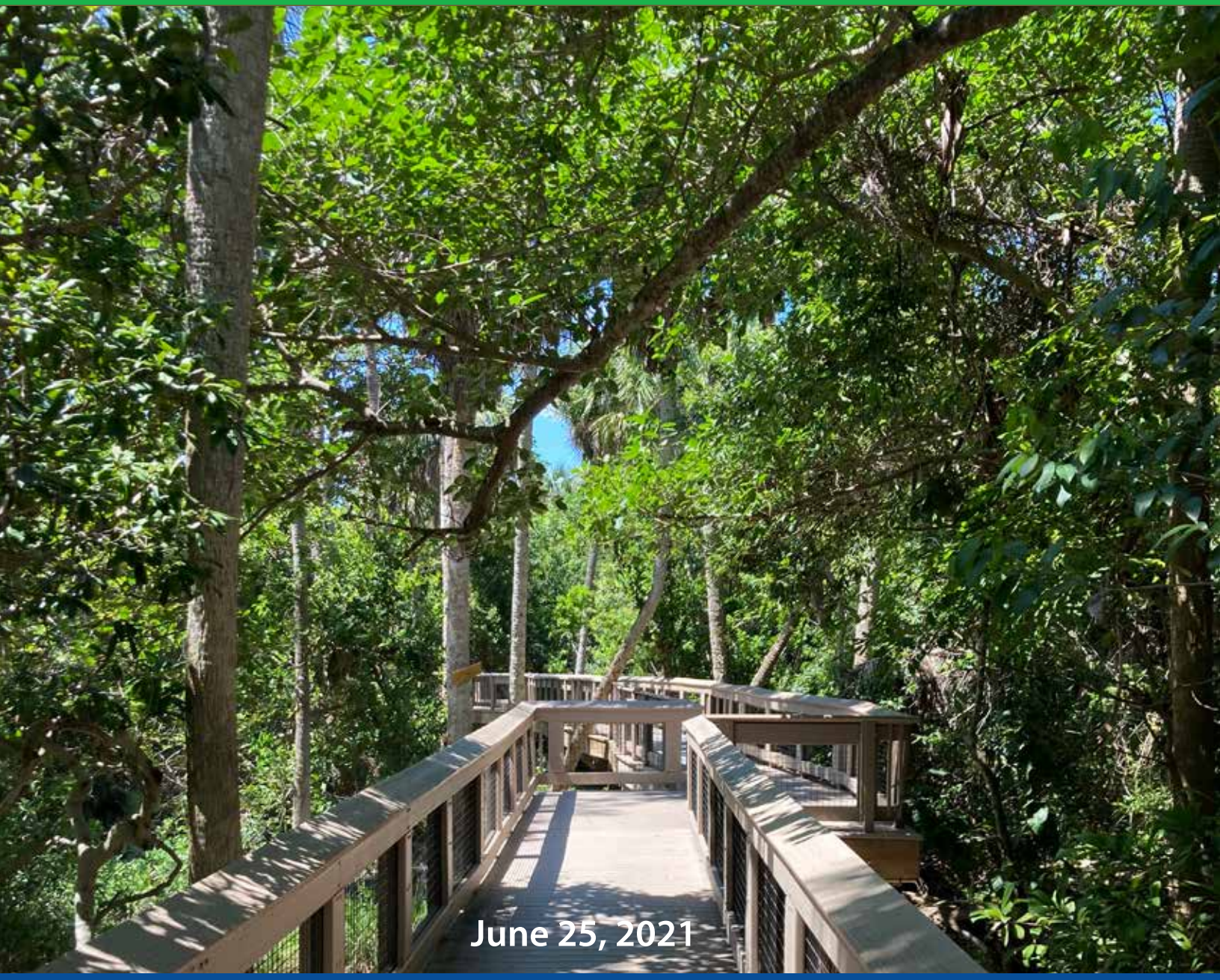
Urban Tree Canopy Assessment

of Boca Raton, Florida



June 25, 2021

An Analysis of Forest Cover and Benefits

City of Boca Raton
Office of Sustainability

Report by the
Green Infrastructure Center Inc.

Green Infrastructure Center

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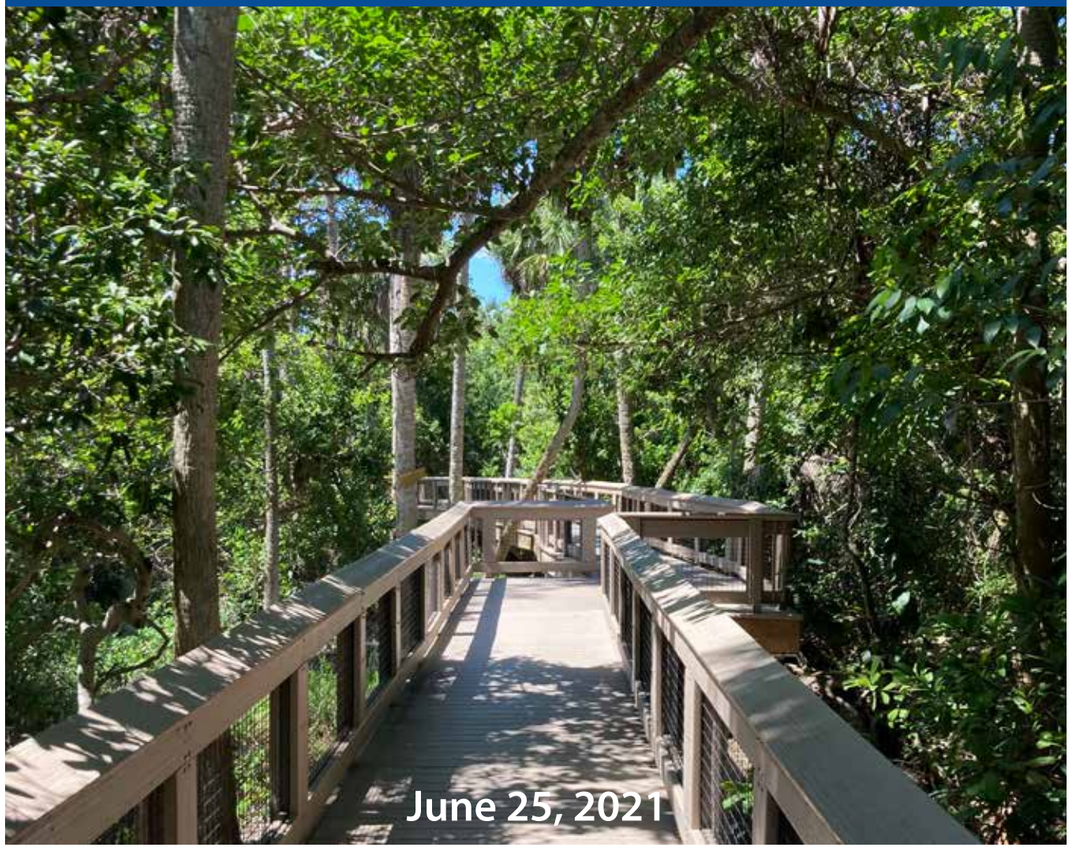

City of Boca Raton
Office of Sustainability

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Project Overview and Findings

This report describes the City of Boca Raton's (City) current tree canopy coverage and the benefits that the its trees provide. The City provided funding to the Green Infrastructure Center (GIC) to conduct the assessment to determine the extent of the tree canopy and plantable areas, and to model environmental benefits. This report can be used by the City to assess and track its tree canopy cover and create strategies to retain or expand it.

Products created from this work include:

- Analysis of the current extent of the urban forest through high-resolution tree canopy mapping.
- A Potential Planting Area analysis to determine where additional trees could be planted.
- Calculations of the environmental and social benefits provided by the City's trees.
- Recommendations for expanding city canopy coverage over time.

Fast Facts & Key Stats

County: Palm Beach

2019 Population Estimate: 99,805 people

Total City Area: 30.3 sq. miles

Land: 27.9 sq. miles; 17,856 acres*

Surface water and wetlands: 1,556 acres

Canals/streams: 1,556 acres

Tree canopy: 4,716 acres
covering 26.5% of the City
(25.9% trees, 0.6% mangroves)

*Includes right of way

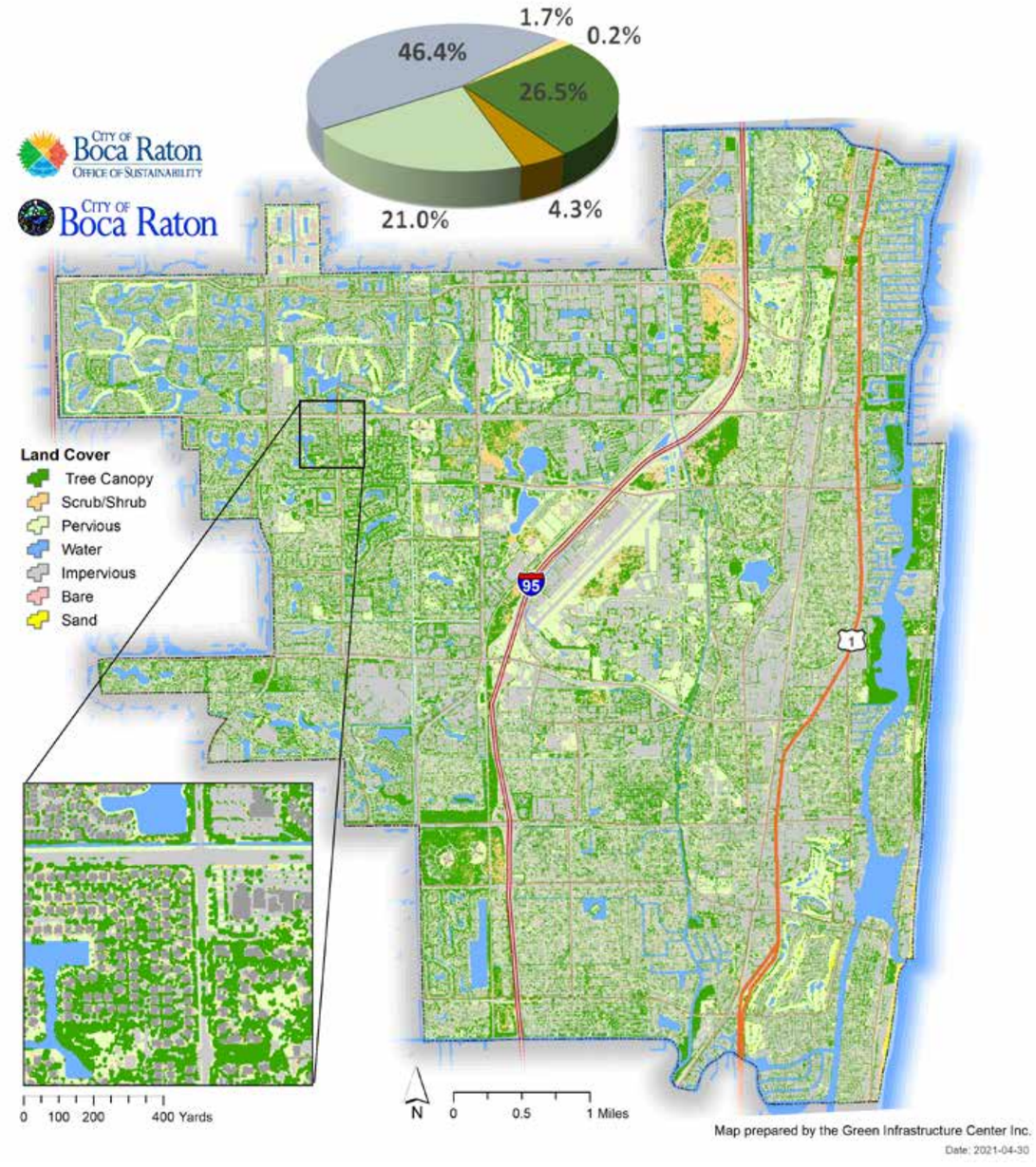
Canopy Cover

The City of Boca Raton has a current tree canopy cover of 26.5%. It is recommended that the City increase its canopy by 1.5%, to achieve 28% canopy cover by 2041 in order to realize additional benefits for clean air, water, walkability, energy savings and economic benefits from sales, rental rates and real estate values.

The City of Boca Raton can use the results of this tree canopy assessment to:

- Track progress toward achieving a recommended tree canopy goal of 28% by 2041.
- Document the environmental and social benefits the City's trees provide.
- Determine the most strategic locations to either retain or plant trees.
- Inform urban forest management with strategic investments in tree care and planting.

Total Land Area (acres)	Tree Canopy (acres)	Tree Canopy %	Impervious Surfaces (acres)	Impervious Surfaces %	OtherLand (acres)	OtherLand %
17,857	4,716	26.5%	8,288	46.4%	4,852	27.2%



Canopy Benefits

An extensive tree canopy can provide a wide range of benefits to a community, such as improved air quality, the mitigation of stormwater runoff and associated water pollution, reduction of urban heating and significant savings in energy consumption.

Air Quality

Trees play a critical role, not only in providing oxygen, but also cleaning the air of particulate matter and ground level ozone (O3), which can harm human health. Trees sequester greenhouse gases, such as sulphur dioxide and carbon dioxide and as these gasses are trapped by trees, the severity of climate change is reduced. Trees also store carbon and prevent its release, further ameliorating the impact of possible climate change. For example the annual carbon storage by the city's trees is equivalent to taking 3,943 cars off the road annually![1]

Stormwater and Water Pollution Uptake

The City's trees mitigate stormwater runoff impacts since they capture rainfall in their canopies, trunks, roots and surrounding soils. Some of that water is released back into the atmosphere through evapotranspiration. One mature, large tree can absorb thousands of gallons of water per year.

The **Trees and Stormwater (TSW) Calculator** tool created for this project can be used to model stormwater uptake for various storms that occur throughout the year. For example, the TSW tool shows that during a 1-year storm event (4.63 inches of water) the City's trees capture 33.1 million gallons of stormwater, or the equivalent of 50 Olympic swimming pools of water!

The City's trees also capture 6% of the nitrogen, 10% of the phosphorus and 11% of the sediment that would otherwise be carried by stormwater runoff to open waters. Thus, trees perform an important "ecosystem service" by taking up stormwater, cleansing the water and reducing flooding.

During a 1-year storm event (4.63 inches of water) the City's trees capture 33.1 million gallons of stormwater, or the equivalent of 50 Olympic swimming pools of water!

Pounds of pollution and greenhouse gases removed by Boca Raton's Trees (Annually unless otherwise noted)

CO (carbon monoxide)	**NO_2** (nitrogen dioxide)	**O_3** (ozone)	**PM_{10}*** (particulate matter 10 microns)	**$PM_{2.5}$** (particulate matter 2.5 microns)	**SO_2** (sulphur dioxide)	**CO_2seq** (carbon dioxide sequestered)	**CO_2storage** (carbon dioxide storage; total, not annual)
5,330	29,346	227,392	64,536	11,617	14,470	47,313,438	1,185,716,215

PM = Particulate matter

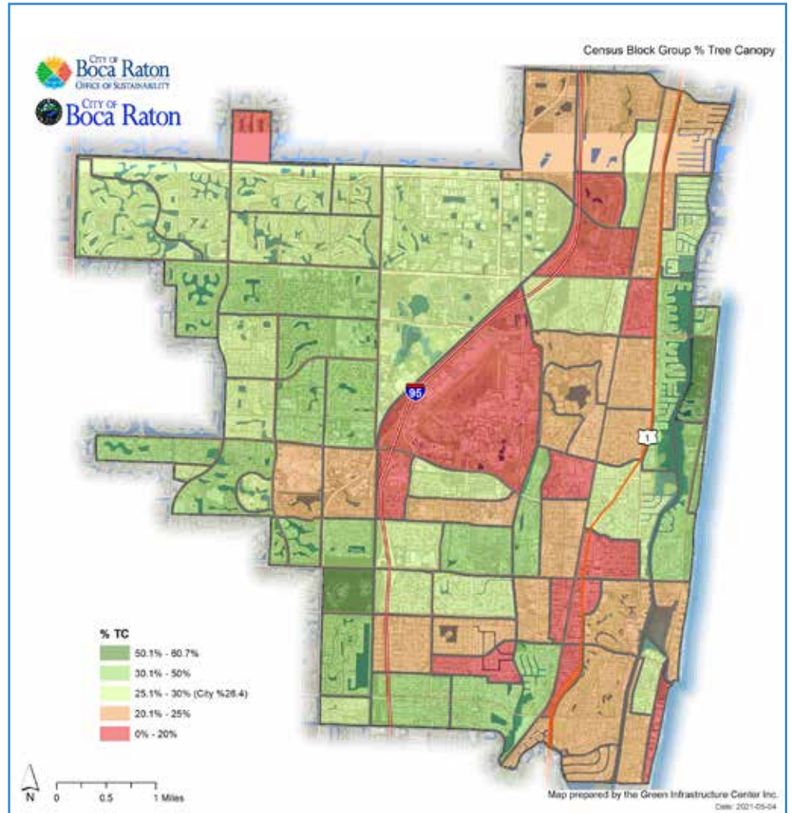
[1] Assuming a relatively efficient car releasing 6 tons of carbon per year. A gas guzzler releases 9 tons.

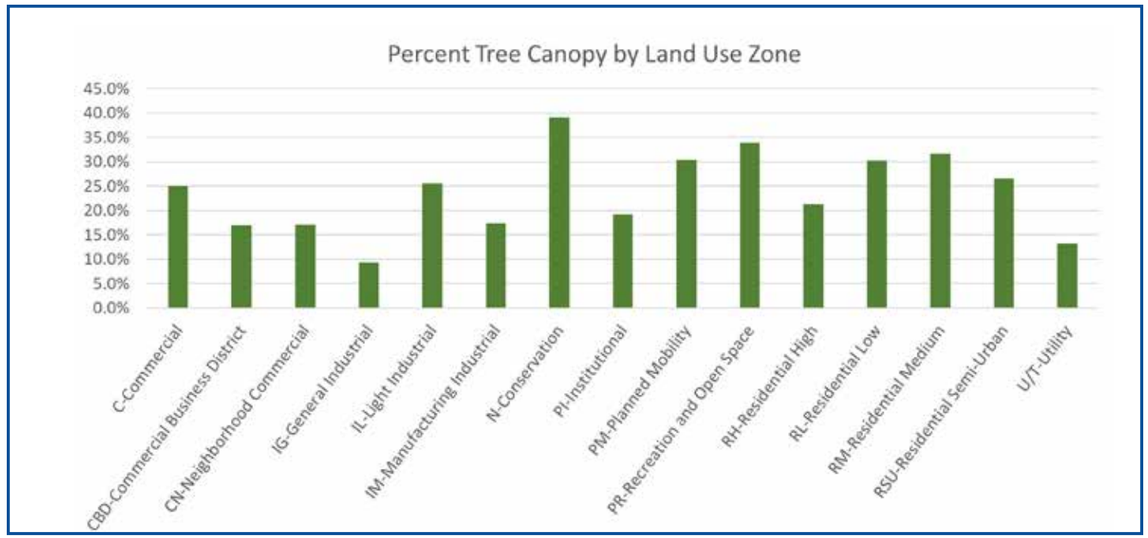
Reducing Urban Heating and Saving Energy

Like many southern cities, the City of Boca Raton suffers from the effects of impervious surfaces, coupled with lack of adequate vegetative cover. Excessive pavement and lack of canopy shade lead to increased temperatures, forming urban heat islands.

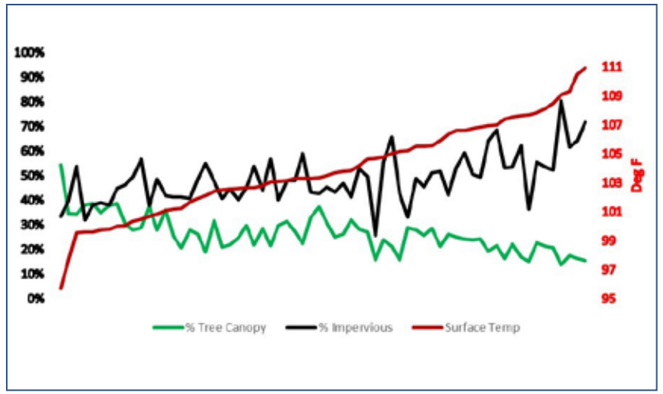
In Boca Raton, higher temperatures were found in lower income Census Block Groups (CBG). A greater percentage of the population from minority classes also experience higher mean temperatures in the City. The City should promote new tree plantings in areas that are hotter, have lower income and a higher percentage of minority classes, in order to help residents who might not be able to afford a new tree.

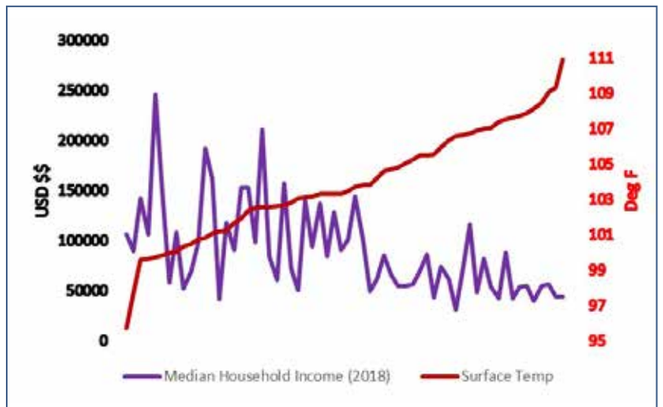
Census data can be used to identify areas where residents might need assistance in planting trees due to lower household income. Areas with lower canopy cover correlate to those with lower incomes.

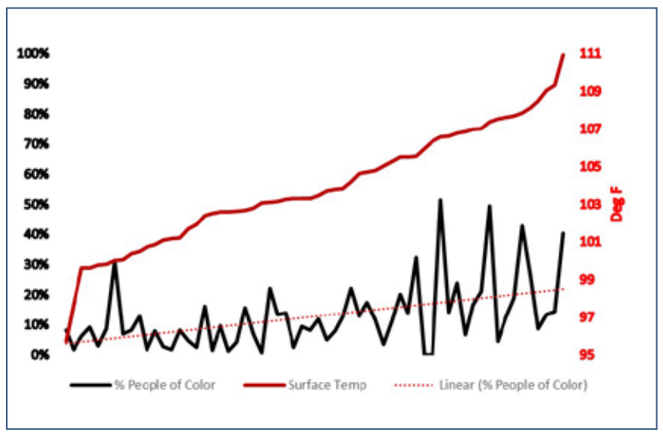




Tree canopy varies across different zoning types.







This assessment also mapped areas where strategically placed trees can do the most good in reducing summer heating and associated cooling costs. As these charts and graphs show, lower income areas are hotter and have less tree cover.

Meeting City Strategies

This assessment supports Boca Raton's Sustainability Action Plan, which describes the City's vision for a "Vibrant and Sustainable City…that achieves a balance between personal livability, environmental stewardship, economic opportunity and community building." The plan calls for increasing shade tree canopy on both public and private properties through a variety of mechanisms, from tree-giveaways and planting projects to new, city-wide policies, such as a requirement to include trees in stormwater management and site planning.

The 30.3 square mile City of Boca Raton has 1,215 acres of municipal parks, beaches and conservation lands, making the City rich in natural amenities that contribute to a high-quality lifestyle. There are plenty of opportunities to enjoy abundant water views and aquatic sports. The City's contains 6.9 miles of the Intracoastal Waterway, including one of the county's four ocean inlets. The Gumbo Limbo Environmental Complex, adjacent to Red Reef Park, provides education and builds public appreciation for the area's ecosystems. The City works to protect these natural assets through its sustainability focus, which guides its Sustainability Action Plan and 2020 Comprehensive Plan (see text box).

Gumbo Limbo Park

BOCA RATON'S SUSTAINABILITY FOCUS

The City's Comprehensive Plan (June 2020) states that, "Boca Raton's guiding principle for future growth can be stated in one word – Sustainability. Environmental experts use the concept of sustainability to describe the ways that communities are designed, built and operated, so that they use energy and natural resources efficiently and equitably."

Boca Raton is also one of seven municipalities that have partnered with Palm Beach County to form the Southeast Florida Coastal Resiliency Partnership (CRP) to complete a joint climate change vulnerability assessment.

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

- **Comprehensive Plan (June 2020)**
- **Sustainability Action Plan: Target 2025 (2019)**
- **City Council Resolution 137-99: A Resolution of the City of Boca Raton supporting the Kyoto Protocol on climate change as a means to reduce greenhouse gas emissions and stabilize the global atmosphere.**
- **Tree City USA designation**
- **Beautification Committee**
- **Community Appearance Board guidelines**
- **Community Rating System from FEMA**
- **Climate Change Vulnerability Assessment (coming soon)**

The gumbo limbo, *Bursera simaruba*, the namesake tree of the Gumbo Limbo Park, is also called the "tourist tree" after its peeling red bark.

A Primer on Tree Benefits

The trees of Boca Raton benefit the City in many ways, including ecologically, economically and socially. This assessment allows the City to measure some of those benefits, and to increase them by planting more trees. The City's tree canopy can be used to maximize many environmental and social benefits in terms of:

- bird and wildlife habitat
- clean air and water
- walkability and fitness
- enhanced natural beauty
- lower vacancy rates
- lower heating and cooling costs
- increased revenues from sales and property taxes

Trees Are Green Infrastructure

The City's trees and other vegetation serve as its "green infrastructure." Just as we manage our grey infrastructure (roads, sidewalks, bridges and pipes), we also need to manage our trees as green infrastructure. Trees support a vibrant, safe and healthful city while adding to the City's historic coastal character. They enhance sustainability by filtering stormwater and reducing runoff, cooling streets, cleaning the air, capturing carbon emissions, and increasing property values.

Boca Raton is designated as a "Tree City USA" by the Arbor Day Foundation in recognition of its 41-year commitment to caring for its urban trees. As the City of Boca Raton redevelops, managing and expanding the urban forest will help the city achieve its vision of being both sustainable and resilient. (See text box on page 7.)

A red bellied woodpecker forages amongst the canopy in Gumbo Limbo Park.

Citizens of Boca Raton planting trees as part of Tree City USA. Photo credit: City of Boca Raton.

The city's trees provide essential shade for playgrounds. Children are more susceptible to heat-related stress.

Gray vs Green

The image on the left shows the City of Boca Raton's gray infrastructure, including buildings and roads. Classified high-resolution satellite imagery (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.

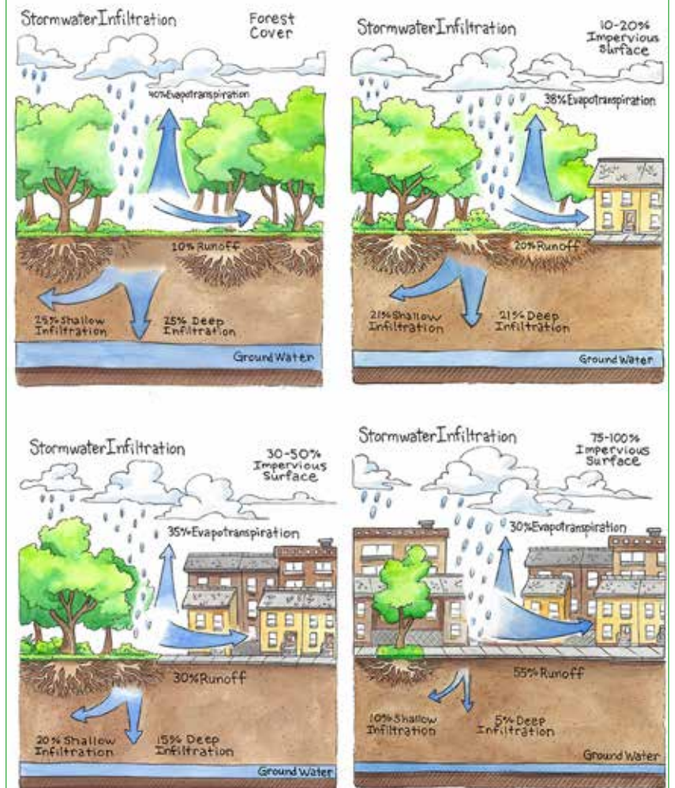
Reducing Stormwater Runoff and Filtering Pollutants

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 in stormwater runoff 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.

Trees filter and clean land runoff before it enters surface waters, ensuring healthy fisheries.

Runoff increases as land is developed.



Data Source: *Federal Stream Corridor Restoration Handbook* (1998)

Excess impervious areas cause hot temperatures and runoff that often flows unfiltered into stormdrains and to city rivers and the sea. This parking lot could be retrofitted to add more trees, bioswales and pervious surfaces.

The average annual precipitation in Boca Raton is 68.54 inches,[2] 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 stormwater ponds and other best management practices (BMPs) 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.

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 species and age.

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. Nitrogen and phosphorus are 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.

This tree saves annual energy costs and captures thousands of gallons of rainfall annually.

An example of a bioswale in a city park. This best management practice included planting trees in the stormwater swale to increase the amount of pollutants removed, while also providing habitat.

2 https://www.weather-us.com/en/florida-usa/boca-raton-climate

Buffering Storm Damage

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 causes increased flooding and property damage, 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.

Mangroves prevent coastal erosion and provide a buffer against wind.

The City of Boca Raton 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 Boca Raton is currently rated as Class 7 in the CRS program, earning its residents and businesses a 15% premium reduction in insurance rates within its special flood hazard areas.[3]

The lower the CRS rating, the higher the premium reductions for flood insurance. Communities can earn point reductions for adopted management plans that protect the critical natural functions of floodplains and native species, while restoring natural habitats.[4] This requires an inventory all species in the plan's geographic purview, action items for protecting one or more of the identified species of interest, restoring natural floodplain functions, and the review and update of the plan every 10 years.

3 https://www.myboca.us/1882/Insure-Your-Property 4 422.c. Natural Functions Open Space (NFOS) - Flood Science Center

Improving Air Quality, Public Health and Economic Values

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). And of course, even a newly planted tree will immediately begin to sequester carbon, clean the air and soak up stormwater. So, while the City will need to expend more funds to increase and to maintain its canopy coverage, those trees will more than pay their way. Trees planted in commercial shopping districts have been shown to increase peoples' time and spending in the district which benefits the city in increased sales revenues.

Trees Cool the City

Increasing shade provides many benefits, especially during Florida's hot summers. 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).

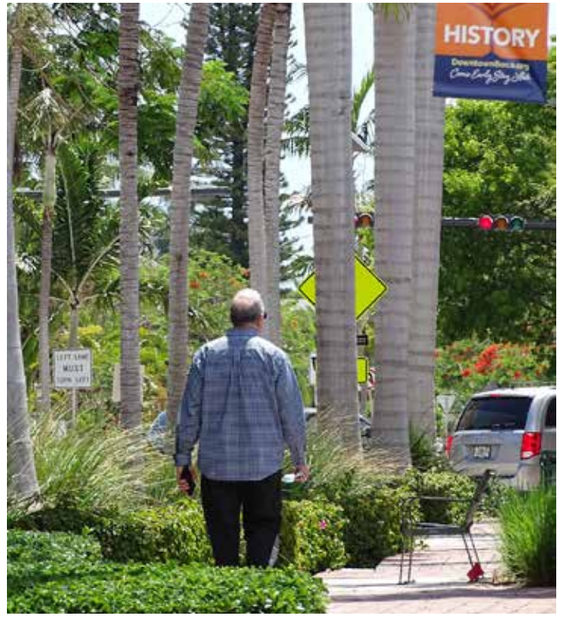
As a result of their year-round cooling effects, trees in Florida provide energy savings for homes and businesses. For instance, a study of Miami's trees showed substantial cooling savings (McPherson et al. 1993). Individual trees can transpire hundreds of liters of water per day which represents a cooling power equivalent to the energy need to power two average household central air-conditioning units per day (Ellison et al 2017).

Tree cover shades streets, sidewalks, parking lots and homes, making 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).

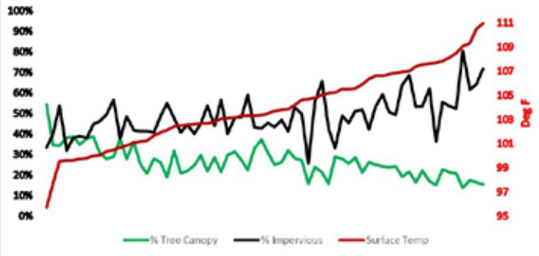
Shaded pavement also has a longer lifespan, so maintenance costs associated with roadways and sidewalks are less (McPherson and Muchnick 2005). These benefits are particularly important in the southeastern United States where average temperatures are generally higher than other parts of the country.

Trees Clean the Air

In addition to cooling surfaces, trees absorb volatile organic compounds and particulate matter from the air, improving air quality. Higher tree canopy is correlated with better air quality. For example, trees clean the air of ground level ozone (O3), and they filter out fine particulate matter, which can damage lungs and lead to respiratory distress and diseases such as asthma. Well treed neighborhoods have been found to have lower rates of respiratory illness (Rao et al 2014). Trees also sequester carbon, which forms greenhouse gases such as sulphur dioxide and carbon dioxide, and this can contribute to a warming planet and associated health problems from excessive heat. By storing carbon and preventing its release, trees mitigate the impacts of climate change.

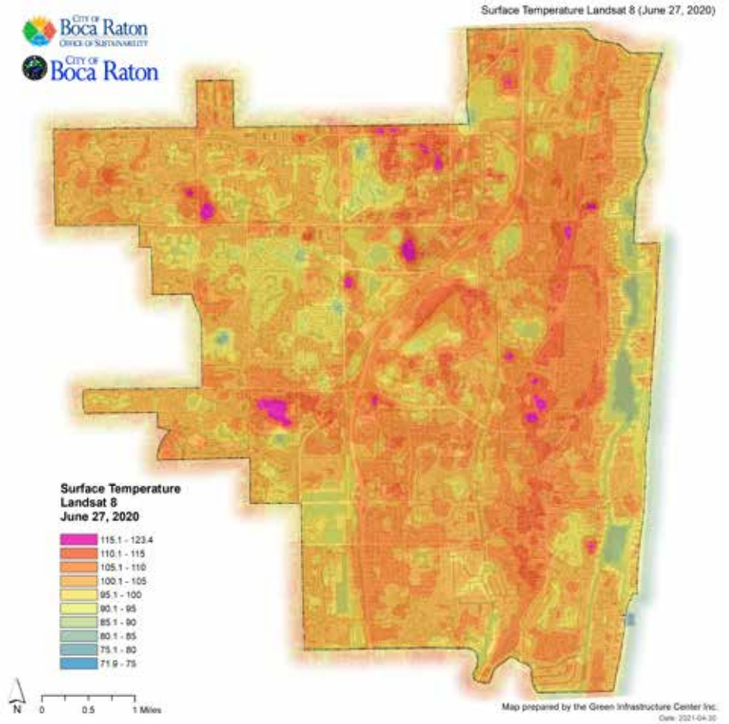


Trees are positively correlated with reductions in surface temperatures.



Heat Map

The hottest areas of the city are also those with the lowest tree canopy. These are also the areas with lower incomes and higher percentages of minority populations.



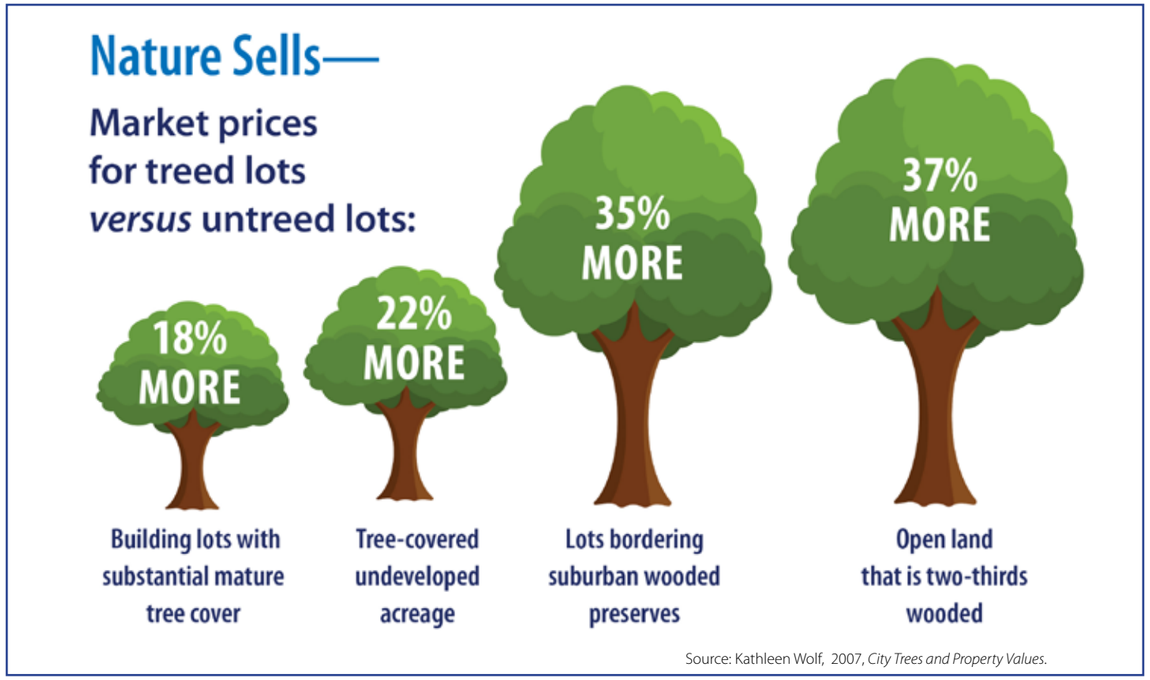
Trees improve cognitive function

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 such as parks or treed landscapes 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.

Trees improve walkability

Trees result in people walking more and walking farther. When trees are not present, people perceive distances to be longer, hotter, and less pleasant, making pedestrians less inclined to walk than if streets are well treed (Tilt, Unfried and Roca 2007).

Well-treed areas encourage people to walk and cycle.



Increasing Property Values

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). Individual trees on lots and forested open spaces also make lots more valuable.

A study by the National Association of Realtors found that 57% of those surveyed were more likely to purchase a home near green space, while 50% were willing to pay 10 percent more for a home located near a park or other protected area. Citizens also appreciate fruit trees for their nourishment and cultural significance to southern Florida.

57% of home buyers were more likely to purchase a home near green space, while 50% of home buyers were willing to pay 10% more for a home located near a park or other protected area.

Methods to Determine Current and Potential Tree Canopy Cover and Values

Methods

This assessment determined the current and potential future tree canopy and quantified the ecosystem services it provided. First, a highly detailed land cover analysis was conducted to determine current and potential tree cover. (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 updates and Sustainability Action 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 Boca Raton. Additional data sets from the City of Boca Raton, the National Wetlands Inventory, and the National Hydrography Dataset were used to classify the following:

1) Tree canopy (including both trees and mangroves), defined as woody vegetation over 10' in height.

2) Those wetlands that are indistinguishable using other spectral/ feature-based image classification tools.

3) Forested open space: compact, continuous tree canopy greater than one acre that is not intersected by buildings or paved surfaces.

LiDAR (light detection and ranging) data were used to determine height, in order to distinguish between large shrubs and trees.[5] 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.

As Boca Raton is a tropical city,[6] palm trees make up part of its canopy. Technically, palms are not trees; they are grasses. This means that, while palms provide some shade, they have shallow, fibrous roots that do not absorb as much water or filter pollutants the same way as a mature shade tree. For more on this, see the box on the next page: Palm Trees: Costs Versus Benefits.

Palm trees do not match the ecosystem benefits of a mature canopy tree, such as a live oak.

[5] 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.

[6] Koppen classification system.

NAIP Aerial Image November 2019

Palm Trees: Costs Versus Benefits

Palm trees are a signature aesthetic element of Palm Beach County and its cities and towns. Palm trees, though, are not technically trees at all; they are "grasses." As such, palms are monocots – plants whose seeds contain only one leaf – and are in the Arecaceae botanical family of perennial flowering plants. Palm forms include climbers, shrubs and other tree-like and stemless plants. Those with a tree-like form are colloquially called "palm trees."

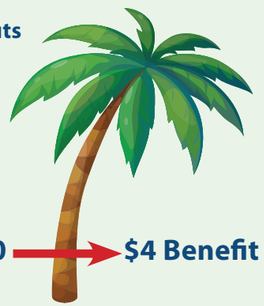
Larger palm trees barely function like actual trees; while they provide some shade, cooling, carbon sequestration and air pollution removal, it is relatively little compared to a large canopy tree. Although palms take up some stormwater, because of their shallow root structure, skinny trunks and narrow, thin canopy, they do not come close to matching the capabilities of a mature canopy tree, such as a live oak, for ecosystem benefits.

Furthermore, 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 palms 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) of maintaining it (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." They require every dead leaf to be manually removed, since 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 other cultivated plant in Florida. Thus, in order to grow well and develop fully, they require routine treatment with expensive fertilizers (Broschat 2010a).

While palm trees are a significant aesthetic element of Palm Beach County's canopy, when hoping to realize the benefits of an abundant tree canopy for shade, stormwater, air quality and health, the City of Boca Raton should consider planting large shade trees – both to save on costs and to realize their greater benefits.

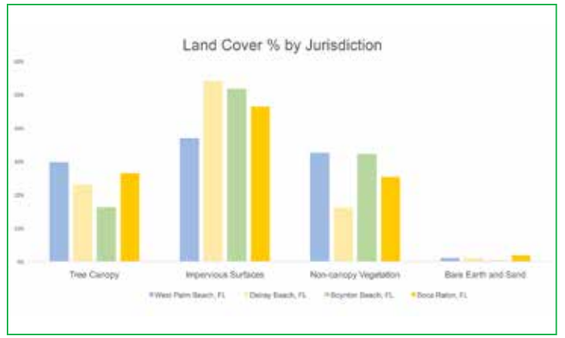
The annual benefits of a typical street palm vs the expenditures result in a net annual loss of $26 per tree.



Cost $30 → $4 Benefit

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

Cost $16 → $80 Benefit



Since mangroves make up a dense part of some of the City's canopy along the intracoastal waterway, mangroves were also included in canopy calculations. However, they present another challenge when calculating canopy cover, since they behave similarly to wetlands, rather than mature forest.

Cities often want to know how they compare to their neighbors. However, when comparing the tree canopy in the City of Boca Raton to other local cities, there are some key distinctions in how tree canopy data have been analyzed between jurisdictions. In the City of Delray Beach, for example, its analysis did not utilize height data and thus its canopy results include a large percentage of shrubs and other low-lying vegetation that are not actually trees.

Because of these differences in methods and landscapes, comparisons between jurisdictions may not be useful. The City of Boca Raton 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 (canopy that is intermingled, or a large canopy tree that partially covers an understory tree). It is important to note that, Boca Raton does not have many open space areas available to plant new trees since only about 3% open space is available for planting.

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, a parking lot could be redesigned in order to accommodate more tree canopy to absorb and clean stormwater runoff. Some cities have lowered their parking minimums (number of required spaces) and others have also adopted a parking maximum (a cap on the number of spaces to avoid over paving). If less spaces are required, more space is available to plant trees.

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

Eligible planting areas are limited by their proximity to buildings, power lines and other above and underground utility infrastructure, sidewalks, and roads because these features can interfere with a tree's growth and the tree also can damage these features. The PPA map avoids these conflicts by not including these locations as plantable area. The PPA map also excludes other inappropriate planting areas, such as cemeteries, playing fields and drainage canals. The resulting PPA map 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 vegetable gardens or swimming pools, require full sun.

Based on an analysis of existing pervious surfaces, 3% of the City's land area could be planted with additional trees. Since it is not practical or desirable to plant every open space, we recommend planting about half of the available open space or 1.5% to achieve a canopy coverage of 28% total coverage. This equates to 49,485 trees to be planted (also accounting for losses as trees age or are lost to storms).

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' and 40' diameter for individual mature canopy trees were used, with priority given to 40' diameter trees, since larger trees provide more benefits.

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' or 20', which represents a 20' or 40' diameter canopy. These individual tree canopies are then merged to form a Potential Canopy Area.

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

Potential Planting Area (PPA) shown in orange

Potential Planting Spots (PPS)

Potential Canopy Area (PCA) shown in light green

Maps and Findings

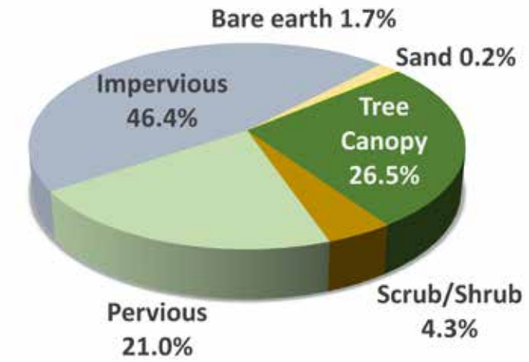
The *Tree Canopy Map* will be used to plan for tree conservation and as a benchmark to gauge future progress in tree canopy gains. An ArcGIS geodatabase with all GIS shape files produced during the study has been provided to the City.

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

- census block groups
- parcels
- parks
- schools
- streets
- watersheds
- future land use

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.

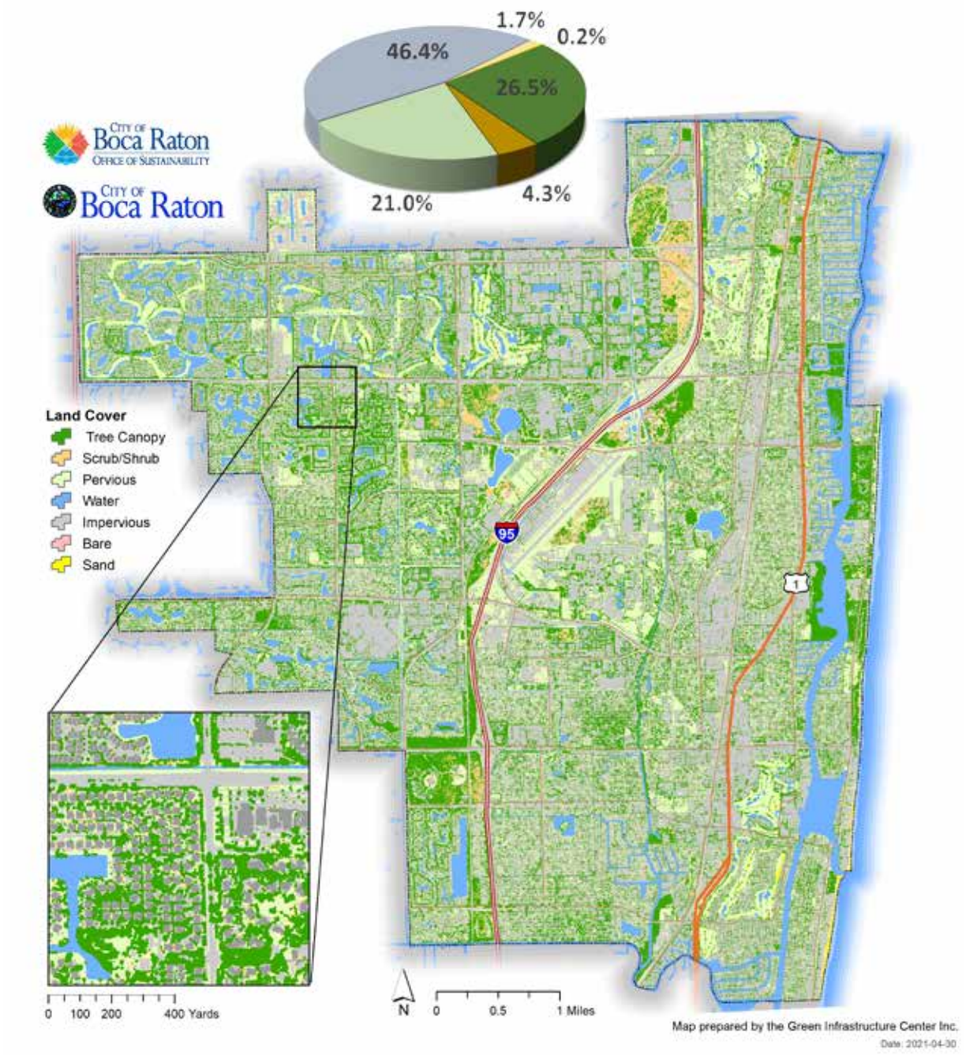
Boca Raton Percent Land Cover



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

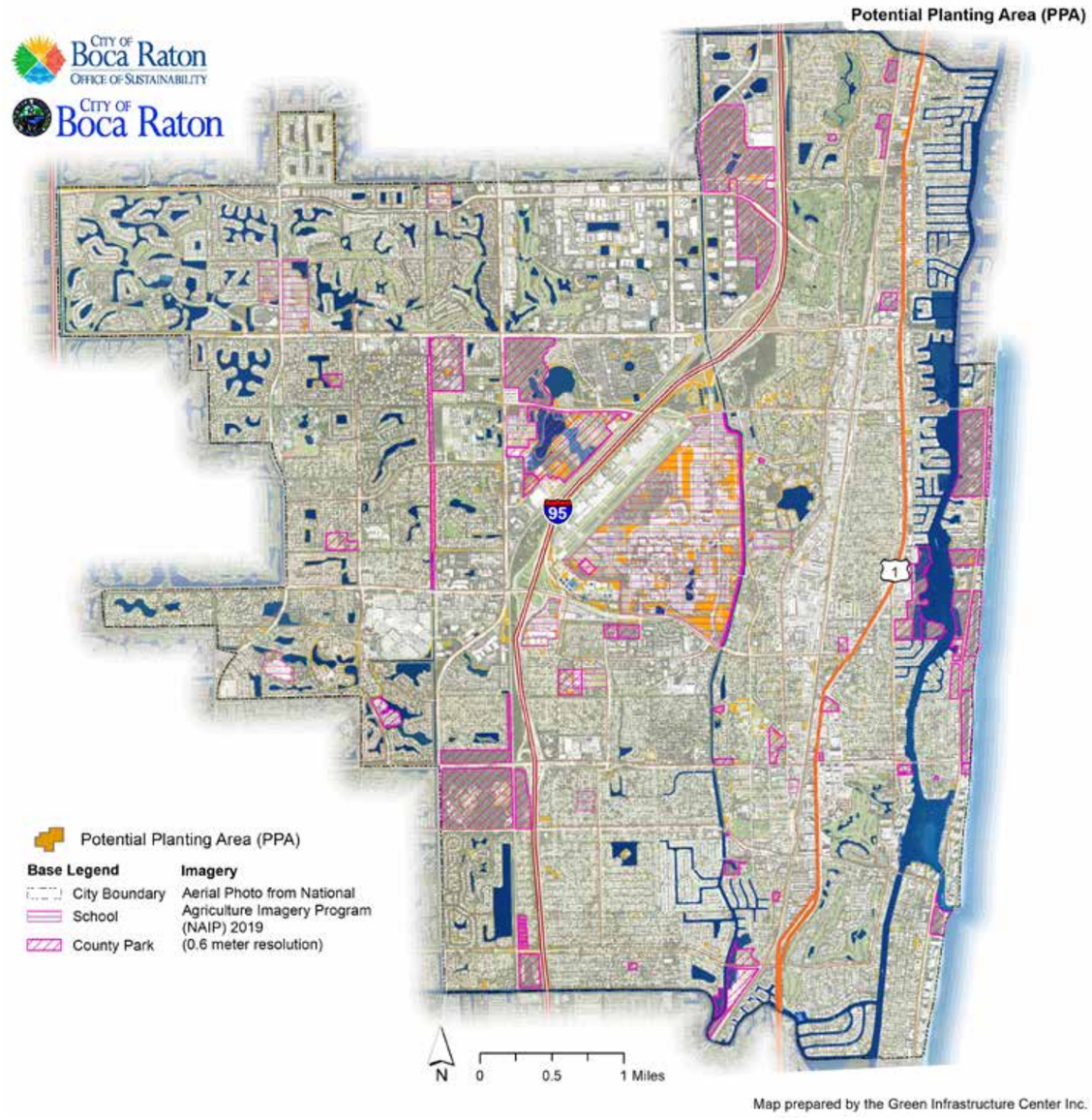
City Land Cover and Tree Canopy

Total Land Area (acres)	Tree Canopy (acres)	Tree Canopy %	Impervious Surfaces (acres)	Impervious Surfaces %	OtherLand (acres)	OtherLand %
17,857	4,716	26.5%	8,288	46.4%	4,852	27.2%



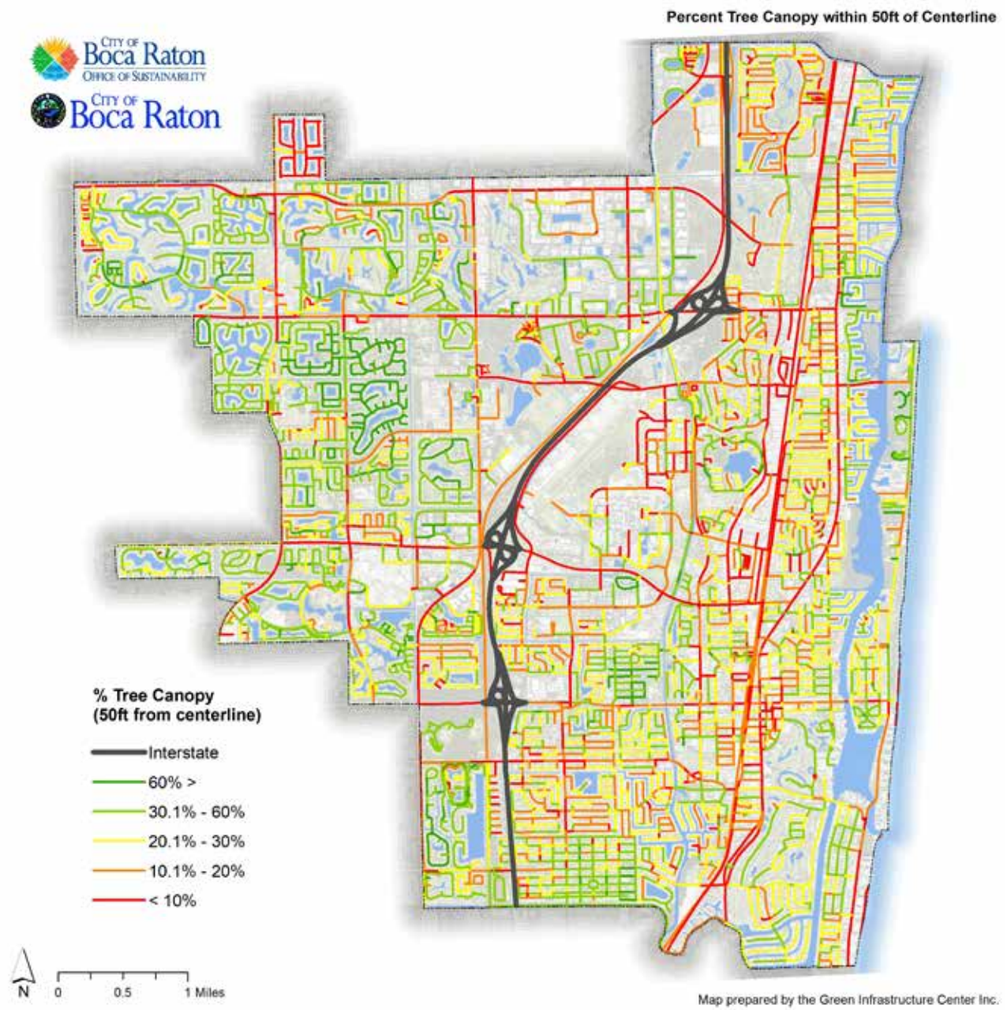
This map shows the current tree canopy for the City of Boca Raton; it covers 26.5% of the total area. This canopy is reducing urban heating, cleaning the air, facilitating exercise, absorbing stormwater runoff, adding beauty and increasing property values.

Potential Planting Areas



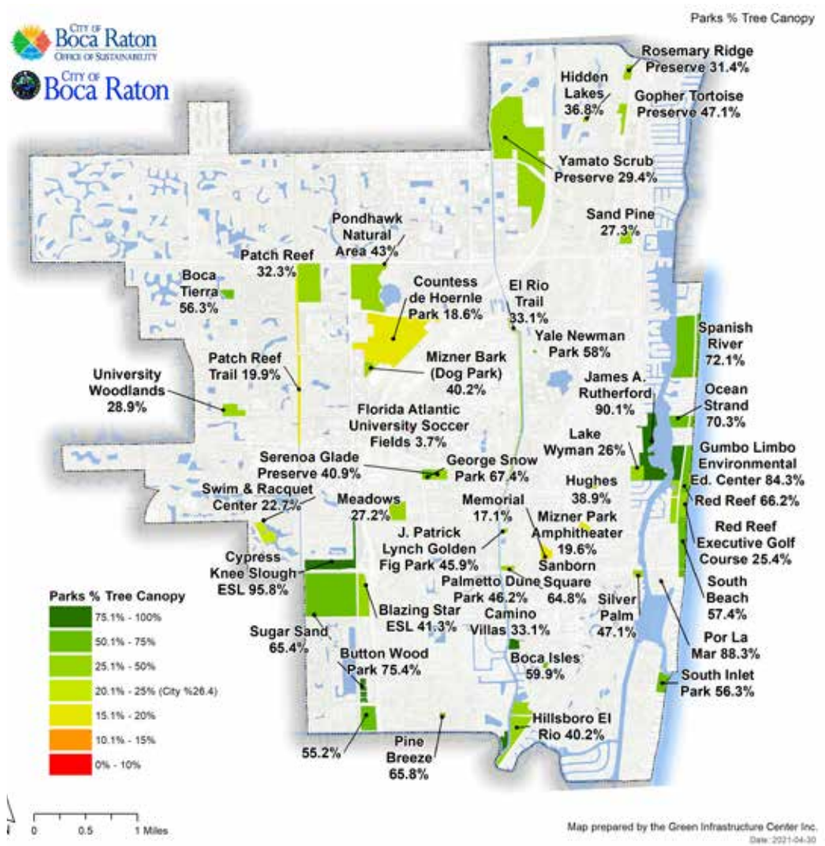
The Potential Planting Area (PPA), shown here in orange, depicts areas where it may be possible to plant trees. All sites would need to be confirmed in the field prior to planning planting. The map shows PPAs on both private and public lands.

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 as appropriate for planting to facilitate specific City goals, such as safe routes to school or beautifying a shopping district. As noted, people walk longer and farther in well treed landscapes. Trees also add a traffic calming effect by adding visual stimuli to the streetscape, causing people to drive more slowly.

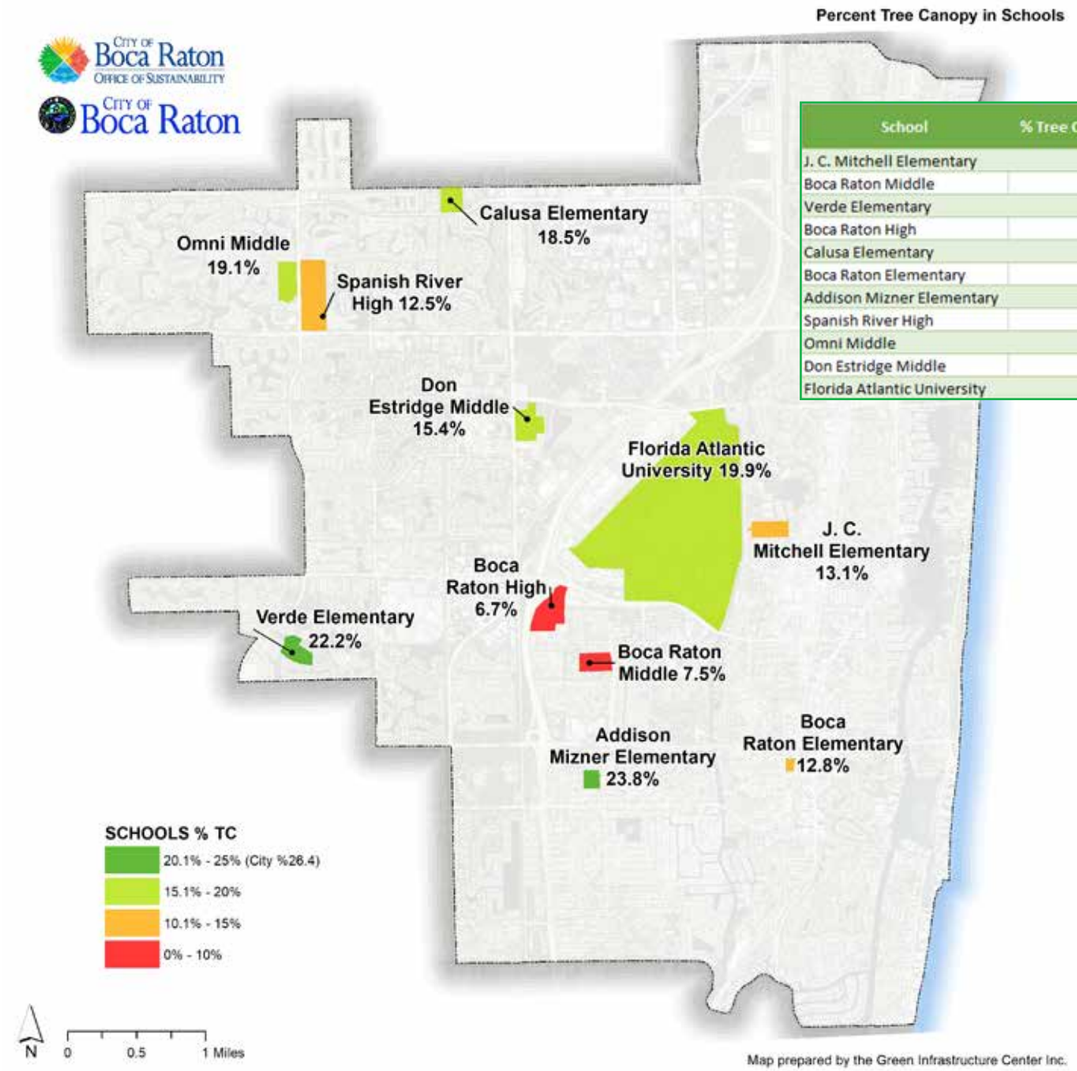
City Park Canopy



City Park	% Tree Canopy
Blazing Star ESL	41.3%
Boca Isles	59.9%
Boca Tierra	56.3%
Button Wood Park	75.4%
Camino Villas	33.1%
Countess de Hoernle Park	18.6%
Cypress Knee Slough ESL	95.8%
El Rio Trail	33.1%
F I N D MSA 690	94.8%
Florida Atlantic University Soccer Fields	3.7%
George Snow Park	67.4%
Gopher Tortoise Preserve	47.1%
Gumbo Limbo Environmental Ed. Center	84.3%
Hidden Lakes	36.8%
Hillsboro El Rio	40.2%
Hughes	38.9%
J. Patrick Lynch Golden Fig Park	45.9%
James A. Rutherford	90.1%
Lake Wyman	26.0%
Meadows	27.2%
Memorial	17.1%
Mizner Bark (Dog Park)	40.2%
Mizner Park Amphitheater	19.6%
Ocean Strand	70.3%
Palmetto Dune Park	46.2%
Patch Reef	32.3%
Patch Reef Trail	19.9%
Pine Breeze	65.8%
Pondhawk Natural Area	43.0%
Por La Mar	88.3%
Red Reef	66.2%
Red Reef Executive Golf Course	25.4%
Rosemary Ridge Preserve	31.4%
Sanborn Square	64.8%
Sand Pine	27.3%
Serenoa Glade Preserve	40.9%
Silver Palm	47.1%
South Beach	57.4%
South Inlet Park	56.3%
Spanish River	72.1%
Sugar Sand	65.4%
Swim & Racquet Center	22.7%
University Woodlands	28.9%
UNK	55.2%
Yale Newman Park	58.0%
Yamato Scrub Preserve	29.4%

This map shows the tree canopy for City parks,. Parks with trees provide healthier landscapes by encouraging walking, better air quality and less heat related health impacts. They also soak up standing water.

School Canopy Coverage



School	% Tree Canopy
J. C. Mitchell Elementary	13.1%
Boca Raton Middle	7.5%
Verde Elementary	22.2%
Boca Raton High	6.7%
Calusa Elementary	18.5%
Boca Raton Elementary	12.8%
Addison Mizner Elementary	23.8%
Spanish River High	12.5%
Omni Middle	19.1%
Don Estridge Middle	15.4%
Florida Atlantic University	19.9%

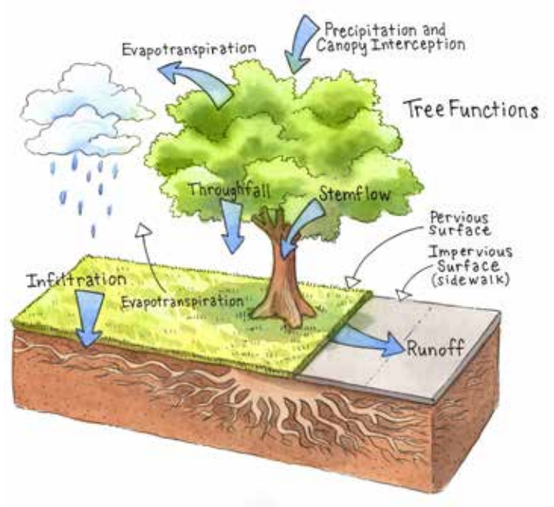
Planting at school sites can save energy costs for cooling and can and provide a boost to learning, since exposure to trees increases cognitive abilities.

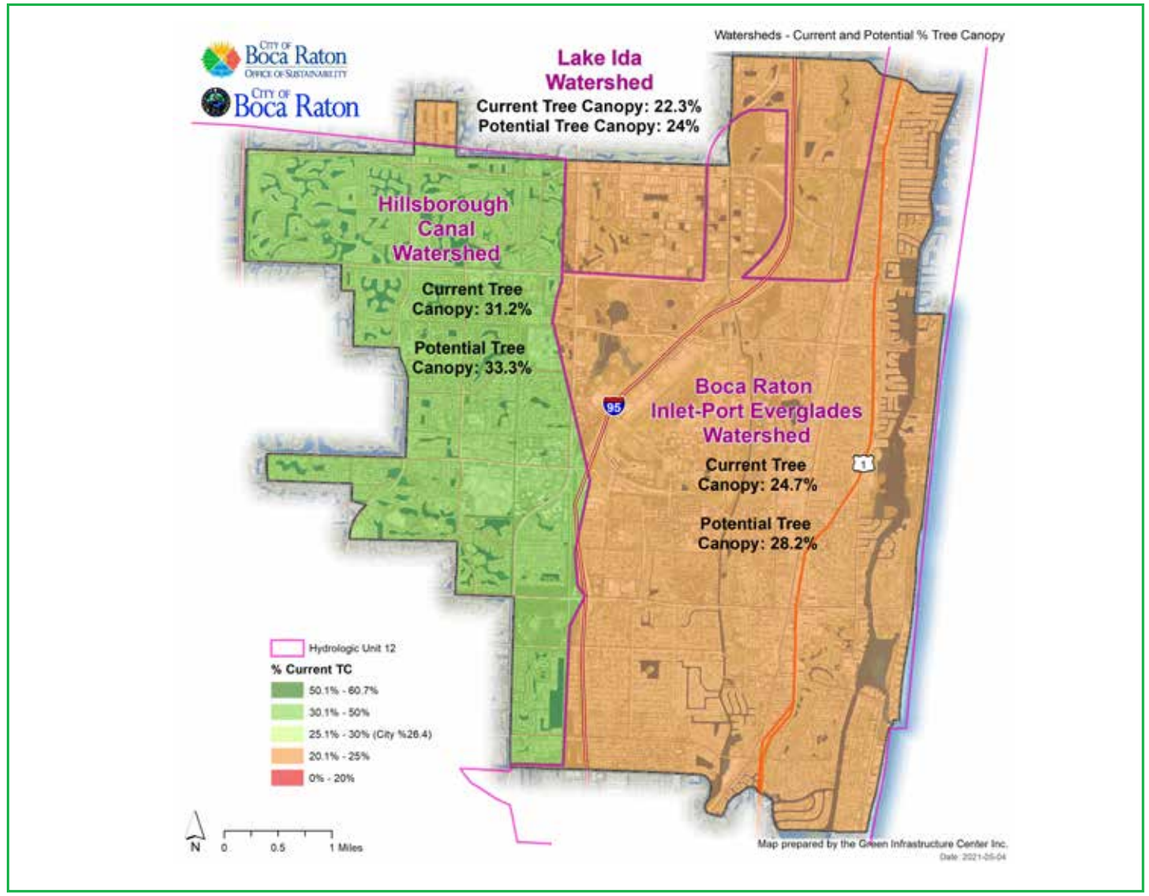
Methods to Calculate Environmental Benefits

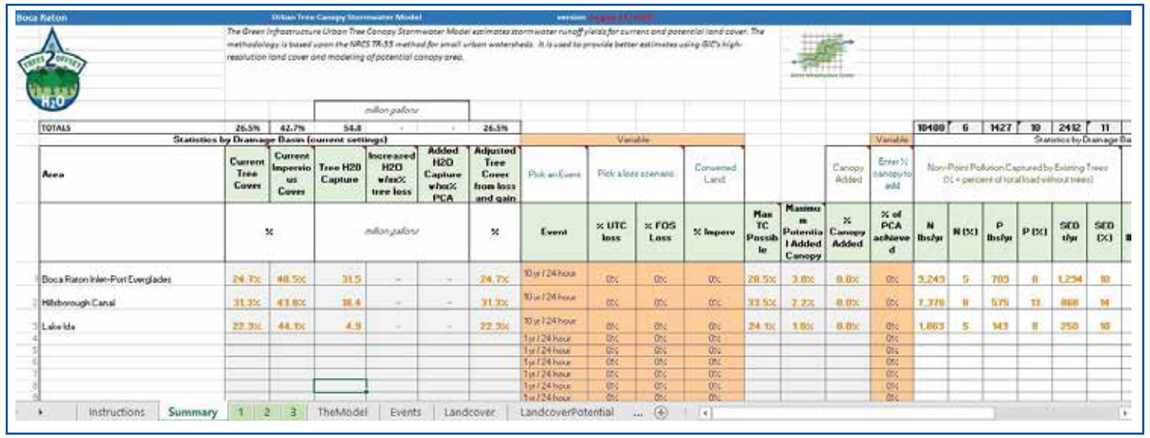
Stormwater Uptake

Trees and forests are the best land cover for taking up urban stormwater as recognized by many forestry scientists and civil engineers (Kuehler 2017, 2016). Trees intercept, take up, and slow the rate of stormwater runoff. Canopy interception varies from 100 percent at the beginning of a rainfall event and slowing to about three percent at maximum rain intensity. (Xiao et al. 2000).

Stormwater runoff and uptake by the City's tree canopy was evaluated using GIC's Trees and Stormwater Calculator (TSC) tool. This 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 hydrologic conditions of the soil. 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. See the diagram, at right, of tree water flow for more details.







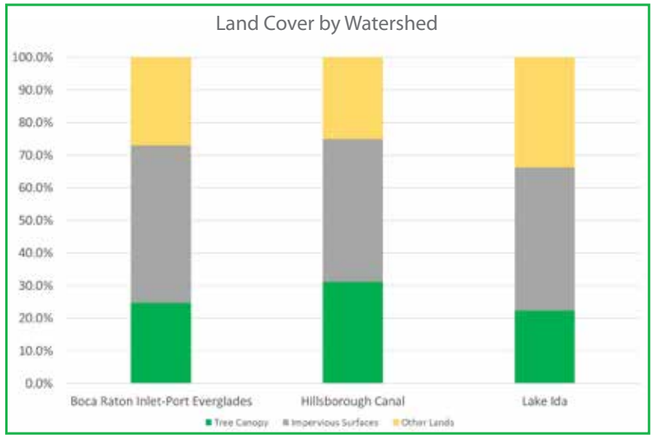
The TSC Tool allows the City to model water uptake by the existing canopy and impacts from changes, whether positive (adding trees) or negative (removing trees).

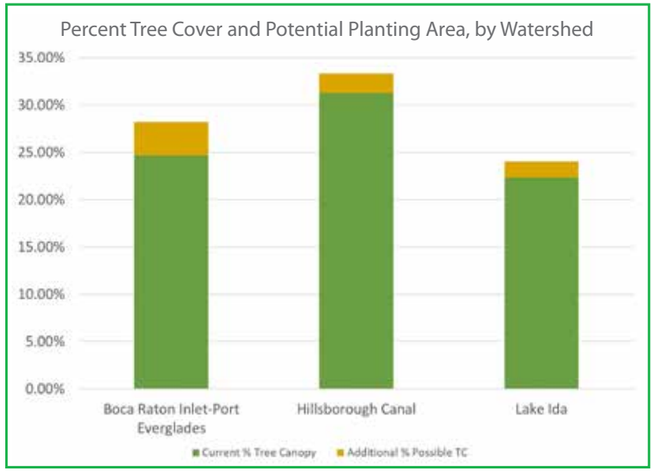
The amount and type of open space under and around a tree and the condition of its surrounding surface soils affect the infiltration of water. The GIC's TSC tool includes a data field to hypothetically add trees to calculate outcomes for stormwater uptake from new tree plantings. The TSC tool uses PPA data to determine how many 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 1.2 million gallons of stormwater runoff (more than 1.8 Olympic swimming pools of water). By contrast, if the full available PPA of each watershed was planted with new tree canopy, the TSC tool shows a decrease in stormwater runoff of 200,000 gallons of water per 10-year storm event.

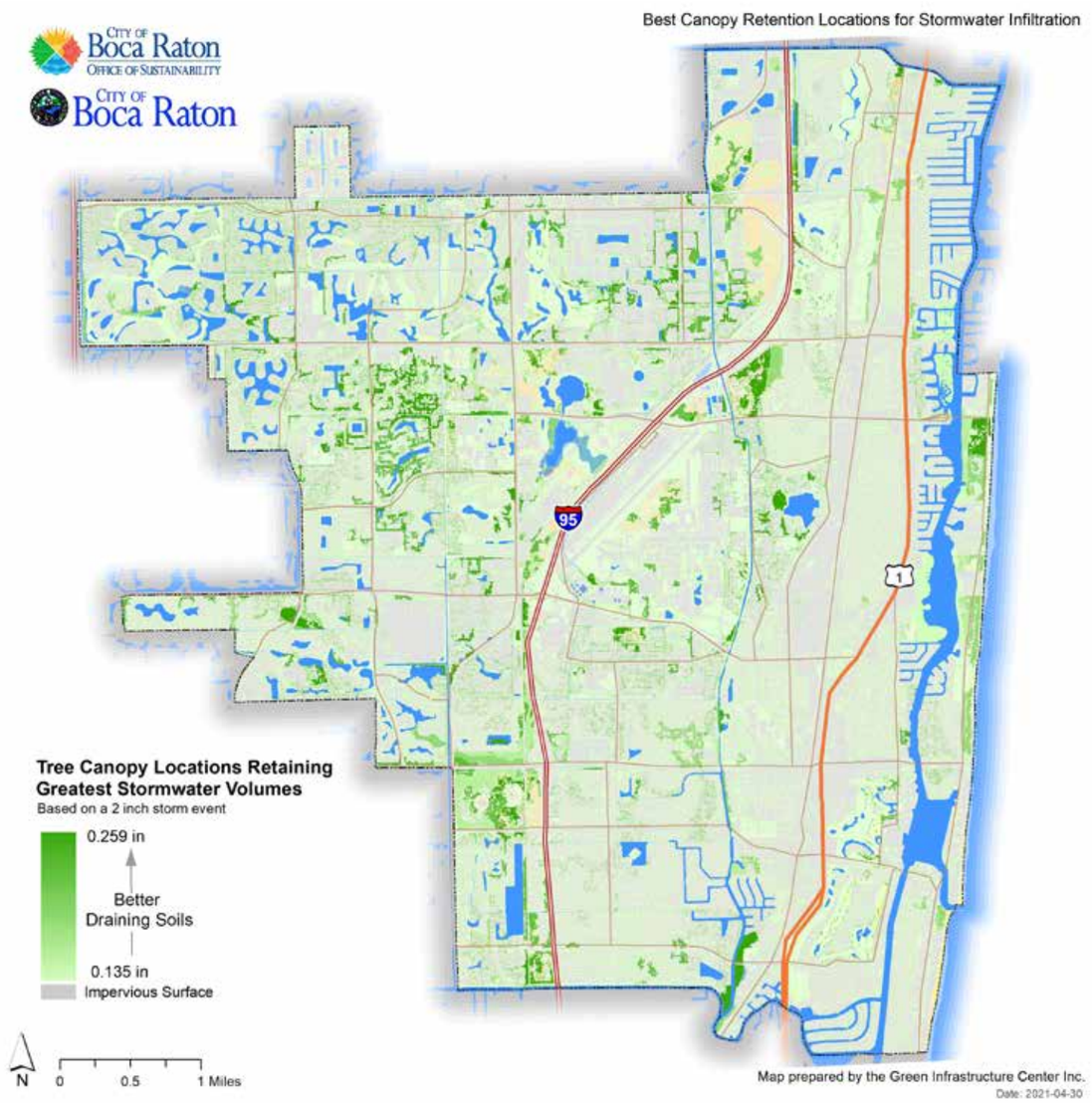
Thus, the tool can model the results of either adding or losing tree canopy, as well as resultant increases or decreases in nitrogen, phosphorus and sediment pollution.

Removal of mature trees and existing forest generates the greatest impact for stormwater runoff. As more land is developed or re-developed, the City should seek to maximize tree conservation, in order to maintain its surface water quality and groundwater recharge. The following maps show 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. It is based on the types of soils present.



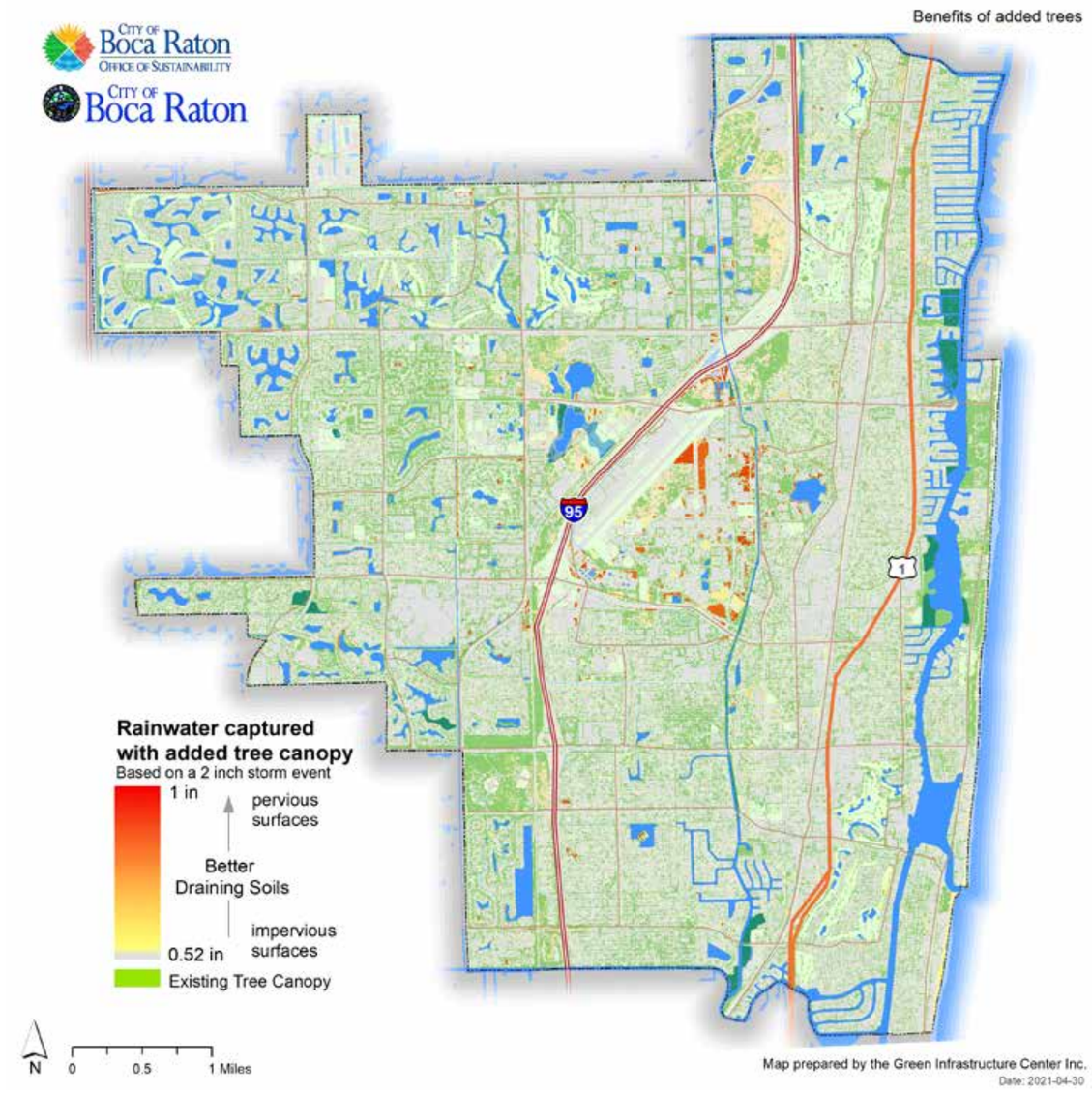


Impact of Tree Loss



The TSC model was applied to map the locations where tree loss will result in the greatest stormwater runoff.

Benefits of Added Trees



The TSC model was applied to map locations where adding trees will result in the greatest stormwater capture.

Air Quality Multipliers		
Pollutant (Abbrev.)	**Benefit Description**	**Removal rate (lbs/year)**
CO	Carbon monoxide removed annually	5,330
NO_2	Nitrogen dioxide removed annually	29,436
O_3	Ozone removed annually	227,392
PM_{10}	Particulate matter greater than 2.5 microns and less than 10 microns removed annually	64,536
$PM_{2.5}$	Particulate matter less than 2.5 microns removed annually	11,617
SO_2	Sulfur dioxide removed annually	14,470
CO_2 seq	Carbon dioxide sequestered annually in trees	47,213,438
CO_2 stor	Carbon dioxide stored in trees (note: this benefit is not an annual rate)	1,185,706,215

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 i-Tree model values for urban areas were used to multiply acres of canopy to derive the pollution removal values calculated are shown in the table above.

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 either release that carbon back into the atmosphere, or it enters the duff layer (the layer of soil, leaves and other organic matter on a forest floor) to form a reservoir of carbon within the soil. As greenhouse gases take the form of carbon-based molecules, they cause atmospheric warming. As is widely accepted, so much carbon is being produced from fossil fuels and other sources, the Earth's temperature is warming, leading to sea level rise, wetter and more severe storms and more very hot days, which can have wider health impacts than just poor air quality. Planting trees helps absorb and trap this excess carbon which, when considered on a global scale, each locality's efforts can add up to make a significant difference.

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 and sulfur dioxide also irritate airways in the respiratory system and aggravate respiratory conditions such as asthma.

PM_{10} is particulate matter measuring 10 micrometers or less in diameter and $PM_{2.5}$ is particulate matter 2.5 micrometers or less in diameter (a human hair is about 100 micrometers = about 40 fine particles). $PM_{2.5}$ 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.

Urban Tree Loss – Reversing the Trend

Potential Planting Areas

Many streets and public properties, such as this school, private yard, and road frontage have room for more trees to add shade, beauty, and improve air quality.

Boca Raton is not unique in having had trees losses from storms, development and old age. Widespread loss of tree canopy is occurring in urban areas throughout the world. Fortunately this loss can be reversed. The first step – having an accurate assessment of the community's tree cover – has now been achieved. The second step is to expand tree planting to overcome losses and eventually to increase overall canopy coverage.

Current Status

Boca Raton now has baseline data to monitor progress on canopy protection or expansion, and to measure the stormwater and water quality benefits of its urban forest. The City can also use the data to prioritize canopy restoration in specific areas where it is most needed. A regular planting program will be needed just to maintain the City's canopy coverage at 26.5%, as it ages or is lost to storms.

While the City has been planting an average of 330 trees per year on City property and has been giving away around 300 additional trees to residents to plant, 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 (minority class). Tree canopy coverage varies across the City and it is less in census block groups that have lower incomes and higher percentages of minority populations. This analysis showed that in census block groups where people's income range is moderate-to-low, the average canopy percentage is around 23%, which is about 3.5% less than the City average of 26.5%. The higher income neighborhoods in the city have an average canopy coverage of 28%, with the highest income neighborhood having a canopy coverage of 40%.[7]

7 This is based on the top five highest income neighborhoods by census block group.

Why Are Urban Trees Declining?

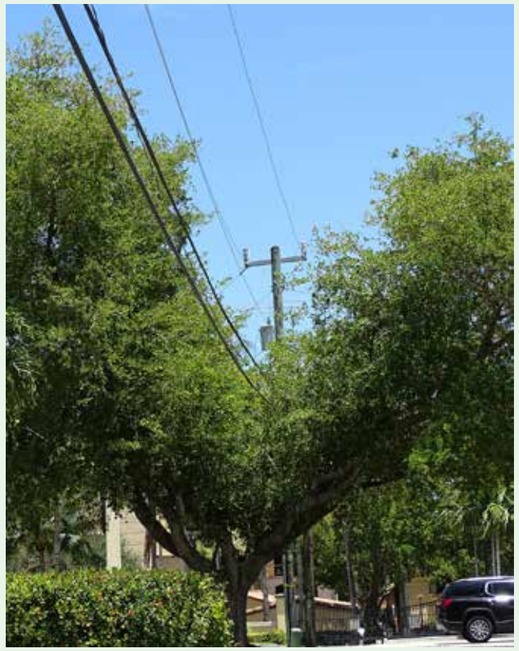
Tree loss is not a unique problem to any city in Palm Beach County. A 2007 study found a decline of 38% in forest cover in the county's urbanized areas from 2004 to 2006, primarily from hurricanes (American Forests). Development and growth are also a significant cause of tree loss in southern Florida. As a mostly built out city, tree loss in Boca Raton comes from redevelopment when larger houses replace smaller structures and the entire parcel is cleared.

Tree losses have consequences for air quality and public health. When modeled for the effect of tree decline on increased pollutants in the county's air, those pollutants were found to have increased by 2.3 million pounds.

Increasing Canopy Cover

Each year, trees in Boca Raton are lost to storms, development and old age, as well as removals by individuals. 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, 50 will survive only 13-20 years, largely because of poor planting conditions and care (Roman et al 2014). So, 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.



Tree pruning for power line safety can make trees unstable, planting large trees under power lines should be avoided.

To change the downward trajectory of tree cover in south Florida and realize the tremendous ecosystem services trees provide, the City of Boca Raton should plant trees to increase its canopy cover. The City already partners with such nonprofit organizations as Community Greening and the Arbor Day Foundation to plant trees annually (see text box), and such outreach can be expanded. Volunteer programs that involve the community in widespread tree planting can also have a significant effect. While the City is currently planting an average of 330 trees annually and giving away another 300, if it and its partners planted a total of 2,500 trees annually, beginning in 2021, Boca Raton could achieve 28% canopy coverage by the year 2041. This equates to planting 1.5% of the existing available open space of 3%. Private property owners are a key partner and much of the land in the City is privately owned, including 1.6% of the area identified as plantable.

Expanding the city's canopy can 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 tree canopy goal aligns with the City's Sustainability Action Plan. The plan notes that "Urban trees, a type of afforestation, can both remove carbon as well as mitigate heat." For more strategies from the plan related to urban trees see the text box. The city also provides recommendations on which trees are resilient to storms and how to care for urban trees at https://www.myboca.us/1477/Sustainable-Tree-Maintenance.

Community Review

The City of Boca Raton held a virtual community meeting on May 12 (a recording of which was posted for later viewing on the city's website) to present this study's findings and elicit community response. The city also provided a survey for residents to also add their comments.[8] The top reason respondents thought planting trees was important was to cool streets and neighborhoods in the city (12). The second most important reason was for beautifying neighborhoods (7). The third reason was a three-way tie between capturing greenhouse gases, wildlife habitat and stormwater reduction (5). Sixty percent of respondents said they were willing to plant and care for a tree on their own property to help increase tree canopy.

Respondents also suggested that city should apply the same tree and vegetation requirements to its own developments as it does to private developments. They also wanted the city to make it easier to learn about putting trees in the right spot (i.e. not under power lines, or too close to a residence) and not planting nuisance trees such as Norfolk Island pine. Respondents noted that a "nice push for public education on the importance of the urban tree canopy (from school-aged to senior citizen) may go a long way in encouraging residents to think green and plant on their own property." Another respondent added encouragement to the city's tree focus stating that "I am so excited to see the effort going in to the tree canopy assessment and the steps proposed to increase canopy cover even further. I am happy to help in any way I can with tree canopy (and any natural resource) projects."

For the full list of comments see Appendix D.

Boca Raton supports community tree planting

The City of Boca Raton's Beautification Committee, its Recreation Services Department and its Office of Sustainability recently partnered with Community Greening on Project Shade Tree to commemorate Arbor Day. They offered residents 15 gallon trees, delivered and installed, at half the normal price. More than 70 trees were given away to be planted!

Image credit: Community Greening

Local tree planting groups such as Community Greening have partnered with the city to help bring trees to residents, even during the Pandemic.

[8] The survey link was distributed by the City and made available on its website. The survey was kept open for two weeks from Wednesday 5.12.2021 to Wednesday 5.26.2021. It is not a scientific survey and respondents do not necessarily represent the population or views of the public at-large.

Actions to Increase Canopy

Increasing tree canopy meets a number of goals within the City's Sustainability Action Plan. "Tree canopy provides many benefits to the community. Aside from being beautiful, shade cools the surrounding area making it more comfortable to walk and bike, slows rainfall and helps prevent stormwater flooding, provides habitat for birds, and has even been demonstrated to slow traffic and reduce accidents. The City will promote trees and canopy in the following ways:

Provide incentives for homeowners to plant trees. Provide education to the community regarding the benefits of trees. Create incentives for homeowners to plant trees, such as free tree giveaways at City events.

Require shade canopy trees in zoning regulations. Review the Zoning and Development code for opportunities to increase trees maintained or planted as parcels are developed or redeveloped. Maintenance of existing tree canopy should be a priority for any project, private or public. Increasing shade tree canopy is the priority. Trees should be considered as part of a stormwater strategy. Revise and uphold the Community Appearance Board requirements.

Increase shade tree canopy on public lands. Continue to plant trees on public properties. Develop a policy for City landscaping which prioritizes shade trees, shades pedestrian facilities, and uses trees in stormwater maintenance."

Shade impervious areas. Address the land development code and the requirements for trees in new development to ensure that trees added are increasing canopy cover and strategically placed to cool buildings and pavement. Consider the use of green walls to further cool buildings.

Kids at the City's "Camp Boca" plant sea grapes. Image credit City of Boca Raton

Increase pervious area. Consider design requirements which increase pervious area in developments. Examples may be reduction of parking requirements, requirements of green or pervious parking, pervious pavements, and green roofs. These permeable areas can include new trees.

Adding permeable pavers to driveways is an attractive way to help reduce stormwater runoff.

Sustainability Action Plan, adopted July 2019.

Community Participation

To meet the recommended canopy cover of 28%, the City of Boca Raton should launch an expanded tree planting campaign and engage developers, residents, gardening groups, 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 and more sustainable city. As the City works to meet the canopy goal, they can document progress by tracking trees planted by location and species.

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, parks, schools, and specific streets, such as entrance corridors and downtown areas. The City should, as much as possible, promote the planting of tree species with a high ecological value, such as native and drought-tolerant species, hurricane-resistant species and those that support biodiversity.

As part of this project, the city has been provided with a Tree Planting Cost Calculator to determine the numbers of trees to plant within the Potential Planting Areas across specific target geographies.

New tree planting is key to the City's success in both retaining and expanding canopy.

Image credit: City of Boca Raton

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

Recommendations – Next Steps

1 Establish a tree canopy goal of 28% tree cover. To meet this goal, trees will need to be planted each year on public and private property to maintain current levels and to expand canopy cover.

2 Plant trees in areas identified as low income (to help residents afford a tree) and in neighborhoods that show excessive surface heating and low canopy cover (based on maps provided for this project) to support community health.

3 Engage with key stakeholders and communities over the next year to create multiple avenues to plant and care for new trees.

4 Evaluate how best to fund tree plantings, form new partnerships to support and fund planting and ensure ongoing maintenance of the City's tree canopy.

5 Utilize the *Trees and Stormwater Calculator* tool and other ecosystem benefit multipliers provided to determine the benefits of maintaining or increasing City tree canopy. Use the carbon credit calculators to integrate tree canopy benefits into the citywide greenhouse gas emissions inventory, which is used to track progress on the Sustainability Action Plan.

6 Consider integrating trees with other green infrastructure best management practices such as bioswales or intensive green rooftops.

7 Utilize this analysis to guide implementation of recommendations from the regional climate change vulnerability assessment (CCVA) related to heat and green infrastructure. Tree canopy can be considered as part of the community's "adaptive capacity," and its ability to cope with climate change impacts, such as extreme heat and flooding.

8 Undertake a code 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 through development and design.

9 Create an ordinance to limit the impervious cover on city lots to prevent additional stormwater runoff and to ensure there is room to plant trees for shade and stormwater capture.

10 Create an urban Forest Management Plan to ensure the city has detailed and actionable processes to care for and better manage its trees. Grant funding is available from the Florida Forest Service for tree inventories and management plans.

11 Conduct a tree inventory to assess the health of trees in key areas, such as business districts or near water resources, within parks and schools, and other places where trees serve as "green infrastructure." As noted above, this can also be funded by the Florida Forest Service.

12 Develop a formal Forestry Emergency Response Plan. This should be coordinated with Palm Beach County and adjacent cities and towns that share similar concerns about tree storm debris removal or repurposing. Although the city currently strives to replace lost trees, a formal plan including a budget is needed for such activities to ensure they occur.

13 Lastly, conduct a land cover assessment every four years to compare tree canopy coverage change over time, in order to track progress on meeting canopy goals. 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 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.

The City's trees are part of its history. The "tree of knowledge" is the historic landmark of the African-American neighborhood of Pearl City.

Appendixes

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 Boca Raton.

The land cover map was created at 0.6 meter resolution using NAIP imagery from November 20, 2019, LiDAR Imagery provided by the city from 2018 and an existing land cover dataset provided by the city from 2015. In addition, various available vector data not uniform across the city were used where possible (for example, sidewalks, driveways and other impervious surfaces). Features such as "Tree Canopy over Impervious" were created/estimated using buffers from road centerlines and the existing 2015 landcover map where tree canopy matched the 2019 classification.

The procedures were as follows: 1) An NDVI was created using the NAIP imagery 2) Feature Height layer created using the LiDAR. Areas reflecting green (0 to 1) in the NDVI and above 10' from the Feature Height were classified as Tree Canopy – the remaining green features where classified as pervious surfaces. Impervious surfaces where then added where available including existing data and additional image classification. Bare earth was selected from the pervious surfaces class where NDVI was -0.1. Some artifacts were produced where tree canopy was lost between acquisition date of LiDAR and NAIP.

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'.
2. **Tree Canopy over impervious:** These are features that overlap Impervious surfaces and are primarily created from existing vector data, where available.
3. **Tree Canopy over Water:** Where Tree Canopy classified from NDVI/LiDAR intersects the vector dataset from the City representing water.
4. **Water:** Water class created from city datasets representing canals and lakes and other inland water.
5. **Mangroves:** These were created from visual inspection of imagery, local knowledge and on-the ground verification
6. **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.
7. **Turf/Pervious:** These are features identified as "green" or typically above 0 in NDVI, but have a feature height less than 1 meter.
8. **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.
9. **Bare earth and Sand:** These can be easily confused with impervious surfaces, but have a NDVI value closer to 0.

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

Note: '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 such places, so, the overall area of the class is small as a total percentage of City land cover.

In addition to data check procedures, ground imagery was also obtained to cross check satellite imagery interpretation with ground conditions. A GPS camera was used to capture vegetation images and then compare that with assessed imagery. That was found to be 99.3% accurate.

The NAIP 2019 image was originally used as the primary input. 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).

Number of points sampled based on class size										
ClassValue	Tree Canopy	Tree Canopy ove	Pervious	ScrubShrub	Water	TCoverWater	Imperv	Bare	Total	U_Accuracy
Tree Canopy	48	0	0	0	0	0	0	0	48	100.0%
Tree Canopy over imperv	0	11	0	0	0	0	1	0	12	91.7%
Pervious	0	0	10	0	0	0	0	0	10	100.0%
ScrubShrub	0	0	0	48	0	0	0	0	48	100.0%
Water	0	0	0	0	20	0	0	0	20	100.0%
TCoverWater	0	0	0	0	0	10	0	0	10	100.0%
Imperv	0	1	0	1	0	0	105	0	106	99.1%
Bare	1	0	0	0	0	0	0	9	10	90.0%
Total	49	12	10	49	20	10	105	9	274	
P_Accuracy	98.0%	92.0%	100.0%	98.0%	100.0%	100.0%	100.0%	100.0%		99.3%

Potential Planting Area Dataset

The Potential Planting Area dataset has 3 components:

- Potential Planting Area (PPA)
- Potential Planting Spots (PPS)
- 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 page 21.

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' 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 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.

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' and 40' mature tree canopy with a 30% overlap. Therefore, the planting spots are 16' and 32' apart, respectively.

NAIP Aerial Image November 2019

Potential Planting Area (PPA) shown in orange

Potential Planting Spots (PPS)

Potential Canopy Area (PCA) shown in light green

The **Potential Canopy Area** (PCA) is created from the PPS. The potential 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' or 20', to result in 20' and 40' 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.

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 design reviews.

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

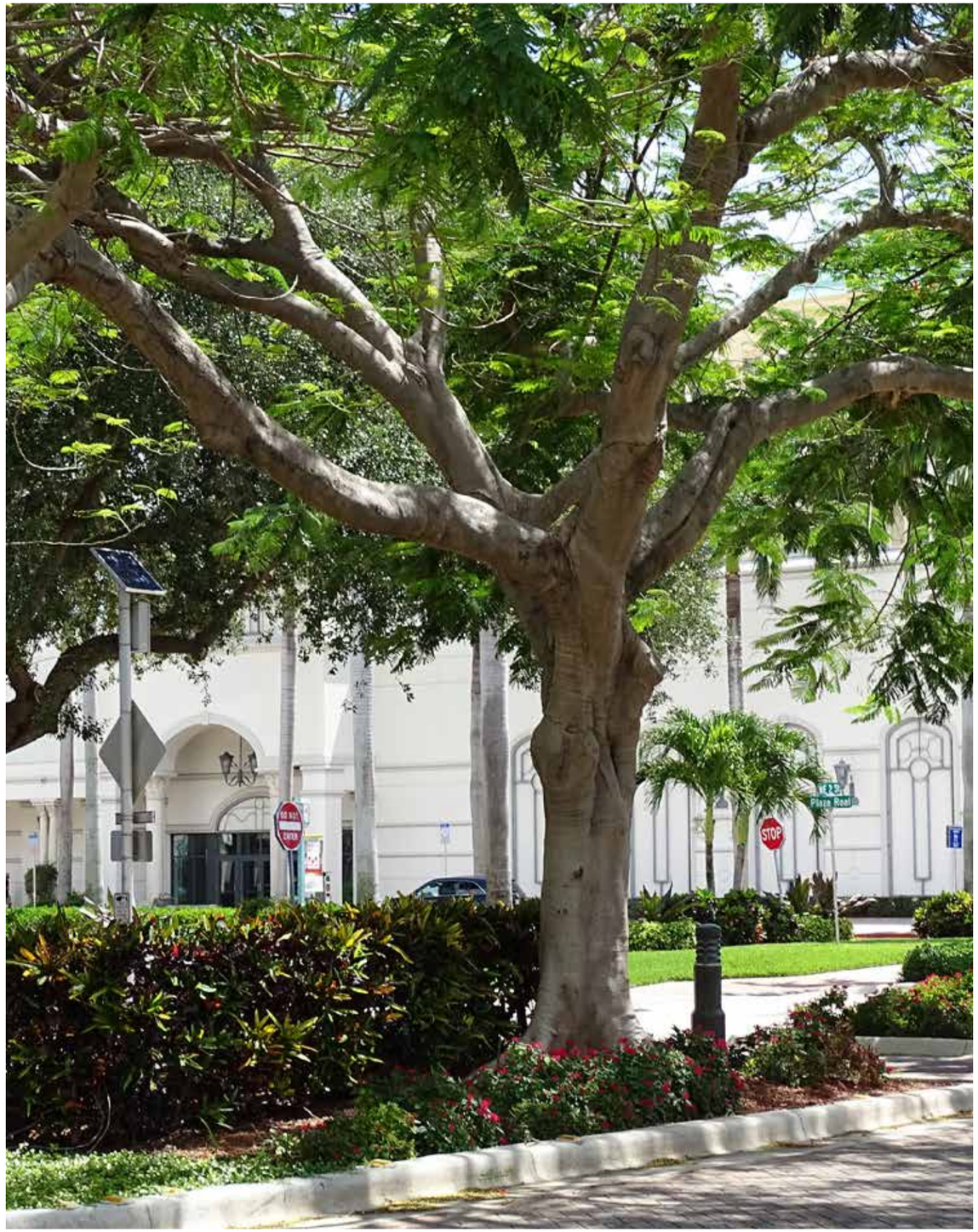
Trees over forest

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 include 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



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Appendix D: Community Survey

Posted for 2 weeks on the city's website. Number of survey respondents: 15

Q1: What do you feel are the most important reasons for increasing tree canopy in Boca Raton? (check up to 3)
The top reason respondents thought planting trees was important was to cool streets and neighborhoods in the city (12). The second most important reason was for beautifying neighborhoods (7). The third reason was a three-way tie between capturing greenhouse gases, wildlife habitat and stormwater reduction (5).

Q2: Please rank where you think City government should prioritize tree plantings.
Respondents thought the City government should prioritize tree plantings in the order of along streets (3.93), in public parks (3.13), in schools (2.93), in low income neighborhoods (2.73) and lastly in parking lots/plazas (2.27).

Q3. Would you be willing to help increase tree canopy in the City by planting and caring for a tree on your property?
60% of respondents said they were willing to plant and care for a tree on their own property to help increase tree canopy. Another 13% responded maybe and 27% said they did not own property to plant trees on. No one responded "no" to this question.

Q4. A follow up question to the people who responded "No" or "Maybe" to question 3; What, if anything, would motivate you to plant a tree?
The answers of "I don't own property" (3), and "I am a renter and don't know if I have permission" (2) were the most common reasons. This suggests the City and any partner groups will need to engage with landlords and property management companies on the benefits of planting trees and encourage them to add more trees on properties they manage.

Q5. Do you agree or disagree with the Canopy Goal set by the City?
Only three people responded to this question, as they may not have seen the goal in the presentation but all those who responded strongly agreed with the recommended goal.

Q6. This was a follow-up question to **Q5** respondents as to why they chose to agree (or disagree) with the canopy goal.
Respondents reasons are listed below:
• Trees make a city more attractive, cooler in hot weather, and helps with runoff.
• After watching the webinar, I know how important it is to get as many trees into the space we have as quickly as possible.

All comments from respondents on **Q6**.
- Make the Boca Teeca golf course into a park. TY park in Hollywood great example with many beautiful oak trees. Also JC Mitchell has many unused acres the could be planted on.
- Ensure trees planted a not messy trees, strong enough to withstand hurricane winds and fly over and looks for large gaps.
- Add trees to Ocean Breeze property since it won't be used for golf.
- Add trees to the Camino Real median from El Rio Canal to I-95. The county will remove existing trees and vegetation from the medians and swales as part of a resurfacing project. In addition, as part of this project (Military to SW 3rd Ave.) the county will increase impermeable surface at the ends of many of the medians.
- The city should apply the same tree and vegetation requirements to its own developments as it does to private developments.
- If the city doesn't already make this information available, it should make it easier to learn about putting trees in the right spot (i.e. not under power lines, too close to your house) and not planting nuisance trees such as Norfolk Island pine.
- Publicly recognize property owners who install and maintain (long term) things that enhance tree canopy.
- Encourage homeowners to hire legitimate tree trimming companies that carry insurance, know the basics of trimming trees and take away the waste they create. Instead, especially in ungated neighborhoods, you get itinerant trimmers going door-to-door. These people tend to do shoddy work that endangers the health of trees and leaves behind giant piles of yard waste for the city to remove.
- We should strongly prefer native trees that provide ecological services to wildlife and humans
- Free tree programs and more information campaigns
- Only use Florida native trees, oaks in particular are the best and most useful for wildlife. Get rid of all these grassy areas so the leaves can fall and be used as natural mulch which is also necessary for wildlife. Grass is a DESERT to birds and wildlife. Please read "Nature's Last Hope" by Doug Tallamy and put his videos on the City website to educate and encourage people to plant native trees.
- As mentioned in the Tree Canopy Assessment presentation, most of the area where canopy can be increased is on private property. A nice push for public education on the importance of the urban tree canopy (from school-aged to senior citizen) may go a long way in encouraging residents to think green and plant on their own property.
- Make available easily interpreted info on picking the right tree for the right place and how to maintain healthy trees.
- I trust the City will do what they can with City property, but for private property, a tree giveaway and info session would help increase participation.

Q8. What barriers or challenges do you think the City will face?
The biggest barriers/challenges respondents thought the City would face are the constraints of a highly built out urban environment. The lack of space, impervious surfaces and conflicts with other infrastructure will make it a challenge for the city to realize its goal, particularly in the rights-of-way. Another challenge is the maintenance and care of trees on private properties, especially on commercial properties where approved city landscaping died after installation. Finally, they identified costs and ability (e.g. staffing) by the City to maintain existing and new canopy.

All comments from respondents on **Q8**.
- Upkeep.
- Expense to maintain the trees. New buildings or development should be required to cover/leave some trees in place for shade, especially open parking areas
- Property owners who lose trees often fail to replace them. This is common with commercial properties, which start with a fancy landscape plan that the city approves. The owner then fails to properly maintain the landscape either due to cost considerations or ignorance. The city could probably be in the same position.
- Homeowners will plant or inherit trees that aren't suitable for the landscape. It then kills their grass, screws up their foundation, clogs their sewer lines, disrupts their driveway and so on. They often improperly trim, hatrack or remove the tree. The removed tree is often replaced with sod and we're back to square one.
- Impermeable median strips and densely packed building development downtown.
- The idea that trees are messy.
- The City needs to educate the public that NATIVE trees that are not over pruned to look like lollipops will beautify and honor our South Florida environment. We have to get away from the non-native tropical landscaping and GRASS everywhere. We need to get rid of the grass and add more native trees and understory. A good example is the Broward County public building near Copans and Powerline(?) - they have a lot of beautiful native landscaping in front of their building. Please require developers to STOP using palm trees and start putting in only native landscaping.
- Greening streets is an important goal of building Boca's urban forest and enhancing tree canopy, but the right-of-ways are often very narrow and also constrained by infrastructure (i.e. utilities, sidewalks, etc.). I am sure it is difficult to find places to plant anything besides shrubs and palms in the right-of-ways. I would imagine this is a challenge as palm trees are costly in comparison to the ecosystem services (benefits) they provide. Finding creative ways to overcome this barrier will be important.
- Money. Damage to infrastructure. Trees block swale and yard parking. Interference with utilities.
- Space mainly. I don't think residents will oppose adding more trees or be upset about it.

Q11. Any additional comments.
All comments from respondents on **Q11**.
- Native trees.
- Add in a budget for marketing the benefits and beauty trees, bring to all. Mandate new construction and renovations include concept of "greening"
- I already responded and had some more thoughts. -- Brian Stenberg
- Thank you very much, I only wish our community could be more ambitious in combating the heat-island effect with less dense development and impermeable surfaces.
- You rock
- I HATE seeing all that grass outside the Spanish River library and other public areas. Such a DESERT to birds and wildlife. We can do better than that. Don't bow to the pressure of the uneducated public. Also, the Cypress Knee Slough Preserve is OVERRUN with non-natives and needs to be rescued ASAP. Huge non-native, invasive trees are killing all the oaks, dahoon hollies, red maples, etc. Very sad. Let's save it by removing the invasives and replacing with natives. I'll help!
- I moved to Boca in 2019, but prior to that I was a conservation superintendent for a municipality in CT. Part of my job was serving as the Town's tree warden, so I am very much aware of the struggles that go along with maintaining the urban forest! When I moved to Boca, I was so impressed with how well the parks are maintained and managed. I am so excited to see the effort going in to the tree canopy assessment and the steps proposed to increase canopy cover even further. I am happy to help in any way I can with tree canopy (and any natural resource) projects.
- Thank you for all the detailed info that you presented.