residential - 20	2,495	44%	26%	29%	0%	1%
Residential - 35	1,869	30%	23%	41%	1%	5%
Residential - 50	119	28%	17%	54%	0%	1%
Residential - 83	87	29%	21%	49%	0%	1%
Rural Estate - 10	289	18%	80%	1%	1%	0%
Regional Mixed Use - 100	1,232	12%	18%	65%	1%	4%
Suburban Mixed Use - 3	3,489	20%	52%	17%	2%	9%
Suburban Mixed Use - 6	4,821	46%	23%	24%	0%	7%
Transitional Use - 24	507	32%	23%	33%	1%	11%
Urban Mixed Use - 60	1,023	18%	22%	56%	2%	3%

In order to consider the citywide implications of FLU for the tree canopy, it is necessary to examine the total land area within each category. The graph below shows the FLU categories with more than 500 acres of all vegetation, tree canopy plus grass/shrub. Residential 10 units/acre and Environmentally Sensitive Areas remain the categories with the most tree canopy and total vegetation. In fact, these two categories include 12,993 acres of tree canopy which is near equal to the total of all other FLU categories combined (13,254 acres). It will not surprise anyone who has driven on Tampa's tree-lined neighborhood streets that the Right-of-Way FLU category has the third largest acreage of tree canopy (2,797 acres) and an even larger area of grass/shrub (3,316 acres) where some additional tree planting conceivably could be done.

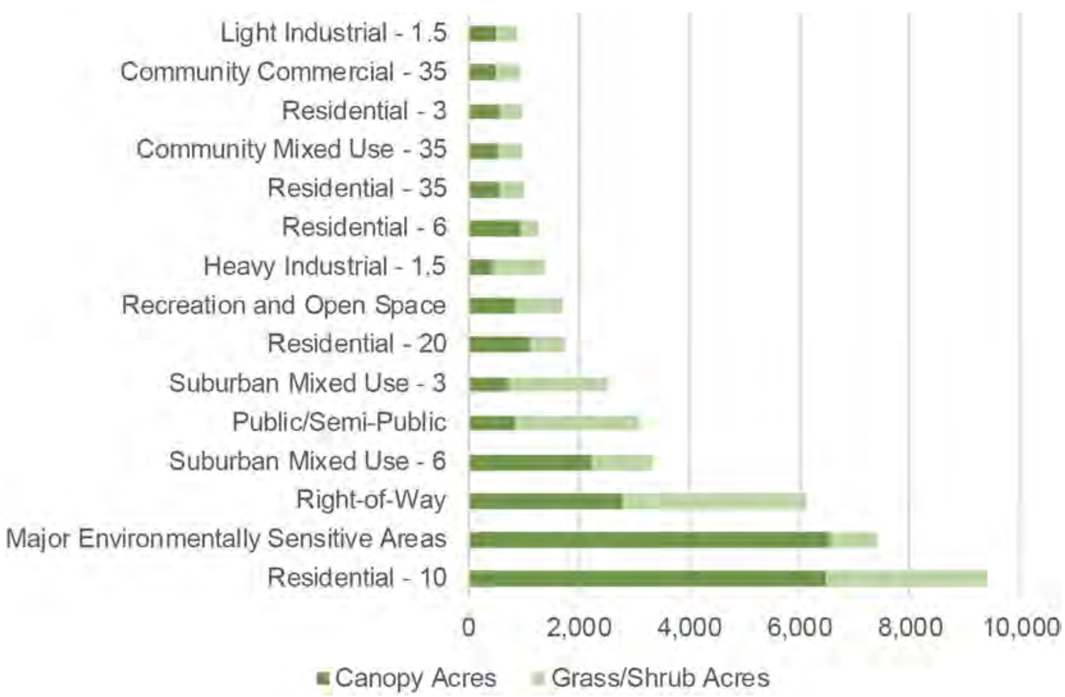


Figure 39. Future Land Use categories with more than 500 total acres of vegetation.

Zoning and Land Development Code

The City of Tampa Zoning and Land Development Code has three primary purposes: 1) to implement the public purpose and objectives of the Tampa Comprehensive Plan; 2) promote the public health, safety, morals, convenience, comfort, amenities, prosperity and general welfare of the City; and 3) divide the City into districts of such number, shape, characteristics, area, common unity of purpose, adaptability or use as will accomplish the objectives of the Tampa Comprehensive Plan. Development standards are set in the Zoning and Land Development Code. Similar to the Future Land Use results, the MacDill AFB is excluded from all zoning results, and the area of Bruce B. Downs Boulevard and interstate highways 75 and 275 are also excluded.

Table 14 summarizes tree canopy and other land cover classes within each Zoning and Land Development Code Category. The buildings and other impervious classes are combined into a single impervious class. Tree canopy cover as a percentage of the area within a zoning category is highest in the Community Unit (78%), a zoning category unique to the Tampa Palms area that includes large tracts of forested wetlands. Similarly, Planned Development Alternative includes large areas of forested wetlands in New Tampa and has a high tree canopy cover (48%). All of the single-family residential zoning categories, except Ybor City, have greater than 40% tree canopy cover. Zoning categories in Ybor City, Central Business District and Channel District have the lowest percentage of tree cover, though these areas have substantial grass/shrub areas where tree planting is possible.

The proportion of tree canopy in a Zoning and Land Development Code category may be less important when the total land area is small. The majority of categories comprise less than 1,000 acres of land and less than 500 acres of total vegetation cover. The graph below shows the acreage of tree canopy and grass/shrub within the zoning categories with at least 500 acres of total vegetation. Out of the 25,792 acres of tree canopy included within the zoning results, 16,404 acres, or 63% of all canopy, are represented by the Planned Development Alternative, Residential Single-Family (RS-50 and RS-60) and Community Unit categories. Dedicated residential zoning categories, excluding the mixed-use, Planned Development and Community Unit, comprise 11,816 acres of tree canopy. These results illustrate the importance of households and families for the management of tree canopy within the City of Tampa.

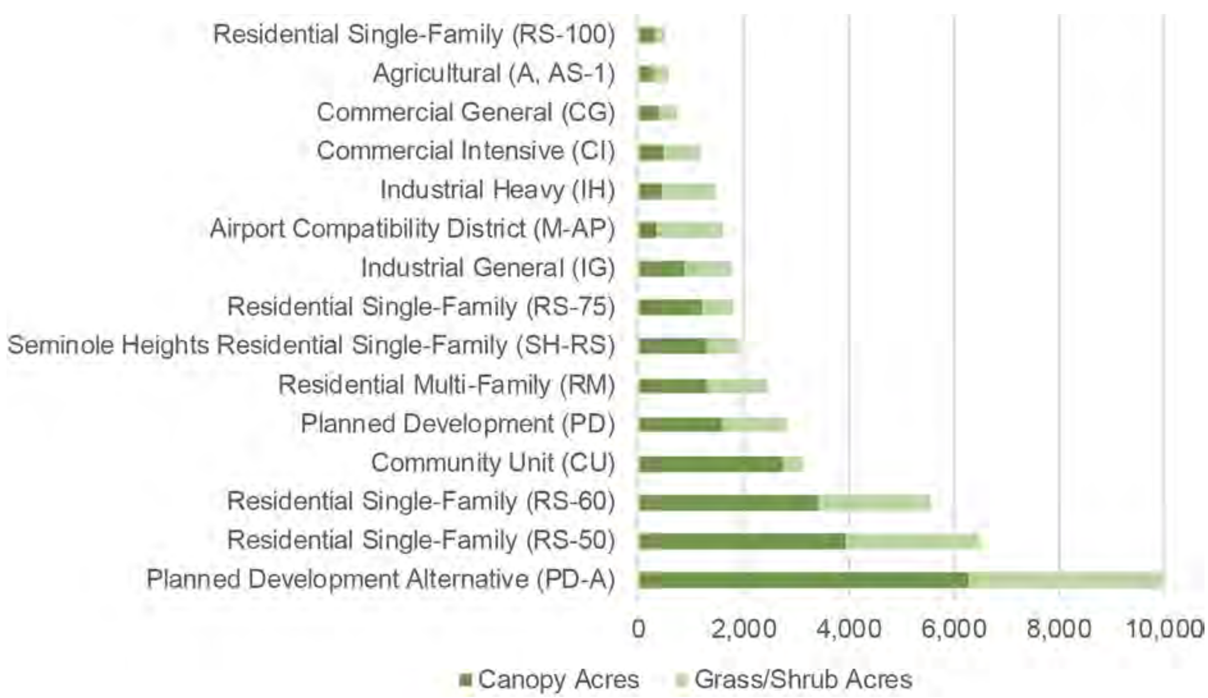


Figure 40. Zoning and Land Development Code Categories with more than 500 total acres of vegetation.

Table 14. Total acres and cover type for each Zoning and Land Development category.

Zoning & Land Development Code Category	Acres	Tree Canopy	Grass/ Shrub	Imper-vious	Bare Earth	Water
Agricultural (A, AS-1)	588	49%	50%	1%	0%	0%
Airport Compatibility District (M-AP)	2,980	11%	43%	45%	1%	1%
Central Business District (CBD)	518	7%	12%	76%	1%	4%
Channel District (CD)	131	4%	15%	80%	1%	1%
Commercial General (CG)	2,203	16%	18%	65%	0%	1%
Commercial Intensive (CI)	3,251	15%	21%	63%	1%	1%
Commercial Neighborhood (CN)	92	26%	26%	47%	1%	1%
Community Unit (CU)	3,520	78%	12%	8%	0%	3%
Industrial General (IG)	3,272	27%	28%	41%	2%	4%
Industrial Heavy (IH)	3,738	12%	27%	57%	3%	1%
Neighborhood Mixed Use (NMU)	117	18%	29%	44%	1%	8%
Office Professional (OP)	309	14%	18%	66%	0%	2%
Planned Development (PD)	5,306	30%	23%	40%	1%	6%
Planned Development Alternative (PD-A)	13,122	48%	28%	17%	1%	6%
Residential Multi-Family (RM)	3,988	33%	29%	36%	1%	2%
Residential Office (RO)	250	30%	17%	52%	0%	0%
Residential Single-Family (RS-100)	714	41%	29%	25%	1%	4%
Residential Single-Family (RS-150)	374	52%	23%	12%	2%	11%
Residential Single-Family (RS-50)	9,283	43%	27%	29%	0%	1%
Residential Single-Family (RS-60)	7,996	43%	27%	27%	0%	3%
Residential Single-Family (RS-75)	2,565	47%	23%	27%	0%	3%
Seminole Heights Commercial General (SH-CG)	123	26%	17%	55%	0%	2%
Seminole Heights Commercial Intensive (SH-CI)	264	17%	11%	72%	0%	1%
Seminole Heights Commercial Neighborhood (SH-CN)	3	25%	18%	58%	0%	0%
Seminole Heights Planned Development (SH-PD)	4	44%	25%	31%	0%	0%
Seminole Heights Residential Multi-Family (SH-RM)	72	44%	20%	34%	0%	2%
Seminole Heights Residential Office (SH-RO)	3	47%	14%	40%	0%	0%
Seminole Heights Residential Single-Family (SH-RS)	2,535	52%	23%	22%	0%	2%
Seminole Heights Residential Single-Family Attached (SH-RS)	0.3	58%	27%	16%	0%	0%
University Community District (UC)	805	29%	27%	41%	0%	3%
Ybor City - Central Commercial Core (YC-1)	75	8%	8%	84%	0%	0%
Ybor City - Community Commercial (YC-6)	89	9%	22%	68%	0%	0%
Ybor City - General Commercial (YC-5)	76	12%	18%	69%	1%	0%
Ybor City - Hillsborough Comm. College (YC-3)	33	17%	22%	59%	0%	1%
Ybor City - Mixed Use (YC-7)	59	14%	23%	63%	0%	0%
Ybor City - Mixed Use Redevelopment (YC-4)	64	16%	25%	59%	0%	0%
Ybor City - Residential (YC-2)	193	24%	31%	45%	0%	0%
Ybor City - Residential Single-Family (YC-8)	87	31%	26%	42%	0%	0%
Ybor City - Site Plan Controlled (YC-9)	4	4%	24%	72%	0%	0%

Neighborhood Associations

The City of Tampa maintains a neighborhood registry that is the official list of active neighborhood associations. A neighborhood is defined as an integrated area related to a larger community of which it is a part, and may consist of residential districts, a school or schools, shopping facilities, religious buildings and open spaces. Neighborhood associations are formed by residents and the boundaries of these neighborhoods are defined by the association members, based on approval by the City of Tampa's Neighborhood Services Department. The summary of tree canopy by neighborhood was created using the neighborhood association boundaries provided by the City. Seminole Heights (Combined) was added to represent the total of all of the individual Seminole Heights neighborhoods. Similarly, Hunter's Green (Combined) was added to represent the full area of Hunter's Green.

The proportion of neighborhood land area covered by tree canopy ranged from 4% in the Channel District and 7% in the Tampa Downtown Partnership to a high of 73% in Tampa Palms, 71% in Tampa Palms North, and 65% in Culbreath Bayou. The amount of other vegetation, or land available for potential tree planting, is equal to or greater than the existing proportion of tree canopy in 23 of the 104 neighborhoods listed. The average tree canopy percentage within all neighborhoods is 36.5%.

The graph shows the acreage of tree canopy and grass/shrub for all neighborhoods with at least 500 acres of total vegetation. The total area covered by tree canopy and other vegetation is closely related to the total land area within the neighborhood. The three largest neighborhoods (i.e., Seminole Heights (Combined), Tampa Palms and Tampa Palms North) also have the most acreage of tree canopy. In fact, out of all the neighborhood associations within the City of Tampa, 29% of the acreage of tree canopy is within these three areas.

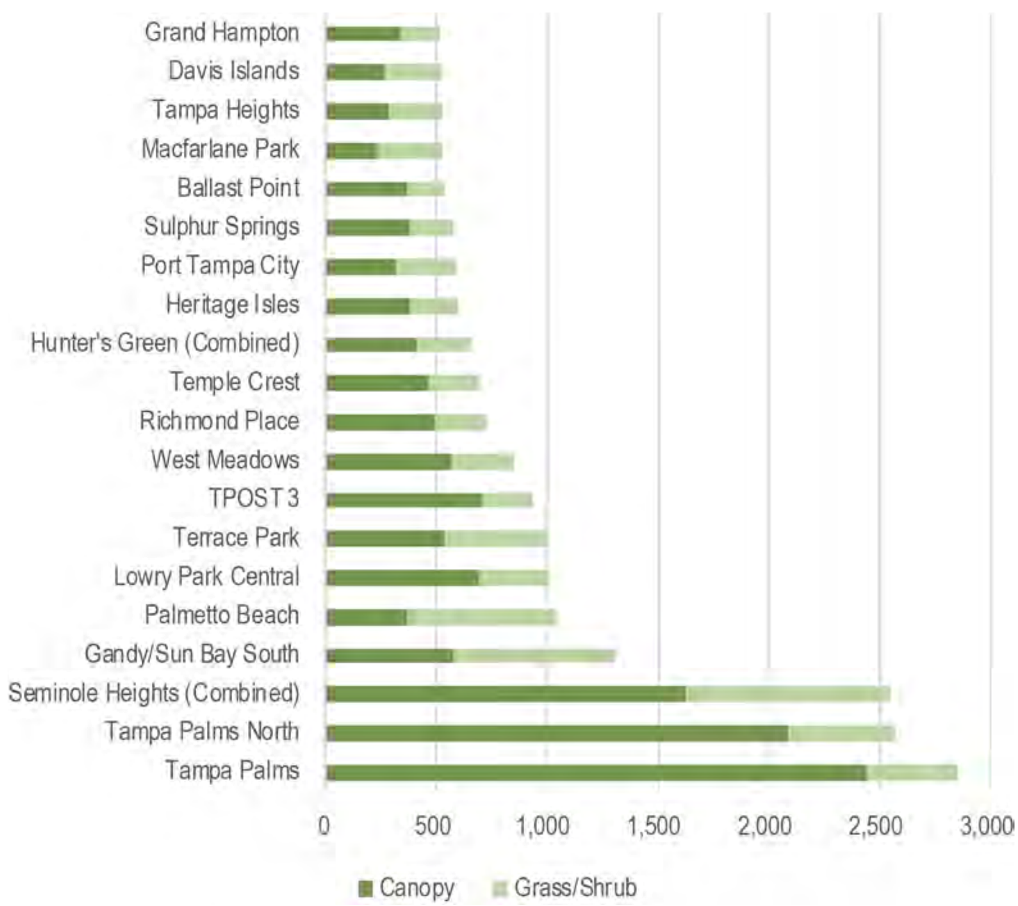


Figure 41. Neighborhoods with more than 500 total acres of vegetation.

Photo of Tom Olson talking to kids about trees. Tom was a beloved horticulturist with Parks and Recreation who passed away in 2016.

Table 15. Summary of cover type by neighborhood.

Neighborhood Association	Acres	Tree Canopy	Grass/ Shrub	Impervi-ous	Bare Earth	Water
Arbor Greene	593	45%	19%	26%	0%	10%
Armory Gardens	161	32%	30%	38%	0%	0%
Ballast Point	745	50%	22%	26%	0%	2%
Bayshore Beautiful	617	52%	18%	30%	0%	0%
Bayshore Gardens	129	37%	17%	46%	0%	1%
Bayside West	620	28%	31%	38%	2%	2%
Beach Park	557	48%	17%	35%	0%	0%
Beach Park Isles	26	25%	21%	52%	1%	1%
Bel Mar Shores	79	38%	20%	42%	0%	0%
Belmar Gardens	165	46%	21%	32%	0%	2%
Bon Air	81	36%	22%	42%	0%	0%
Bowman Heights	54	32%	23%	30%	0%	15%
Carver City / Lincoln Gardens	554	13%	26%	60%	0%	1%
Channel District	90	4%	15%	80%	1%	1%
College Hill	67	38%	26%	36%	0%	0%
Cory Lake Isles	590	28%	21%	28%	0%	23%
Courier City / Oscawana	160	22%	14%	64%	0%	0%
Culbreath Bayou	40	65%	12%	24%	0%	0%
Culbreath Heights	97	33%	27%	40%	0%	0%
Culbreath Isles	89	41%	21%	37%	1%	1%
Davis Islands	873	31%	29%	38%	1%	2%
Downtown River Arts Neighborhood	167	9%	13%	70%	0%	8%

Table 15, continued. Summary of cover type by neighborhood.

Neighborhood Association	Acres	Tree Canopy	Grass/ Shrub	Impervi- ous	Bare Earth	Water
Drew Park	828	18%	24%	58%	0%	1%
East Forest Hills	761	32%	23%	44%	0%	1%
East Tampa Business & Civic	830	32%	28%	40%	0%	0%
East Ybor Historic	541	16%	25%	58%	0%	0%
Eastern Heights	291	35%	42%	23%	0%	0%
Easton Park	520	16%	57%	15%	0%	13%
Fair Oaks/Manhattan Manor	659	23%	28%	48%	0%	1%
Florence Villa/ Beasley/Oak Park	162	22%	28%	41%	0%	9%
Forest Hills Community	286	44%	27%	29%	0%	0%
Forest Hills Neighborhood	505	42%	35%	19%	0%	4%
Gandy/Sun Bay South	2238	26%	33%	39%	1%	2%
Golfview	340	45%	29%	25%	1%	1%
Grand Hampton	749	46%	23%	20%	0%	11%
Grant Park	158	35%	30%	36%	0%	0%
Gray Gables	46	43%	18%	39%	0%	0%
Hampton Terrace	162	53%	18%	28%	0%	1%
Harbour Island	186	33%	9%	54%	0%	4%
Heritage Isles	763	50%	29%	15%	0%	5%
Highland Pines	447	26%	31%	40%	1%	2%
Historic Hyde Park	207	42%	17%	40%	0%	1%
Historic Ybor	405	12%	21%	67%	0%	0%
Hunter’s Green (Combined)	867	47%	28%	9%	0%	16%
Hunter’s Green - Cypress Ridge	13	50%	20%	30%	0%	0%
Hunter’s Green - Heather Downs	14	55%	16%	29%	0%	0%
Hunter’s Green - Pinnacle	7	55%	15%	30%	0%	0%
Hyde Park Spanishtown Creek	186	23%	16%	60%	0%	0%
Hyde Park Preservation	142	44%	15%	40%	0%	1%
Interbay	405	43%	34%	17%	1%	6%
Jackson Heights	621	32%	25%	43%	0%	0%
K Bar Ranch	496	28%	44%	17%	2%	10%
Live Oaks Square	243	44%	25%	31%	0%	1%
Lowry Park Central	1463	48%	21%	30%	0%	1%
Macfarlane Park	1000	23%	30%	47%	0%	0%
The Marina Club Of Tampa	22	12%	22%	38%	0%	29%
New Suburb Beautiful	82	58%	12%	31%	0%	0%
North Bon Air	174	23%	25%	52%	0%	0%
North Hyde Park	308	19%	25%	56%	1%	0%
North Tampa Community	693	36%	24%	40%	0%	0%
Northeast Community	284	42%	21%	29%	0%	8%
Northview Hills	86	29%	36%	36%	0%	0%
Oakford Park	244	31%	24%	45%	0%	0%
Old West Tampa	239	25%	26%	49%	0%	0%
Palma Ceia	569	40%	21%	39%	0%	0%
Palma Ceia Pines	280	29%	15%	55%	0%	0%

Table 15, continued. Summary of cover type by neighborhood

Neighborhood Association	Acres	Tree Canopy	Grass/ Shrub	Impervi-ous	Bare Earth	Water
Palma Ceia West	244	35%	22%	42%	0%	0%
Palmetto Beach	2371	16%	28%	48%	5%	4%
Parkland Estates	171	45%	16%	39%	0%	0%
Plaza Terrace	332	30%	23%	41%	0%	7%
Port Tampa City	790	41%	34%	23%	2%	0%
Rainbow Heights	164	42%	26%	32%	0%	0%
Richmond Place	1057	47%	22%	25%	0%	6%
Ridgewood Park	83	39%	21%	24%	0%	16%
Riverbend	442	49%	23%	23%	0%	5%
Rivergrove	121	46%	19%	21%	0%	15%
Riverside Heights	446	43%	25%	27%	0%	6%
Seminole Heights (Combined)	3748	43%	25%	28%	0%	4%
East Seminole Heights	322	34%	24%	41%	0%	0%
Old Seminole Heights	2612	44%	26%	26%	0%	4%
South Seminole Heights	387	44%	21%	29%	0%	6%
Southeast Seminole Heights	427	47%	20%	33%	0%	0%
Stadium Area	329	26%	25%	46%	3%	1%
Stoney Point	17	41%	20%	38%	1%	1%
Sulphur Springs	930	41%	21%	37%	0%	1%
Sunset Park	513	48%	18%	32%	0%	1%
Swann Estates	244	40%	20%	40%	0%	0%
Tampa Downtown Partnership	351	7%	12%	79%	1%	2%
Tampa Heights	926	31%	26%	40%	0%	3%
Tampa Palms North	2938	71%	16%	10%	0%	3%
Tampa Palms	3341	73%	12%	11%	0%	4%
Temple Crest	1120	41%	21%	26%	0%	12%
Terrace Park	1682	32%	27%	39%	0%	1%
TPOST 3	1139	62%	20%	16%	0%	2%
University Square	655	36%	25%	37%	0%	1%
Virginia Park	456	46%	20%	34%	0%	0%
VM Ybor	266	33%	22%	45%	0%	0%
Wellswood	600	35%	26%	36%	0%	3%
West Meadows	1179	49%	23%	19%	0%	9%
West Riverfront NHW	135	22%	28%	49%	1%	0%
West Riverside Heights	124	34%	19%	39%	0%	8%
Westshore Palms	162	26%	25%	48%	0%	0%
Woodland Terrace NHW	120	53%	25%	22%	0%	0%
Ybor Heights	211	36%	21%	42%	0%	1%

Parcel and Demographic Summaries

Tree Cover and Parcel Characteristics

These data include only Residential Single-Family parcels. The total number of parcels included in these summaries was greater than 80,000 from within the City of Tampa. Average percent tree canopy and grass/shrub cover was calculated for building age and size categories that contained at least 20 parcels. One of the benefits of creating the high resolution land cover map is that we can calculate the amount of each cover type for every property parcel in the City. It is then possible to examine how the amount of tree canopy or grass/shrub relates to different property or demographic characteristics.

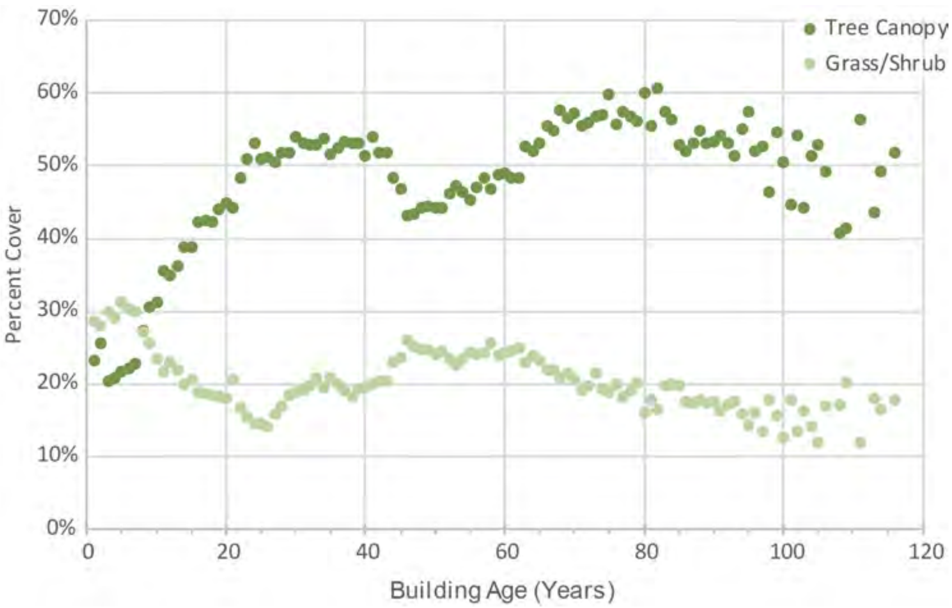


Figure 42. Tree and grass/shrub cover by building age for single-family parcels.

Trees and tree canopy grow over time, so it is not surprising the average tree canopy on single-family properties increases over the first 20 years after a home is built. The dip in canopy for homes built 40-60 years ago (@ 1956-76) could be related to tree deaths, differences in housing types, storm impacts or other factors.

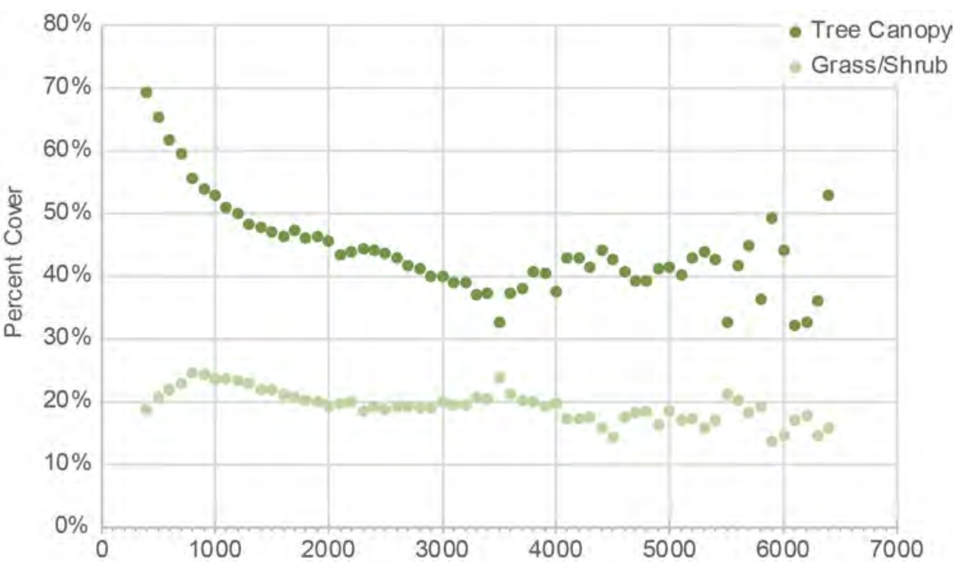


Figure 43. Tree and grass/shrub cover by house size for single-family parcels.

In general, single-family properties with larger houses have less room for trees than properties with smaller houses. There is a decrease in average tree canopy as Tampa house sizes increase to @ 3,000 ft^2 and then somewhat of a leveling off for larger homes.

Tree Cover and Demographic Characteristics

These data provide a summary of the average percent tree canopy and grass/shrub cover based on the demographic characteristics of the City of Tampa. Demographics were provided by the U.S. Census American Community Survey (www.census.gov/programs-surveys/acs/), and represent the years 2011-2015. The Census Block Group was the unit of analysis. In order to exclude outliers, only Block Groups located within the City of Tampa with at least 50 households were included. A total of 326 Block Groups were included, with a total population that ranged from 173 to 4,947 people, and total households of 87 to 1,609. Average percent tree canopy and grass/shrub were calculated only for demographic values with at least three (3) Block Groups. A linear trendline for tree canopy is shown on the graph when the R^2 is greater than 0.5 (R^2 is a measure of how well the line represents the trend in the data points).

Figure 44. Tree and grass/shrub cover by population density.

When we compare cities around the world, we generally find less tree canopy in urban areas with greater population density. However, there does not appear to be a strong relationship between population density and average tree canopy within the City of Tampa.

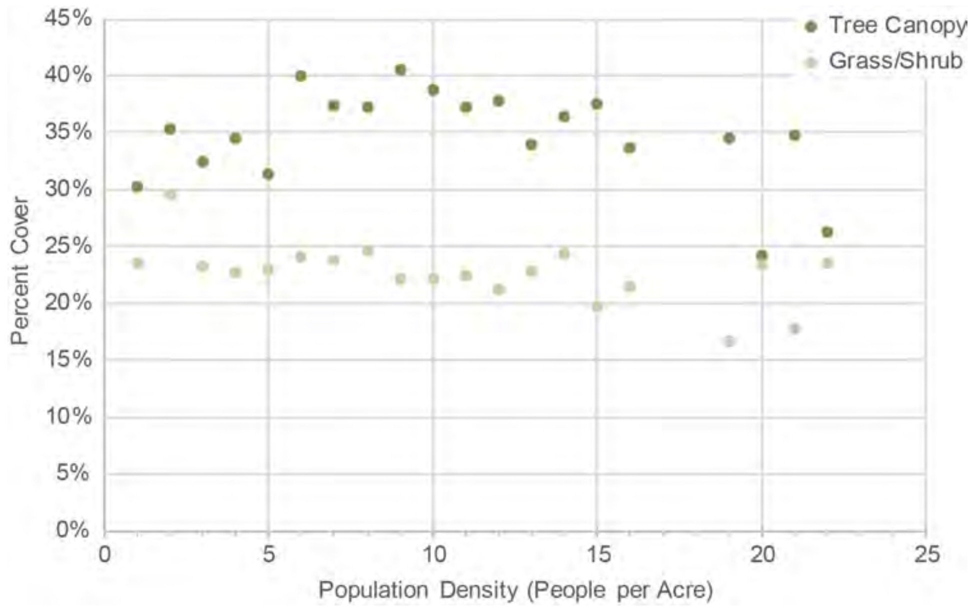
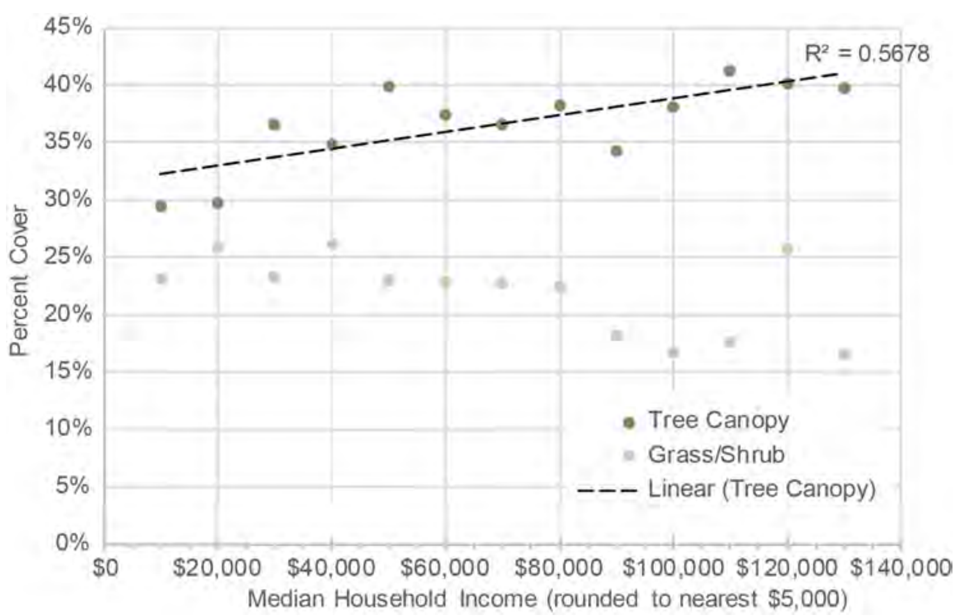


Figure 45. Tree and grass/shrub cover by median household income.

Research from many cities around the world suggests that tree canopy is greater in wealthier neighborhoods*. The results from Tampa suggest a similar trend.



* Schwarz K, et al. (2015) Trees grow on money: Urban tree canopy cover and environmental justice. *PLoS ONE*, 10(4): e0122051.

Figure 46. Tree and grass/ shrub cover by percentage renters.

The average tree canopy cover is lower in neighborhoods with a higher proportion of renters.

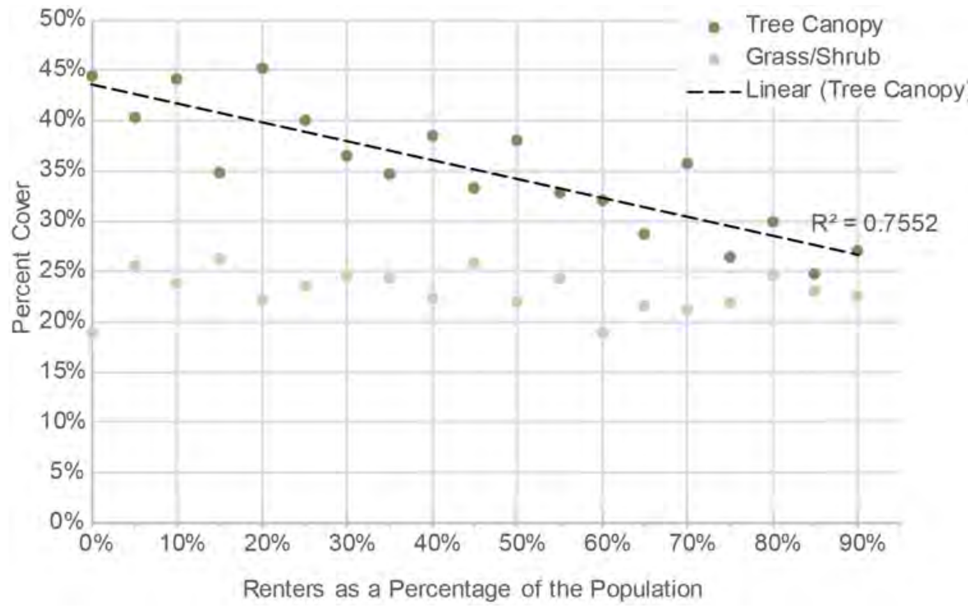
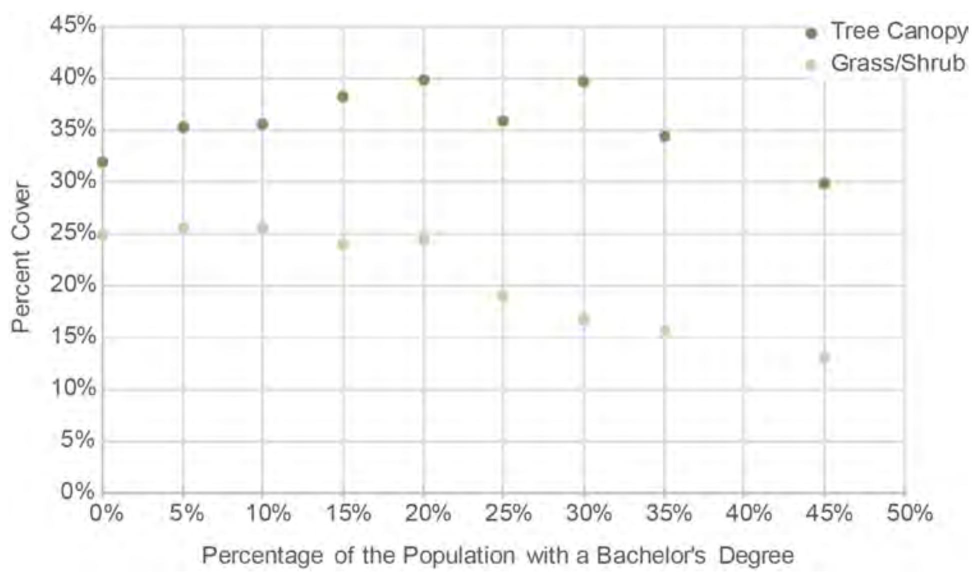


Figure 47. Tree and grass/ shrub cover by percentage with Bachelor's degree.

Although some scientific studies have found a positive relationship between the amount of tree canopy and the education level of residents, there does not appear to be much of a trend within Tampa.



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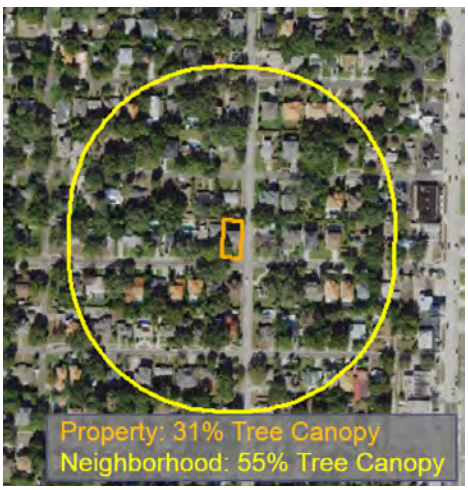
The Value of Trees for Single-Family Home Sales

We estimated the impact of tree canopy and trees on the sales price of single-family homes using the hedonic method, a statistical technique commonly used to estimate the value of natural resources that are hard to value using traditional appraisal methods. The hedonic analysis method used for this Tampa study estimates the contribution that tree canopy adds to the sales price of homes by considering all of the other important variables that influence sales price.

This analysis focused on single-family homes, the majority of residential properties in Tampa. Property and house data for single-family parcels that sold between May 2015 and May 2016 were obtained from the Hillsborough County Property Appraisers Office, Computer-Assisted Mass Appraisal database on June 2, 2016. New construction was excluded by eliminating parcels built in 2015 or later. A total of 4,848 parcels were included in the analysis.



This analysis used multiple regression[1] to model sale prices based on location attributes (e.g., neighborhood desirability, schools, nearby amenities) and property attributes (e.g., number of bedrooms, number of baths, number of stories, house square footage, parcel acreage, year built, presence/absence of a garage, presence/absence of a carport, presence/absence of a porch, presence/absence of a pool, architectural style, roof construction, type of air conditioning, and whether the home was on waterfront property). Additionally, the tree canopy mapping noted above was used to develop two separate tree canopy variables: 1.) canopy cover of canopy cover of trees originating on the individual property, and 2.) canopy cover in the surrounding neighborhood. The latter attribute was based on the tree canopy within a 500-foot radius (18 acres) surrounding the property of interest. In modeling sale price, we assessed the impact for each 1% increase of canopy added. At the neighborhood level, this would be on par with adding 6.7 average trees, or 4.6 mature live or laurel oaks.

[1] The authors of this report have published scientific articles using the same statistical methods. Examples include:
Donovan, G. H., & Butry, D. T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning*, 94(2), 77-83.
Donovan, G. H., & Butry, D. T. (2011). The effect of urban trees on the rental price of single-family homes in Portland, Oregon. *Urban Forestry & Urban Greening*, 10(3), 163-168.
Landry, S. M., & Pu, R. (2010). The impact of land development regulation on residential tree cover: An empirical evaluation using high-resolution IKONOS imagery. *Landscape and Urban Planning*, 94(2), 94-104.

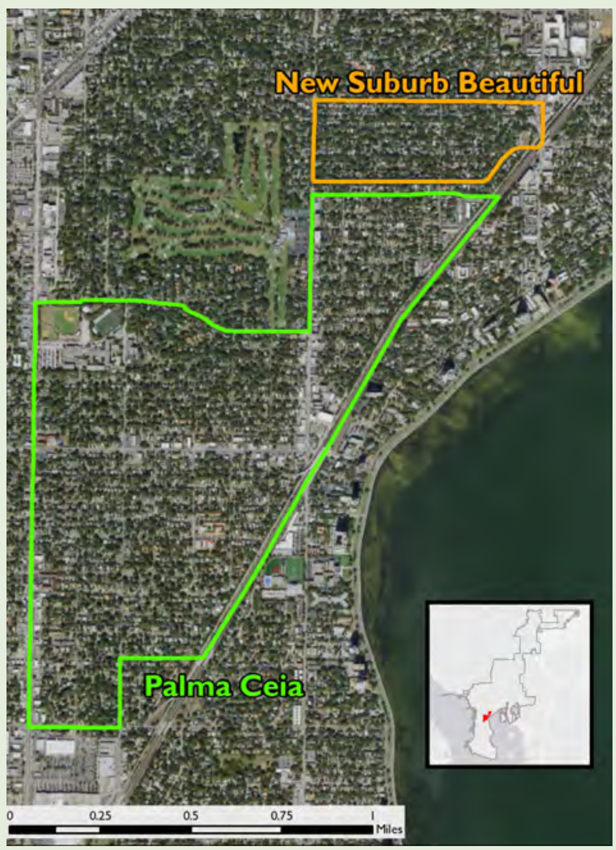
Results

Our models explained over 90% of the differences seen in home sales prices (i.e., R-squared > 0.9). The results showed that the sales price of a house was significantly affected by the canopy cover in the 500-foot radius neighborhood, but not the canopy cover of trees originating on the individual property that sold. In other words, having a large tree on one's lot in a relatively treeless neighborhood does not give the same benefit as having a house in an area with high canopy coverage. These results support the old "location, location, location" mantra of real-estate agents.

The full statistical model results are included in Appendix B. The following is a summary of the hedonic pricing analysis:

- A 1% increase in tree canopy cover in the neighborhood adds $155 to $164 to the sales price of an individual single-family home. This effect is compounding. A 10% increase would add $1,550 to the sale price.
- Given this neighborhood effect, more than just the houses modeled benefit. If there were 60 homes within the buffer area used, a 1% increase in canopy would be worth $9,271 to the combined home values in a neighborhood ($155 * 60).
- An average-sized tree adds $1,378 to the combined sales in a neighborhood ($9,271 / 6.7 trees).
- A mature oak tree adds $2,028 to the combined sales in a neighborhood ($9,271 / 4.6 trees).

To illustrate the value that tree canopy has on sales prices, consider the adjacent neighborhoods New Suburb Beautiful and Palma Ceia. New Suburb Beautiful has 58% tree canopy, while Palma Ceia has 40% tree canopy, an 18% difference. The results of this analysis suggest that the tree canopy in Palma Ceia adds $6,180 (40% * $155) to the sales price of an individual single-family homes, while the canopy in New Suburb Beautiful adds $8,962 (58% * $155) to the sales price of an individual home. The collective value of tree canopy for the 303 single-family houses in New Suburb Beautiful could be $2.7 million, and the collective value for the 1,864 single-family homes in Palma Ceia could be $11.5 million.



The Value of Tampa’s Urban Forest

The urban forest provides countless benefits, including serving as a habitat for plants and animals (Goddard et al. 2017), decreasing human stress (Jiang et al. 2016), and providing ecological functions such as air filtration (Chen et al. 2017) and stormwater management (Xiao and McPherson 2017). In the following sections we will discuss the benefits of energy conservation, air pollution removal, carbon storage and sequestration, structural values, and avoided stormwater runoff, all considered to be ecosystem services due to their positive impact on human health and welfare (Escobedo et al. 2011). The i-Tree Eco model helps calculate an economic value for these more tangible services, which in turn allows managers and citizens to gauge the importance of the urban forest. In 2016 Tampa’s urban forest provided an estimated $139.8 million/year worth of ecosystem services and an additional $2.01 billion in overall structural value (Tables 16 and 17).

Table 16. Summary of ecosystem services and annual values of Tampa’s trees in 2016.

Ecosystem Services	Annual Value (million $)
Building energy savings[a]	7.0
Avoided carbon emissions[b]	1.4
Gross carbon sequestration[b]	8.0
Carbon storage[b]	112.0
Air pollution removal[c]	3.4
Avoided health care costs	3.4
Avoided stormwater runoff[d]	3.4
Total Annual Benefits	138.8

a Energy saving value is calculated based on the prices of $116.15 per MWH and $17.30 per MBTU.

b Carbon is valued at $129.73 per ton.

c Pollution removal value is calculated based on the prices of $1,468.513 per ton (CO), $3,300.350 per ton (O3), $478.842 per ton (NO2), $158.472 per ton (SO2), $140,169.976 per ton (PM2.5).

d Avoided runoff value is calculated by the price $0.067/ft³ and 55.8 inches of total annual precipitation.

Structural Values

Structural value is based on local estimates of the cost of replacing a tree that has been lost intentionally or unintentionally (e.g., storm) with a similar tree. Structural value of an urban forest often rises as the number and size of healthy trees increases. Structural values are estimated in i-Tree Eco using valuation procedures of the Council of Tree and Landscape Appraisers. Tampa’s urban trees had a total structural value of $2.01 billion, with live oaks and laurel oaks making up around 46% of the total structural value of the forest (Table 17).

Table 17. The structural values of 10 species in Tampa’s urban forest in 2016.

Species	Structural Value ($)*	Percentage of Forest’s Total Structural Value (%)
Live oak	$525,665,102	26.1%
Laurel oak	$403,883,122	20.0%
Cypress species	$182,456,399	9.1%
Cabbage palm	$70,158,630	3.5%
Brazilian pepper	$69,002,653	3.4%
Swamp tupelo	$43,543,450	2.2%
Carolina laurelcherry	$40,502,642	2.0%
Longleaf pine	$36,605,675	1.8%
Mexican fan palm	$30,268,178	1.5%
Ear tree	$28,059,088	1.4%
All Other Species	$584,640,073	29.0%
All species citywide	**$2,014,785,011**	**100.0%**

*Structural value is the compensatory value calculated based on the local cost of having to replace a tree with a similar tree.

Shading of buildings and air conditioning units can reduce cooling costs.

Energy Conservation

Urban trees play a role in energy consumption and can contribute to reduced energy usage in adjacent buildings by providing shade, serving as windbreaks, and through evaporative cooling (Pataki et al. 2011). This reduction in energy consumption can result in financial savings for residents and an overall decrease in the demand for fossil fuels. Trees that were at least 20 feet tall and within 60 feet of a residential building under 3 stories were included in calculations (McPherson and Simpson 1999). The i-Tree Eco model provides energy conservation estimates in megawatt hours (MWh; electricity use) and million British thermal unit (MBtu; natural gas use), as well as the related carbon emissions avoided due to a reduction in fossil fuel use. Energy conservation estimates were calculated for residential buildings using the average statewide consumption rates of $116.15 per MWh, $17.30 per MBtu, and a sequestration value of $129.73 per ton of carbon.

Tampa's trees are estimated to reduce annual energy consumption by a total of 63,921 MWh of energy valued at $7.4 million (Table 18). Excess expenditure on higher costs of heating for tree-shaded homes was 1,019 MWh at a value of around $118,300. The City's trees also provide an extra $1.4 million in value by decreasing the amount of carbon released by fossil-fuel based power plants by 10,878 tons.

Table 18. Annual energy savings and associated dollar values due to the proximity of residential buildings to trees in 2016.

Type	Heating	Cooling	Total	Price ($)	Value ($)
Natural Gas (MBtu)[a]	(22,058)	n/a	(22,058)	$17.30	($381,664)
Electricity (MWh)[b]	(1,019)	64,940	63,921	$116.15	$7,424,386
Carbon Avoided (ton)	(642)	11,520	10,878	$129.73	$1,411,208
Net Savings ($):	-	-	-	-	**$8,453,930**

Estimates that represent an increase in energy use, carbon emissions, and costs are represented by the red colored values in parentheses. Energy and carbon savings are calculated based on the prices of $116.15 per MWh, $17.30 per MBtu, and $129.73 per ton carbon.

a Million British thermal units
b Megawatt-hours

Air Pollution Removal

Airborne pollutants are a concern as they can harm both living components (e.g., human health) and non-living (e.g., built infrastructure) components, alter ecosystem processes, and reduce visibility. Some of the most toxic pollutants include carbon monoxide (CO), nitrogen dioxide (NO_2), ground-level ozone (O_3), fine particulate matter ($PM_{2.5}$), and sulfur dioxide (SO_2). Carbon monoxide is a gas that is released into the atmosphere through the burning of fossil fuels, including activities such as driving. Nitrogen dioxide is a respiratory irritant which reacts with other volatile organic compounds in sunlight to form ground-level ozone (O_3 or smog), which can also cause respiratory problems. Fine particulate matter under 2.5 micrometers in size ($PM_{2.5}$) describes inhalable particles that can penetrate the lungs and create respiratory issues. Finally, sulfur dioxide is a compound that can harm the respiratory system and react to form other sulfur oxides, acid rain, and components of particulate matter.

Table 19. Average annual tonnage and associated dollar values for pollutants removed by trees and shrubs in 2016.

Pollutant	Removal (US short ton)	Value ($)*
CO	12	$17,648
NO_2	51	$24,327
O_3	683	$2,253,552
$PM_{2.5}$	16	$2,261,329
SO_2	46	$7,360
Total:	808	$4,564,216

* Pollutant prices are based on the figures $1,469 per ton (carbon monoxide), $3,300 per ton (ozone), $479 per ton (nitrogen dioxide), $158 per ton (sulfur dioxide), and $140,170 per ton (particulate matter less than 2.5 microns).

Trees in the urban forest can help combat these airborne pollutants by removing pollutants directly through uptake or deposition (Chen et al. 2017) and indirectly reducing pollutant emissions from power sources by decreasing energy consumption (Simpson 2002). Additionally, the rate of ground-level ozone formation increases with rising temperatures, therefore trees can reduce the rate of ozone creation by helping lower urban temperatures (Livesley et al. 2016; Nowak & Dwyer 2007). Trees regularly uptake gaseous pollutants such as carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide through specialized openings on their leaves called stomata. Particles that cannot be taken up by stomata can still get caught on leaf surfaces and thereby removed from the air (Grantz et al. 2003).

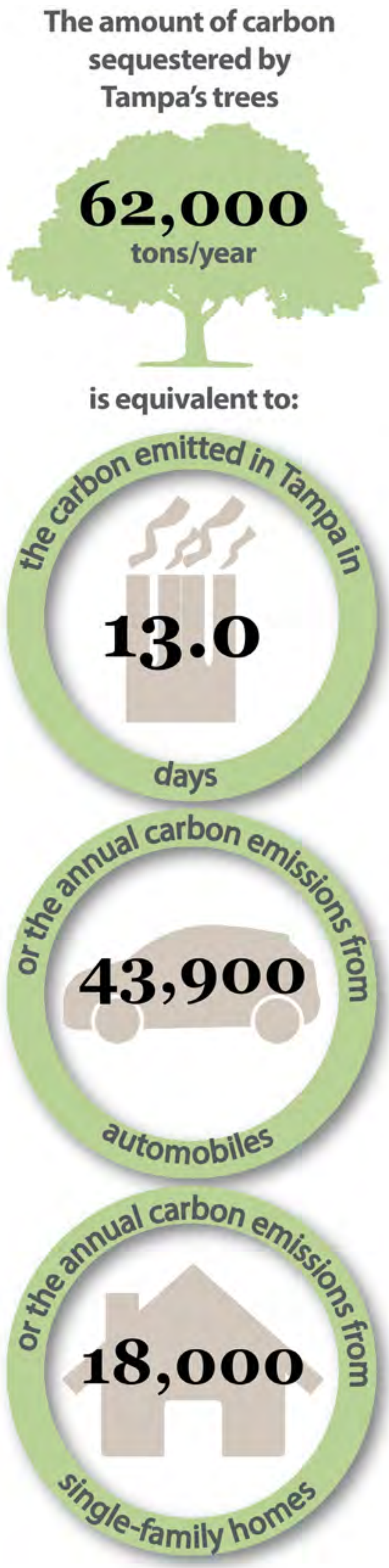
In 2016, the trees and shrubs of Tampa's urban forest removed a total of 808 tons of pollutants from the atmosphere at an estimated value of $4.5 million (Table 19). The i-Tree Eco model calculates the amount of pollution eliminated based on local incidence of adverse health effects and national median externality costs using the 2013 Environmental Protection Agency (EPA) air pollution and weather monitors in Tampa. Value estimates for CO are based on the median externality value and producer price index following guidelines by Murray et al. (1994). The number of adverse health effects and associated value estimates for NO_2, O_3, $PM_{2.5}$ and SO_2 were calculated using US EPA's Environmental Benefits Mapping and Analysis Program (BenMAP) (US EPA 2015).

The BenMAP model used by i-Tree Eco estimates the reduction in health impacts and associated economic benefits, including potential savings in health care costs that result from fewer pollutants in the City's atmosphere. The estimated reduction in airborne pollutants caused by Tampa's trees and shrubs results in approximately $4.5 million in savings in health care costs (Table 20).

Table 20. Estimated annual economic benefits of reduced health impacts from airborne pollutant reduction by trees and shrubs in 2016.

	Value ($/Year)			
	NO_2	O_3	$PM_{2.5}$	SO_2
Tree	$18,026	$1,657,312	$1,745,806	$5,372
Shrub	$6,301	$596,240	$515,523	$1,988
Subtotal	**$24,327**	**$2,253,552**	**$2,261,329**	**$7,360**
Total		**$4,539,208**		

"Value" is the economic value is associated with the incidence of adverse health effects.



Carbon Sequestration and Storage

Carbon dioxide (CO_2) is a major greenhouse gas and contributor to global climate change. Urban trees help mitigate climate change indirectly by reducing energy consumption and associated emissions from fossil-fuel burning energy plants and directly by removing and using atmospheric carbon (Abdollahi et al. 2000; Nowak & Crane 2002). Trees process carbon dioxide during photosynthesis and incorporate it into their tissue, thereby sequestering or holding the carbon until the tree dies. Since carbon is incorporated into new tissue, vigorous, healthy trees often sequester carbon at higher rates than unhealthy ones. Sequestration rates also vary by tree species and size. Using wood from deceased trees for energy production or recycling it into long-term use items can also help decrease carbon emissions from tree decomposition.

Gross carbon sequestration is the total amount of carbon sequestered (i.e., removed) by trees, whereas net carbon sequestration is the amount of carbon sequestered minus the amount that is released back into the atmosphere once the tree dies. The annual gross carbon sequestration of Tampa's urban trees in 2016 was about 62,000 tons with an associated value of $8.04 million. Net carbon sequestration in the urban forest was approximately 58,200 tons with an associated value of $7.56 million, indicating that Tampa's urban forest is a carbon "sink" which removes more atmospheric carbon than it releases. Gross carbon sequestration varies by species with laurel oak as the top species (11,346 tons), followed by cypress (9,829 tons) and live oak (9,220) (Figure 48).

Tampa's urban trees stored approximately 865,715 tons of carbon at a value of $112.31 million. Laurel oak stores and sequesters the most carbon (approximately 28.4% of the total carbon stored and 18.3% of all sequestered carbon.) (Figures 48 and 49). Residential Single-Family areas have the greatest amount of storage with 357,341 tons of carbon stored (41.3% of the total). These were followed by Natural and Conservation Lands (142,015 tons and 16.4% of total stored) (Table 21). Public Communications Utility, Agricultural, and Water land use areas store the least amount of carbon. The sequestered carbon is stored in the tree's tissue until the tree dies and decomposes, so keeping trees healthy and alive slows the release of carbon.

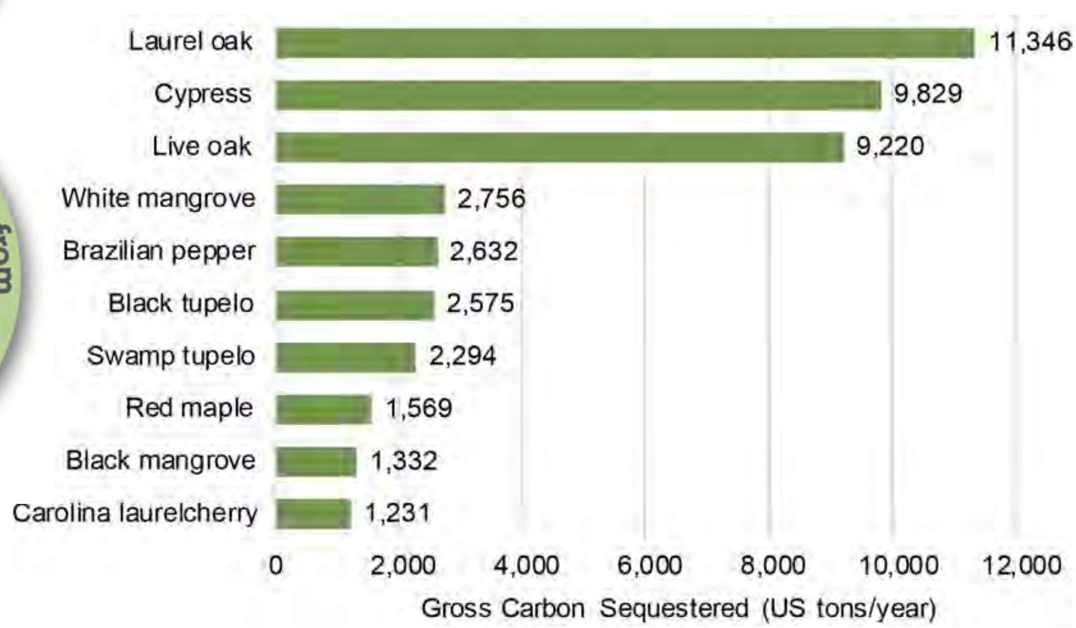


Figure 48. The 10 species in Tampa's urban forest which sequestered the most carbon in 2016.

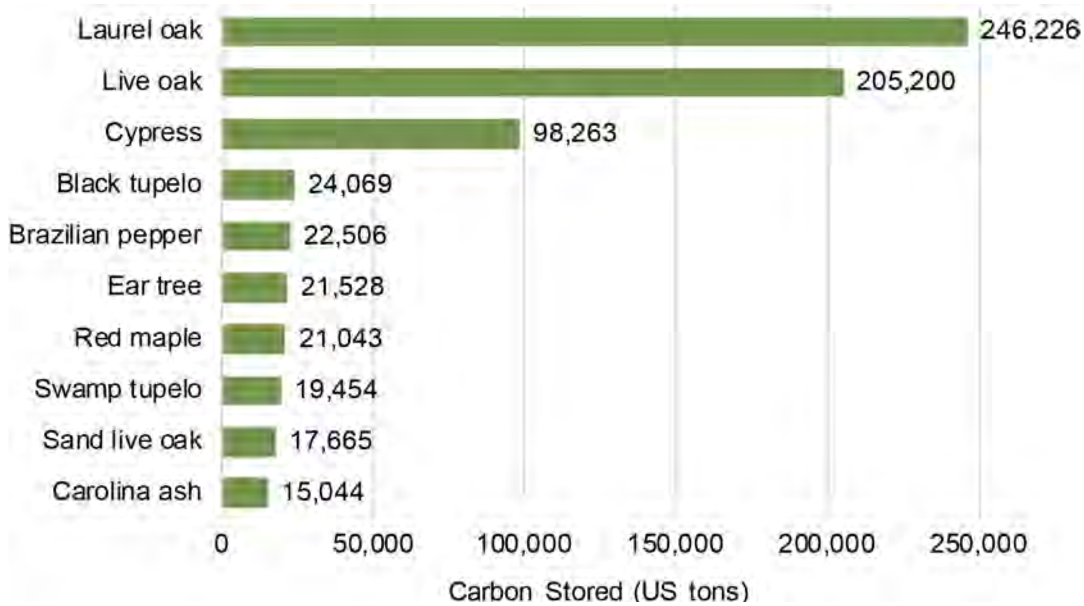


Figure 49. The 10 species in Tampa's urban forest which stored the most carbon as of 2016.

Table 21. Carbon storage of trees by land use and percent acreage.

Carbon storage (%) is the percentage of citywide carbon storage within that land use, and percent of city (%) is the percent of land area represented by that land use.

Note: Agricultural category is represented by only one sample plot.

Land Use	Carbon Storage (tons)	Carbon Storage (%)	Percent of City (%)
Residential Single-Family	357,342	41.3 %	27.6%
Natural / Conservation Lands	142,015	16.4 %	6.2%
Commercial	94,828	11.0 %	9.2%
Right-of-Way / Transportation	83,404	9.6 %	17.3%
Private Institutional	54,092	6.2 %	3.1%
Residential Multi-Family	52,374	6.0 %	4.5%
Industrial	28,376	3.3 %	3.9%
Parks / Recreation	26,841	3.1 %	3.4%
Mangrove	16,334	1.9 %	1.6%
Public Institutional	9,836	1.1 %	17.3%
Public Communications Utility	274	0.0 %	0.5%
Agricultural	-	0.0 %	2.2%
Water	-	0.0 %	3.2%
Total	**865,714**	**100 %**	**100.0%**

Avoided Runoff

When precipitation falls onto the land some of it is intercepted by trees and other vegetation, another portion of it infiltrates ground, and the rest becomes surface runoff. In urban environments impervious surfaces like paved roads and parking lots prevent infiltration, thus increasing surface runoff. Some of this runoff flows towards the nearest body of water, picking up pollutants along the way. Urban trees can help mitigate the negative effects of excessive and polluted surface runoff by catching precipitation before it hits the ground (Livesley et al. 2014; Inkiläinen et al. 2013; Xiao and McPherson 2011). Additionally, tree roots can help encourage infiltration into urban soils that are often hard to penetrate (Bartens et al. 2008).

The i-Tree Eco model estimates avoided surface runoff as the difference between annual runoff with and without vegetation based on the rainfall intercepted by vegetation. The model also takes into account estimated number of trees and their associated leaf area and local weather data. In 2016 Tampa's urban forest (trees and shrubs) reduced the amount of runoff by 65.8 million cubic feet with an associated value of $4.4 million, and trees alone reduced runoff by 50.3 million cubic feet at a value of $3.4 million. Live oak, laurel oak, cabbage palm, and cypress trees contributed to the most runoff avoided for a combined amount of 24.2 million cubic feet per year (nearly 50% of the total runoff avoided by trees) at a value of $1.6 million (Table 22). These species also make up nearly 50% of the total leaf area. The land use category where the most runoff was avoided by trees was Residential Single-Family, which accounted for approximately 43% of the total runoff avoided at a value of $1.45 million (Table 23).

Table 22. Amount of avoided runoff and water intercepted by 10 tree species in 2016.

Species Name	Water Intercepted (ft^3/yr)	Avoided Runoff (ft^3/yr)*	Avoided Runoff Value ($/yr)
Live oak	35,195,562	7,094,052	$474,208
Laurel oak	31,776,172	6,404,836	$428,137
Cabbage palm	27,817,951	5,607,013	$374,806
Cypress	25,105,885	5,060,367	$338,264
Queen Palm	10,192,614	2,054,433	$137,330
Swamp tupelo	7,510,039	1,513,731	$101,187
Brazilian pepper	7,300,804	1,471,557	$98,367
Areca palm	7,235,508	1,458,396	$97,488
Longleaf pine	6,871,144	1,384,955	$92,578
Carolina laurelcherry	5,581,628	1,125,038	$75,204

*Avoided runoff value is calculated by the price $0.067/$ft^3$ and the user-designated weather station report of 55.8 inches of total annual precipitation.

Table 23. Avoided runoff and water intercepted by trees within each land use (excluding the Water category) in 2016. *Note: Agricultural category is represented by only one sample plot.*

Land Use	Water Intercepted (ft^3/yr)	Avoided Runoff (ft^3/yr)*	Avoided Runoff Value ($/yr)
Residential Single-Family	107,751,360	21,718,469	$ 1,451,789
Natural / Conservation Lands	38,724,178	7,805,283	521,751
Right-of-Way / Transportation	26,183,085	5,277,488	352,778
Commercial	22,978,930	4,631,656	309,607
Parks / Recreation	11,686,900	2,355,623	157,464
Residential Multi-Family	11,439,061	2,305,668	154,124
Private Institutional	11,149,276	2,247,259	150,220
Public Institutional	7,512,382	1,514,203	101,218
Industrial	6,491,605	1,308,454	87,465
Mangrove	5,646,259	1,138,065	76,075
Public Communications Utility	224,568	45,264	3,026
Agricultural	-	-	-
Study Area	249,787,604	50,347,432	$ 3,365,517

*Avoided runoff value is calculated by the price $0.067/$ft^3$ and the user-designated weather station report of 55.8 inches of total annual precipitation.

Appendices

Appendix A: Ecological Assessment Species Level Results

Table 24. List of all tree species found in Tampa's urban forest.
For each species percentage of tree population, percentage of all leaf area, importance value, and native/invasive status is given.

[a] Percent of the leaf area of all trees in Tampa

[b] Importance Value (IV) = percent of the entire Tampa tree population + percent of leaf area

[c] Native, exotic (non-native), and invasive status (FLEPPC 2017) of tree species

[d] Wind resistance is based on research suggesting tree species resistance to wind damage (Duryea et al. 2007).

Common Name	Scientific Name	% Population	% Leaf Area[a]	IV[b]	N, E, I[c]	Wind Resistance[d]
Alexander palm	*Ptychosperma elegans*	0.1	0.1	0.2	E, I	H
American elm	*Ulmus americana*	0.9	1.5	2.4	N	ML
American elderberry	*Sambucus nigra* subsp. *canadensis*	0.0	0.0	0.1	N	UNK
American holly	*Ilex opaca*	0.2	0.1	0.3	N	H
American sycamore	*Platanus occidentalis*	0.1	0.8	0.9	N	ML
Apamate	*Tabebuia rosea*	0.0	0.0	0.0	E	ML
Areca palm	*Dypsis lutescens*	0.4	2.9	3.3	E	H
Avocado	*Persea americana*	0.0	0.0	0.1	E	ML
Benjamin fig	*Ficus benjamina*	0.3	0.2	0.6	E	L
Bird of paradise tree	*Strelitzia nicolai*	0.0	0.2	0.2	E	UNK
Black cherry	*Prunus serotina*	0.1	0.3	0.4	N	ML
Black mangrove	*Avicennia germinans*	6.3	0.9	7.1	N	H
Black tupelo	*Nyssa sylvatica*	2.0	1.5	3.5	N	MH
Boxelder	*Acer negundo*	0.0	0.1	0.1	N	ML
Brazilian pepper	*Schinus terebinthifolius*	8.3	2.9	11.2	E, I	UNK
Buttonbush	*Cephalanthus occidentalis*	2.3	0.2	2.6	N	UNK
Button mangrove	*Conocarpus erectus*	0.0	0.1	0.1	N	H
Cabbage palm	*Sabal palmetto*	4.6	11.1	15.8	N	H
Camellia	*Camellia japonica*	0.0	0.0	0.1	E	UNK
Camphor tree	*Cinnamomum camphora*	0.2	0.5	0.7	E, I	ML
Canary island date palm	*Phoenix canariensis*	0.0	0.3	0.3	E	H
Carolina ash	*Fraxinus caroliniana*	1.5	1.7	3.2	N	MH
Carolina laurelcherry	*Prunus caroliniana*	1.3	2.2	3.6	N	L
Carrotwood	*Cupaniopsis anacardioides*	0.3	0.2	0.5	E, I	UNK
Chapman oak	*Quercus chapmanii*	0.1	0.1	0.2	N	UNK
Chinaberry	*Melia azedarach*	0.1	0.7	0.8	E, I	UNK
Chinese elm	*Ulmus parvifolia*	0.2	0.4	0.6	E	L
Christmas palm	*Veitchia merrillii*	0.0	0.0	0.0	E	UNK
Citrus spp.	*Citrus spp.*	0.3	0.1	0.4	E	ML
Common crapemyrtle	*Lagerstroemia indica*	0.6	0.6	1.2	E	H
Common fig	*Ficus carica*	0.0	0.0	0.0	E	L
Common persimmon	*Diospyros virginiana*	0.2	0.0	0.3	N	MH
Costalplain willow	*Salix caroliniana*	1.8	0.4	2.3	N	ML
Cypress	*Taxodium* spp.	11.3	10.1	21.4	N	H

Table 21, continued: List of all tree species found in Tampa's urban forest.

Common Name	Scientific Name	% Population	% Leaf Area[a]	IV[b]	N, E, I[c]	Wind Resistance[d]
Dahoon	*Ilex cassine*	2.1	1.3	3.4	N	H
Earpod tree	*Enterolobium contortisiliquum*	0.0	1.0	1.0	E	ML
Eastern red cedar	*Juniperus virginiana*	0.2	0.8	1.0	N	L
Eastern redbud	*Cercis canadensis*	0.1	0.1	0.2	N	MH
Edible banana	*Musa acuminata*	0.0	0.1	0.2	E	UNK
Fetterbush	*Lyonia lucida*	0.5	0.0	0.5	N	UNK
Florida royalpalm	*Roystonea regia*	0.1	0.6	0.7	N	MH
Florida strangler fig	*Ficus aurea*	0.1	0.4	0.5	N	ML
Florida swampprivet	*Forestiera segregata*	0.0	0.0	0.0	N	UNK
Frangipani	*Plumeria rubra*	0.0	0.0	0.0	E	UNK
Glossy privet	*Ligustrum lucidum*	0.1	0.0	0.1	E, I	UNK
Goldenrain tree	*Koelreuteria paniculata*	0.1	0.1	0.2	E	UNK
Grapefruit	*Citrus* x *aurantium*	0.1	0.0	0.1	E	ML
Green ash	*Fraxinus pennsylvanica*	0.1	0.1	0.2	N	ML
Guiana chestnut	*Pachira aquatica*	0.0	0.0	0.0	E	UNK
Horseradishtree	*Moringa oleifera*	0.0	0.0	0.1	E	UNK
Inkberry	*Ilex glabra*	0.1	0.0	0.1	N	H
Japanese ligustrum	*Ligustrum japonicum*	0.9	0.8	1.7	E	UNK
Jerusalem thorn	*Parkinsonia aculeata*	0.1	0.0	0.1	E	UNK
Laurel oak	*Quercus laurifolia*	6.3	12.7	19.0	N	L
Lemon	*Citrus* x *limon*	0.0	0.0	0.1	E	ML
Live oak	*Quercus virginiana*	2.5	14.1	16.6	N	H
Longleaf pine	*Pinus palustris*	1.7	2.8	4.5	N	ML
Loquat tree	*Eriobotrya japonica*	0.3	0.0	0.3	E	ML
Mango	*Mangifera indica*	0.1	0.6	0.7	E	ML
Mazapan	*Malvaviscus penduliflorus*	0.0	0.0	0.0	E	UNK
Mexican fan palm	*Washingtonia robusta*	0.3	0.3	0.6	E, I	L
Mountain ebony	*Bauhinia variegata*	0.0	0.1	0.1	E, I	ML
Norfolk island pine	*Araucaria heterophylla*	0.0	1.0	1.0	E	L
Northern white cedar	*Thuja occidentalis*	0.0	0.1	0.1	E	UNK
Orange	*Citrus* x *aurantium*	0.2	0.0	0.2	E	ML
Other		0.1	0.0	0.1		UNK
Paper mulberry	*Broussonetia papyrifera*	0.1	0.3	0.4	E, I	UNK
Parsley hawthorn	*Crataegus marshallii*	0.1	0.0	0.1	N	UNK
Pear spp	*Pyrus* spp.	0.0	0.1	0.1	E	L
Pecan	*Carya illnoinensis*	0.0	0.1	0.1	E	L
Pink trumpet tree	*Tabebuia impetiginosa*	0.0	0.0	0.1	E	ML
Plumeria spp.	*Plumeria* spp.	0.2	0.0	0.3	E	UNK
Pygmy date palm	*Phoenix roebelenii*	0.3	0.3	0.6	E	H
Queen palm	*Syagrus romanzoffiana*	0.8	4.1	4.9	E, I	L
Red mangrove	*Rhizophora mangle*	1.4	0.3	1.7	N	H
Red maple	*Acer rubrum*	1.6	1.6	3.2	N	ML
Redbay	*Persea borbonia*	0.2	0.0	0.2	N	ML
Rubber plant	*Ficus elastica*	0.0	0.0	0.1	E	ML
Rusty staggerbush	*Lyonia ferruginea*	0.2	0.0	0.2	N	UNK

Table 21, continued: List of all tree species found in Tampa's urban forest.

Common Name	Scientific Name	% Population	% Leaf Area[a]	IV[b]	N, E, I[c]	Wind Resistance[d]
Sago palm	*Cycas revoluta*	0.0	0.0	0.1	E	UNK
Saltbush	*Baccharis halimifolia*	0.4	0.1	0.4	N	UNK
Sand live oak	*Quercus geminata*	0.2	0.9	1.0	N	H
Sand pine	*Pinus clausa*	0.1	0.2	0.3	N	L
Schefflera	*Schefflera actinophylla*	0.1	0.0	0.1	E, I	UNK
Sea grape	*Coccoloba uvifera*	0.3	0.8	1.1	N	MH
Sea hibiscus	*Hibiscus tiliaceum*	0.0	0.0	0.1	E, I	UNK
Senegal date palm	*Phoenix reclinata*	0.1	1.0	1.1	E, I	H
Shining sumac	*Rhus copallinum*	0.1	0.0	0.2	N	UNK
Slash pine	*Pinus elliottii*	0.5	1.0	1.5	N	ML
Small-leaf arrowwood	*Viburnum obovatum*	0.1	0.0	0.1	N	UNK
Sour orange	*Citrus* x *aurantium*	0.0	0.0	0.0	E	ML
Southern magnolia	*Magnolia grandiflora*	0.1	0.5	0.6	N	H
Sparkleberry	*Vaccinium arboreum*	0.1	0.0	0.1	N	H
Stiff dogwood	*Cornus foemina*	0.3	0.2	0.5	N	H
Strawberry guava	*Psidium cattleianum*	0.0	0.0	0.1	E, I	UNK
Surinam cherry	*Eugenia uniflora*	0.0	0.0	0.0	E, I	H
Swamp bay	*Persea palustris*	1.8	0.2	2.0	N	ML
Swamp tupelo	*Nyssa sylvatica* var. *biflora*	2.5	3.0	5.5	N	MH
Sweet viburnum	*Viburnum odoratissimum*	0.6	0.1	0.7	E	UNK
Sweetbay	*Magnolia virginiana*	0.3	0.3	0.6	N	MH
Sweetgum	*Liquidambar styraciflua*	1.5	0.7	2.1	N	MH
Traveler's tree	*Ravenala madagascariensis*	0.2	0.1	0.3	E	UNK
Turkey oak	*Quercus laevis*	0.0	0.2	0.2	N	H
Water oak	*Quercus nigra*	1.3	1.1	2.3	N	L
Wax myrtle	*Morella cerifera*	5.3	0.9	6.2	N	ML
Weeping bottlebrush	*Melaleuca viminalis*	0.1	0.9	1.0	E, I	UNK
White lead tree	*Leucaena leucocephala*	1.5	1.9	3.4	E, I	UNK
White mangrove	*Laguncularia racemosa*	16.9	1.5	18.4	N	H
Winged elm	*Ulmus alata*	0.0	0.0	0.0	N	MH
Woman's tongue	*Albizia lebbeck*	0.1	0.0	0.1	E, I	UNK
Yew podocarpus	*Podocarpus macrophyllus*	0.2	0.1	0.3	E	H
Yucca	*Yucca* spp.	0.1	0.0	0.1	N	UNK

Appendix B: Hedonic Pricing Analysis Statistical Models

The Hedonic Pricing Analysis was used to estimate the marginal increase in the sales price of single-family homes associated with the percentage of tree canopy located on the property and/or the percentage of tree canopy in the neighborhood surrounding the property. The analysis was led by Geoffrey Donovan, PhD (U.S. Forest Service) and Shawn Landry, PhD (Univ. South Florida), following the published methods of Donovan and Butry (2010)[2].

Property and house data was obtained from the Hillsborough County Property Appraisers Office (HCPA) on June 2, 2016. In order to correspond to the time period of the 2016 tree canopy cover assessment data, only single-family parcels that sold between May 2015 and May 2016 were included. New construction was excluded by eliminating parcels built in 2015 or later. A total of 4,848 parcels were included in the analysis. Housing and property attributes where provided by the HCPA's Computer-Assisted Mass Appraisal (CAMA) database and include the range of variables that impact the value of a house. Variables included in the final statistical models are shown in Table 25. Excluded from the models were the variables that were not significant, including location in flood zone.

The tree canopy mapping included in this 2016 Tampa Tree Canopy Study and Urban Forest Analysis was used to develop two separate tree canopy variables: canopy cover of trees originating on the individual property, and canopy cover in the neighborhood. Canopy cover for trees in the neighborhood was based on the tree canopy within a 500-foot radius surrounding the property of the home. The total area of this 500-foot radius is 785,398 square feet or 18 acres. Based on a count of homes in single-family neighborhoods, there is an average of 60 homes within each 500-foot radius neighborhood.

In addition to estimating the value associated with percent tree canopy, it is also possible to estimate the value of an average-sized tree. Based on the 785,398 square feet total area of the 500-foot radius neighborhood, a one percent increase in tree canopy within this neighborhood is equal to 7,854 square feet (1% * 785,398 ft2). Results from field sampling data (described in this report) for single-family residential parcels indicate that the average canopy area for all trees greater than 8 feet tall is 1,167 ft^2, and the average canopy area for a mature live or laurel oak is 1,718 ft^2. Therefore, the value of a 1% increase in tree canopy within the 500-foot neighborhood is the same as adding 6.7 average trees (7,854/1,167) or 4.6 mature oaks trees (7,854/1,718).

The hedonic pricing statistical methods used several types of regression models, including advanced methods to address potential problems caused by geographic data that can invalidate normal regression analysis. For example, when analyzing spatial phenomena it is important to address the issue of spatial autocorrelation: the sales price of a house is influenced by the sales price of neighboring houses. The results of an initial ordinary least squares regression model (not shown) indicate that there was spatial autocorrelation between sales prices of nearby homes. To address this issue, we estimated four hedonic models that address the spatial autocorrelation: 1) A linear mixed model that included a random effect for a house's neighborhood (MIXED); 4) A spatial error model that allowed for spatial correlation among error terms (ERROR); 3) A spatial lag model that allowed for spatial correlation among sales prices (LAG); and 4) A joint lag and error model that allowed for spatial correlation among both sales prices and error terms (LAG AND ERROR).

Spatial models use a spatial-weights matrix that defines the spatial covariance structure of the model. Specifically, the weights matrix defines the spatial extent of any spatial correlation and how this spatial correlation diminishes as the distance between two houses increases. We used a semivariogram of residuals from the ordinary least squares model to define the spatial weights matrix: the sales price of homes greater than @2.5 miles (4,000 meters) apart are spatially independent, and spatial correlation declines with the inverse distance between houses.

Model results are presented in Table 25. The dependent variable for all models is the natural log of sales price (transformed for statistical reasons). The model results explained over 90% of the variation in home sales prices (i.e., R-squared > 0.9). Dummy variables for architecture style indicate the marginal increase or decrease in sales price for styles other than a basic one-story home. For example, there is a fairly large increase in sales prices associated with the updated pre-1940 style (e.g., bungalows). Not surprisingly, the AC Type dummy variables show a large decrease in sales price for homes lacking central air conditioning. Individual dummy variables for Roof Type are too numerous to show in the table, but statistically significant coefficients range from 0.292 to 0.398 compared to an asbestos roof. Similarly, dummy variables for Neighborhood are not shown but statistically significant coefficients range from -1.535 to 1.051 (i.e., a fairly large effect) compared to the arbitrarily chosen Port Tampa neighborhood.

Tree canopy on the property was not significantly correlated with the sales price of the single-family homes in this analysis, and thus not shown in the model results. Tree canopy in the neighborhood was significantly correlated with sales price, and the similarity of the coefficient in all models (0.0936 to 0.0993) further boosts our confidence in the results of this analysis. After applying a reverse transformation to the natural log sales price that was used as a dependent variable, the model results indicate that a 1% increase in tree canopy in the 500-foot neighborhood adds $155 to $164 to the sales price of each and every home in the neighborhood.

2 Donovan, G. H., & Butry, D. T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning*, 94(2), 77-83.

Table 25. Hedonic Model Results. Dependent variable was the natural log of sales price.
*Significance level of coefficients indicated as * p>0.95, ** p>0.99 and *** p>0.999.*

	MIXED	*ERROR*	*LAG*	*LAG AND ERROR*
VARIABLES	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Number of Bedrooms	0.0492***	0.0541***	0.0540***	0.0523***
Number of Bathrooms	0.0616***	0.0569***	0.0584***	0.0587***
Heated Area (sq. ft)	0.000291***	0.000282***	0.000277***	0.000275***
Number of Stories	-0.0627*	-0.0657**	-0.0622*	-0.0616*
Property Acreage	0.420***	0.440***	0.440***	0.444***
Year Built (Actual)	0.00647***	0.00674***	0.00671***	0.00671***
Garage (0=No/1=Yes)	0.150***	0.143***	0.140***	0.142***
Carport (0=No/1=Yes)	0.0659***	0.0624***	0.0615***	0.0632***
Open Front Porch (0=No/1=Yes)	0.0681***	0.0659***	0.0643***	0.0638***
Pool (0=No/1=Yes)	0.0933***	0.0892***	0.0867***	0.0873***
Waterfront Property (0=No/1=Yes)	0.422***	0.438***	0.446***	0.447***
Tree Canopy in Neighborhood (%)	**0.0936***	**0.0965****	**0.0962****	**0.0993****
ARCHITECTURE STYLE (Omitted: basic 1 story)				
Basic Multi-Story	-0.0156	-0.0048	-0.00925	-0.00788
Contemporary 1-Story	0.00936	0.00419	0.0059	0.0114
Contemporary Multi-Story	-0.0708	-0.0732	-0.0812*	-0.0769
Mansion	-1.478***	-1.406***	-1.402***	-1.382***
Pre-1940 1-Story	0.0928**	0.0985***	0.0919**	0.0930**
Pre-1940 Multi-Story	0.279***	0.279***	0.269***	0.276***
Unique Design	-0.514	-0.528	-0.503	-0.512
Updated Basic 1-Story	0.216***	0.215***	0.212***	0.213***
Updated Basic Multi-Story	0.182**	0.176**	0.169**	0.170**
Updated Contemporary 1-Story	0.300**	0.298**	0.284**	0.274**
Updated Contemporary Multi-Story	0.044	0.0332	0.0391	0.0557
Updated Pre-1940 1-Story	0.532***	0.539***	0.526***	0.531***
Updated Pre-1940 Multi-Story	0.661***	0.667***	0.660***	0.668***
Updated Unique Design	0.326	0.33	0.313	0.318
AC TYPE (Omitted: central)				
Non-ducted (i.e., window)	-0.282***	-0.267***	-0.266***	-0.267***
No AC	-0.628***	-0.629***	-0.623***	-0.626***
ROOF TYPE Dummy Variables	a	a	a	a
NEIGHBORHOOD Dummy Variables		b	b	b
SPATIAL REGRESSION VARIABLES				
lambda		-1.812***		-0.730**
rho			0.448***	0.504***

[a] Statistically significant coefficients for Roof Type dummy variables range from 0.292 to 0.398 compared to an asbestos roof.

[b] Statistically significant coefficients for Neighborhood dummy variables range from -1.535 to 1.051 compared to the arbitrarily chosen Port Tampa neighborhood.

Appendix C: Potential and Current Pest Impacts

Insect and disease infestations pose a threat to urban tree survival and health and the associated value of the entire urban forest. Potential pest risks differ between cities depending on the tree hosts, climate, and other factors. The i-Tree Eco model calculates potential pest impact by examining 36 significant pests and the pest range maps (Forest Health Technology Enterprise Team 2014) for the contiguous United States to determine pest proximity to Hillsborough County. Based on this and the specific host trees present in the research area, fifteen pest species showed up as potential threats. Four of these fifteen pests are listed as being present in Hillsborough County, five are within 750 miles of the county, and six are over 750 miles from the county. Below is a description of the four pests present in the county and their potential impacts on Tampa's urban forest (Figure 50), as well as a table showing all fifteen of the pests and their potential impacts (Table 26).

Dutch elm disease (DED)

Dutch elm disease (DED) is a fungal pathogen that has decimated the native elm population in the United States since its reported appearance in the 1930s, resulting in a substantial loss of street trees across the country (Northeastern Area State and Private Forestry 1998). Other elm species (*Ulmus* spp.) such as winged elm (*U. alata*) are susceptible, although the level of susceptibility differs between individual trees. Based on i-Tree estimates, Tampa could potentially lose 0.9 percent of its trees to DED, worth $18 million in structural value.

Fusiform rust (FR)

Fusiform rust (FR) is a fungal disease in the southern United States that affects most Florida pine species (*Pinus* spp.) but is especially damaging to slash pine (*P. elliottii*) and loblolly pine (*P. taeda*). It does not transfer directly from pine to pine, but instead must undergo a lifecycle stage on nearby oak leaves before moving to the next pine (Powers et al. 1981). It could potentially impact 0.5 percent of Tampa's trees at a loss of $21.4 million in structural value.

Laurel wilt (LWD)

Laurel wilt (LWD) is caused by the fungus (*Raffaelea lauricola*) and is spread by the redbay ambrosia beetle (*Xyleborus glabratus*). It affects trees in the laurel family (Lauraceae), including camphor (*Cinnamomum camphora*), swamp bay (*Persea palustris*), red bay (*Persea borbonia*), and avocado (*Persea americana*). Based on i-Tree Eco estimations, this pest threatens 2.2 percent of Tampa's tree population, which represents a potential loss of $16.5 million in structural value.

Southern pine beetle (SPB)

The southern pine beetle (SPB) attacks most pine species, but loblolly (*P. taeda*), pond (*P. serotina*), spruce (*P. glabra*), and sand pines (*P. clausa*) are especially susceptible (Clarke & Nowak 2009). This pest threatens 2.3 percent of Tampa's tree population, amounting to a loss of $59 million in structural value.

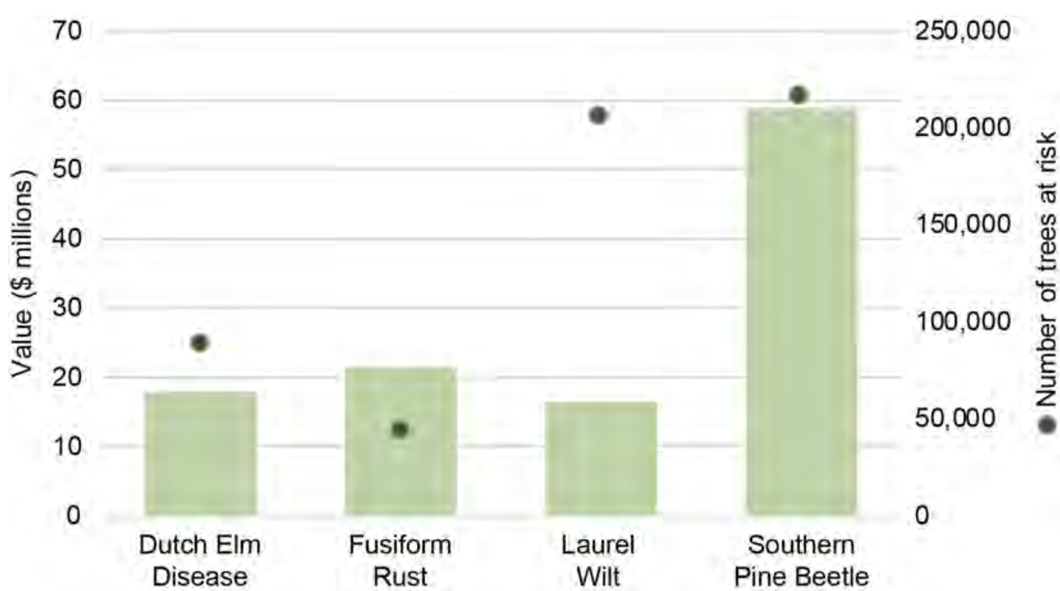


Figure 50. Number of trees at risk (points) and associated structural value (bars) for most threatening pests in Hillsborough County.

The i-Tree Eco model (v6) does not currently report any information on pest or diseases affecting palms. While palms only represent 7% of the total tree population, they provide numerous ecosystem services and contribute an estimated $186 million in structural value to the urban forest. Some known disease and pest issues of palms currently found in Tampa were added to the i-Tree generated potential pest list. The addition of palm diseases allows for a more thorough understanding of pest and disease impacts to Tampa's urban forest.

Fusarium wilt (FW)

Fusarium wilt is caused by the fungus *Fusarium oxysporum*. This fungal diseases creates vascular wilt in palms by obstructing the xylem (water-conducting) tissue, resulting in leaf desiccation and eventual tree death (Elliot 2017; Elliot 2016). Two different FW diseases, which have pathogen subspecies that are very host specific, currently effect palms in the Tampa area. *Fusarium oxysporum* f. sp. *canariensis* has a primary host of Canary Island date palm (*Phoenix canariensis*) while *Fusarium oxysporum* f. sp. *palmarum* is host specific to both queen palms and Mexican fan palms. Experimental data suggests other Phoenix species such as edible date palm (*Phoenix dactylifera*), Senegal date palm (*Phoenix reclinata*), and wild date palm (*Phoenix sylvestris*), may be susceptible to *Fusarium oxysporum* f. sp. *canariensis* but actual field cases are extremely rare. Currently there is no known cure for this lethal disease but disinfecting pruning tools between palms has been shown to be an effective prevention measure for spreading the disease. While the two FW diseases only threaten less than 1% of the total tree population, the host species represents $65 million in structural value to Tampa's urban forest.

Texas Phoenix palm decline (TPPD)

Texas Phoenix palm decline (TPPD) is a fatal, systemic bacterial disease caused by a phytoplasma (bacteria with no cell wall). The phytoplasma is transmitted into the phloem tissue of palms by the piercing and sucking parts of insects however the exact species of insect vectoring the TPPD is currently unknown. Preventative treatment of healthy susceptible palms is possible with antibiotic injections every three to four months.

This bacterial disease mainly affects Phoenix species such as Canary Island date palm, edible date palm, wild date palm and Senegal date palm. Cabbage palm, Florida's state tree, has also been identified as a primary host for TPPD. Texas Phoenix palm decline was first identified in the Tampa area in 2006 and was the confirmed cause of decline in cabbage palms throughout the area in 2008 (Harrison and Elliott 2016). Canary Island date palm, Senegal date palm, and cabbage palm represent 71% of all the palm species in the City of Tampa which corresponds to a structural value of $86 million.

Table 26. Potential pest risks and their associated values in Tampa's urban forest.

Code	Scientific Name	Common Name	Trees at Risk (#)*	Value ($ millions)**
AL	*Phyllocnistis populiella*	Aspen Leafminer	172,613	8.2
ALB	*Anoplophora glabripennis*	Asian Longhorned Beetle	437,340	53.3
DA	*Discula destructiva*	Dogwood Anthracnose	30,943	0.9
DED	*Ophiostoma novo-ulmi*	Dutch Elm Disease	88,566	18.1
EAB	*Agrilus planipennis*	Emerald Ash Borer	150,454	12.6
FR	*Cronartium quercuum* f. sp. *fusiforme*	Fusiform Rust	43,304	21.5
GM	*Lymantria dispar*	Gypsy Moth	1,340,608	1,031.8
LAT	*Choristoneura conflictana*	Large Aspen Tortrix	172,613	8.2
LWD	*Raffaelea lauricola*	Laurel Wilt	205,294	16.5
OW	*Ceratocystis fagacearum*	Oak Wilt	968,275	978.5
PSB	*Tomicus piniperda*	Pine Shoot Beetle	216,441	59.0
PSHB	*Euwallacea* nov. sp.	Polyphagous Shot Hole Borer	3,577	2.6
SPB	*Dendroctonus frontalis*	Southern Pine Beetle	216,441	59.0
SW	*Sirex noctilio*	Sirex Wood Wasp	216,441	59.0
WM	*Operophtera brumata*	Winter Moth	1,516,968	1,007.3
Total			**5,779,878**	**3,336.3**

* The number of trees at risk reflects only the known host species that are likely to experience mortality.

** Value is based on the structural value of susceptible trees.

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