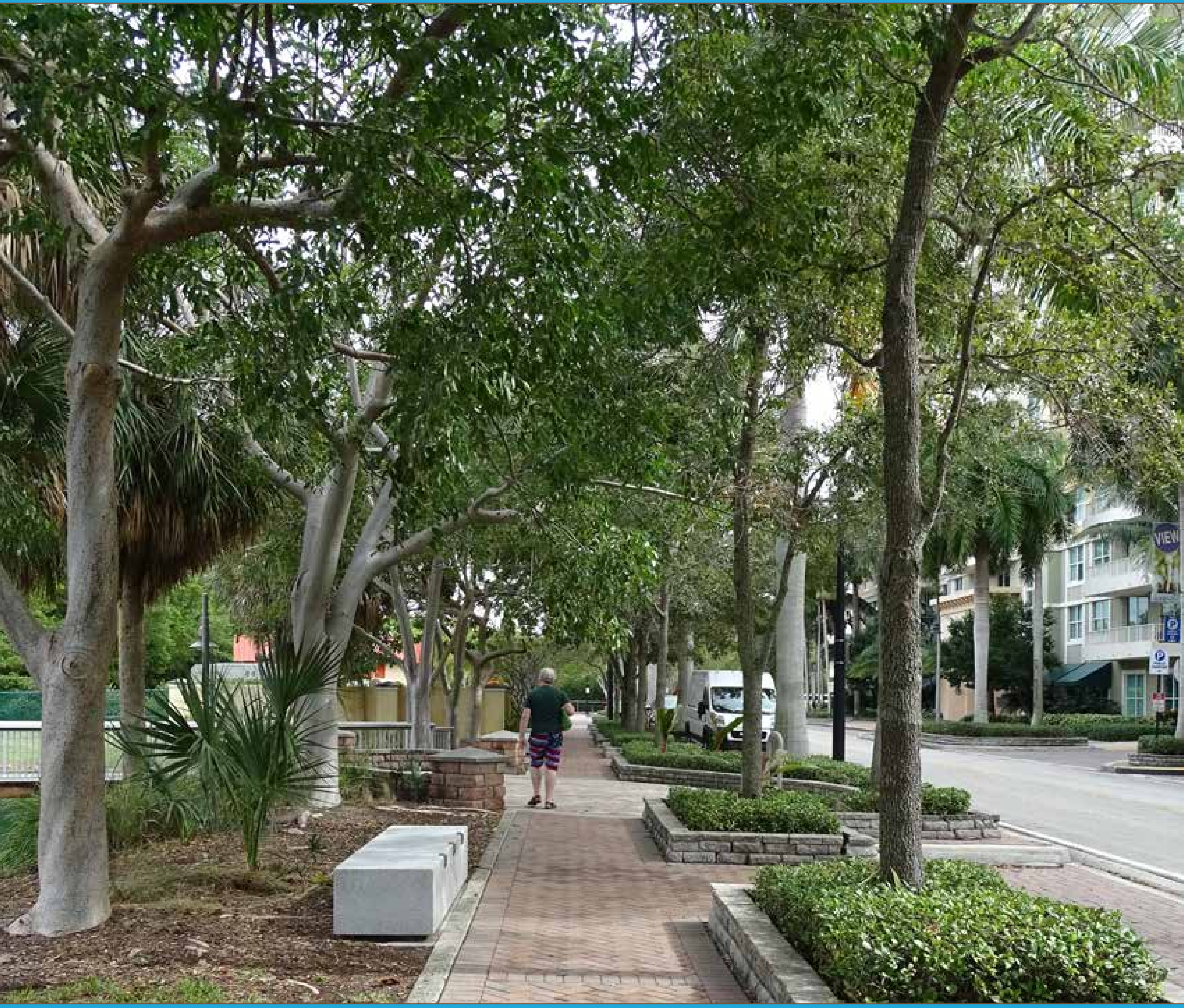
Urban Tree Canopy of Boynton Beach, FL

An Analysis of Forest Cover and Benefits



CITY OF BOYNTON BEACH

July 24, 2020

This report and analysis were funded by the City of Boynton Beach, Florida, under a contract to the Green Infrastructure Center Inc. (GIC) Additional analysis was supported by the Southern Region of the US Forest Service (USFS). The mention of trade names, commercial products, services or organizations does not imply endorsement by the City of Boynton Beach or the USFS. All images and maps were produced by the GIC unless otherwise credited.

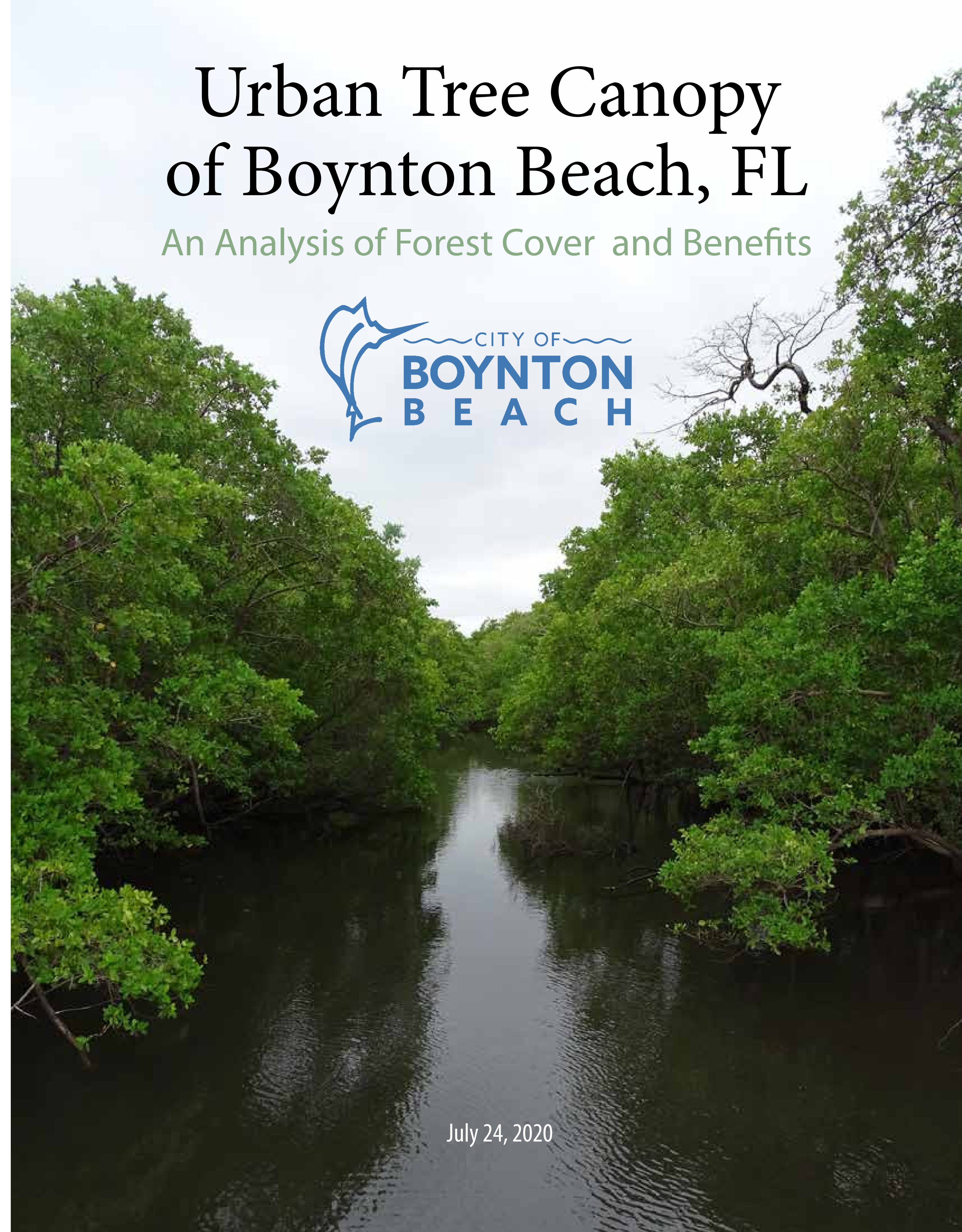
Publication Date: July 24, 2020

CITY OF BOYNTON BEACH

Urban Tree Canopy of Boynton Beach, FL

An Analysis of Forest Cover and Benefits

CITY OF BOYNTON BEACH



July 24, 2020

Table of Contents

PROJECT OVERVIEW AND EXECUTIVE SUMMARY 1
- Why Map Urban Canopy 2
- Summary Outcomes 3
- Canopy Trends and Expansion Goal 4

CANOPY ASSESSMENT 5
- Introduction 5
- How the Urban Forest Benefits Boynton Beach 6
  - Reducing Stormwater Runoff and Filtering Pollutants 6
  - Air Quality and Surface Heating 8
  - Social Values 9
  - Increasing Property Values and Sales 9

CURRENT AND POTENTIAL CANOPY AND ECOSYSTEM SERVICES MODELING 10
- Methods 10
  - Determining Plantable Acreage 11

MAPS AND FINDINGS 13
- City Land Cover and Tree Canopy 14
- Potential Planting Areas 15
- Street Tree Coverage 16
- City Park Canopy 17

CALCULATING BENEFITS TREES PROVIDE 19
- Stormwater Uptake 19
- Air Quality 23

URBAN TREE LOSS – REVERSING THE TREND 24
- A Downward Trend 24
- Increasing Canopy Cover 25
- Recommendations – Next Steps 28

APPENDIXES 30
- Appendix A: Land Cover Analysis Methods 30
- Appendix B: Trees and Stormwater Calculator 32
- Appendix C: Bibliography 34

Project Overview and Executive Summary

This tree canopy assessment was funded by the City of Boynton Beach (City), Florida. The City contracted with the nonprofit Green Infrastructure Center to evaluate the extent of the City's tree canopy and plantable areas, and to determine the environmental benefits the trees provide. The City is designated as a "Tree City USA" by the Arbor Day Foundation in recognition of its 35-year commitment to caring for its urban trees. This assessment provides data to help the City track its tree canopy and create strategies to expand it.

This assessment supports the City's vision of creating "a greener Boynton Beach by enhancing the tree canopy and native plant and wildlife communities," as articulated in the 2020 Climate Action Plan (CAP). The CAP identifies Urban Forestry (Strategy C-1.5) as a priority to reduce community-wide greenhouse gas emissions, while achieving co-benefits of public health, economic development, ecosystem protection, and climate resilience. This assessment supports CAP goals by providing data for the City's tree canopy location and opportunities to expand or conserve tree cover.

The City of Boynton Beach can use the results of this tree canopy assessment to:

- Document the environmental and social benefits the City's trees provide
- Determine the most strategic locations to either retain or plant trees for environmental benefits
- Provide baseline data to track progress toward achieving a tree canopy goal of 20% by 2035
- Provide data to inform management of the City's urban forest and to support investments in tree care and planting
- Contribute to meeting the goals and targets established by the Climate Action Plan and other City plans and programs

Photo by: Rebecca Harvey

Why Map Urban Canopy?

Trees are declining throughout the southern United States. Causes for this decline arise from multiple sources, including land conversion for development, storm damage, hurricanes, and lack of tree replacement as older trees die. Communities in Palm Beach County are beginning to map their tree canopies and establish goals to expand canopy. This report provides the City of Boynton Beach with a baseline set of data to support its commitment to a citywide tree canopy goal, monitor canopy protection progress, measure environmental benefits of city trees, and prioritize restoration of canopy where it is most needed.

The City's trees and other vegetation serve as the "green infrastructure." Just as we manage our grey infrastructure (roads, sidewalks, bridges and pipes), we also need to manage this green infrastructure. Green infrastructure provides many values that support a vibrant, safe and healthful city. Trees add to the City's historic coastal character, and they enhance its livability by filtering stormwater and reducing runoff, cooling streets, cleaning the air, capturing carbon emissions, and increasing property values. As the City of Boynton Beach grows and redevelops, it will continue to manage and expand its urban forest in order to maintain a livable city and achieve its vision of being "a regional and national leader in sustainability."

The image on the left shows The City of Boynton Beach's gray infrastructure, including buildings and roads. Classified high-resolution satellite imagery (image on the right) adds the City's green infrastructure data layer (trees and other vegetation). This green infrastructure provides cleaner air and water, energy savings, and natural beauty.

Photo by: Rebecca Harvey

CITY OF BOYNTON BEACH

Fast Facts & Key Stats

County: Palm Beach

2019 Population Estimate: 77,696

Total City Area: 16.5 sq. miles

Land: 15.26 sq. miles; 9,779.9 acres

Lakes/ponds: 474.8 acres

Streams/Canals: 29.2 miles; 276.3 acres

Tree canopy:
1,597 acres covering 16.1% of the City
(14.6% trees, 1.2% palms, 0.3% mangroves)

Summary Outcomes

Canopy

The City of Boynton Beach has a tree canopy (including mangroves and palm trees) that covers 16.1% of its total land acreage. Sixteen percent tree canopy is fairly typical for a developed urban area, but is lower than neighboring cities in Palm Beach County. This assessment found that 7.4% of the City's land area could be planted with additional trees, providing many benefits to residents and visitors. These benefits, or ecosystem services, include better air and water quality, cooler temperatures, and stormwater uptake.

Air quality

Trees play a critical role in providing oxygen and cleaning the air of pollutants that can harm human health. Trees also help to mitigate climate change by capturing carbon dioxide (CO_2) from the atmosphere and storing carbon in their leaves, trunks, and roots. Each year, the trees in Boynton Beach remove more than 14.6 million pounds of CO_2, 70,331 pounds of ground level ozone (O_3), and 19,960 pounds of particulate matter from the air.

Heat Island

Excessive pavement and lack of canopy shade lead to increased temperatures, forming urban heat islands. In Boynton Beach, higher temperatures and lower tree canopy were found in lower income neighborhoods and those with higher percentages of African Americans and Hispanics. Adding canopy trees can reduce household cooling costs by up to 28% (Peper et al 2010), increasing equity across our communities.

Stormwater Uptake

The City's trees mitigate stormwater runoff impacts as they capture rainfall in their canopies, trunks, roots, and surrounding soils. This means less flooding of streets and less pollution of surface and ground waters. During a typical two-inch rainfall event, the trees in Boynton Beach:

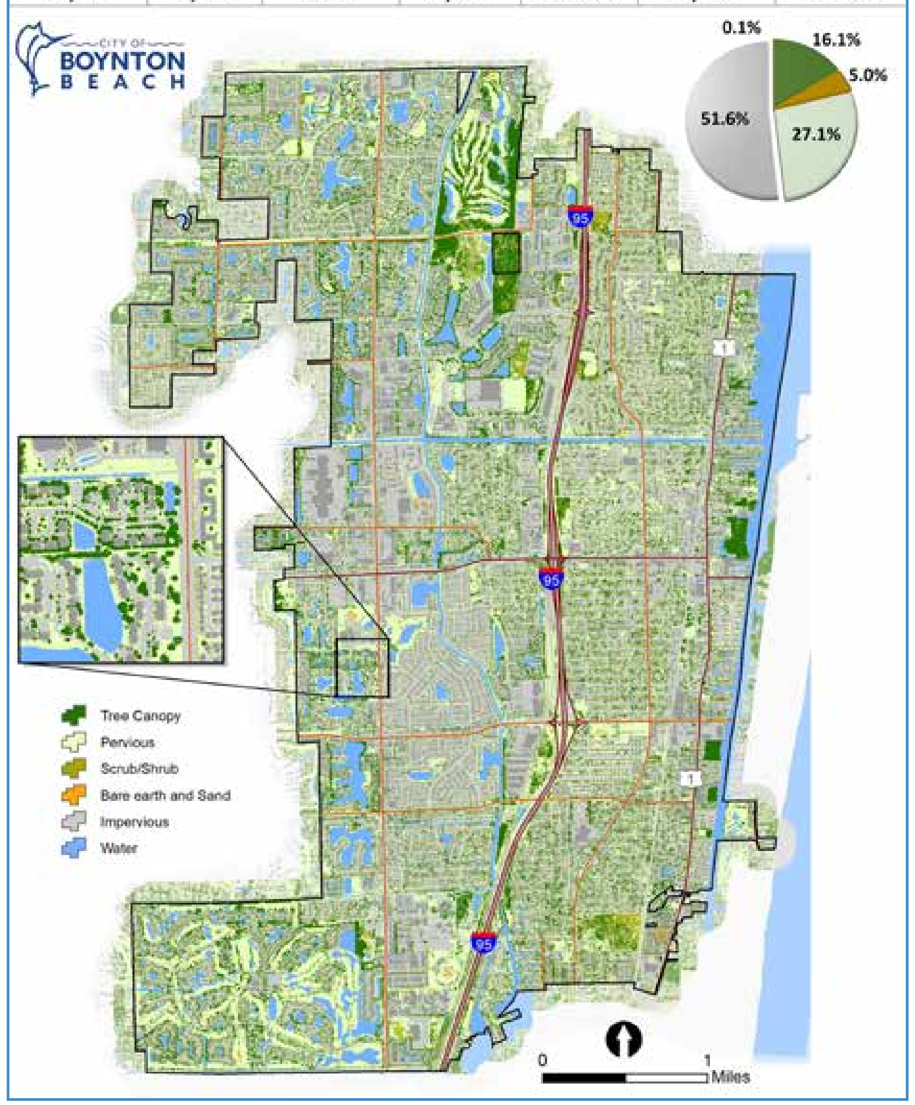
- Soak up 11.3 million gallons of water
- Reduce runoff pollution by 3% for nitrogen, 5% for phosphorus and 6% for sediment.

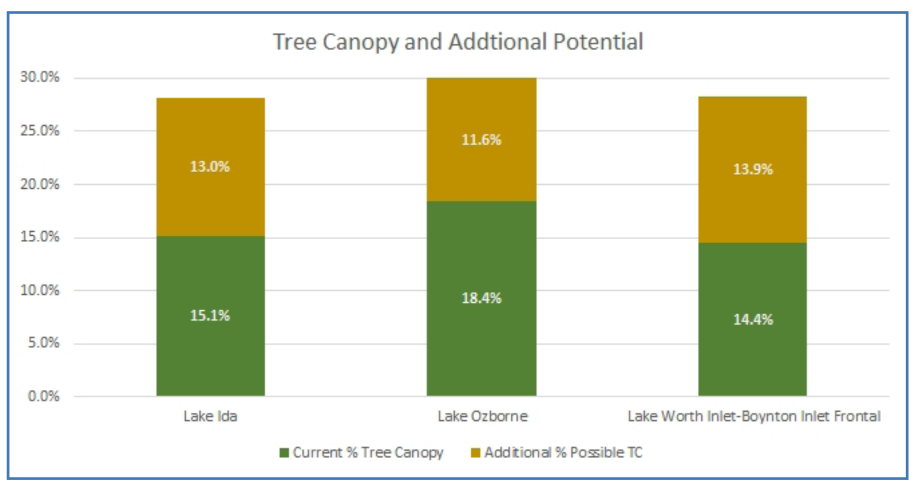
Canopy Trends and Expansion Goal

Maintaining canopy, while keeping up with losses as older trees age and die, are lost to storms, or are cleared for development, will require the City to plant trees continually. As the City develops, it will be important to maintain existing coverage and plant replacement trees to overcome losses. Based on analysis of change in City canopy over two years (2017-19), the City lost 1% of its tree canopy, equal to about 900 trees each year. If this trend continued, the City's canopy coverage would decline. Concerted action to plant more trees and reduce removals of healthy trees is needed. In other words, just to maintain canopy, the City will need to increase its level of planting.

Based on results of this assessment, the Green Infrastructure Center and the Sustainability Coordinator recommend that the City of Boynton Beach commit to a tree canopy goal of 20% coverage by the year 2035. The City's current tree canopy coverage (including palms) is 16.1%. Increasing the canopy by 4% will entail planting approximately 30% of the City's Potential Planting Area, or about 392 acres of additional canopy.

Total Area (acres)	Tree Canopy (acres)	Tree Canopy %	Impervious (acres)	Impervious %	Grass/ Open Space (acres)	Grass/Open Space %
10,552	1,577	16.1%	5,042	51.6.8%	2,651	27.1.1%





The City of Boynton Beach has plenty of room to plant additional trees. More trees equate to better air quality, shade and energy savings, greenhouse gas reduction, stormwater uptake, and improved water quality too!

Canopy Assessment

Introduction

Boynton Beach is a 16.5 square-mile coastal community in southeastern Palm Beach County, Florida, and is the third largest city in Palm Beach County, with an estimated 2019 population of 77,696. The City's racially and ethnically diverse population includes 62.4% non-Hispanic Whites, 31.7% Black/African Americans, and 15.8% Latino residents[1].

The City, often called the "Gateway to the Gulfstream," adjoins four miles of the Intracoastal Waterway, including one of the county's four ocean inlets. Boynton Beach's mission is to be "a vibrant and sustainable community that provides exceptional services" and its vision is "to be a welcoming and progressive coastal community that celebrates culture, innovation, and business development." With 253 acres of municipal parks, beach and conservation lands, the City is rich in natural amenities that contribute to its high-quality lifestyle that includes plenty of opportunities to enjoy the abundant water views and aquatic sports.

This report describes the City's current canopy coverage, as well as the canopy assessment method utilized for the analysis of the canopy's environmental benefits, and the City's strategies to sustain and expand the urban forest. These products have been created:

- Analysis of the current extent of the urban forest through high-resolution tree canopy mapping
- Potential Planting Area analysis to determine where additional trees could be planted
- A calculation of the environmental benefits and pollution removal by the City's tree canopy

Additional benefits of improved canopy.

The City can utilize its tree canopy to maximize many environmental and social benefits:

- A healthful and vibrant community
- Aesthetic values and natural beauty
- Decreased urban heat island and reduced heating and cooling costs
- Bird and wildlife habitat
- Walkability and multimodal transportation
- Revenue from tourism and retail sales

[1] https://www.census.gov/quickfacts/boyntonbeachcityflorida

Assessing and enhancing the City's tree canopy supports the goals of a number of City plans and policies:

- Climate Action Plan
- Strategic Plan
- Comprehensive Plan
- Community Redevelopment Plan
- Complete Streets Policy
- Greenways, Blueways, and Trails Plan
- Vision Zero Resolution
- Sustainable Development Standards
- Climate Change Vulnerability Assessment
- National Flood Insurance Program's Community Rating System
- Downtown Stormwater Master Plan
- National Pollutant Discharge Elimination System Stormwater

One of the City's many beautiful trees provides shade for sidewalks and playground.

How the Urban Forest Benefits Boynton Beach

The trees of Boynton Beach benefit the City in myriad ways: ecological, economic and social. This assessment allows the City to measure some of those benefits, and to increase them by planting more trees.

Reducing Stormwater Runoff and Filtering Pollutants

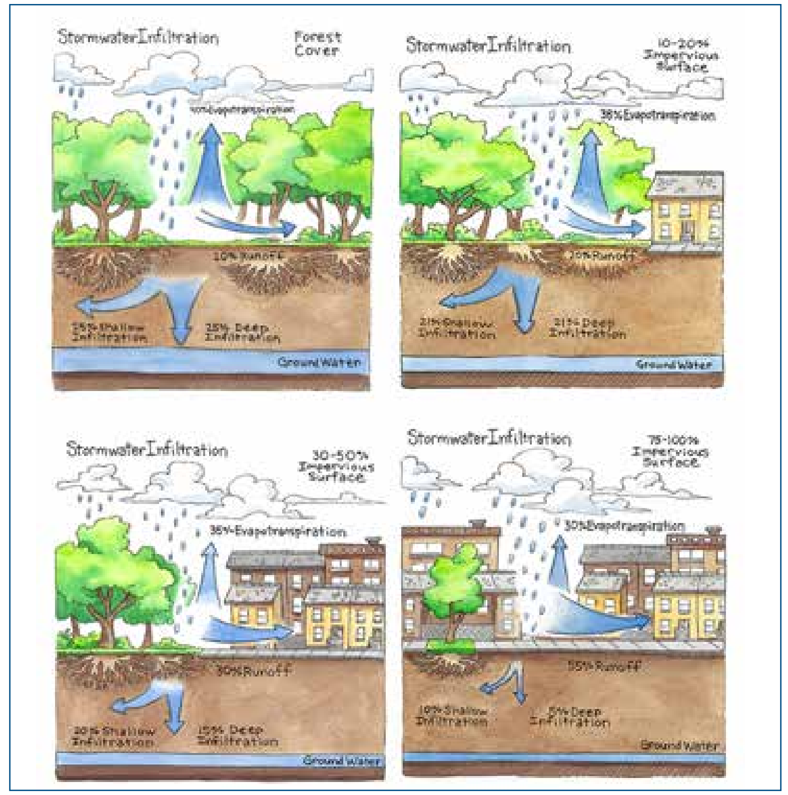
Trees protect cities from problems associated with stormwater runoff. As forested land is converted to impervious surfaces, runoff increases. Excess stormwater runoff can cause temperature spikes in receiving waters, increased pollution of surface and ground waters, and greater potential for flooding.

Trees reduce nitrogen, phosphorus, and sediment in stormwater runoff by cleaning rainfall of these pollutants. Increased loads of nutrients reduce oxygen in surface water, causing harm to fish and other aquatic life. The presence of trees means fewer pollutants reach drainage canals, the Intracoastal Waterway, and the ocean.

In a typical two-inch rainfall in Boynton Beach, its trees take up 11.3 million gallons of runoff, or about 16.5 Olympic swimming pools of water!

The average annual precipitation in Boynton Beach is 61.3 inches (155 cm), much of which currently runs off into canals and then to the Atlantic Ocean, conveying surface pollutants from the land. Large paved areas contribute significant volumes to this runoff. While some of that runoff is treated through stormwater management features, such as the bioswale at right, much of the city's landscape predates requirements for stormwater management.

During a one-inch rainfall event, one acre of pavement, such as a retail parking lot, will release 27,000 gallons of runoff. Compare this to an acre of forest, where only 750 gallons of water run off. In sandy soils, the infiltration rate is much higher! While stormwater ponds and other best management practices are designed to mimic rainfall release by detaining and filtering runoff, they do not fully replicate pre-development hydrology. In addition, older parts of the City may lack stormwater management practices that are required for new developments, so not all runoff is captured or treated before it flows into open waterways.



Runoff increases as land is developed.

Data Source: Federal Stream Corridor Restoration Handbook (1998)

The City's best management practices include planting trees in stormwater swales to increase the amount of pollutants removed, while also providing habitat for birds and amphibians.

Excess impervious areas cause hot temperatures and runoff. This parking lot could be retrofitted to add more trees.

Buffering Storms and Flooding

Another benefit of conserving trees and forests is buffering against storms and losses from flooding. According to the U.S. Environmental Protection Agency (EPA), excessive stormwater runoff accounts for more than half of the pollution in the nation's surface waters and causes increased flooding and property damages, as well as public safety hazards. The EPA recommends a number of ways to use trees to manage stormwater in its book *Stormwater to Street Trees*.

Retaining trees and forests along coasts provides a wind break and helps evaporate and reduce standing water. In addition, utilizing trees as green infrastructure provides a basis for reimbursement from FEMA for storm-damaged trees. To qualify, trees must be inventoried and specifically utilized for stormwater management, buffers or other "green infrastructure" functions.

The City of Boynton Beach participates in the National Flood Insurance Program's Community Rating System (CRS). The CRS is a voluntary incentive system that allows local governments to earn flood insurance premium discounts for policyholders in the community. Local governments receive points, both for actions and for policies that reduce flooding and flood damage; these points earn premium discounts as high as 45%. The City of Boynton Beach is currently rated as Class 6 in the CRS program, earning its residents and businesses a 20% premium reduction in insurance rates within its special flood hazard areas.[2]

Mangroves prevent coastal erosion and provide a buffer against wind.

Additionally, communities can earn credit for adopted management plans that protect the critical natural functions of floodplains and native species, while implementing habitat restoration projects. CRS requirements include an inventory of all species in the plan's geographic purview, action items for protecting species of interest, restoring natural floodplain functions, and the review and update of the plan every 5 years. This report's data can also be used to create a citywide Green Infrastructure Plan. Such a plan can be applied to the City's point reduction credits in the CRS to further lower flood insurance premiums.

Since trees filter stormwater and reduce overall flows, planting or conserving trees is a natural way to mitigate stormwater. Each tree plays an important role in stormwater management. Based on the GIC's review of canopy rainfall interception studies, a typical street tree's crown can intercept between 760 and 3,000 gallons of water per year, depending on the species and age. In a typical two-inch rainfall in Boynton Beach, its trees take up 11.3 million gallons of runoff, or about 16.5 Olympic swimming pools of water. In a larger rainfall event (5 inches of rain) the trees take up 13.3 million gallons!

As tree cover is lost and impervious areas expand, excessive urban runoff results in pollutants, such as oils, metals, lawn chemicals (e.g., fertilizer and herbicides), pet waste, trash, and other contaminants reaching surface waters. Trees help capture and filter that urban runoff. The GIC's stormwater model for Boynton Beach shows that, during a typical two-inch rainfall event, the City's trees capture:

- 4,798 lbs. of nitrogen
- 378 lbs. of phosphorus
- 591 lbs. of sediment

Nitrogen and phosphorus are plant nutrients that cause harmful algal blooms, while sediment can clog fish gills, smother aquatic life, and necessitate additional dredging of canals and waterways. Algal blooms can also reduce oxygen levels, further harming fish and other aquatic life.

[2] 2019 City of Boynton Beach Repetitive Loss Area Analysis

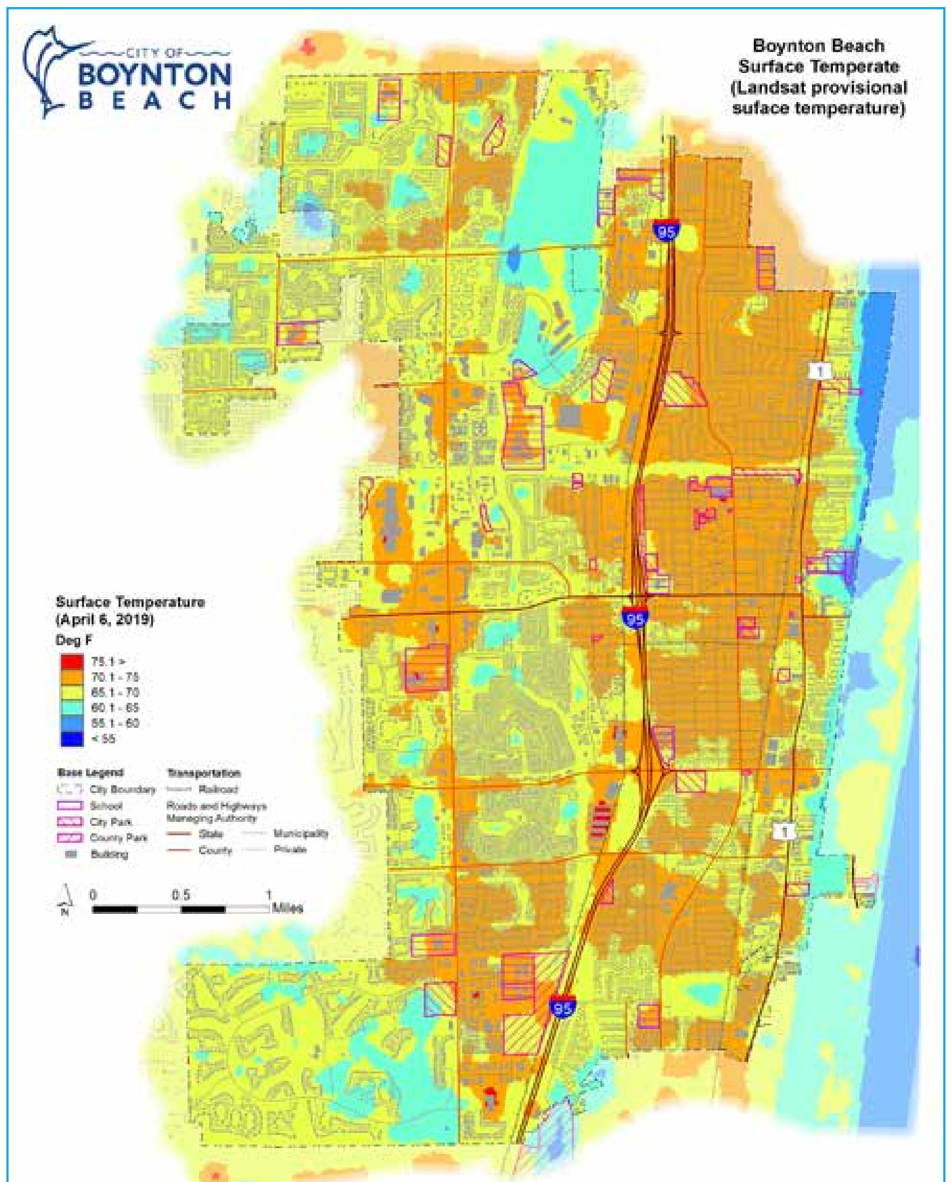
Air Quality and Surface Heating

Trees Cool the City

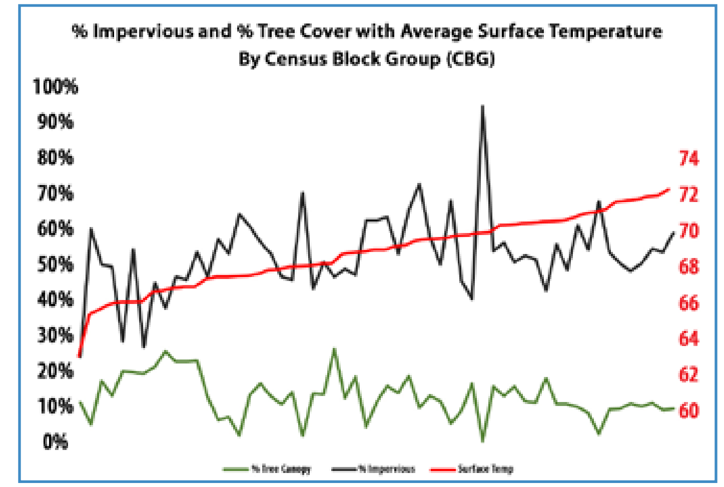
During Florida's hot summers, more shade is always appreciated. Excessive heat can lead to heat stress, which especially affects infants and children up to four years of age, those 65 years of age and older, those with obesity issues, and those on certain medications (CDC 2020).

Tree cover shades streets, sidewalks, parking lots, and homes, making southern urban locations cooler and more pleasant for walking or biking. Multiple studies have found significant cooling (2-7° F) and energy savings from having shade trees in cities (McPherson et al 1997, Hashed et al 2001).

Shaded pavement also has a longer lifespan, so maintenance costs associated with roadways and sidewalks are less (McPherson and Muchnick 2005).



Hot areas of the city are also those with the lowest tree canopy. This map shows temperatures in April.



Trees are positively correlated with reductions in surface temperatures.

Trees Clean the Air

In addition to cooling surfaces, trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Trees also clean the air of ground level ozone (O_3), which can harm human health. Trees sequester carbon which forms greenhouse gases such as sulphur dioxide and carbon dioxide, which contribute to a warming planet. By storing carbon and preventing its release, trees mitigate the impacts of climate change. Even at the neighborhood level, trees reduce pollutants. Well-treed neighborhoods suffer less respiratory illnesses, such as asthma (Rao et al 2014).

Social Values

Trees Improve Cognitive Function

Children who suffer from Attention Deficit Hyperactivity Disorder (ADHD) benefit from living near forests and other natural areas. One study showed that children who moved closer to green areas have better and improved cognitive function after the move, regardless of level of affluence (Wells 2000). Thus, communities with greener landscapes benefit children and reduce ADHD symptoms. Exposure to green spaces for 20 minutes a day can also improve cognitive function – so providing natural areas on or near school grounds as well as greening routes to school can better prepare children to learn.

Well-treed areas encourage people to walk and bike.

Trees Improve Walkability

Trees cause people to walk more and walk farther. This is because, when trees are not present, distances are perceived to be longer, hotter, less pleasant, and destinations farther away, making people less inclined to walk than if streets are well treed (Tilt, Unfried and Roca 2007).

Increasing Property Values and Sales

Developments that include green space or natural areas in their plans sell homes faster and for higher profits than those that take the more traditional approach of building over an entire area without providing community green space (Benedict and McMahon 2006).

A study by the National Association of Realtors found that 57 percent of voters surveyed were more likely to purchase a home near green space, while 50 percent were more willing to pay 10 percent more for a home located near a park or other protected area. Fruit trees also add value for citizens who appreciate them for their nourishment and cultural significance.

Nature Sells—

Market prices for treed lots *versus* untreed lots:

Building lots with substantial mature tree cover

Tree-covered undeveloped acreage

Lots bordering suburban wooded preserves

Open land that is two-thirds wooded

Source: Kathleen Wolf, 2007, *City Trees and Property Values*.

Current and Potential Canopy and Ecosystem Services Modeling

Methods

In order to determine the current tree canopy, model scenarios for future tree coverage, and quantify their ecosystem services, a highly detailed land cover analysis and an estimate of potential future planting areas was developed (see Appendix A for details). In addition to urban forest planning, this new land cover data can be used for other purposes, such as to analyze urban cooling, walkability, and street tree plantings; or to inform area plans and the City's Comprehensive Plan.
Satellite imagery from the National Agricultural Imagery Program (NAIP) distributed by the USDA Farm Service Agency was classified based on 4 infrared bands to determine the types and extent of different land covers in Boynton Beach. Two canopy maps were created using NAIP imagery data – one from 2017 data and one from 2019 data. Additional data sets from the City of Boynton Beach, the National Wetlands Inventory, and the National Hydrography Dataset were used to classify the following:

1) Tree canopy (including trees, palms, and mangroves).
2) Wetlands that are indistinguishable using spectral/feature-based image classification tools.
3) Forested open space (compact, continuous tree canopy greater than one acre) not intersected by buildings or paved surfaces.

Palm Trees Costs Versus Benefits

Palm trees are a signature aesthetic element of Palm Beach County and its cities and towns. Technically, though, palms are more similar to grasses than they are to conifers and hardwood trees. Palms and grasses are both monocots – plants whose seeds contain only one leaf. Palms are in the Arecaceae botanical family of perennial flowering plants in the monocot order Arecales. Palm growth forms include climbers, shrubs, stemless and tree-like plants. Those with a tree-like form are colloquially called "palm trees." Larger palm trees function like trees in providing some shade, cooling, wildlife habitat, carbon sequestration and air pollution removal. Although palms take up some stormwater, due to their shallow root structure, skinny trunks and narrow, thin canopy, they do not match the abilities of a native hardwood tree, such as a live oak, for ecosystem benefits.

Although "palm trees" are ubiquitous to Florida, they are expensive to maintain as a street "tree." In a study of Central Florida, the US Forest Service found that palm trees can be "very expensive to plant and maintain." Research shows that annual benefits and expenditures for a typical palm used as a street tree (sabal palm) were $4 and $30, respectively, resulting in a net annual loss of $26 per tree. Compare that to a large live oak in a yard 20 years after planting, for which the total value of environmental benefits alone ($80) is five times the total annual cost ($16) (Peper et al 2010).

One reason palm trees are so expensive to maintain compared to typical trees, is that many palms in Florida are "non-self-cleaning." These palms require that every leaf produced be manually removed. Fallen palm fronds do not biodegrade into turf and soil as do the leaves of many broadleaf tree species. Palms also require more nutrients than any cultivated plant in Florida. To grow well and develop fully, palm trees require routine treatment with expensive palm fertilizers (Broschat 2010a).

As a key aesthetic element of Palm Beach County, palm trees are here to stay. But when looking to realize the benefits of an abundant tree canopy for shade, stormwater, air quality and health, the City of Boynton Beach should consider planting more large shade trees – both to save on costs and to realize the true benefits of large, native trees.

The annual benefits of a typical street palm vs the expenditures result in a net annual loss of $26 per tree.

Cost $30 → $4 Benefit

Cost $16 → $80 Benefit

The environmental benefits of a large live oak in a yard 20 years after planting, is five times the total annual cost.

Tree canopy included woody vegetation over 10 feet in height. LiDAR (light detection and ranging) data were used to determine vegetation height, to distinguish between large shrubs versus trees. This allows the GIS analyst to separate bushes from trees and other vegetation. This distinction of tree/non-tree vegetation is very important when modeling tree benefits since the modeled pollution-removal benefits are based on trees, and do not necessarily translate to smaller, non-woody vegetation.

Because Boynton Beach is a sub-tropical city, palm trees make up part of the City's canopy. Technically, though, palms are more similar to grasses than they are to trees. This means that, while palm trees provide some shade, they have shallow, fibrous roots that do not absorb as much water or filter pollutants the same way as a mature tree. So, while tall palms were included in the canopy coverage calculations for the City, they were separated out, as much as practicable, when calculating pollution removal values. For more see box on Palm Tree Costs Versus Benefits.

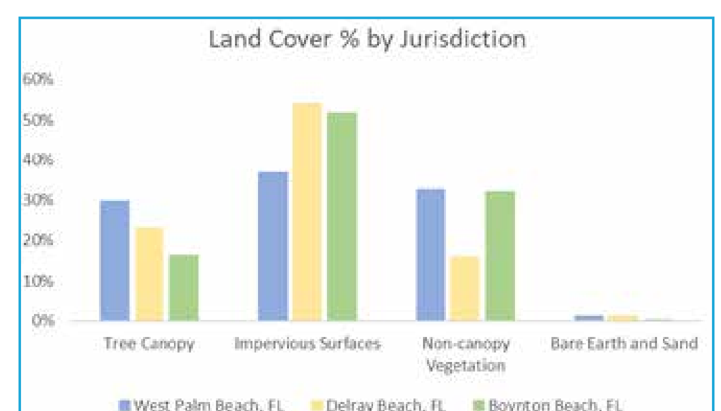
Mangroves behave similarly to wetlands, as some are in hydric/clay soils. Since they make up a dense part of some of the City's canopy along the intracoastal waterway, they were included in canopy calculations.

NAIP Aerial Image November 2019

Potential Planting Area (PPA) shown in orange

Cities often want to know how they compare to their neighbors. Following is a short discussion of differences in comparing the City of Boynton Beach to other local cities. There are some key distinctions in how tree canopy data were analyzed between jurisdictions. In the City of Delray Beach, the analysis performed did not utilize height data and thus the canopy results likely include a large percentage of shrubs and other low-lying vegetation that are not actually trees. Adding in shrubs and other lower vegetation to The City of Boynton Beach's canopy calculation yields a canopy coverage percent similar to that for Delray Beach. In West Palm Beach, areas around the Grassy Waters Preserve had higher tree canopies, while several downtown neighborhoods have similar canopy percentages to Boynton Beach.

Due to these differences in methods and landscapes, comparisons between jurisdictions may not be useful. The City of Boynton Beach is best served by focusing on its own goal to expand and better manage its urban areas with respect to tree coverage.



Determining Plantable Acreage

Potential Planting Areas
In urban areas, realistic goals for expanding urban canopy depend on an accurate assessment of plantable open acreage. A Potential Planting Area (PPA) map estimates areas where it may be feasible to plant trees. The PPA is estimated by selecting those land cover features that have space available for planting trees and accounts for the overlap of canopy (i.e., canopy that is intermingled or a large canopy tree that partially covers an understory tree). Based on an analysis of existing pervious surfaces, 7.4% of the City's land area could be planted with additional trees.

Of the nine land cover classes mapped, only pervious and turf were considered for the PPA. However, some paved areas could be removed or reduced, soils conditioned, and then used to plant new canopy. For example, parts of a parking lot could be removed and planted with trees to absorb and clean stormwater

Eligible planting areas are also limited by their proximity to features that interfere with a tree's natural growth (such as buildings) or where a tree might affect the feature, such as power lines, sidewalks or roads. City staff and the GIC reviewed the draft PPA map and removed playing fields, cemeteries and other known land uses, such as drainage canals, that would be inappropriate for planting trees. The resulting PPA represents the maximum potential places trees can be planted and grow to full size. The GIC recommends no more than half the available PPA is realistic to plant, since many other uses, such as tomato gardens or sunbathing by the pool, require full sun where shade is not desired.

[3] LiDAR is Light Detection and Ranging. It is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. The shorter the return interval, the taller the item.

[4] Koppen classification system.

Potential Planting Spots (PPS)

Potential Planting Spots

Potential Planting Spots (PPS) are created from the PPA. A GIS modeling process is applied to select spots where a tree can be planted, depending on the desired mature size. For this analysis, expected sizes of 20 ft. and 40 ft. diameter for individual mature canopy trees were used, with priority given to 40 ft. diameter trees, since larger trees provide more benefits.

There are many places where new trees can be planted in the City.

Potential Canopy Area (PCA)

Potential Canopy Area

The Potential Canopy Area (PCA) is created from the PPS. Once potential planting spots are selected, a buffer around each point is created to represent the mature canopy spread. For this analysis, that buffer radius is either 10 ft. or 20 ft. which represents a 20 ft. or 40 ft. diameter canopy. These individual tree canopies are then merged together to form a Potential Canopy Area. The potential canopy area shows that 12.75% more canopy could be added to the City.

Percent Street Trees is calculated using the Land Cover Tree Canopy and road centerlines, which are buffered to 50 ft. from each road segment's centerline. The percent value represented is the percentage of tree cover within that 50 ft. buffer.

Maps and Findings

Areas for Analysis

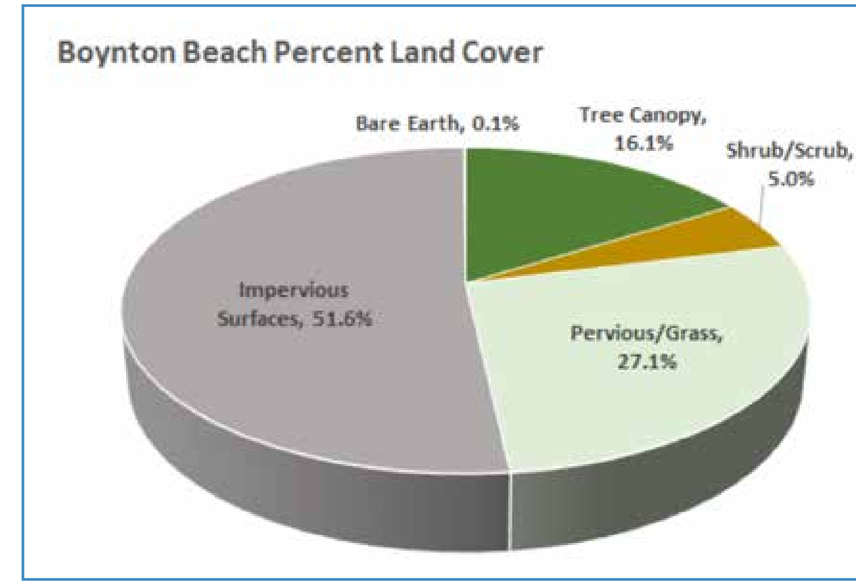
The Tree Canopy Map will be used to plan for tree conservation and as a benchmark to gauge future progress in tree canopy gains. An ArcGIS geodatabase with all GIS shape files produced during the study was provided to the City.

Citywide forest cover is 16.1%.

In addition, the City requested statistics for canopy in the following areas:

- Census tracts and block groups
- Parcels
- Parks
- Schools
- Downtown
- Community Redevelopment Agency (CRA) districts
- Streets
- Watersheds

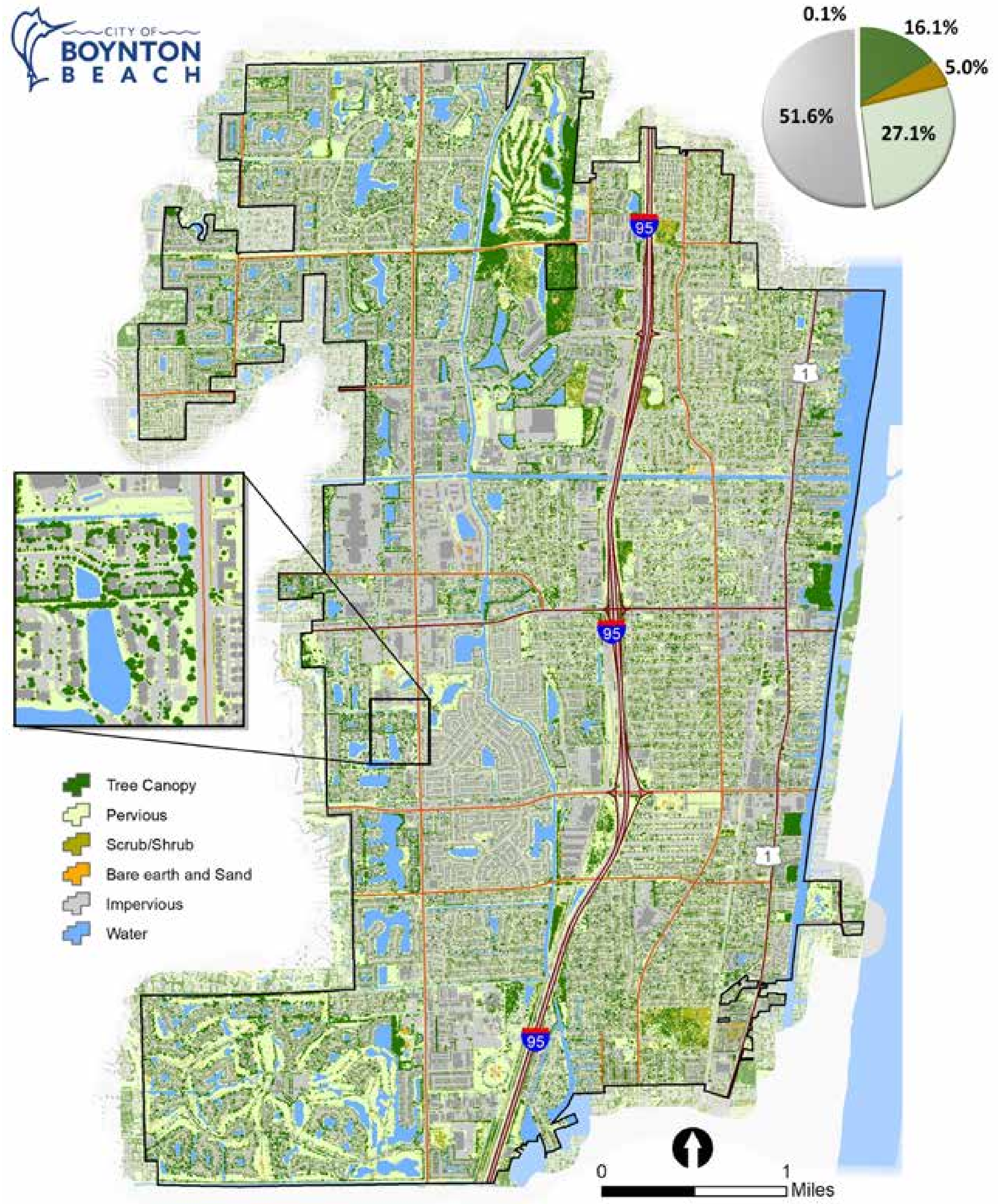
The canopy data and the Potential Planting Area Map can inform tree planting decisions to meet many goals, such as walkability, greenhouse gas emission reduction, energy savings, urban heat island reduction, and economic revitalization.



One mature tree can absorb thousands of gallons of water per year.

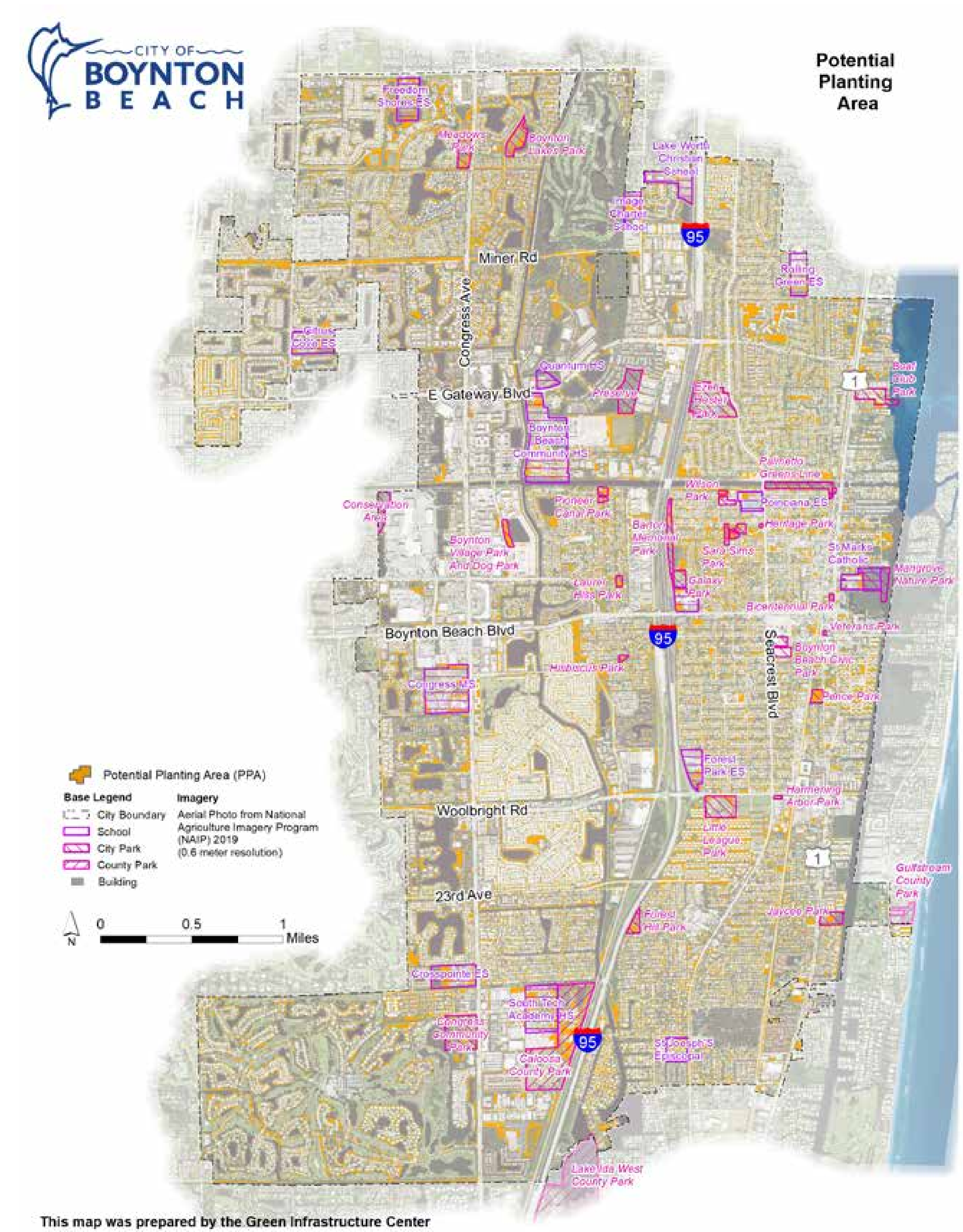
City Land Cover and Tree Canopy

Total Area (acres)	Tree Canopy (acres)	Tree Canopy %	Impervious (acres)	Impervious %	Grass/ Open Space (acres)	Grass/Open Space %
10,552	1,577	16.1%	5,042	51.6.8%	2,651	27.1.1%



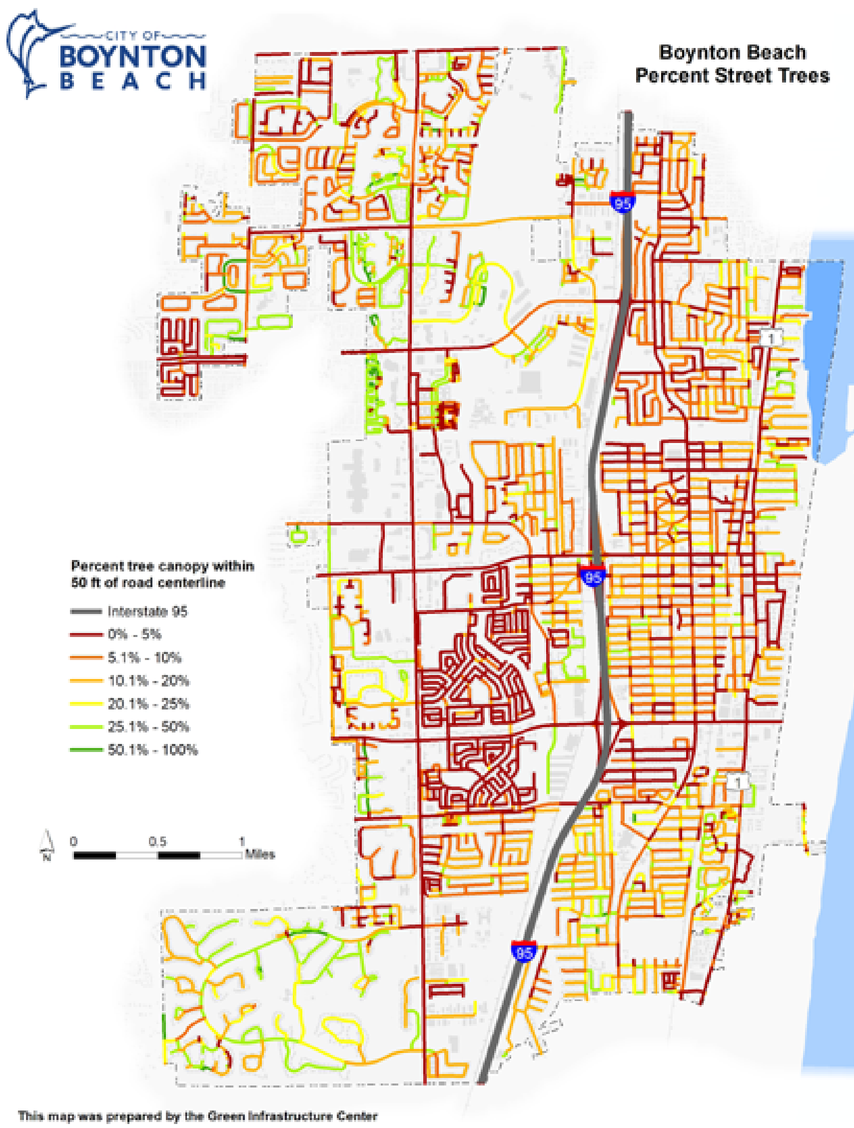
This map shows the tree canopy for the City of Boynton Beach; it covers 16.1% of the total area.

Potential Planting Areas



The Potential Planting Area (PPA), shown here in orange, depicts areas where it may be possible to plant trees.
All sites would need to be confirmed in the field, and may be on either private or public lands.

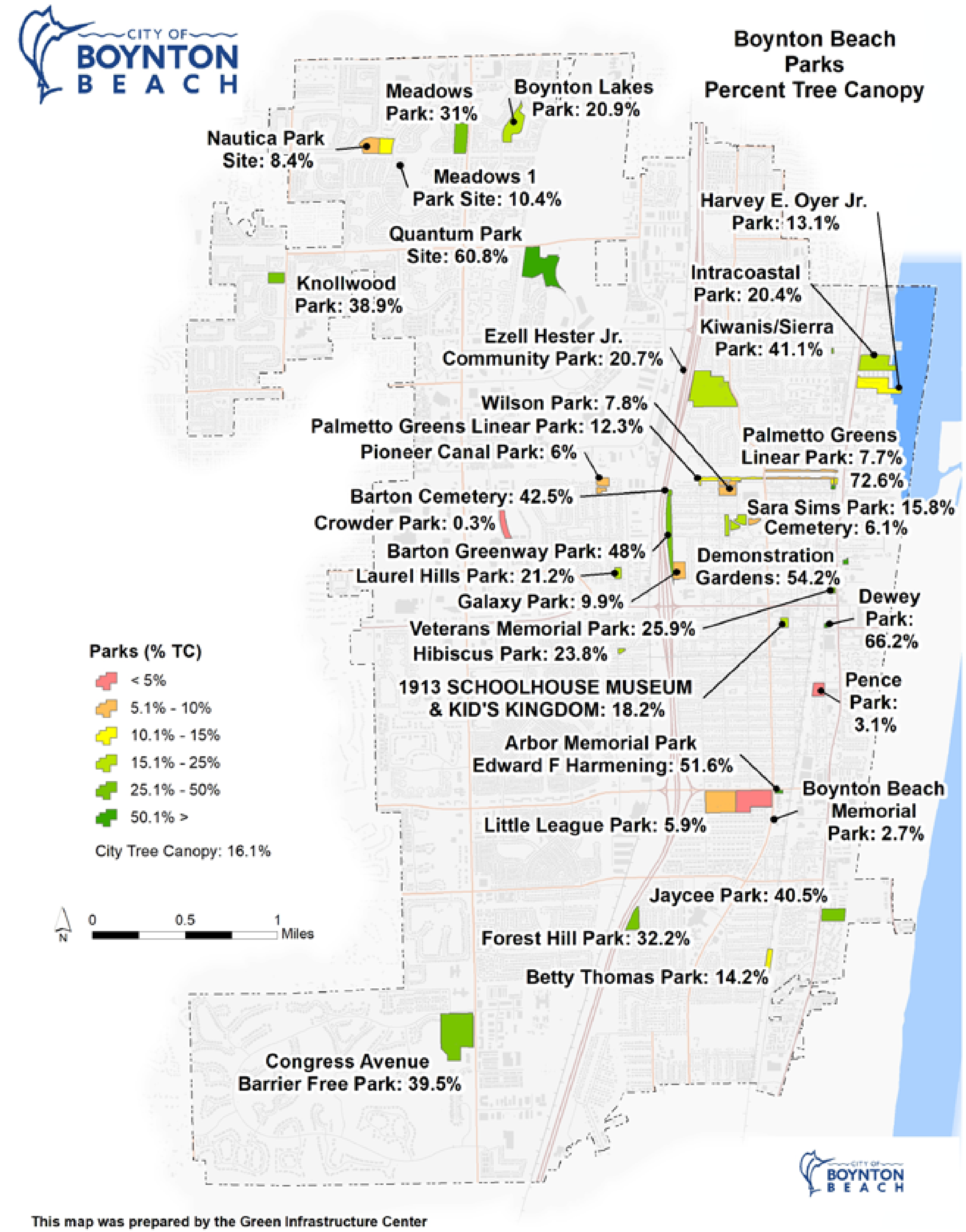
Street Tree Coverage



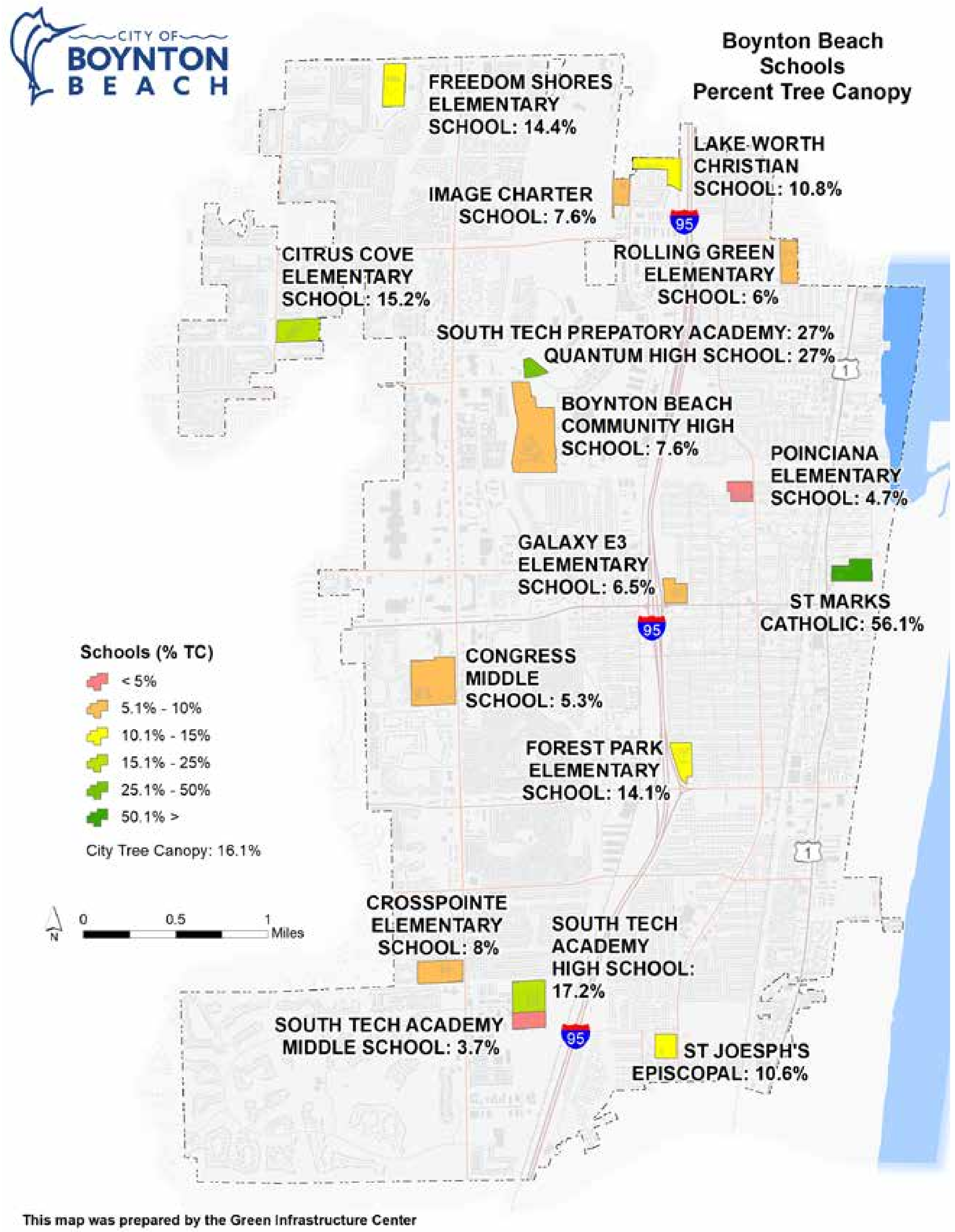
The Street Trees Map shows those streets that have the most canopy (dark green) and those that have the least (red). Streets that lack good coverage can be targeted for planting to facilitate specific City goals, such as safe routes to school or beautifying a shopping district.

City Park	% Tree Canopy
Dewey Park	66.2%
Quantum Park Site	60.8%
Demonstration Gardens	54.2%
Arbor Memorial Park Edward F Harmening	51.6%
Barton Greenway Park	48.0%
Barton Cemetery	42.5%
Kiwanis/Sierra Park	41.1%
Jaycee Park	40.5%
Congress Avenue Barrier Free Park	39.5%
Knollwood Park	38.9%
Forest Hill Park	32.2%
Meadows Park	31.0%
Palmetto Greens Linear Park	30.9%
Veterans Memorial Park	25.9%
Hibiscus Park	23.8%
Laurel Hills Park	21.2%
Boynton Lakes Park	20.9%
Ezell Hester Jr. Community Park	20.7%
Intracoastal Park	20.4%
1913 Schoolhouse Museum & Kid's Kingdom	18.2%
Sara Sims Park	15.8%
Betty Thomas Park	14.2%
Harvey E. Oyer Jr. Park	13.1%
Meadows 1 Park Site	10.4%
Galaxy Park	9.9%
Nautica Park Site	8.4%
Wilson Park	7.8%
Sara Simms Cemetery	6.1%
Pioneer Canal Park	6.0%
Little League Park	5.9%
Pence Park	3.1%
Boynton Beach Memorial Park	2.7%
Crowder Park	0.3%
Boynton Beach Oceanfront Park	n/a

City Park Canopy



School Canopy Coverage



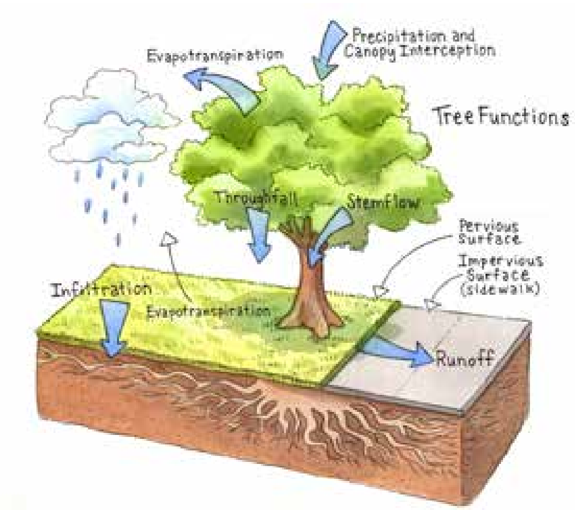
Planting at school sites can save buildings' energy costs and provide a boost to learning, since exposure to trees increases cognitive abilities.

Calculating Benefits Trees Provide

Stormwater Uptake

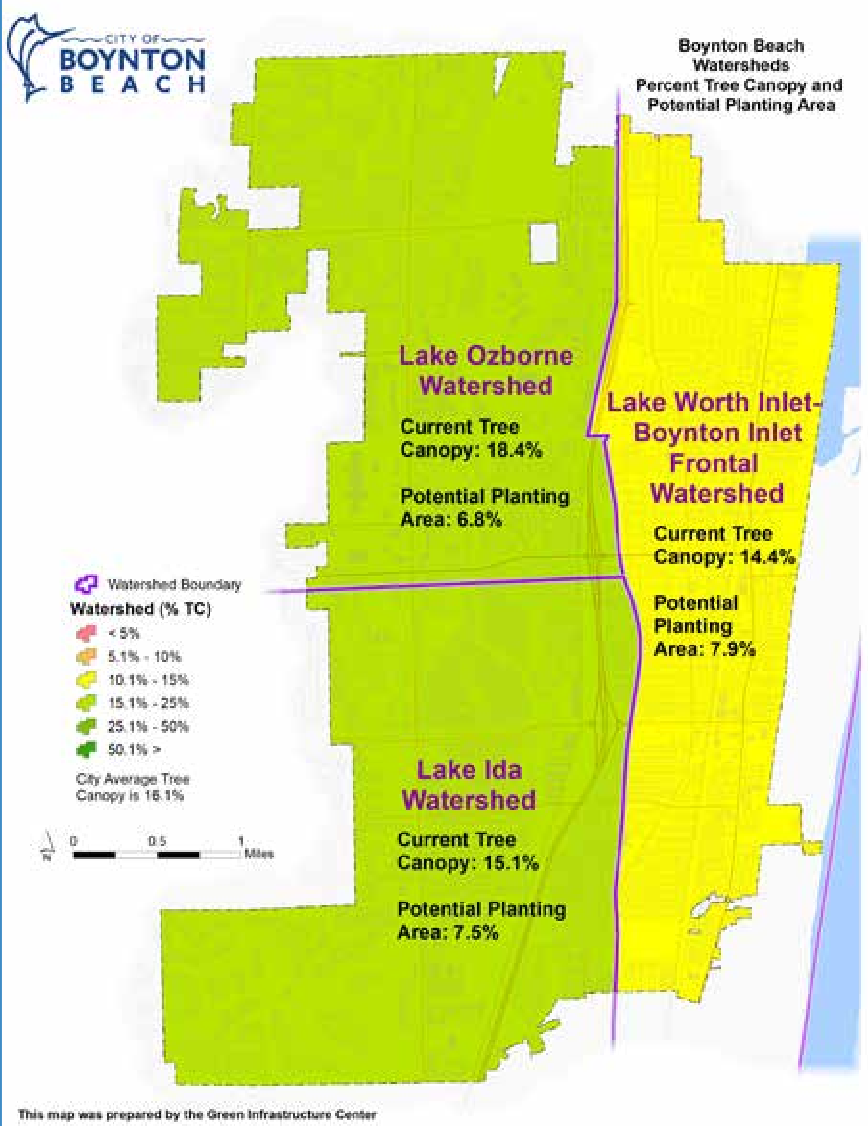
Trees and forests are the best land cover for taking up urban stormwater. Stormwater runoff and uptake by the City's tree canopy was evaluated using GIC's Trees and Stormwater Calculator (TSC) Tool. This tool estimates the capture of precipitation by tree canopies and the resulting reductions in runoff yield. It takes into account the interaction of land cover and soil hydrologic conditions. It can also be used to run 'what-if' scenarios, specifically losses of tree canopy from development or storms, and increases in tree canopy from tree planting programs.

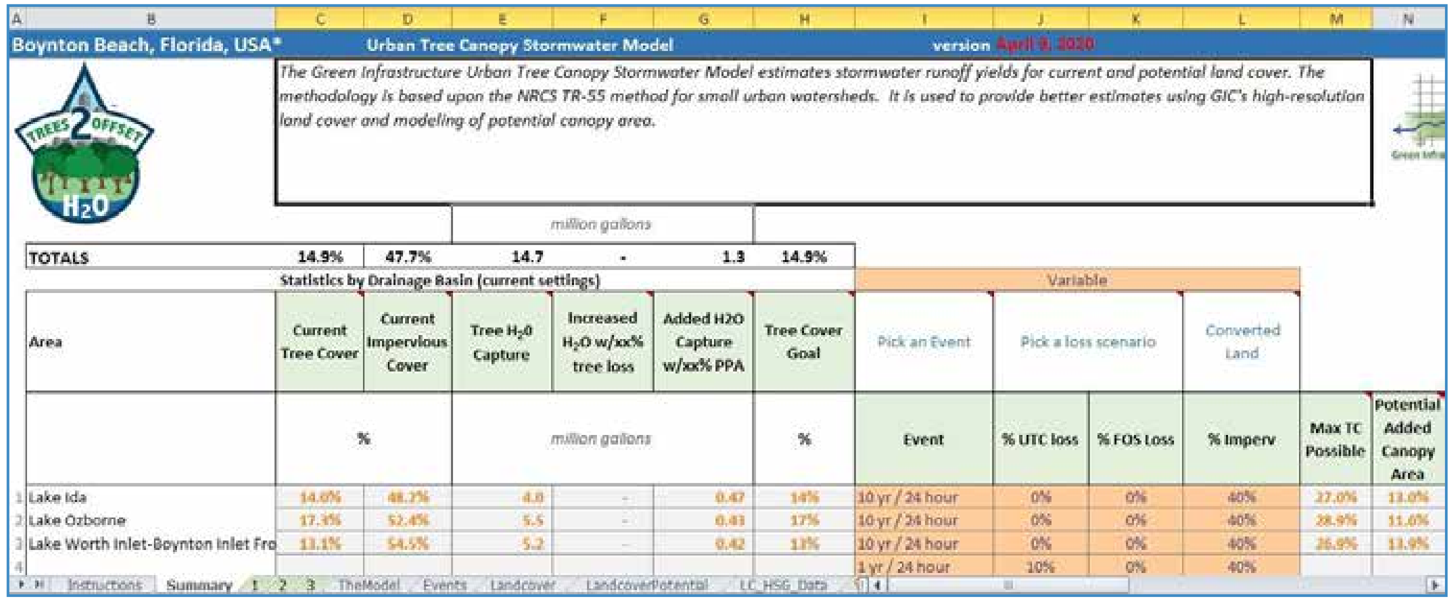
Trees intercept, take up, and slow the rate of stormwater runoff. Canopy interception varies from 100% at the beginning of a rainfall event to about 3% at maximum rain intensity. Trees take up more water early on during storm events and less as storm events proceed and the ground becomes saturated (Xiao et al. 2000). Many forestry scientists, as well as civil engineers, have recognized that trees have important stormwater benefits (Kuehler 2017, 2016). (See diagram of tree water flow below.)



The amount and type of open space under and around a tree and the condition of its surrounding surface soils affect the infiltration of water.
The GIC's TSC tool includes has a data field to hypothetically add trees to calculate outcomes for stormwater uptake from new tree planting. The TSC tool uses PPA data to determine how many

Watersheds





Boynton Beach, Florida, USA* Urban Tree Canopy Stormwater Model version April 9, 2020

The Green Infrastructure Urban Tree Canopy Stormwater Model estimates stormwater runoff yields for current and potential land cover. The methodology is based upon the NRCS TR-55 method for small urban watersheds. It is used to provide better estimates using GIC's high-resolution land cover and modeling of potential canopy area.

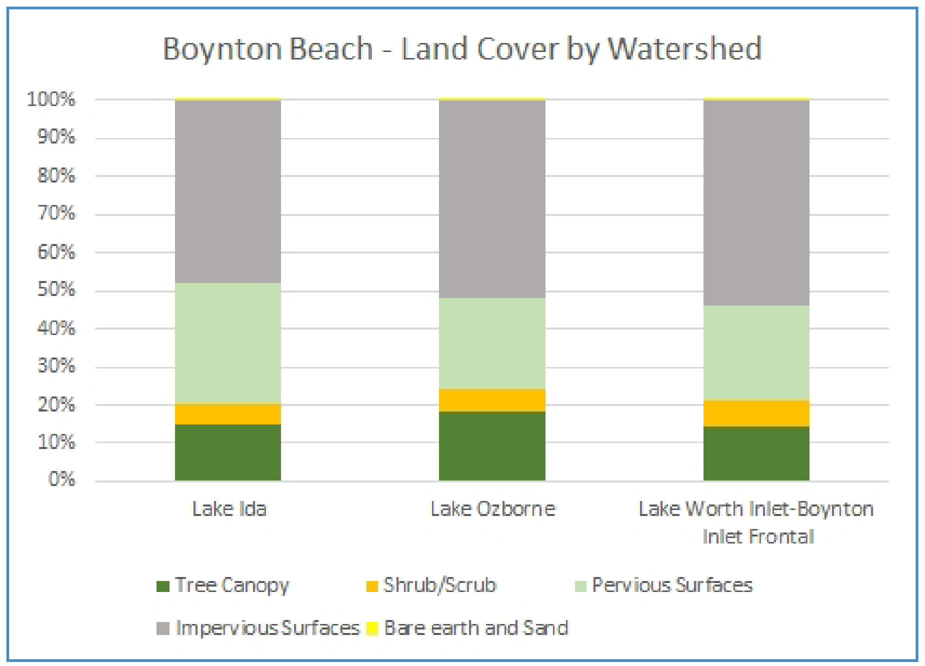
Area	Current Tree Cover	Current Impervious Cover	Tree H_2O Capture	Increased H_2O w/xx% tree loss	Added H2O Capture w/xx% PPA	Tree Cover Goal	Event	% UTC loss	% FOS Loss	% Imperv	Max TC Possible	Potential Added Canopy Area
TOTALS	14.9%	47.7%	14.7	-	1.3	14.9%						
	%		million gallons			%						
1 Lake Ida	14.0%	48.2%	4.0	-	0.47	14%	10 yr / 24 hour	0%	0%	40%	27.0%	13.0%
2 Lake Ozborne	17.3%	52.4%	5.5	-	0.41	17%	10 yr / 24 hour	0%	0%	40%	28.9%	11.6%
3 Lake Worth Inlet-Boynton Inlet Fro	13.1%	54.5%	5.2	-	0.42	13%	10 yr / 24 hour	0%	0%	40%	26.9%	13.9%
4							1 yr / 24 hour	10%	0%	40%		

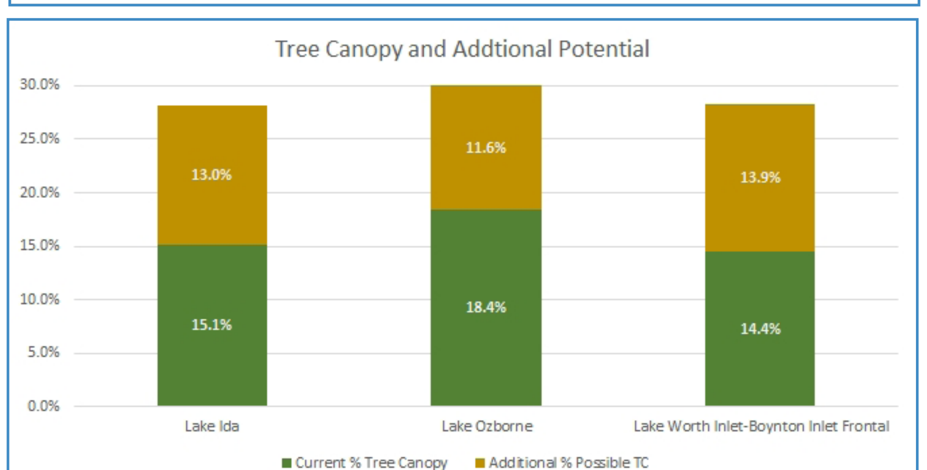
The TSC Tool allows the City to model water uptake by the existing canopy and impacts from changes, whether positive (adding trees) or negative (removing trees).

more trees could be planted. The tool also calculates the amount of nitrogen, phosphorus, and sediment the trees and their surrounding soils take up. For more about the stormwater calculator tool, see Appendix B.

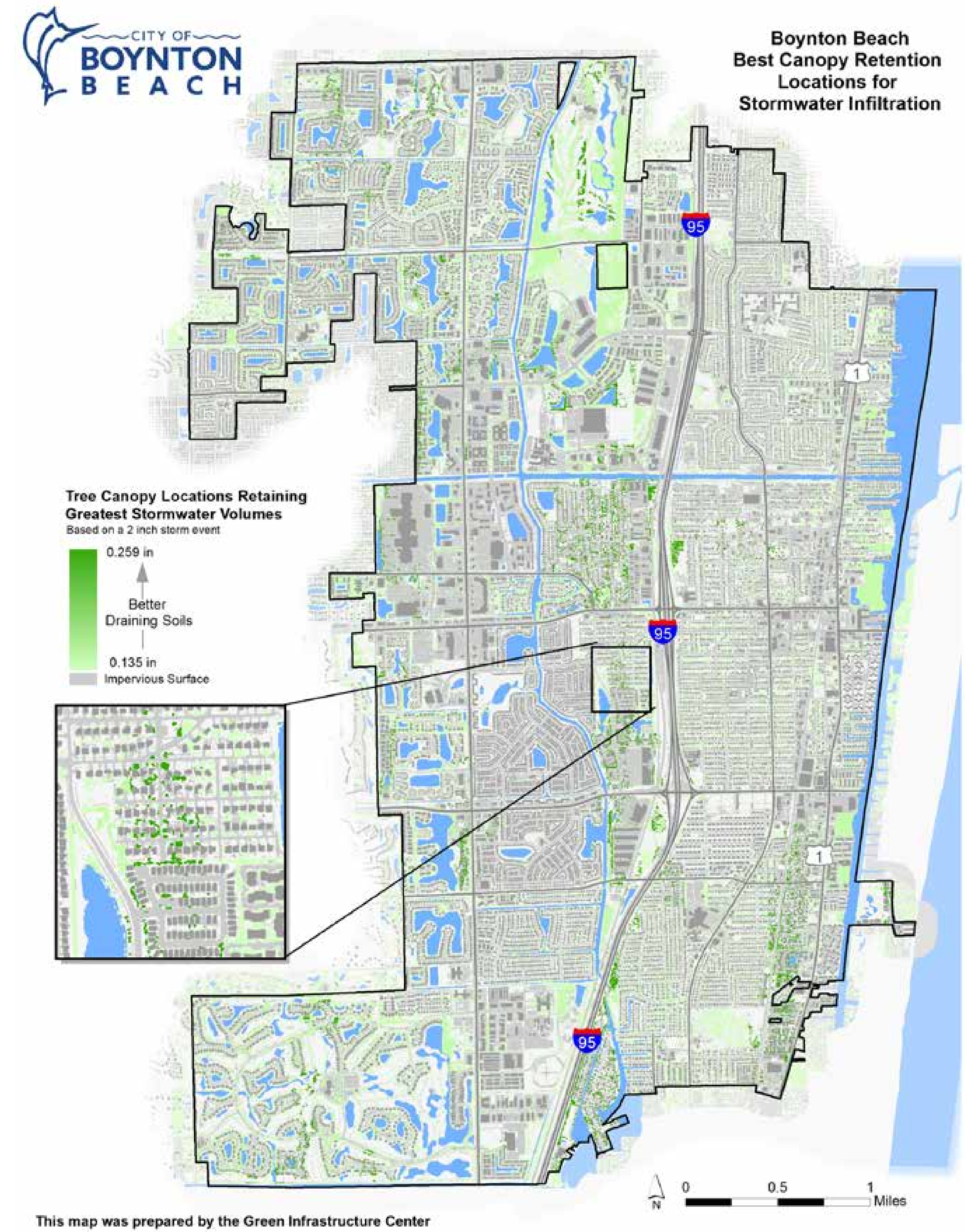
As an example of how the TSC tool works, if the City had a 5 percent loss of tree canopy, during a 10-year storm event, there would be an additional 2.7 million gallons of stormwater runoff (more than 4 Olympic swimming pools of water). If half the available PPA of each watershed was planted – increasing tree canopy – the TSC tool shows a decrease in stormwater runoff (or increase in capture) of 1.3 million gallons of water. Thus, the tool can be used to model the results of adding or losing tree canopy and the pollution increases or decreases (nitrogen, phosphorus, sediment).

Removal of mature trees and existing forest generates the greatest impact for stormwater runoff. As more land is developed, the City should seek to maximize tree conservation, in order to maintain its surface water quality and groundwater recharge. The following maps show both those areas where it is most important to retain trees for stormwater uptake and those where tree planting will have the most benefits for stormwater uptake. This is based on the types of soils present.



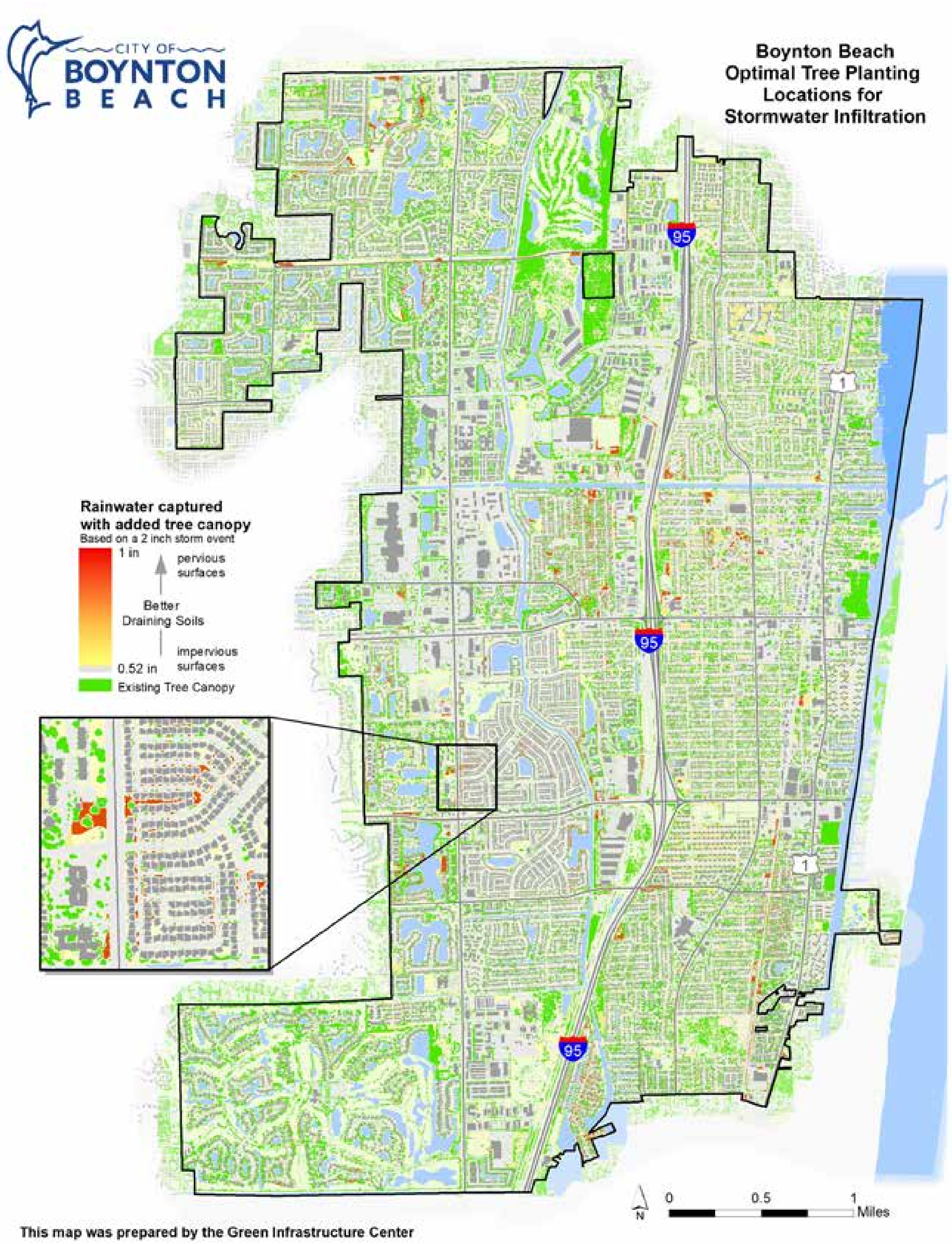


Impact of Tree Loss



This map applies the TSC model to show the places where tree loss will result in the greatest stormwater runoff.

Benefits of Added Trees



This map applies the TSC model to show the places where adding trees will result in the greatest stormwater capture.

Air Quality

The benefits of trees for air quality were calculated by applying the multipliers used by the i-Tree models. I-Tree is a peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefit assessment tools. The i-Tree researchers developed standard pollution removal values per acre for various air pollutants. The following i-Tree model values for urban areas were used to multiply acres of canopy to derive the pollution removal values calculated.

Carbon contributes to climate change. Trees mitigate climate change by sequestering carbon from carbon dioxide (CO_2) in their leaves, trunk, and roots, and prevent it being released into the atmosphere where it can form greenhouse gasses. As trees die, they release that carbon back to the atmosphere. As greenhouse gases are formed, they can cause warming. So much carbon is being produced from fossil fuels and other sources that the Earth's temperature is warming, leading to sea level rise, wetter and more severe storms and more very hot days, which can have other health impacts. Planting trees helps absorb and trap excess carbon.

Ground level ozone, O_3, is another air pollutant of concern because it can cause severe respiratory problems in humans. It can make lung muscles constrict, trapping air in the alveoli, leading to wheezing and shortness of breath, which is particularly harmful to those with respiratory diseases or chronic conditions, such as asthma. Nitrogen dioxide (NO_2) and sulfur dioxide also irritate airways in the respiratory system and aggravate respiratory conditions, such as asthma.

PM10 is particulate matter measuring 10 micrometers or less in diameter and PM2.5 is particulate matter 2.5 micrometers or less in diameter (a human hair is about 100 micrometers = about 40 fine particles). PM2.5 is generally described as "fine particles." Finer particles have the potential for greater harm since they may lodge deeper in the lungs. Trees are able to filter and clean such particles from the air.

Pollutant Removal Multipliers for Urban Areas from i-Tree Model

Pollutant (Abbrev.)	Benefit Description	Removal rate (lbs/acres/year)
CO	Carbon monoxide removed annually	1.13
NO_2	Nitrogen dioxide removed annually	6.241
O_3	Ozone removed annually	48.212
PM10	Particulate matter greater than 2.5 microns and less than 10 microns removed annually	13.683
PM2.5	Particulate matter less than 2.5 microns removed annually	2.463
SO_2	Sulfur dioxide removed annually	3.068
CO_2 seq	Carbon dioxide sequestered annually in trees	10,010.27
CO_2 stor	Carbon dioxide stored in trees (note: this benefit is not an annual rate)	251,395.36

Pounds of air pollution and greenhouse gases removed annually by City trees in Boynton Beach

CO	NO_2	O_3	PM10*	PM2.5	SO_2	CO_2seq	CO_2stor
1,648.42	9,104.24	70,330.68	19,960.48	3,592.97	7,922.58	14,602,773.76	366,730,432.92

Urban Tree Loss – Reversing the Trend

Boynton Beach now has baseline data to monitor progress on canopy protection and expansion, and to measure the stormwater and water quality benefits of its urban forest. It can also use the data to prioritize canopy restoration in specific areas where it is most needed. Currently, the City's canopy coverage is 16.1%, but the City plans to expand it significantly.

A Downward Trend

The City's recent canopy trend is downward. Based on this study's analysis of canopy change over two years (2017-19), the City suffered a net loss of 1% of its tree canopy, which can be modeled as 1,800 trees over two years, or 900 annually (estimated). The GIC modeled this loss as 690 small trees and 1,119 large shade trees[5]. If this trend continues, the City's canopy could decline to considerably low levels. This is why new action is needed to regrow the canopy.

Many streets have room for more trees to add shade, beauty, and air quality.

To change the loss trajectory, the City needs to actively plant trees to replace those lost to natural mortality (old age), storms, development, pests, neglect, or poor care. As older trees die (or before they die), younger trees need to be planted to replace older canopy. While the City has been planting some trees, far more trees are needed, especially in those areas where the canopy is at its lowest.

This tree canopy assessment also mapped canopy coverage percentages by income and by race. Tree canopy coverage varies across the City and it is less in census tracts that have lower incomes and higher percentages of minority populations. This analysis showed that in census tracts where people's income range is moderate-to-low, the average canopy percentage is around 13%, which is about 3% less than the City average.

Why Are Urban Trees Declining?

Tree loss is not a unique problem to Boynton Beach. Trees are declining throughout the southern United States. Cities are also losing older, established trees as a result of the cumulative impacts of land development, storms, diseases, old age, and other factors (Nowak and Greenfield 2012). A 2007 study of Palm Beach County found a decline of 38% of forest cover in the county's urbanized areas from 2004 to 2006, primarily from hurricanes (American Forests). This decline was modeled to increase air pollutants by 2.3 million pounds.

It is not just development and storms that contribute to tree loss. Millions of trees are lost when they reach the end of their life cycle through natural causes. Choosing the wrong tree for a site or climate, planting it incorrectly, or caring for it poorly can also lead to tree canopy loss. For every 100 street trees planted, only 50 will survive 13-20 years, largely due to poor planting conditions and care (Roman et al 2014). Even in older developed areas with a well-established tree canopy, redevelopment projects may remove trees. It is also important to realize that a well-treed neighborhood of today may not have good coverage in the future unless young trees – the next generation – are planted now.

Tree topping – cutting off the upper limbs – can harm and kill trees and should never be practiced.

5 This is a modeled and not an actual number. For greater accuracy, a longer time interval – aka 4 years apart – is necessary. A satellite image can show tree loss but it may not capture young saplings or new trees under 10 feet that have not yet reached maturity.

Increasing Canopy Cover

To change the downward trajectory and realize the tremendous ecosystem services that trees provide, the Green Infrastructure Center and the City's Sustainability Coordinator recommend that the City of Boynton Beach adopt a goal to achieve 20% canopy coverage by the year 2035. The City's current tree canopy coverage (including palms) is 16.1%. Increasing the canopy by 4% will entail planting approximately 30% of the City's Potential Planting Area, or about 392 acres of new canopy.

Expanding the City's tree canopy will meet several objectives:

- Reduce urban heat island effect
- Beautify neighborhoods and improve property values
- Improve community health and equity
- Mitigate stormwater to reduce flooding risks
- Help meet the City's greenhouse gas reduction targets

The proposed tree canopy goal aligns with the City's 2020 Climate Action Plan target of reducing community-wide greenhouse gas emissions 50% below 2015 levels by the year 2035.

Each year, trees in Boynton Beach are lost to storms, development and old age as well as removals by individuals. Based on canopy comparisons over a recent two-year period, the City lost approximately 1800 trees (900 per year). However, the City does not expect annual tree removals to continue at that rate in the coming years. First, the annual population growth from 2019 to 2035 is projected to be 0.86% per year, lower than the 2.5% per year rate from 2017 to 2019. In addition, the City will encourage development plans that include tree retention in site layouts and protect trees during construction. For these reasons, the City estimates future annual tree removals of 600 trees or less.

Trees planted by City residents in their yards are key to meeting the planting goal.

Image credit: Community Greening

In May 2020 residents were able to safely obtain free trees to plant through the Trees in Trunks event.

Meeting the 20% by 2035 canopy goal (including reducing tree removals as noted) would require planting a total of about 45,000 trees in 15 years, or approximately 3,000 trees per year. It is recommended that about 30% of new plantings be large canopy trees (40' wide canopy spread) and about 70% be understory trees (20' wide canopy spread).

The recommended citywide goal of 3,000 trees planted per year will require financial investments by the City of Boynton Beach, private developers, and residents, with supplemental funding by grants and corporate sponsorships. To motivate the private sector's contribution, the City will launch a tree planting campaign and engage developers, residents, garden clubs, environmental organizations, and other stakeholders in doing their part to reach the planting goal. The campaign may include ways to donate trees to the City and to recognize citizens, companies, and sponsors who contribute to a cleaner, greener city. As the City works to meet the canopy goal, they will document progress by tracking trees planted by location and species.

Costs of trees vary based on size and method of planting, as shown in the table on page 26. The City could utilize a variety of planting methods to achieve its portion of the canopy goal. Funding for tree planting and maintenance will be included in the City's future fiscal year budgets, as well as through potential new revenue sources such as the establishment of a "tree fund." In addition, the City expects to be more competitive for grant funding after completing this assessment and committing to the tree planting goal. As the City considers the cost of planting and caring for more trees, it's important to note that studies have shown that "twenty years after planting, average annual benefits for all public trees exceed costs of tree planting and management" (Peper et al 2010). So, while the City will need to expend more funds to increase its canopy coverage, those trees will more than pay their way.

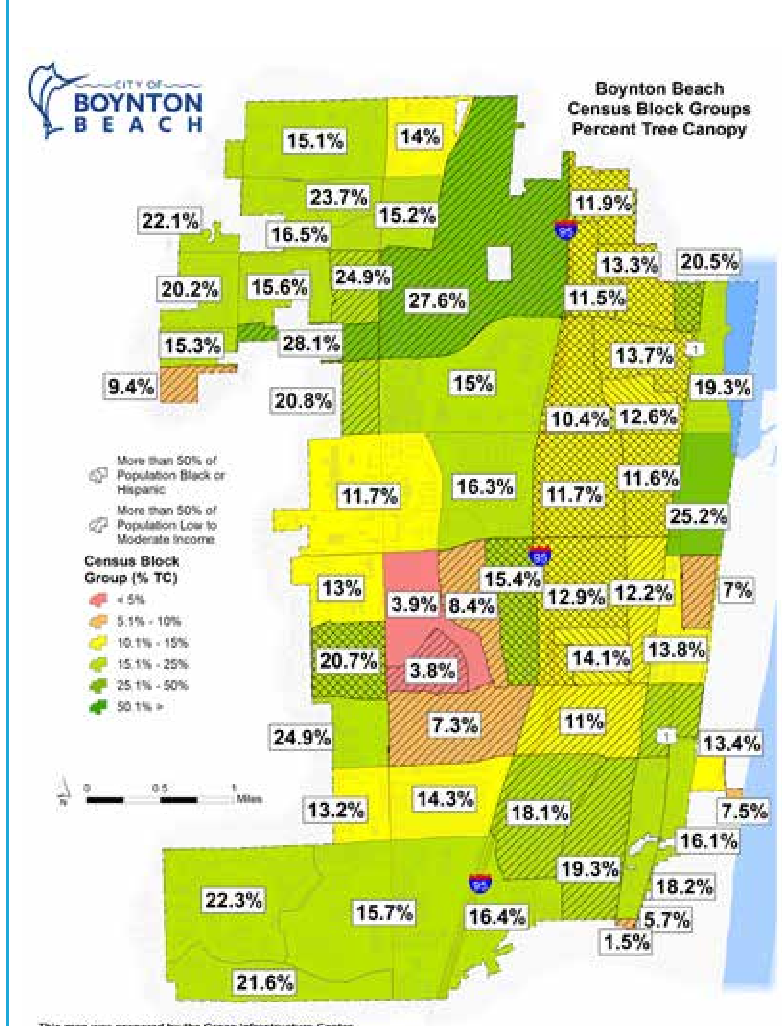
Type of tree planting	Tree size	Estimated cost per tree
Large specimen ("instant canopy") trees planted by City staff on City-owned lands	45 gallon+, 4" caliper and 14' height per City code	$300+
Medium-size trees planted by contractor in right-of-way and public lands	25 gallon, 2-3" caliper	$270
Small trees planted by contractor on City and public-private lands (parks, schools, churches, non-conforming lots)	15 gallon, 1-2" caliper	$190
Trees distributed to residents at Tree Giveaways	3 gallon	$35

The next step is for the City to select and prioritize target areas for implementation of the tree planting goal, such as census block groups with highest mean temperatures, City parks, schools, and/or specific streets. For a list of canopy cover by parks, see Appendix D. The City will use the tree planting and cost calculator developed by GIC to determine numbers of trees to plant within the Potential Planting Areas across specific target geographies. The city should also review its relevant City codes and ordinances using GIC's policy analysis tool and create an Urban Forest Management Plan to better care for and replant the City's canopy.

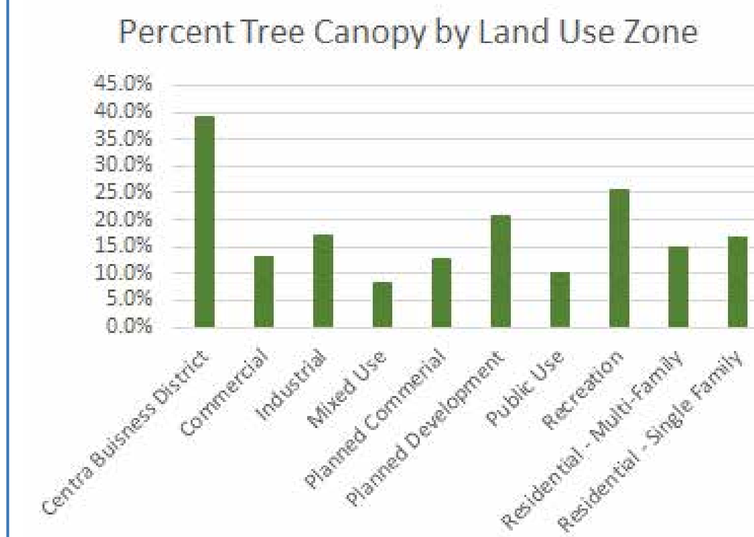
Image credit: Community Greening

Community planting is key to the City's success in meeting the new canopy goal.

Tree Canopy Census Block Groups



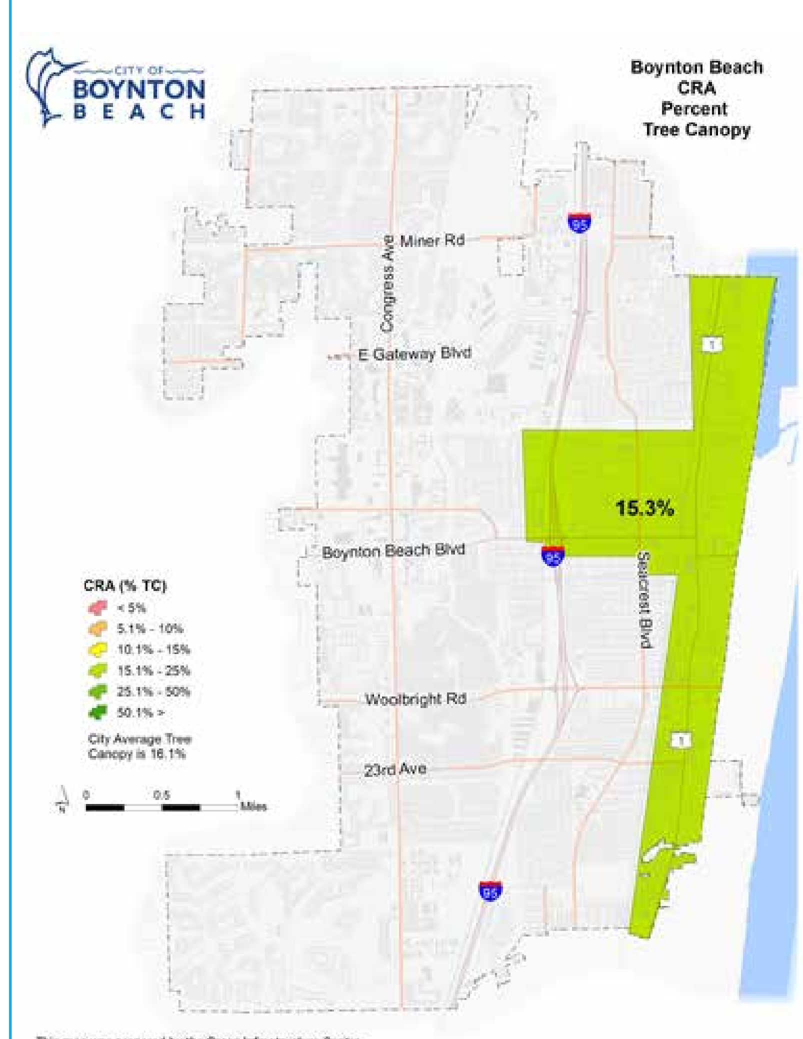
Census data can be used to target trees to areas based on income. Areas with lower income also correlate to those places with lower canopy levels



Meeting the 20% canopy goal by 2035 requires planting approximately 3,000 trees per year.

Tree canopy varies by zoning class. Note the Central Business District canopy is high because it includes mangroves along the waterways.

Targeted Tree Canopy



Tree planting can also be targeted to city redevelopment areas to meet City goals for revitalization.

Recommendations – Next Steps

To achieve the recommended citywide canopy coverage goal of 20%, a concerted Tree Planting Campaign will be needed. The City will engage with key stakeholders and communities over the next year to create multiple avenues to plant and care for new trees. The City staff and Commission will evaluate how best to fund tree plantings as well as ongoing maintenance of the City's tree canopy.

1. The City of Boynton Beach can use the TSC tool and other ecosystem benefit multipliers to determine the benefits of maintaining or increasing tree canopy. They can also use carbon credit calculators to integrate tree canopy benefits into the citywide greenhouse gas emissions inventory, which is used to track progress on the Climate Action Plan.

2. The City will share results of this analysis with the consultants who are conducting a multi-jurisdictional climate change vulnerability assessment for the Coastal Resilience Partnership of Southeast Palm Beach County. Tree canopy will be considered as part of the community's "adaptive capacity," or its ability to cope with climate change impacts, such as extreme heat and flooding.

3. It is recommended that Boynton Beach undertake a codes and ordinance evaluation using GIC's Trees and Stormwater Codes and Practices Audit tool to identify all the ways in which the City can reduce impervious areas and improve tree canopy and management.

4. The City will plant and promote the planting of tree species with high ecological value as much as possible—including native and drought-tolerant species, hurricane-resistant species, and those that support biodiversity.

5. An urban Forest Management Plan is another key study the City should undertake to ensure that it has detailed and actionable processes to care for and better manage its trees. Grant funding is available from the Florida Forest Service for such activities.

6. The City does not have a plan for replacing trees lost to natural disasters, such as hurricanes or other storms. A key aspect of urban forest management is developing a Forestry Emergency Response Plan. This should be coordinated with Palm Beach County and adjacent cities and towns that share similar concerns about storm debris and removal or repurposing waste wood. Given the many benefits that trees provide, the City should plan for and fund tree replacement following natural disasters.

7. Lastly, it is recommended that the City conduct a land cover assessment every four years to compare tree canopy coverage change over time in order to track progress on meeting the canopy goal of 20% coverage. Keeping tree canopy coverage at levels that promote public health, walkability, and clean water is vital for livability and meeting state water quality standards.

These, and other practices, implemented to provide long-term care, protection, and best planting practices for the urban forest, will ensure that investments in City trees will pay dividends by reducing stormwater runoff, as well as cleaning the air and water, lowering energy bills, raising property values, and providing natural beauty long into the future.

Combining tree plantings with best management practices, such as permeable parking, can dramatically reduce stormwater runoff volumes while capturing and cleaning pollutants.

Image credit: Community Greening

Appendix A: Land Cover Analysis Methods

This section provides technical documentation for the methodology used to classify land cover and create Potential Planting Spots and Potential Canopy Area scenarios for the City. Land cover classifications are an affordable way to use aerial or satellite images to obtain information about large geographic areas. Algorithms are trained to recognize various types of land cover based on color and shape. In this process, the pixels in the raw image are converted to one of several types of pre-selected land cover types. In this way, the raw data (images) are turned into information about land cover types of interest, such as what is pavement and what is vegetation. This land cover information can be used to gain knowledge about certain issues; for example: What is the tree canopy percentage in a specific neighborhood?

Method

Satellite imagery from the National Agricultural Imagery Program (NAIP) distributed by the USDA Farm Service Agency was classified to determine the types and extent of different land covers in Boynton Beach.

Two canopy maps were created using the NAIP imagery – one from October 30, 2017 at 1-meter resolution, and one from November 20, 2019 at 0.6m resolution (higher resolution than 2017). Feature height data were derived from LiDAR 2017 (Light Detecting and Ranging high resolution elevation data) from the US Geologic Survey and existing hydrological and infrastructure data provided by the City of Boynton Beach. These data sets were used to determine the following nine feature classes:

1. Tree Canopy: These are features identified as "green" or typically above 0 in NDVI (Normalized Differential Vegetation index), and that have a feature height above 10 feet.
2. Tree Canopy over impervious: These are features that overlap Impervious surfaces and are primarily created from existing vector data, where available.
3. Mangroves: These were identified based on local knowledge and on-the-ground visual inspection.
4. Palm trees: These were identified, where possible, as Tree Canopy type features smaller than 10 square meters in diameter. They were ground-truthed in many cases by GIC field staff.
5. Scrub/Shrub: Spectrally, these features appear very similar to tree canopy but do not meet the height requirement to be considered as trees, but are above 1 meter in height.
6. Turf/Pervious: These are features identified as "green" or typically above 0 in NDVI, but have a feature height less than 1 meter.
7. Impervious surfaces: These were created using an object-based recognition tool ArcGIS add-on called Feature Analyst, as well as existing vector data, such as road edge and building polygons. These features are typically below 0 on an NDVI.
8. Bare earth and Sand: These can be easily confused with impervious surfaces, but have a NDVI value closer to 0.

In the Table below, 'Bare earth' is easily misidentified as pervious surfaces. But curve numbers in the TSC tool are similar and so this does not affect that analysis. In some places, sidewalks or golf cart paths were identified as bare earth under canopy. But there are only a few places like this; so, the overall area of the class is small as a total percentage of City land cover.

The NAIP 2017 image was originally used as the primary input. However, during the course of the project, 2019 NAIP imagery became available. Therefore, the 2019 classification was created using an NDVI image that showed where tree canopy had changed (i.e. It went from being the 2017 tree canopy to an NDVI value of less than 0, indicating that it had become an impervious feature).

A Confusion Matrix was run to test the accuracy of the canopy data, with these results:

Class Value	Tree Canopy	Mangrove	Scrub/ Shrub	Pervious	Water	Impervious	Bare earth	Points Sampled	Accuracy
Tree Canopy	37	0	0	0	0	0	0	37	100.0%
Mangrove	0	10	0	0	0	0	0	10	100.0%
Scrub/Shrub	0	0	11	0	0	0	0	11	100.0%
Pervious	0	0	0	63	0	0	0	63	100.0%
Water	0	0	0	0	19	0	0	19	100.0%
Impervious	1	0	0	1	0	117	0	119	98.3%
Bare earth	0	0	0	1	0	3	6	10	60.0%
Points Sampled	38	10	11	67	19	120	6	269	97.0%

Potential Planting Area Dataset

The Potential Planting Area dataset has 3 components:

1. Potential Planting Area (PPA)
2. Potential Planting Spots (PPS)
3. Potential Canopy Area (PCA)

These three data layers were created using the land cover layer and relevant data, in order to exclude unsuitable tree planting locations or where they would interfere with existing infrastructure. Images of these data are found in the report on pages 14-15.

NAIP Image 2017

Potential Planting Area (PPA)

The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees, then eliminating areas that would interfere with existing infrastructure.
Initial Inclusion selected from GIC-created land cover pervious surfaces class.
Exclusion Features:

- The pervious surfaces were buffered in 10 ft. from all impervious surfaces, including buildings and roads.
- Playing fields were identified from NAIP imagery to be excluded. (Digitized by GIC.)
- Once this initial phase was completed, the Potential Planting Area data were reviewed by the City and manually edited to best represent City expectations of where planting was allowed (e.g. not along canals or on play fields). Exclusions such as 'distance from canals and other utilities' were applied during this review phase. In addition, areas that were known to be planned for development were removed.

This additional work to exclude known areas that could not be planted resulted in a more accurate and realistic calculation of plantable areas and the number of new trees that could be added.

Potential Planting Spots (PPS)

The Potential Planting Spots (PPS) were created from the PPA.

- They were run through a GIS model that selected those spots where a tree can be planted, depending on the size of the tree.
- Tree planting scenarios were based on a 20 ft. and 40 ft. mature tree canopy with a 30% overlap. Therefore, the planting spots are 16 ft. and 32 ft. apart, respectively.

The Potential Canopy Area (PCA) is created from the PPS. The possible planting spots are given a buffer around each point that represents a tree's mature canopy. First, larger canopy trees are digitally added, followed by smaller trees in the remaining spaces. Planting spots are then assigned a buffer of 10 ft. or 20 ft., to result in 20 ft. and 40 ft. tree canopy that overlaps by 30%. This reduces gaps that would be found at the corners of adjacent circles and reflects the reality that trees overhang and intermingle with adjacent trees.

Potential Canopy Area (PCA)

Appendix B:
Trees and Stormwater Calculator

The Trees and Stormwater Calculator (TSC) tool developed by GIC uses modified TR-55 curve numbers to calculate stormwater uptake for different land covers, since they are widely recognized and understood by stormwater engineers. A canopy interception factor is added to account for the role trees play in the interception of rainfall, based on location and planting conditions (e.g. trees over pavement versus trees over a lawn, or in a forest).

Cities usually use TR-55 curve numbers developed by the Natural Resources Conservation Service (NRCS) to generate expected runoff amounts. The modified TR55 curve numbers (CN) provided by GIC includes a factor for canopy interception. Cities can use the stormwater calculator tool for setting goals at the watershed scale for planting trees and for evaluating consequences of tree loss as it pertains to stormwater runoff. Curve numbers produced for this study can be utilized in the City's modeling and master plans for areas of the city.

Tree canopy reduces the proportion of precipitation that becomes stream and surface flow, also known as water yield. A study by Hynicka and Divers (2016) modified the water yield equation of the NRCS model by adding a canopy interception term (Ci) to account for the role that canopy plays in capturing stormwater, resulting in:

$$R = \frac{(P - C_i - I_a)^2}{(P - C_i - I_a) + S}$$

Where R is runoff, P is precipitation, Ia is the initial abstraction, which is the fraction of the storm depth after which runoff begins, and S is the potential maximum retention after runoff begins for the subject land cover (S = 1000/CN – 10).

Major factors determining CN are:

- The hydrologic soil group (defined by surface infiltration rates and transmission rates of water through the soil profile, when thoroughly wetted).
- Land cover types.
- Hydrologic condition – density of vegetative cover, surface texture, seasonal variations.
- Treatment – design or management practices that affect runoff.

Tree over street

Trees over forest

Tree over lawn

Tree over parking lot

This new approach allows for more detailed assessments of stormwater uptake based on the landscape conditions of the City's forests. It distinguishes whether the trees are within a forest, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. This is because the conditions and the soils in which the tree is living affect the amount of water the tree can intercept.

The analysis can be used to create plans for where adding trees, or better protecting them, can reduce stormwater runoff impacts and improve water quality. This methodology was developed and tested in 13 communities in the southern US including three in Florida, under a grant from the Southern Region of the USDA Forest Service. For more about the project, please visit http://www.gicinc.org/trees_stormwater.htm

Improved tree canopy coverage means a cleaner Intracoastal Waterway!

Appendix B: Bibliography

______ American Forests. 2007. Urban ecosystem analysis, Palm Beach County, Florida: calculating the value of nature. Washington, DC. 16 p.

______ Appendix: Hynicka, Justin, and Marion Divers. "Relative reductions in non-point source pollution loads by urban trees", in Cappiella, et al, *Recommendations of the Expert Panel to Define BMP Effectiveness for Urban Tree Canopy Expansion*, 2016.

________Runoff and infiltration graphic. EPA Watershed Academy Website. Accessed February 19, 2019: https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=170

_______"Complete Green Streets. Smart Growth America". Website accessed February 20, 2018: https://smartgrowthamerica.org/resources/complete-and-green-streets/

_______ Penn State Extension, Trees and Stormwater: Website accessed Jan. 1. 2020 http://extension.psu.edu/plants/green-industry/landscaping/culture/the-role-of-trees-and-forests-in-healthy-watersheds

_______"Stormwater to Street Trees". U.S. Environmental Protection Agency, September 2013. EPA report # EPA 841-B-13-001.Web site accessed June 1, 2016: https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf

Akbari, Hashem, Melvin Pomerantz, and Haider Taha. "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas" in *Solar energy*, Vol. 70, No. 3 (2001): pp295-310.

Benedict, Mark A., and Edward T. McMahon, *Green Infrastructure: Linking Landscapes and Communities*. Washington, D.C.: Island Press, 2006.

Benedict, Mark A. and Edward T. McMahon, "*Green Infrastructure: Smart Conservation for the 21st Century*." Washington, D.C., Sprawl Watch Clearing House, May 2002. Accessed February 2018: http://www.sprawlwatch.org/greeninfrastructure.pdf

Booth, Derek B., David Hartley, and Rhett Jackson, "Forest cover, impervious-surface area, and the mitigation of stormwater impacts" in JAWRA *Journal of the American Water Resources Association*, Vol. 38, No. 3 (2002): pp 835-45.

Broschat, T.K. 2010a. Palm nutrition and fertilization. Accessed May 2020 at: https://edis.ifas.ufl.edu/pdffiles/EP/EP26100.pdf

Cappiella, Karen, Sally Claggett, Keith Cline, Susan Day, Michael Galvin, Peter MacDonagh, Jessica Sanders, Thomas Whitlow, and Qingfu Xiao. "Recommendations of the Expert Panel to Define BMP Effectiveness for Urban Tree Canopy Expansion", 2016.

Correll, Mark R., Jane H. Lillydahl, and Larry D. Singell, "The effects of greenbelts on residential property values: some findings on the political economy of open space." *Land economics*, Vol. 54, No. 2 (1978): pp207-17.

Dwyer, John F., E. Gregory McPherson, Herbert W. Schroeder, and Rowan A. Rowntree. "Assessing the benefits and costs of the urban forest" in *Journal of Arboriculture*, Vol. 18 (1992), pp 227-34

Ernst, Caryn, Richard Gullick, and Kirk Nixon, "Conserving forests to protect water", *American Water Works Association*, Vol. 30 (2004): pp 1-7.

Fazio, James R. "How trees can retain stormwater runoff", in *Tree City USA*, Bulletin 55 (2010): pp1-8.

Gregory, J.H., et al, "Effect of urban soil compaction on infiltration rate", *Journal of Soil and Water Conservation*, Vol. 61 No. 3 (2006), pp117-24.

Gregory, Justin H., , et al, "Effect of urban soil compaction on infiltration rate", *Journal of Soil and Water Conservation*, Vol. 61, No. 3 (2006): pp117-24.

Kuehler, Eric, Hathaway, Jon, and Tirpak, Andrew, "Quantifying the benefits of urban forest systems as a component of the green infrastructure stormwater treatment network" in *Ecohydrology*, Vol. 10, No. 3 (2017).

McPherson, E.G. 1993. Evaluating the cost effectiveness of shade trees for demand-side management. *The Electricity Journal*. Vol. 6, No. 9 (1993): pp: 57–65.

McPherson, E. Gregory, and Muchnick, Jules, "Effect of street tree shade on asphalt concrete pavement performance", in *Journal of Arboriculture*, Vol. 31, No. 6 (2005) p303-10.

McPherson, E. Gregory, David Nowak, Gordon Heisler, Sue Grimmond, Catherine Souch, Rich Grant, and Rowan Rowntree. "Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project." *Urban ecosystems* 1, no. 1 (1997): 49-61.

Meenakshi, Rao, L.A. George, T. N. Rosenstiel, V. Shandas, A, Dinno, "Assessing the relationship among urban trees, nitrogen dioxide, and respiratory health" in *Environmental Pollution*, Vol. 194, November 2014: pp 96-104. Accessed on May 1, 2015 at: https://phys.org/news/2014-09-trees-asthma-respiratory-diseases.html#jCp

Nowak, David John. *Assessing urban forest effects and values: Washington, DC's Urban Forest*. Vol. 1. United States Department of Agriculture, Forest Service, Northern Research Station, 2006.

Nowak, D.J., and Greenfield, E.J., "Tree and impervious cover change in U.S. cities", in *Urban Forestry & Urban Greening*, Vol. 11 (2012); pp21-30. Accessed on July 2, 2013 at: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1239&context=usdafsfacpub

Nowak, et al, (2010). *Sustaining America's Urban Trees and Forests*. Accessed on July 2, 2013 at: https://www.fs.fed.us/openspace/fote/reports/nrs-62_sustaining_americas_urban.pdf

Peper, P.J.; McPherson, E.G.; Simpson, J.R.; Xiao, Q. 2009b. City of Orlando, Florida municipal forest resource analysis. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. P. 58

Peper, Paula J.; McPherson, E. Gregory; Simpson, James R.; Albers, Shannon N.; Xiao, Qingfu 2010. Central Florida community tree guide: benefits, costs, and strategic planting. Gen. Tech. Rep. PSW-GTR-230. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. Website accessed May 2020 at: https://www.fs.fed.us/psw/publications/documents/psw_gtr230/

Roman, Lara A., Battles, John J., and McBride, Joe R. , "Determinants of establishment survival for residential trees in Sacramento County, CA", in *Landscape and Urban Planning*, Vol. 129 (2014): pp22-31.

Roman, Lara A., and Scatena, Frederick N., "Street tree survival rates: Meta-analysis of previous studies and application to a field survey in Philadelphia, PA, USA", in *Urban Forestry & Urban Greening*. Vol. 10, No. 4 (2011): pp 269-274.

Souch, C. A., and Souch, C., "The effect of trees on summertime below canopy urban climates: a case study Bloomington, Indiana", in *Journal of Arboriculture*, Vol. 19, No. 5 (1993): pp 303-12.

Tilt, Jenna H., Unfried, Thomas M., and Roca, Belen, "Using objective and subjective measures of neighborhood greenness and accessible destinations for understanding walking trips and BMI in Seattle, Washington", in *American Journal of Health Promotion*, Vol. 21, No. 4, Suppl (2007): pp 371-9.

Wang, Jun, Endreny, Theodore A., and Nowak, David J., "Mechanistic simulation of tree effects in an urban water balance model", in *JAWRA – Journal of the American Water Resources Association*, Vol. 44, No. 1 (2008): pp 75-85.

Wells, Nancy M., "At home with nature: Effects of "greenness" on children's cognitive functioning," in *Environment and Behavior*, Vol. 32, No. 6 (2000): pp 775-95.

Xiao, Qingfu, E. Gregory McPherson, Susan L. Ustin, Mark E. Grismer, and James R. Simpson."Winter rainfall interception by two mature open-grown trees in Davis, California", in *Hydrological processes*, Vol. 14, No. 4 (2000): pp763-84.