# Jacksonville

# TREES TO OFFSET STORMWATER

## Case Study 12: City of Jacksonville, Florida

Green Infrastructure Center

May 2019

Images and illustrations in the report are by the Green Infrastructure Center Inc. (GIC).

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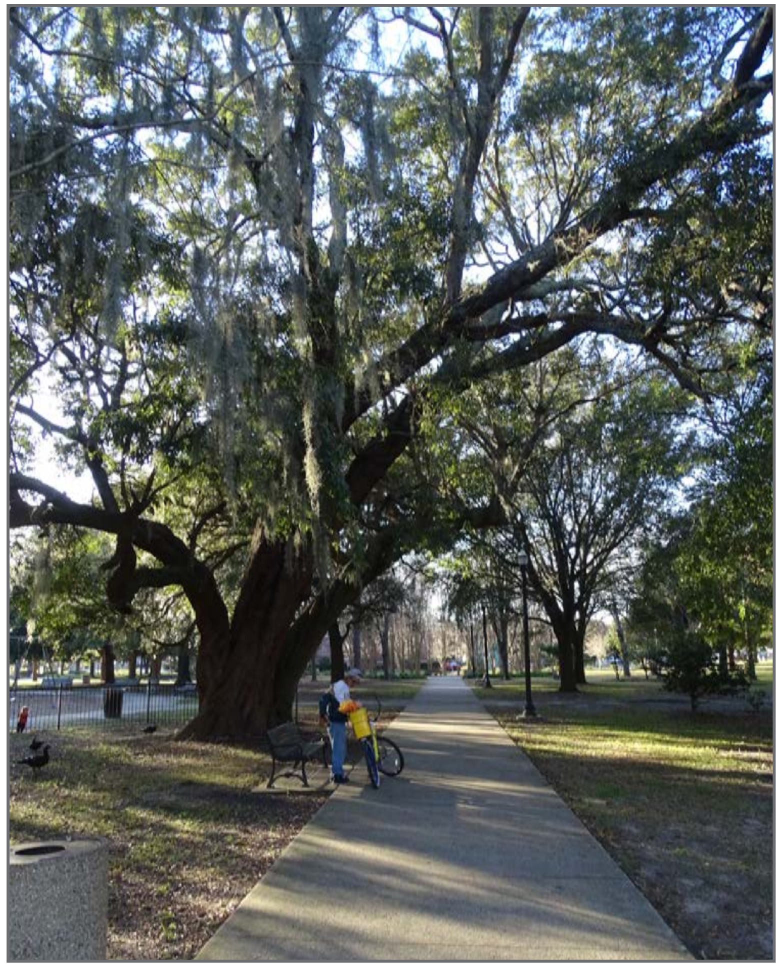
# PROJECT OVERVIEW

The Trees to Offset Stormwater project is a study of the role of Jacksonville's tree canopy in taking up, storing and releasing water. This study was undertaken to assist Jacksonville in evaluating how to better integrate trees into their stormwater management programs. More specifically, the study covers the role that trees play in stormwater management and shows how the city can benefit from tree conservation and replanting. It also evaluates ways for the city to improve forest management as the city develops.

## PROJECT FUNDERS AND PARTNERS

The project was developed by the nonprofit Green Infrastructure Center Inc. (GIC) in partnership with the states of Florida, Georgia, Alabama, South Carolina, North Carolina and Virginia. The GIC created the data and analysis for the project and published this report. This study is one of 12 pilot projects evaluating a new approach to estimate the role of trees in stormwater uptake. Florida received funding from the USDA Forest Service to determine how trees can be utilized to meet municipal goals for stormwater management. The Florida Forest Service administered the pilot studies in Florida and selected Jacksonville to be one of the three test cases. The other Florida municipalities selected were the City of Miami Beach and Orange County.

The project was spurred by the on-going decline in forest cover throughout the southern United States. Causes for this decline arise from multiple sources including land conversion for development, storm damages and inundation from sea level rise (SLR) and lack of tree replacement as older trees die. Many localities have not evaluated their current tree canopy, which makes it difficult to track trends, assess losses or set goals to retain or restore canopy. As a result of this project, Jacksonville now has baseline data against which to monitor canopy protection progress, measures of the stormwater and water quality benefits provided by its urban forest, and locations for prioritizing canopy replanting or retention.



*Jacksonville's majestic trees frame the city's landscape*

## OUTCOMES

This report includes those findings and recommendations that are based on tree canopy cover mapping and analysis, the modeling of stormwater uptake by trees, a review of relevant city codes and ordinances, and input and recommendations for the future of Jacksonville. The city-wide canopy is 55.5 percent. However, as the city includes prior Duvall County lands, that figure also includes rural areas. Downtown canopy coverage is much lower, at just over 12 percent. To maintain a high quality of life and to reduce polluted stormwater runoff, the city will need to plant many more trees in the urban areas and reduce the conversion of rural forest land. This report discusses the benefits of the city's canopy and new tools the city can use to plan for a robust and extensive canopy for the future.

More specifically, the following deliverables were included in the pilot study:

- Analysis of the current extent of the urban forest through high resolution tree canopy mapping,
- Possible Planting Area analysis to determine where additional trees could be planted,
- A method to calculate stormwater uptake by the city's tree canopy,
- A review of existing codes, ordinances, guidance documents, programs and staff capabilities related to trees and stormwater management, and recommendations for improvement,
- Three community meetings to provide outreach and education,
- Presentation of the results of the project at regional, state and national conferences, and
- A case book detailing the study methods, lessons learned and best practices.

| Watershed | Current Tree Cover |
|---|---|
| Black Creek-St. Johns River | 38.8% |
| Doctors Lake-St. Johns River | 61.8% |
| Lower Nassau River Frontal | 72.3% |
| North Fork of Black Creek | 64.2% |
| Ortega River-St. Johns River | 45.0% |
| St. Johns River-Atlantic Ocean | 50.6% |
| Thomas Creek | 75.4% |
| Tolomato River | 51.6% |
| Trout Creek-St. Johns River | 47.3% |
| Upper St. Mary's River | 70.3% |
| Citywide | 55.5% |

The project began in April 2018 and Jacksonville staff members have participated in project review, analysis and evaluation. The following city departments were involved in the project planning and review as the Technical Review Committee (TRC): Public Works Department - Mowing and Landscape Division, Parks Recreation and Community Services - Recreation and Community Programming Division, Planning and Development - Transportation Planning and Community Planning Divisions, Neighborhood Department - Environmental Quality Division, and the Finance and Administration Department. Several consultant, legal, and non-profit organizations also served on the TRC. These included England, Thims, and Miller, St. Johns Riverkeeper Inc., Greenscape of Jacksonville Inc., and the Public Trust - Environmental Legal Institute of Florida. Also representing the state of Florida on the TRC were the St. Johns River Water Management District and the Florida Forestry Commission's Urban and Community Forester and the forester assigned to Duval County.



## COMMUNITY ENGAGEMENT

Three community meetings were held in the first quarter of 2019, one each in Riverside, San Marco and Springfield (workshops were open to all city residents from any area). Meeting topics included an overview of the project, top level recommendations for the city and community engagement. All individual comments from both meetings were provided to the city. Residents were also reminded that they can call 630City to request tree planting on public lands and rights of way areas in front of their homes. For the list of comments see Appendix C of this report.

*Urban forester Richard Leon (right) listens to community ideas.*

Residents emphasized the importance of planting the next generation of trees because many of the city's trees are older, especially in the historic downtown neighborhoods. They also suggested that there are additional opportunities to convert vacant lands to city parks, as was done for Balis Park in San Marco. They also emphasized the importance of planting along creeks. Residents recognized the importance of partnerships and suggested the city coordinate with Greenscape's tree giveaway programs to plant in strategic locations.

*Residents review locations for tree plantings*

*GIC staff listen to community tree policy priorities.*

Residents lamented the problem of lot clearing before development begins as it means that trees are not saved prior to designing a site plan. In terms of land cover, several residents pointed out the issue that the city's pavement regulations cover only rooftops but not patios or driveways so that lots could be very impervious with little to no vegetation to soak up stormwater. Parking standards were also noted as a cause of over-paving the landscape. Everyone noted the fear of storms as a driver for people to cut down or excessively prune their trees and suggested that more education is needed about the value of trees and how to minimize risk without unduly harming the urban forest.

Community members were presented with code/ordinance or practice changes which GIC recommended to the City of Jacksonville. Meeting attendees were asked to choose the top changes they felt would most benefit the urban forest. Popular changes included:

- Work with developers to shrink the development footprint.
- Approve trees as stormwater management practices.
- Increase education about the benefits of trees for private citizens.
- Accommodate large trees in urban areas by providing adequate soil volume.
- Create an urban forest management plan.

*Urban forester Richard Leon (right) explains that Jacksonville considers its trees as 'green infrastructure.'*

## Jacksonville can use this report and its associated products to:

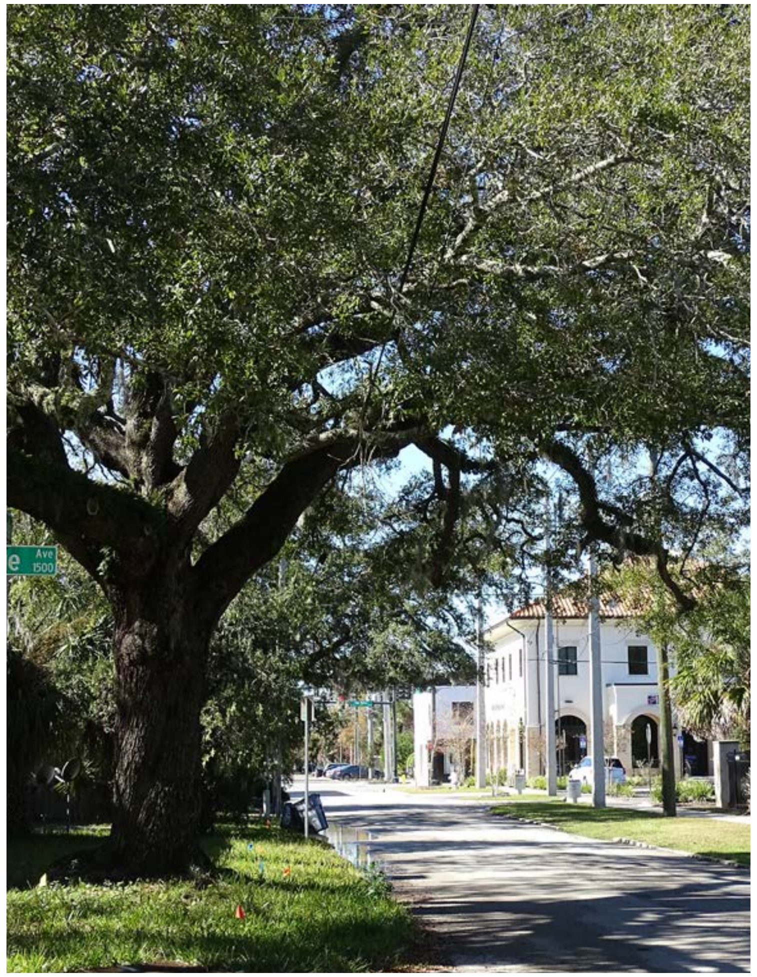
- *Set goals and develop a management plan for retaining or expanding its tree canopy by watershed or community planning areas.*
- *Improve management practices so trees will be well-planted and well-managed.*
- *Educate developers about the importance of tree retention and replacement.*
- *Motivate private landowners (residential, commercial, and institutional) to plant trees and protect them.*
- *Support grant applications for tree conservation projects.*

# SUMMARY OF FINDINGS

The goal of this study was to identify ways in which water entering the city's municipal separate storm sewer system (MS4) could be reduced by using trees to intercept and soak up runoff. In order to determine the tree canopy in the city, satellite imagery was used to classify the types of land cover in Jacksonville. The resulting land cover maps show the city those areas where vegetative cover helps to uptake water and those areas where impervious land cover is more likely to result in stormwater runoff. High-resolution tree canopy mapping provides a baseline to assess current tree cover and to evaluate future progress in tree preservation and planting. An ArcGIS geodatabase with all GIS shape files from the study was provided to Jacksonville. For more on methods see page 16.

Tree canopy serves as 'green infrastructure' that can provide more capacity for the city's grey infrastructure (i.e. stormwater drainage systems) by absorbing or evaporating excess water before it runs off and enters storm drains. The model created shows how the city can reduce potential pollution of its surface waters, which can impact Total Maximum Daily Load (TMDL) outcomes and inform watershed plans.

The detailed land cover analysis created for the project was used to model how much water is taken up by the city's trees in various scenarios. This new approach allows for more detailed assessment of stormwater uptake based on the landscape conditions of the city's forests. It distinguishes whether the trees are growing in a more natural setting (e.g. a cluster of trees in an urban forest or forested wetland), a lawn setting, or over pavement, such as streets or sidewalks. The amount of open space and the condition of surface soils affect the infiltration of water.



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

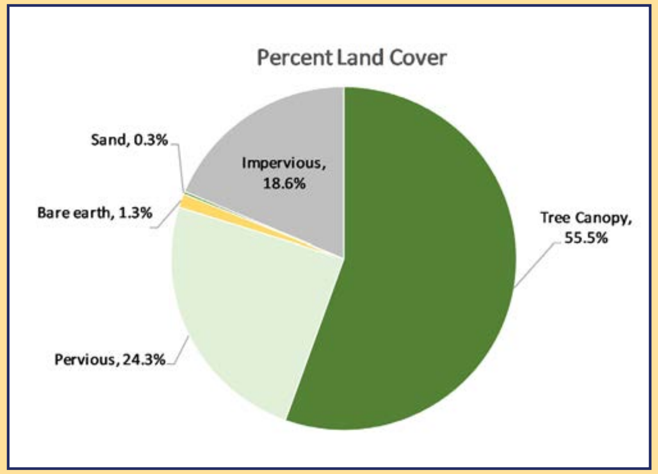
**Citywide tree canopy is 55.5 percent. During an average volume rainfall event in Jacksonville (a 10-year storm), over 24 hours the city's trees take up an average of 1.377 billion gallons of water.**

## *That's about 2,085 Olympic swimming pools of water!*

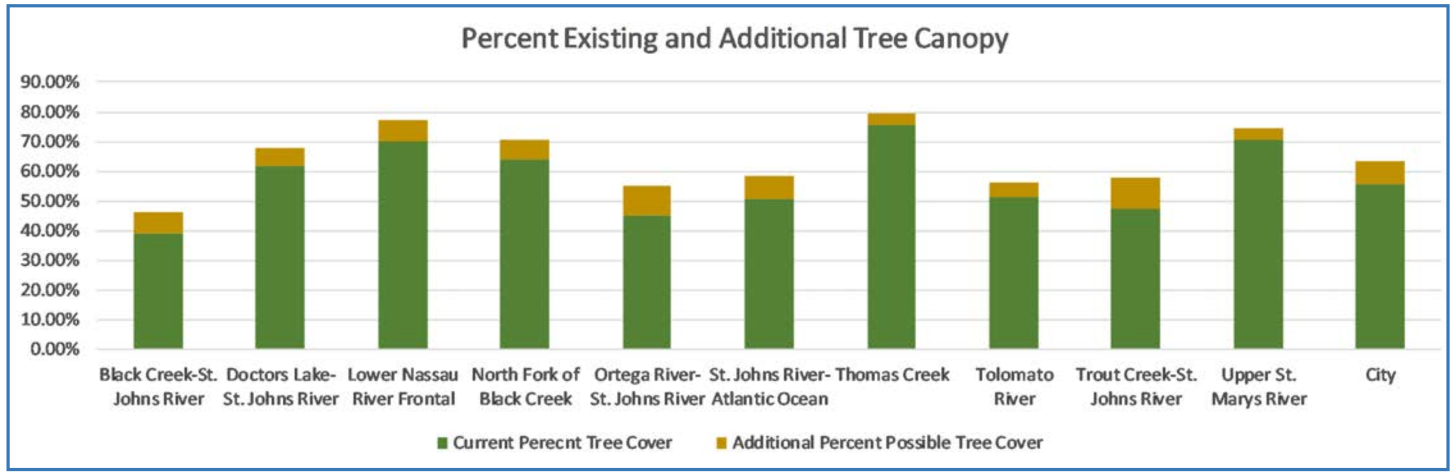
## Jacksonville: Fast Facts & Key Stats

- Coastal community in northeastern Florida.
- County: Duval
- 2017 U.S. Census Population Estimate: ...... 892,062 people
- City Area— Jacksonville and Duvall County merged in 1968.
  - Total area: ...................... 850 sq. mi.
  - Land: ............................... 703 sq. mi.
  - Water: ............................. 98 sq. mi.
  - Streams: ......................... 705.7 miles*
  - Tree Canopy: .................. 250,337 acres (55%)

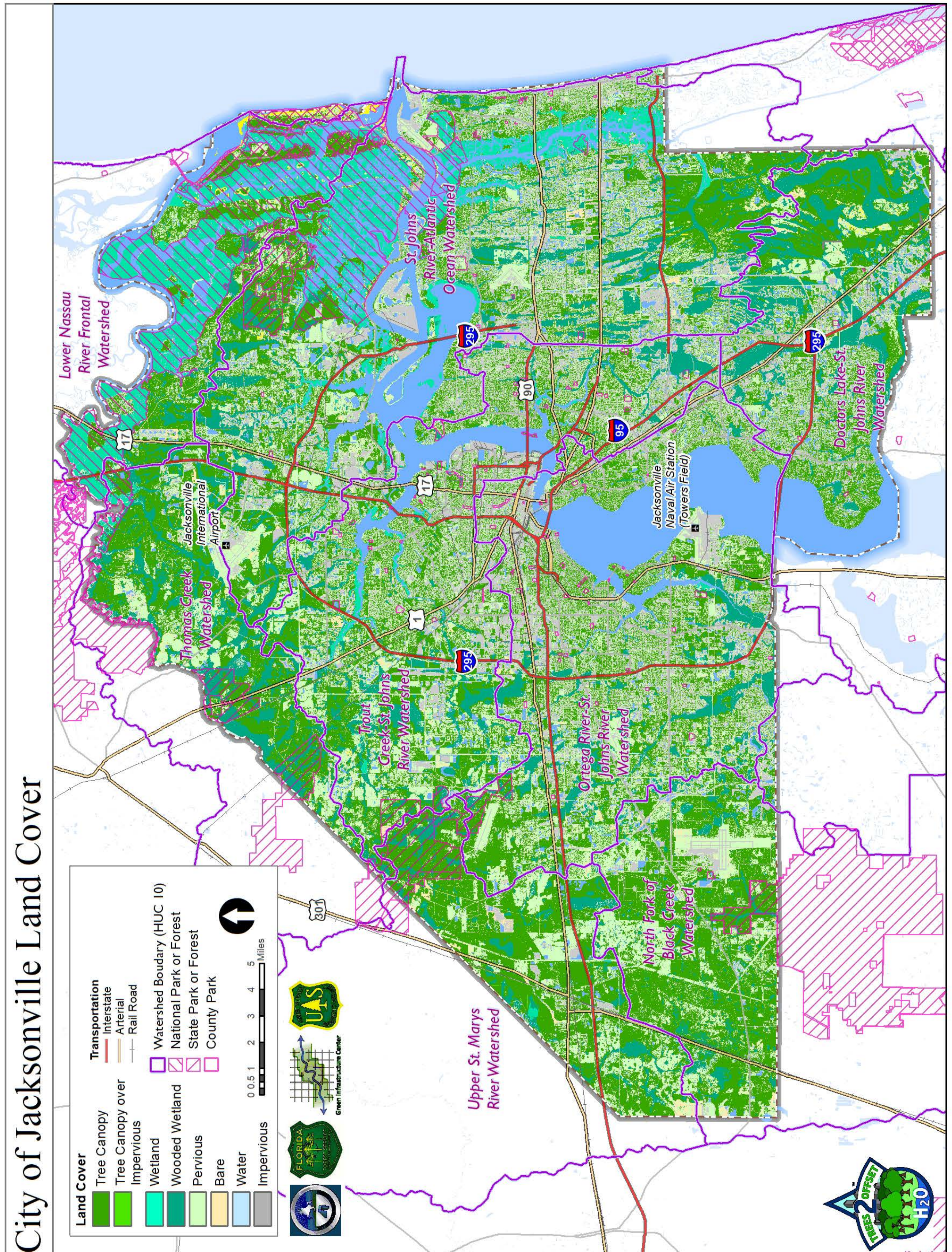
*Source: US Geological Survey



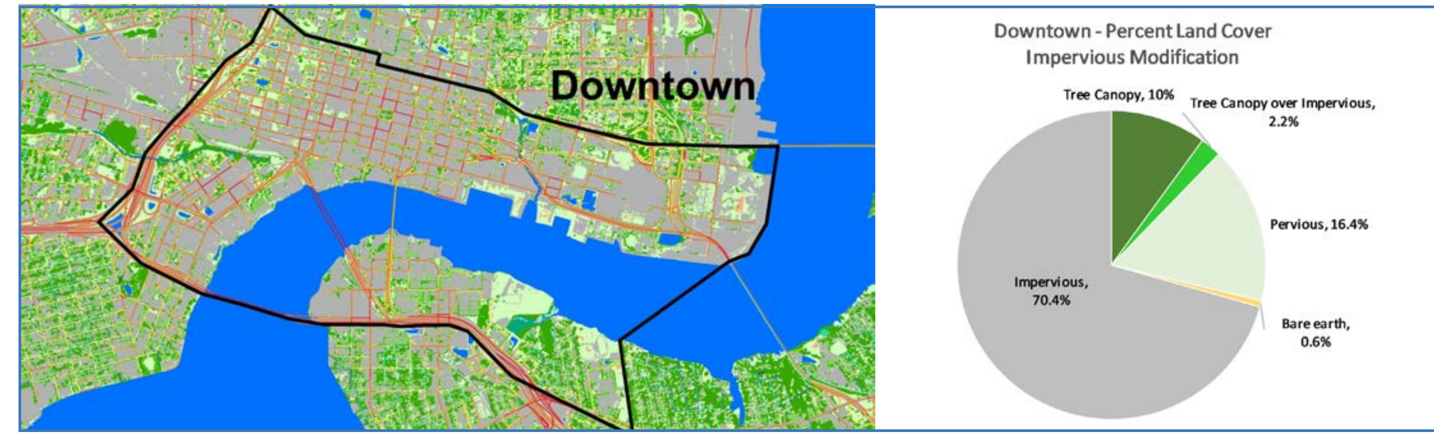

*Citywide tree canopy is 55.5 percent.*




*Percent Tree Cover and Possible Planting Area by Watershed*




This map shows the tree canopy of the city, which covers 55.5 percent of the area




*Although tree canopy is 55.5 percent citywide, it is far less downtown as this clipped area of downtown shows canopy coverage of just 12.2 percent (not including water).*

## WHY PROTECT OUR URBAN FORESTS?

Today, municipalities are losing their trees at an alarming rate, estimated at four million trees annually nationwide (Nowak 2010). This is due, in large part, to population growth. This growth has brought pressures for land conversion to accommodate both commercial and residential development. Cities are also losing older, established trees from the cumulative impacts of land development, storms, diseases, old age and other factors (Nowak and Greenfield 2012). Although Jacksonville's canopy is 55.5 percent, it's important to understand that this coverage is not consistent across the city. For example, downtown canopy is only 12.2 percent. When considering the canopy coverage of 'the city' it is also important to realize that the City of Jacksonville includes rural areas that were once part of Duvall County, some of which are still rural. Large areas that are now used as plantation forests growing pine trees may convert to development in the future. As the city changes and grows, retaining tree canopy and intact forest land is critical to ensuring a healthful landscape for people and wildlife and for reducing risks from stormwater runoff and associated flooding.

*Neighborhood trees.*

Cities, such as Jacksonville, have lost natural forest cover and wetland areas as land has been converted or filled. The city may continue to see losses unless tree canopy retention on private lands becomes a key aim. And for older historic neighborhoods, canopy replanting is critical. As older trees die (or before they die), younger trees need to be planted to replace the older canopy. As noted above, canopy coverage downtown is about 12 percent. However, based on an analysis of existing open space, 3.6 percent more area downtown could possibly be planted, resulting in 15.6 percent canopy. For recommendations on how the city can better protect and manage its urban forests, see the Codes and Ordinances section of this report.

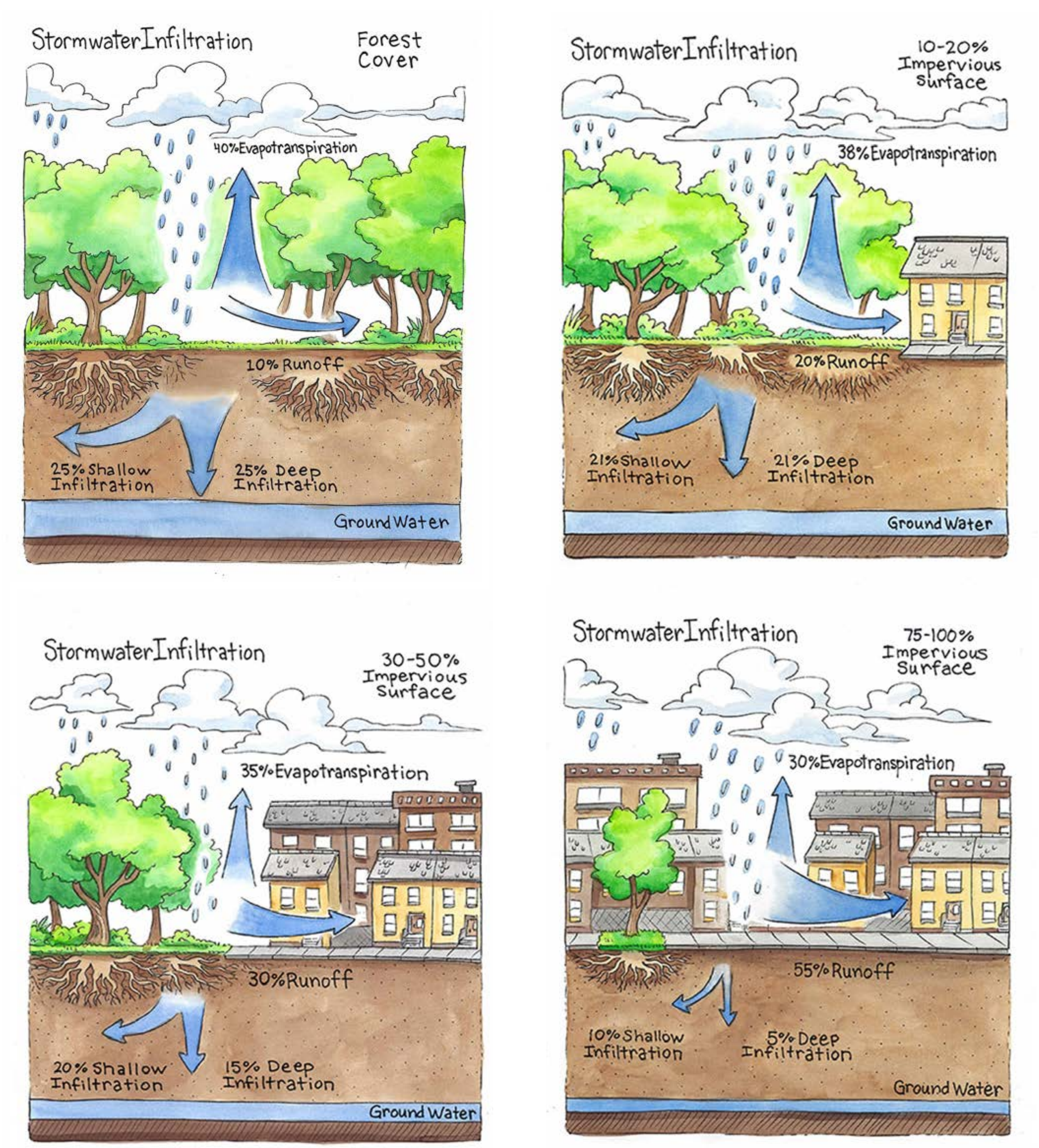
The purpose of this report is not to seek a limit on the city's development, but to help the city better utilize its tree canopy to manage its stormwater. Additional benefits of improved canopy include:

- fostering a healthful and vibrant community
- cleaner air
- aesthetic values
- reduced heating and cooling costs
- decreased urban heat island effects
- buffering structures from wind damage
- increased bird habitat
- fostering walkability and multimodal transportation
- increased revenue from tourism and retail sales

*Assessment and inventory of trees is key to ensuring a healthy forest.*

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 from standing water. The EPA recommends a number of ways to use trees to manage stormwater in the book Stormwater to Street Trees.

In considering runoff, the amount of imperviousness is one consideration; the other is the degree and type of forested land cover, since vegetation helps absorb stormwater and reduces the harmful effects of runoff. As their urban forest canopies have declined across the south, municipalities have seen increased stormwater runoff. Unfortunately, many cities do not have a baseline analysis of their urban forests or strategies to replace lost trees.




*Runoff increases as land is developed. Information source: U.S. EPA*



In Jacksonville, with its tidal rivers and some impacts from sea level rise, the city has seen increasing flooding problems. The city has established action areas for particular focus to address coastal flooding along the shorelines of the St. Johns River and the Intracoastal Waterway, as well as the Trout, Broward, Ribault, Cedar, Ortega and Arlington rivers and Dunn, Pottsburg, Julington and Durbin creeks.

When forested land is converted to impervious surfaces, stormwater runoff increases. This increase in stormwater causes temperature spikes in receiving waters, increased potential for pollution of surface and ground waters and greater potential for flooding. When underground aquifers are not replenished, land subsides.

Another cause of canopy decline are the many recent powerful storms, such as Hurricanes Irma and Florence, that have affected the city with extensive flooding and tree canopy damage. As cities lose trees, they lose the ability to absorb and evaporate excess water. This study was funded to address canopy decline by helping municipalities monitor, manage and replant their urban forests and to encourage cities to enact better policies and practices to reduce stormwater runoff and improve water quality.

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

Urbanizing counties and cities are beginning to recognize the importance of their urban trees because trees provide tremendous dividends. For example, urban canopy can reduce stormwater runoff anywhere from two to seven percent (Fazio 2010). According to Penn State Extension, during a one-inch rainfall event, one acre of forest will release 750 gallons of runoff, while a parking lot will release 27,000 gallons! This could mean an impact of millions of gallons during a major precipitation event. While stormwater ponds and other management features are designed to attenuate these events, they cannot fully replicate the pre-development hydrologic regime. In addition, parts of Jacksonville are older and may lack stormwater management practices that are now required for new developments.

*Excess impervious areas cause hot temperatures and runoff. Some older paved areas predate regulations requiring stormwater management.*

*Planting the next generation of the city's canopy*

*Trees in residential yards also help to soak up rainfall.*

Trees filter stormwater and reduce overall flows. So planting and managing trees is a natural way to mitigate stormwater. Estimates from a Dayton, Ohio study found a seven percent reduction in stormwater runoff due to existing tree canopy coverage and a potential increase to 12 percent runoff reduction as a result of a modest increase in tree canopy coverage (Dwyer et al 1992). Conserving forested landscapes, urban forests, and individual trees allows localities to spend less money treating water through the municipal storm systems and reduces flooding. Each tree plays an important role in stormwater management. For example, based on the GIC's review of multiple studies of canopy rainfall interception, a typical street tree's crown can intercept between 760 gallons to 3000 gallons of water per tree per year, depending on the species and age. If a community were to plant an additional 5,000 such trees, the total reduced runoff per year could amount to millions of gallons or reduced runoff. This means less flooded neighborhoods and reduced stress on storm drainage pipes and decreased runoff into the city's rivers, marshes, bays, and the ocean.

Another compelling fiscal reason for planning to conserve trees and forests as a part of a green infrastructure strategy is minimizing the impacts and costs of natural disasters. Not only do trees reduce the likelihood of extensive flooding, they also serve to as a buffer against storm damages from wind.

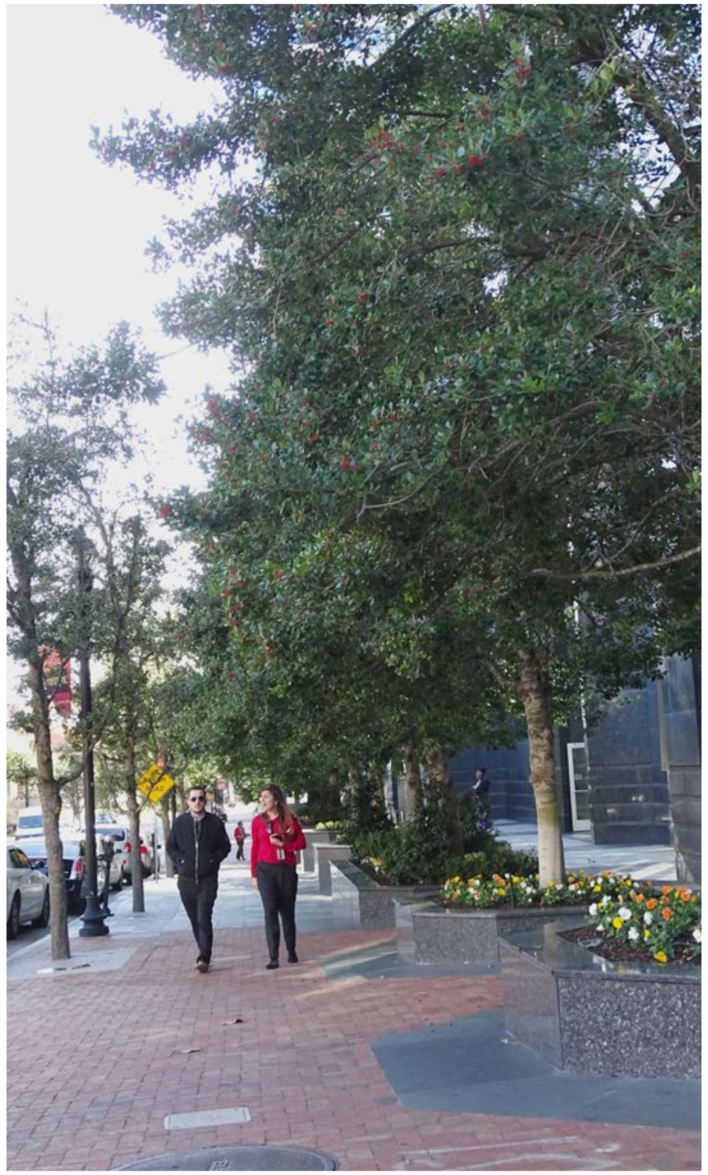
In urban areas, Geographic Information Systems (GIS) software is used to map the extent of the current canopy as well as to estimate how many new trees might be fitted into an urban landscape. A Possible Planting Area (PPA) map estimates areas that may be feasible to plant trees. A PPA map helps communities set realistic goals for what they could plant (this is discussed further on in the Methods Appendix).

*There are many locations where trees can be added to soak up more water.*

## ADDITIONAL URBAN FOREST BENEFITS

### Quality of Life Benefits

During Florida's hot summers, more shade is always appreciated. Tree cover shades streets, sidewalks, parking lots, and homes, making southern urban locations cooler, and more pleasant for walking or biking. An average summer daytime temperature reduction of 6.4 (degrees F) has been documented in association with a typical large tree in Florida (Souch and Souch 1996). In addition, trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Shaded pavement has a longer lifespan thereby reducing maintenance costs associated with repairing or replacing roadways and sidewalks (McPherson and Muchnick 2005).



*Well treed areas encourage people to walk.*

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 the highest level of improved cognitive function after the move, regardless of level of affluence (Wells 2000). Thus, communities with greener landscapes benefit children and reduce ADHD symptoms. Trees also cause people to walk more and walk farther. This is because when trees are not present, distances are perceived to be longer and destinations farther away, making people less inclined to walk than if streets and walkways are well treed (Tilt, Unfried and Roca 2007).

*Communities with greener landscapes benefit children by reducing both asthma and ADHD symptoms.*

*Trees provide substantial shade and can make temperatures 12 degrees cooler for pedestrians and bicyclists.*

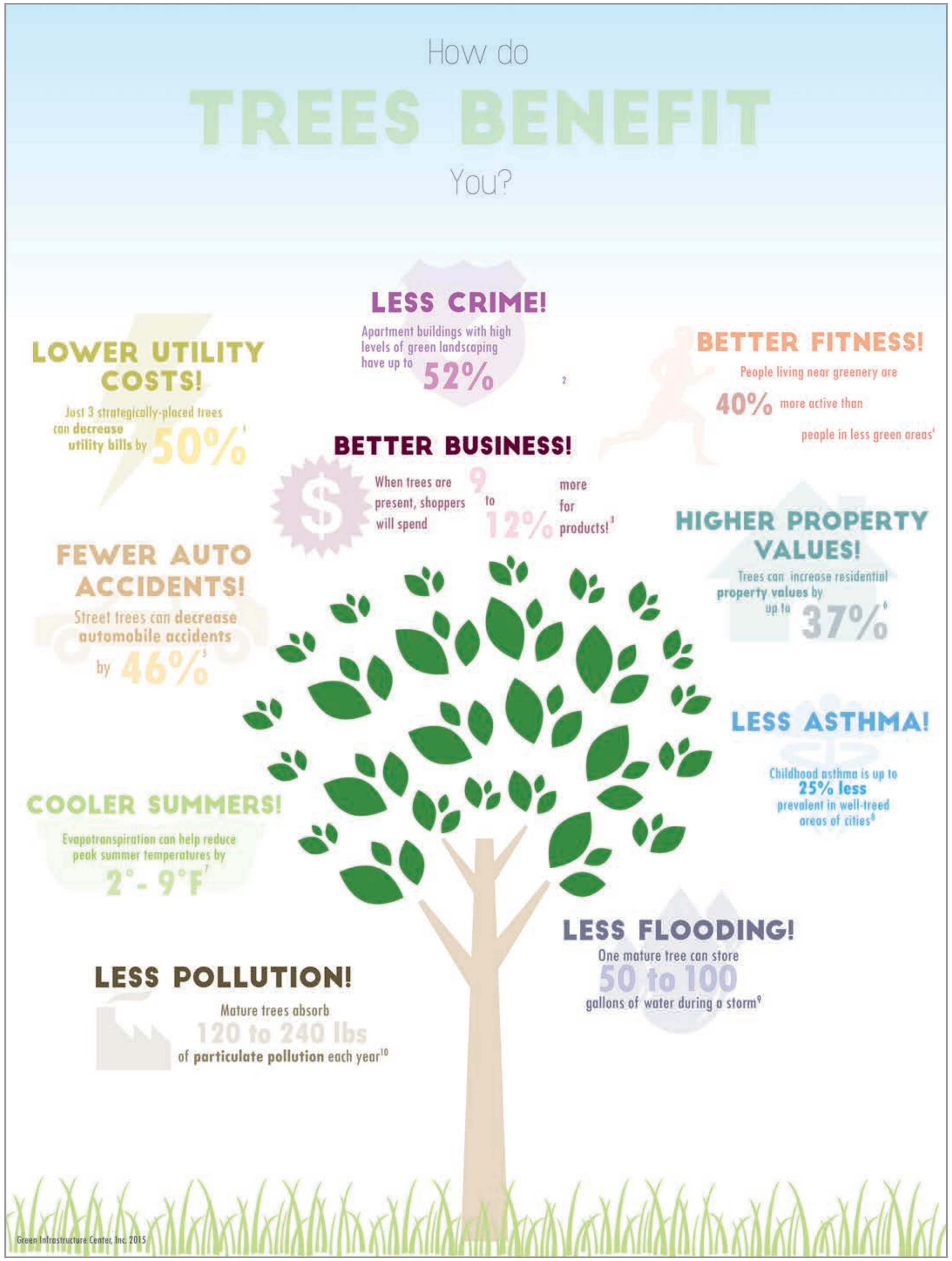
*There are many places where trees can be added downtown for shade and beauty, especially along city creeks where trees can also filter runoff and reduce stream temperatures..*

### Economic Benefits

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 for community green space (Benedict and McMahon 2006). This desire for green space is supported by a National Association of Realtors study which found that 57 percent of voters surveyed were more likely to purchase a home near green space and 50 percent were willing to pay 10 percent more for a home located near a park or other protected area. A similar study found that homes adjacent to a greenbelt were valued 32 percent higher than those 3,200 feet away (Correll et al. 1978).

### Meeting Regulatory Requirements

Trees also help meet the requirements of the Clean Water Act. The Clean Water Act requires Florida to have standards for water quality. When waters are impaired they may require establishment of a Total Maximum Daily Load (TMDL) standard and a clean-up plan (i.e., Best Management Action Plan) to meet water quality standards. Since a forested landscape produces higher water quality by cleaning stormwater runoff (Booth et al 2002), increasing forest cover results in less pollutants reaching the city's surface and ground waters.






# NATURAL ECOLOGY IN CHANGING LANDSCAPES

Natural history, even of an urbanized location, informs planting and other land-management decisions. Jacksonville is located in the Sea Island Flatwoods ecoregion with the southern area (lower Duval County) in the Eastern Florida Flatwoods region. For details see: https://www.plantmaps.com/interactive-florida-ecoregions-l4-map.php The Sea Island Flatwoods are characterized by flat plains on somewhat dissected marine terraces; swamps, and low gradient streams with sandy and silty substrates.

Flatwoods are an ecosystem maintained by wildfire or prescribed fire and are dominated by longleaf pine (*Pinus palustris*), and slash pine (*Pinus elliottii*) in the tree canopy and saw palmetto (*Serenoa repens*), gallberry (*Ilex glabra*) and other flammable evergreen shrubs in the understory, along with a high diversity of herb species. The land is comprised of wet and seasonably saturated mineral soils. The key factor maintaining this habitat type is recurring fire. When fires are suppressed, other woody plants invade the area.

Since much of Duval County is still rural, the landscape supports endemic (native) species found in the flatwoods ecosystem such as red-cockaded woodpeckers (Picoides borealis), and the Wood Stork (Mycteria Americana). Both the wood stork and red cockaded woodpeckers are listed as endangered species, as are the frosted flatwoods salamanders (Ambystoma cingulatum). Gopher tortoises (*Gopherus polyphemus*) and striped newts (Notophthalmus perstriatus) are also found in Duval County and are candidates for listing[1].

## HISTORIC LAND COVER

The Timucuan Indians first settled along the St. John's River and may have reached a population of 150,000. However, the Timucuan declined rapidly following European settlement, followed by the French Huguenots in 1562, the Spanish, the English and others. Significant land changes occurred as English plantations sprang up along the St. John's River and cleared land for cotton, indigo, rice, and vegetables. Slave labor was used to do much of the difficult work on land clearing and farming. The British also harvested a great deal of lumber to supply their navies, as they did elsewhere along the Atlantic coast. The Spanish followed again, but did not hold the area. Eventually, Florida became a U.S. territory in 1822 and a state in 1845, by which time it was known for its cotton, lumber, vegetables and orange crops. The settlement was named for Andrew Jackson in 1822 in a petition to recognize the area as a port, and it eventually became a town in 1832.

*The Treaty Oak (Quercus Virginiana) is an historic tree, approximately 250 years old, which is said to be the site of treaties signed between Native Americans and the Spanish.*

Seceding from the U.S. during the Civil War, Jacksonville was occupied four times, and as a port city, played a large role in blockades during the war. Although the city suffered from consequences similar to many southern cities in the war's aftermath, tourism played a role in the city's growth as people sought the south's warmer climes, giving way to new hotels and eventually a land boom. Railroad development in the first half of the 20th century also spurred tremendous trade and expansion of the city. The addition of military bases also contributed to the city's growth and importance. In 1968 when Jacksonville and Duval County merged, it formed the largest city in the U.S. by land area. For a more detailed recounting of the city's history see http://www.coj.net/about-jacksonville/history.

Today, Jacksonville's downtown is booming with its restaurants, river fronts, the Museum of Contemporary art, the Cummer Museum and others, art and music festivals, and restaurants, as well as vibrant neighborhoods and the historic districts of Springfield, St John's Quarter and Riverside Avondale which showcase the city's cultural diversity. The city is also recognized for its many unique quality of life aspects and careers in rankings by US News (42nd/100 best places to live), and affordability and housing, (3rd best city to live in Florida, Movoto Real Estate Blog).

With its 337 city parks covering 80,000 acres, Jacksonville also offers abundant opportunities to enjoy the outdoors and support native species. City parks and trails, such as Betz-Tiger Point Preserve and the 120-acre Arboretum, are popular places to experience nature in the city and add to the city's livability scores.

[1] *Source: US Fish and Wildlife Service https://www.fws.gov/northflorida/CountyList/Duval.htm*

Jacksonville supports a vibrant and culturally-diverse landscape.

The arboretum provides education about native trees and a quiet retreat for residents.

## GROWTH AND DEVELOPMENT CHALLENGES

Demands for space to meet the needs for housing, commercial, business, and transportation uses put strains on both the city's grey and green infrastructure. As an older city, there are areas that pre-date the 1987 Clean Water Act Amendments which require the treatment of stormwater runoff. Adding stormwater treatment for older areas is achieved by either retrofitting stormwater best management practices into the landscape, or adding them as properties are re-developed. Adding more trees is a best management practice that provides other benefits beyond stormwater uptake, such as shade, air cleansing and aesthetic values. Recommendations for improvements to better utilize trees to manage stormwater and to reduce imperviousness are found in the Codes, Policies and Practices section of this report.

Although Jacksonville sits at a higher elevation than many other Florida coastal cities, sea level rise will affect the city in the future. The Regional Community Institute of Northeast Florida developed a Regional Action Plan to prepare for sea level rise. For more see: https://www.nefrc.org/WiP/PDFs/Resource-Library/Regional-Action-Plan.pdf Although, Jacksonville enjoys higher elevations than many coastal cities, it is still subject to storm surges. A useful tool to look at those areas at risk based on elevation is found at https://coast.noaa.gov/digitalcoast/tools/slr

Planting a tree here would help absorb this standing water.

Reducing imperviousness and increasing vegetation are one way to ease the frequency of flooding because this limits the amount of water that needs to be drained by an already challenged storm drain system. Vegetation reduces water entering the system by intercepting, capturing and transpiring that water.

The requirements set forth by the Clean Water Act of 1972 for the Environmental Protection Agency's National Pollution Discharge Elimination System (NPDES) permitting program, and subsequent amendments in 1987 regulating nonpoint source pollution, form the foundation for the city's stormwater management program.

The city contracts with ETM Corporation to manage its stormwater program and reporting requirements, and the city's NPDES Annual Report, which is reviewed and approved by the Florida Department of Environmental Protection (FDEP). Jacksonville has a Stormwater Utility which helps fund stormwater management improvements and the work of local stormwater action teams. The utility generates the revenue for maintaining and improving the city's stormwater management system and for achieving requirements to protect waterways.

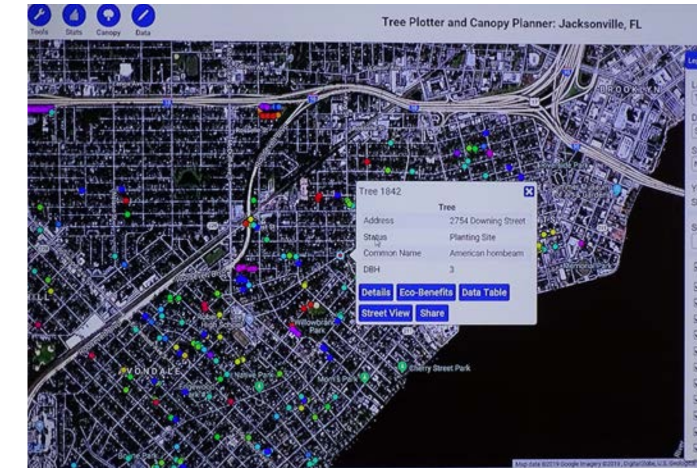


## JACKSONVILLE'S RESILIENT FUTURE

Jacksonville is seeking to redevelop in ways that support a quality lifestyle for residents and visitors alike, while also meeting state and federal mandates for protecting air and water. For example, Jacksonville has embraced the Severe Repetitive Loss Program of the Federal Emergency Management Agency (FEMA). This program uses National Flood Insurance Program funds either to elevate flood-prone homes or to acquire these properties and convert them to open space to mitigate flooding impacts.

In February 2019, the city formed a Storm Resiliency and Infrastructure Development Review Committee to investigate additional ways for the city to become more resilient in the face of climate change, storms and stormwater challenges. That committee should review the recommendations in this report and utilize the stormwater calculator tool to plan for strategic forest conservation and replanting to address stormwater challenges.

Jacksonville has also developed better capacity to manage its urban forest and to share its tree planting work. In the past several years, the city has hired three new positions to manage its urban forest and its tree commission can identify ways to plant more trees. The city has a tree mapping tool for residents to track tree plantings and plans for new plantings: https://pg-cloud.com/JacksonvilleFL/ The city can use the data and maps from the Trees to Offset Water project to target where to plant trees to maximum stormwater mitigation.




Jacksonville's canopy planner tool can be used to view and plan for public tree planting.

Residents can make a difference in runoff by limiting pavement as this residence has done with a partially green driveway.

Planting more trees is key to reducing runoff.

# ANALYSIS PERFORMED

This project evaluated options for how to best model stormwater runoff and uptake by the city's tree canopy. Its original intended use was for planning at the watershed scale for tree conservation. An example is provided on page XX. However, new tools created for the project allow the stormwater benefits of tree conservation or additions to be calculated at the site scale as well.

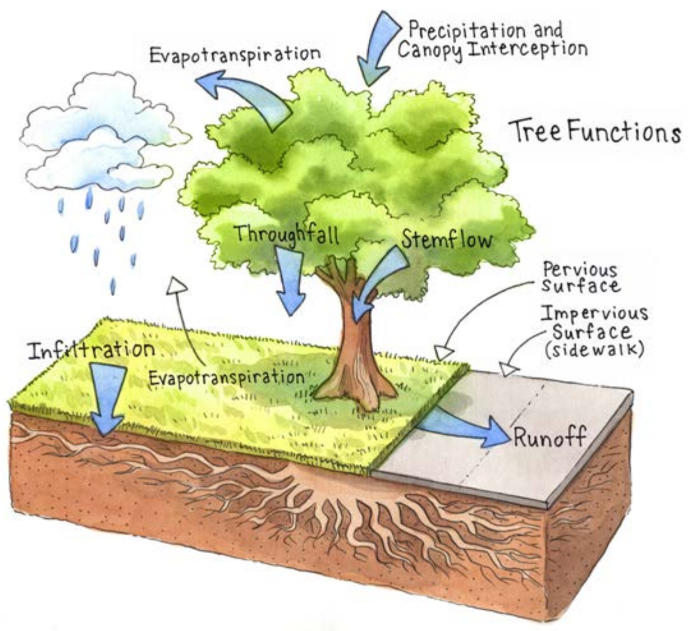
As noted, trees intercept, take up and slow the rate of stormwater runoff. Canopy interception varies from 100 percent at the beginning of a rainfall event to about three percent at the maximum rain intensity. Trees take up more water early on during storm events and less water as storm events proceed 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.

## METHOD TO DETERMINE WATER INTERCEPTION, UPTAKE AND INFILTRATION

This study used the Natural Resources Conservation Service (NRCS) TR-55 curve number method to calculate stormwater runoff. The TR-55 method calculates stormwater runoff and absorption for different land covers, e.g. pavement, lawn, forest. This approach is widely recognized and utilized by stormwater engineers to determine stormwater runoff volumes and most cities use the TR-55 curve numbers to generate expected runoff amounts for land cover changes. It also accounts for the infiltration rate for various soils.

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



*Trees and the Water Cycle*

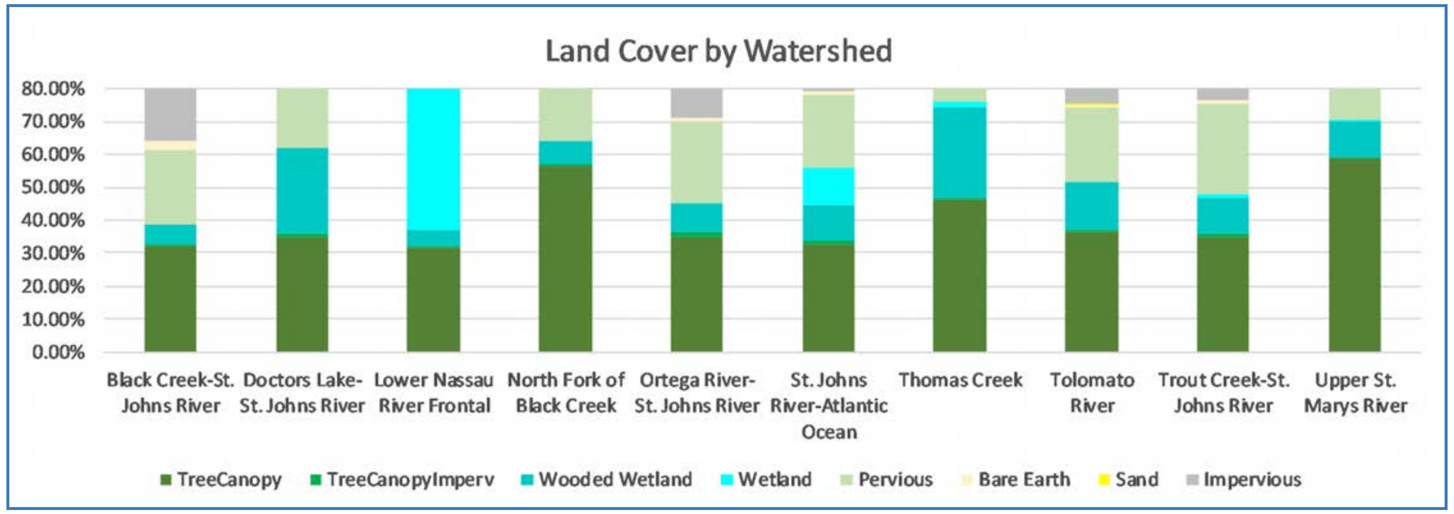
This study modified the TR-55 curve number equation to include a factor for canopy interception (see following equation). Trees capture some of the rainfall before it reaches the ground, while some of the rainfall goes through the branches (throughfall) and down the branches and trunk of the tree (trunk flow). Ordinarily, the runoff calculation is based on soils and ignores the role that trees play in rainwater interception and evaporation. Accounting for the role that trees play in capturing, absorbing and evaporating rainfall is critical in understanding how much water is running off the land and how much is retained.

A canopy interception factor is added to the runoff equation to account for the role trees play in interception of rainfall based on location and planting condition (e.g. trees over pavement versus trees over a lawn or in a forest). Tree canopy reduces the proportion of precipitation that becomes stream and surface flow, also known as water yield. 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 (inches)
- Ia is the initial abstraction for captured water, which is the fraction of the storm depth after which runoff begins
- S is the potential maximum retention after runoff begins for the subject land cover (S = 1000/CN – 10).
- Canopy interception (Ci) is subtracted from precipitation (P) to account for the water that trees take up.





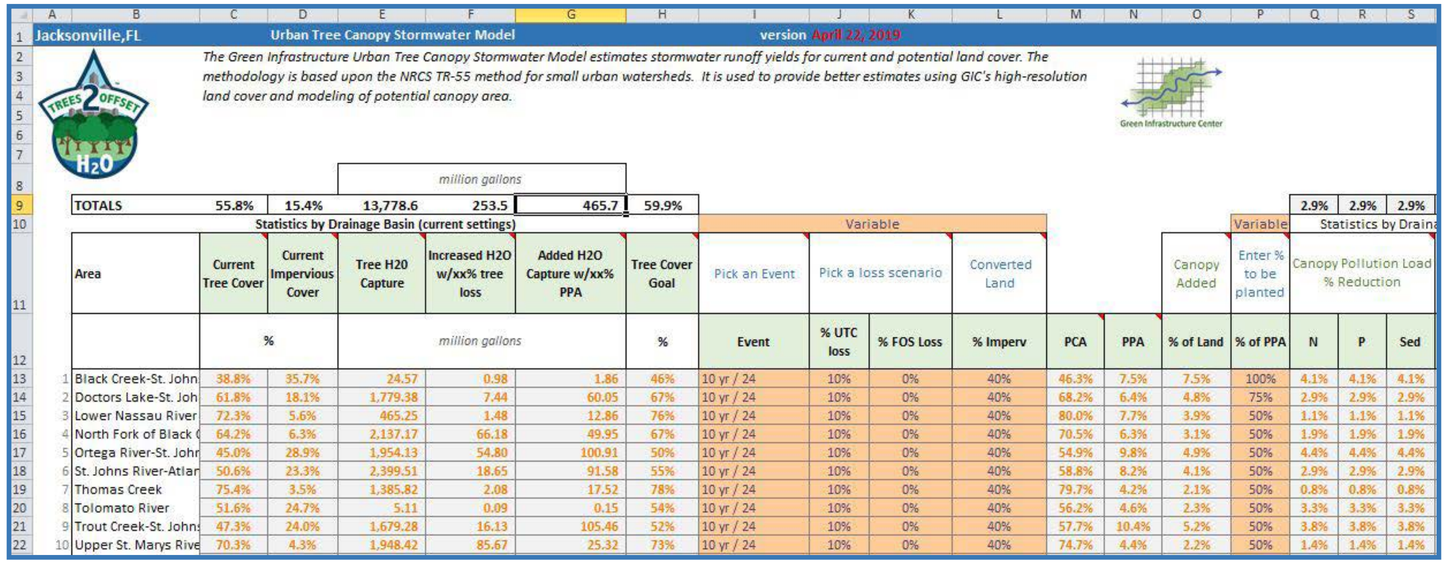

In order to use the equation and model scenarios for future tree canopy and water uptake, the GIC first developed a highly detailed land cover analysis to account for the land conditions in which the trees are found (trees overhanging a parking lot versus trees over a lawn). This is important because rain falling though a tree (throughfall) onto a pervious surface, such as a lawn, can still be absorbed, while rain throughfall to a street will become runoff.

The stormwater runoff model provides estimates of 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. The Trees and Stomwater Calculator Tool also be used to run 'what-if' scenarios, specifically losses of tree canopy from development and increases in tree canopy from tree planting programs.

The city can use the modified TR-55 CN from this study for its modeling and development design reviews, for watershed plans and for setting urban canopy goals. The Trees and Stomwater Calculator Tool makes it very easy for the city to change the curve numbers if they so choose. This project is also a tool for setting goals at the watershed scale for planting trees and for evaluating consequences of tree loss as it pertains to stormwater runoff.

The Trees and Stomwater Calculator Tool provided to Jacksonville allows the city to hypothetically add or reduce tree canopy to see what are the effects for stormwater capture or runoff. For example, during an average volume rainfall event in Jacksonville (a 10-year storm*), over 24 hours the city's trees take up an average of 1.377 billion gallons of water. That's about 2,085 Olympic swimming pools of water! As shown below, for a 10-year, 24-hour storm, a loss of 10 percent of the urban tree canopy would increase runoff by 253.5 million gallons, while increasing canopy coverage from the current 55.4 to 60 percent would decrease runoff by 465 million gallons and reduce loadings of Nitrogen, Phosphorus and Sediment by about 3 percent.

* A 10-year storm refers to the average recurrence interval, or a 10 percent chance of that level of rainfall occurring.


Jacksonville,FL — Urban Tree Canopy Stormwater Model — version April 22, 2019

*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 H20 Capture (million gallons) | Increased H2O w/xx% tree loss (million gallons) | Added H2O Capture w/xx% PPA (million gallons) | Tree Cover Goal (%) | Pick an Event: Event | Pick a loss scenario: % UTC loss | % FOS Loss | Converted Land: % Imperv | PCA | PPA | Canopy Added: % of Land | Enter % to be planted: % of PPA | Canopy Pollution Load % Reduction: N | P | Sed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TOTALS | 55.8% | 15.4% | 13,778.6 | 253.5 | 465.7 | 59.9% | | | | | | | | | 2.9% | 2.9% | 2.9% |
| 1 | Black Creek-St. John | 38.8% | 35.7% | 24.57 | 0.98 | 1.86 | 46% | 10 yr / 24 | 10% | 0% | 40% | 46.3% | 7.5% | 7.5% | 100% | 4.1% | 4.1% | 4.1% |
| 2 | Doctors Lake-St. Joh | 61.8% | 18.1% | 1,779.38 | 7.44 | 60.05 | 67% | 10 yr / 24 | 10% | 0% | 40% | 68.2% | 6.4% | 4.8% | 75% | 2.9% | 2.9% | 2.9% |
| 3 | Lower Nassau River | 72.3% | 5.6% | 465.25 | 1.48 | 12.86 | 76% | 10 yr / 24 | 10% | 0% | 40% | 80.0% | 7.7% | 3.9% | 50% | 1.1% | 1.1% | 1.1% |
| 4 | North Fork of Black ( | 64.2% | 6.3% | 2,137.17 | 66.18 | 49.95 | 67% | 10 yr / 24 | 10% | 0% | 40% | 70.5% | 6.3% | 3.1% | 50% | 1.9% | 1.9% | 1.9% |
| 5 | Ortega River-St. Johr | 45.0% | 28.9% | 1,954.13 | 54.80 | 100.91 | 50% | 10 yr / 24 | 10% | 0% | 40% | 54.9% | 9.8% | 4.9% | 50% | 4.4% | 4.4% | 4.4% |
| 6 | St. Johns River-Atlar | 50.6% | 23.3% | 2,399.51 | 18.65 | 91.58 | 55% | 10 yr / 24 | 10% | 0% | 40% | 58.8% | 8.2% | 4.1% | 50% | 2.9% | 2.9% | 2.9% |
| 7 | Thomas Creek | 75.4% | 3.5% | 1,385.82 | 2.08 | 17.52 | 78% | 10 yr / 24 | 10% | 0% | 40% | 79.7% | 4.2% | 2.1% | 50% | 0.8% | 0.8% | 0.8% |
| 8 | Tolomato River | 51.6% | 24.7% | 5.11 | 0.09 | 0.15 | 54% | 10 yr / 24 | 10% | 0% | 40% | 56.2% | 4.6% | 2.3% | 50% | 3.3% | 3.3% | 3.3% |
| 9 | Trout Creek-St. Johns | 47.3% | 24.0% | 1,679.28 | 16.13 | 105.46 | 52% | 10 yr / 24 | 10% | 0% | 40% | 57.7% | 10.4% | 5.2% | 50% | 3.8% | 3.8% | 3.8% |
| 10 | Upper St. Marys Rive | 70.3% | 4.3% | 1,948.42 | 85.67 | 25.32 | 73% | 10 yr / 24 | 10% | 0% | 40% | 74.7% | 4.4% | 2.2% | 50% | 1.4% | 1.4% | 1.4% |

*The calculator tool developed for this project allows the city to see the water uptake by existing canopy and model impacts from changes, whether positive (adding trees) or negative (removing trees).*

The key finding from this work is that removal of mature trees generates the greatest impacts for stormwater runoff. As more land is developed in Jacksonville, the city should maximize tree conservation for maintenance of surface water quality and groundwater recharge. This will also benefit the city's quality of life by fostering clean air, walkability, and attractive residential and commercial districts.

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 tree cluster, a lawn setting, a forest, or over pavement, such as streets or sidewalks. Tree setting is considered because the condition in which the tree is living affects the amount of water the tree can intercept. The amount of open space and the condition of surface soils affect the infiltration of water. In order to determine these conditions, a detailed land cover assessment was performed as described following. 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.

*Community planting.*

*The key finding from this work is that removal of mature trees generates the greatest negative impact on stormwater runoff.*

## LAND COVER, POSSIBLE PLANTING AREA, POSSIBLE CANOPY AREA ANALYSIS

The land cover data were created using 2017 leaf-on imagery from the National Agriculture Imagery Program (NAIP) distributed by the USDA Farm Service Agency. Ancillary data for roads (from Jacksonville government), the Cooperative Land Cover (CLC) Map (Florida Natural Areas Inventory), and hydrology (National Wetlands Inventory and National Hydrography Dataset) were used to determine:

1) Tree cover over impervious surfaces, which otherwise could not be seen due to these features being covered by tree canopy; and
2) Wetlands not distinguishable using spectral/feature-based image classification tools.


*This shows what is currently treed (green) and areas where trees could be added (orange).*

In cities studied for this project, forested open space was identified as areas of compact, continuous tree canopy greater than one acre, not intersected by buildings or paved surfaces. The final classification of land cover consists of eight classes listed below. The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees. (i.e., areas were the growth of a tree will not affect or be affected by existing infrastructure.) Of the eight land cover classes, only pervious (grass and scrub vegetation) is considered for PPA.

- Tree Canopy
- Tree Canopy over Impervious
- Wetland
- Wooded Wetlands
- Pervious
- Impervious
- Bare earth
- Sand
- Water

Next, these eligible planting areas are limited based on their proximity to features that might either interfere with a tree's natural growth (such as buildings) or places a tree might affect the feature itself, such as power lines, sidewalks or roads. Playing fields and other known land uses that would not be appropriate for tree cover are also avoided. However, there may be some existing land uses (e.g., golf courses) that are unlikely to be used for tree planting areas but that may not have been excluded from the PPA. In addition, the analysis did not take into account proposed future developments (e.g., planned developments) that would not likely be fully planted with trees. Therefore, the resulting PPAs represent the maximum potential places trees can be planted and grow to full size. A good rule is to assume about half the available space could be planted with trees.

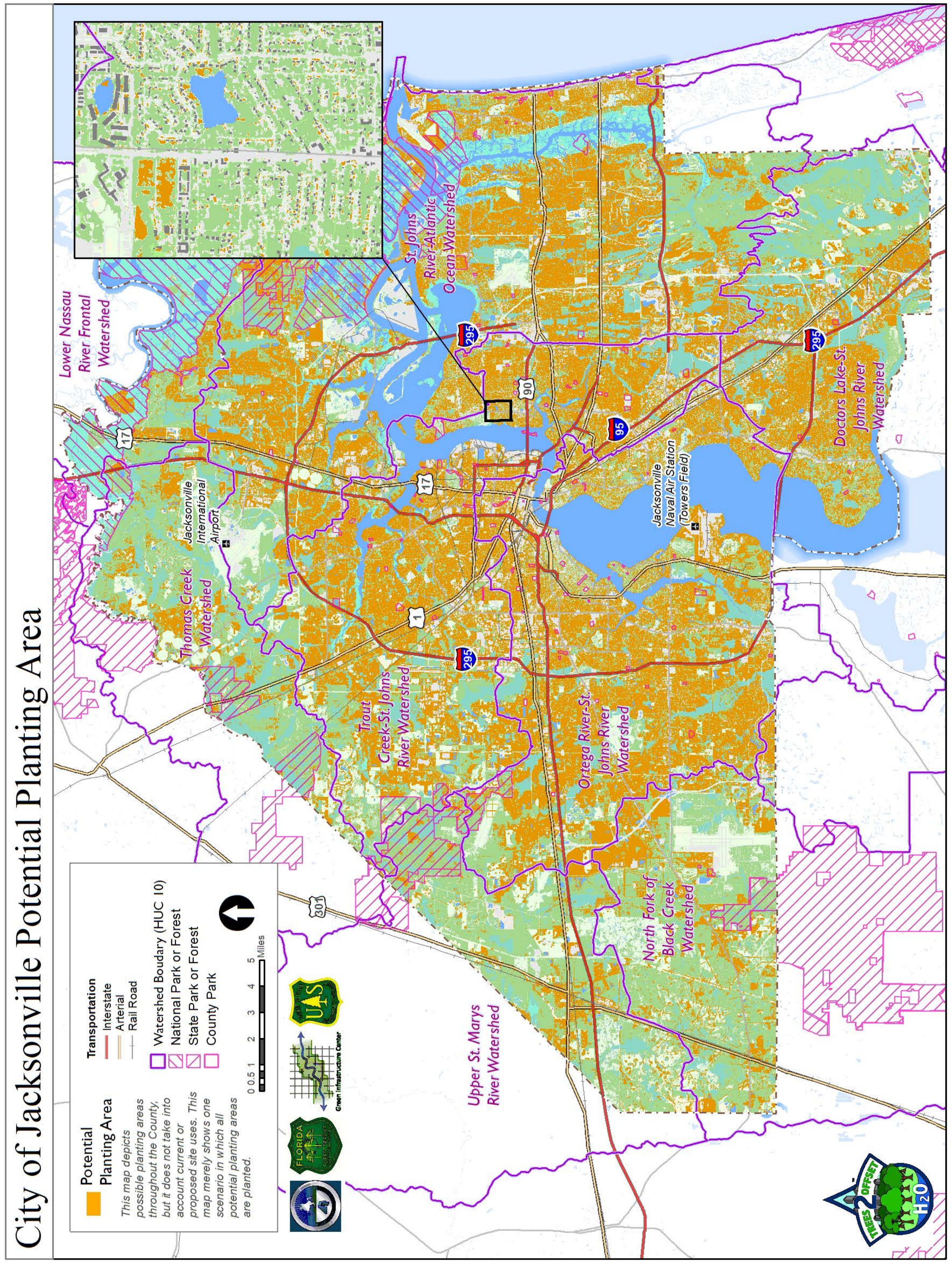
*Trees planted under power lines are often too large and require harmful trimming that can compromise tree stability and safety.*

*Tree over street*

*Trees over forest*

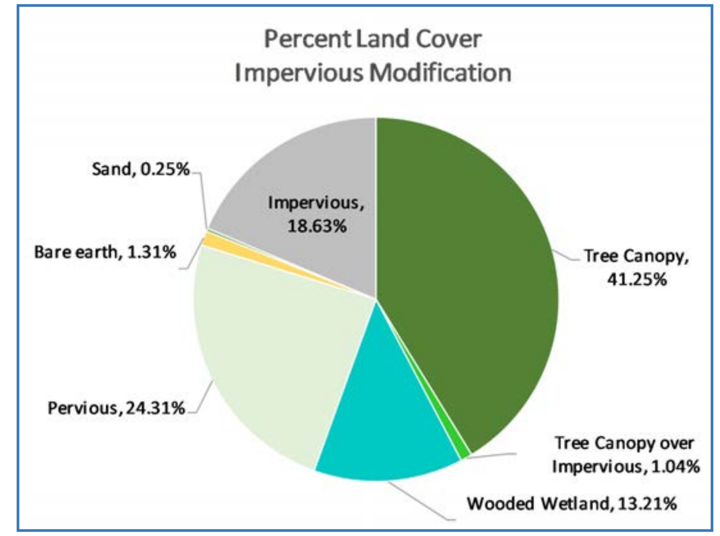
*Tree over lawn*

*Tree over parking lot*




Potential Planting Area (PPA) shown 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 private or public lands.





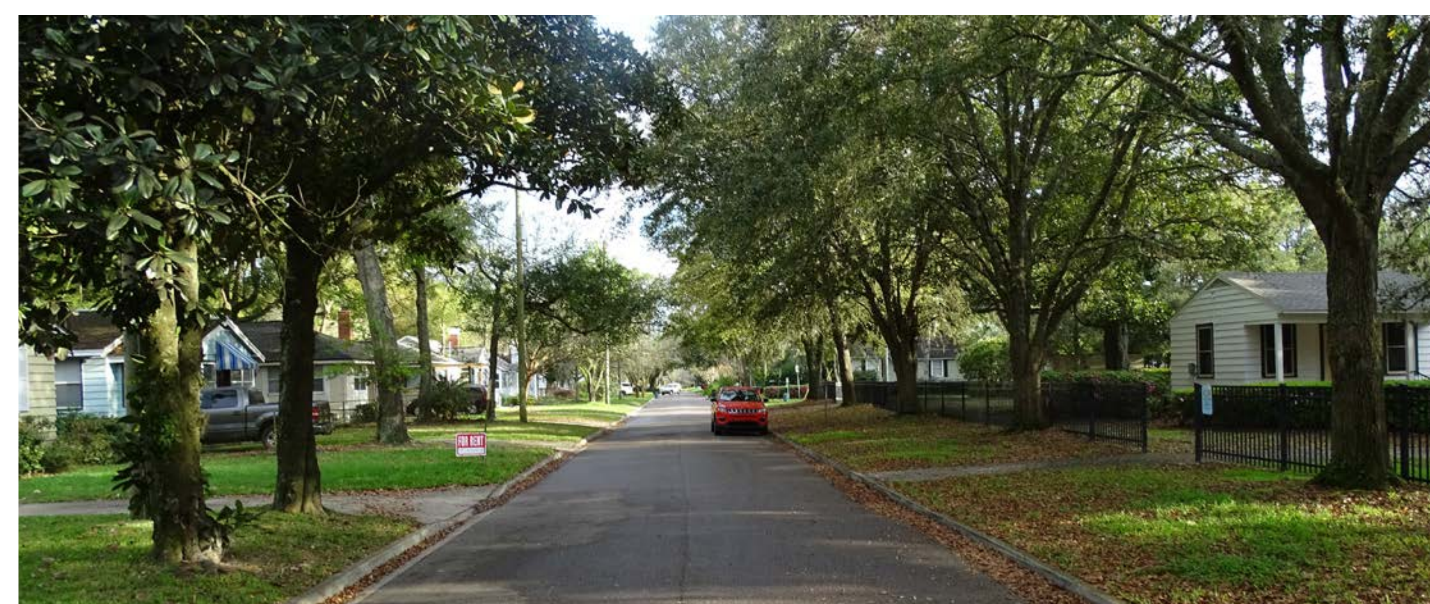

The Potential Planting Spots (PPS) are created from the PPA. The PPA is run through a GIS model that selects those spots where a tree can be planted depending on the size of trees desired. For this analysis, expected sizes of both 20 ft. and 40 ft. diameter of individual mature tree canopy were used with priority given to 40 ft. diameter trees (larger trees have more benefits). It is expected that 30 percent overlap will occur as these trees reach maturity. The result demonstrates a scenario where, if planted today, once the trees are mature, their full canopy will cover the potential planting area and overlap adjacent features, such as roads and sidewalks.

The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are selected, a buffer around each point that represents a tree's mature canopy is created. Similarly, the tree buffer radius is 20 ft. or 40 ft. diameter canopy for each tree. These individual tree canopies are then dissolved together to form the potential overall canopy area.

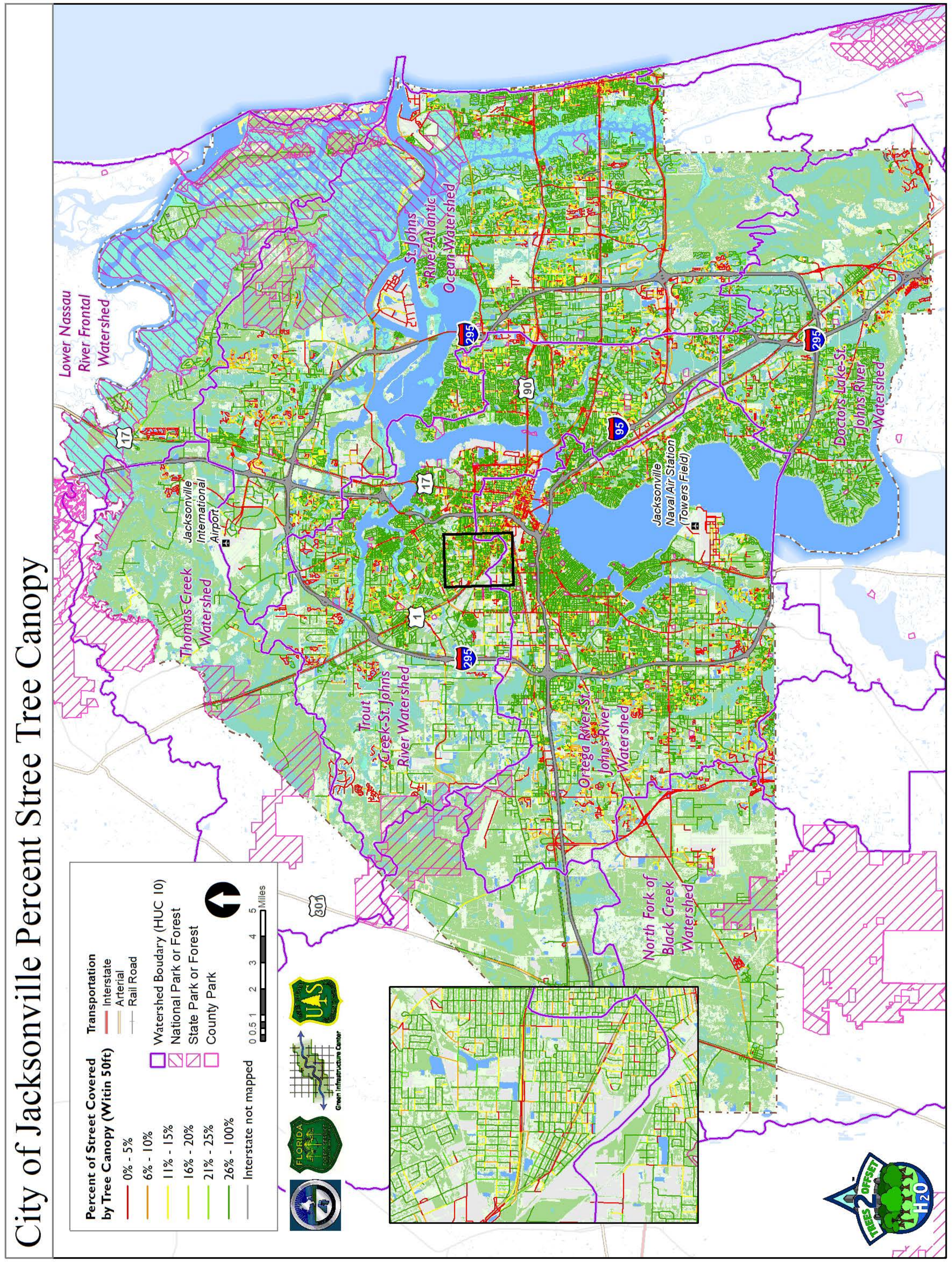
*Potential Planting Spots (PPS)*

*Potential Canopy Area (PCA)*

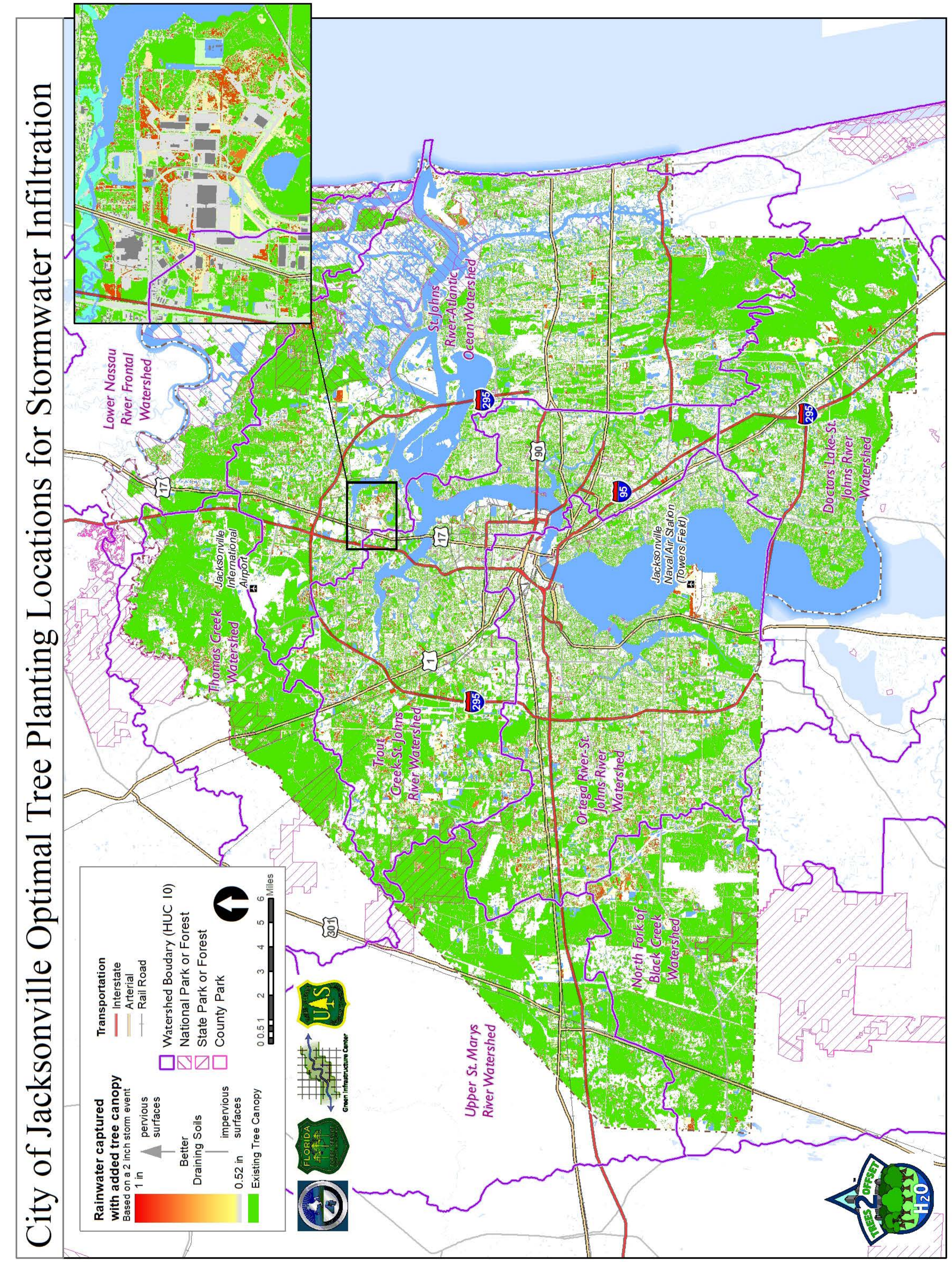
Percent Street Trees is calculated using the Land Cover Tree Canopy and road centerlines, which are buffered to 50 ft. from each road segment's centerline. The percent value represented is the percentage of tree cover within that 50 ft. buffer.



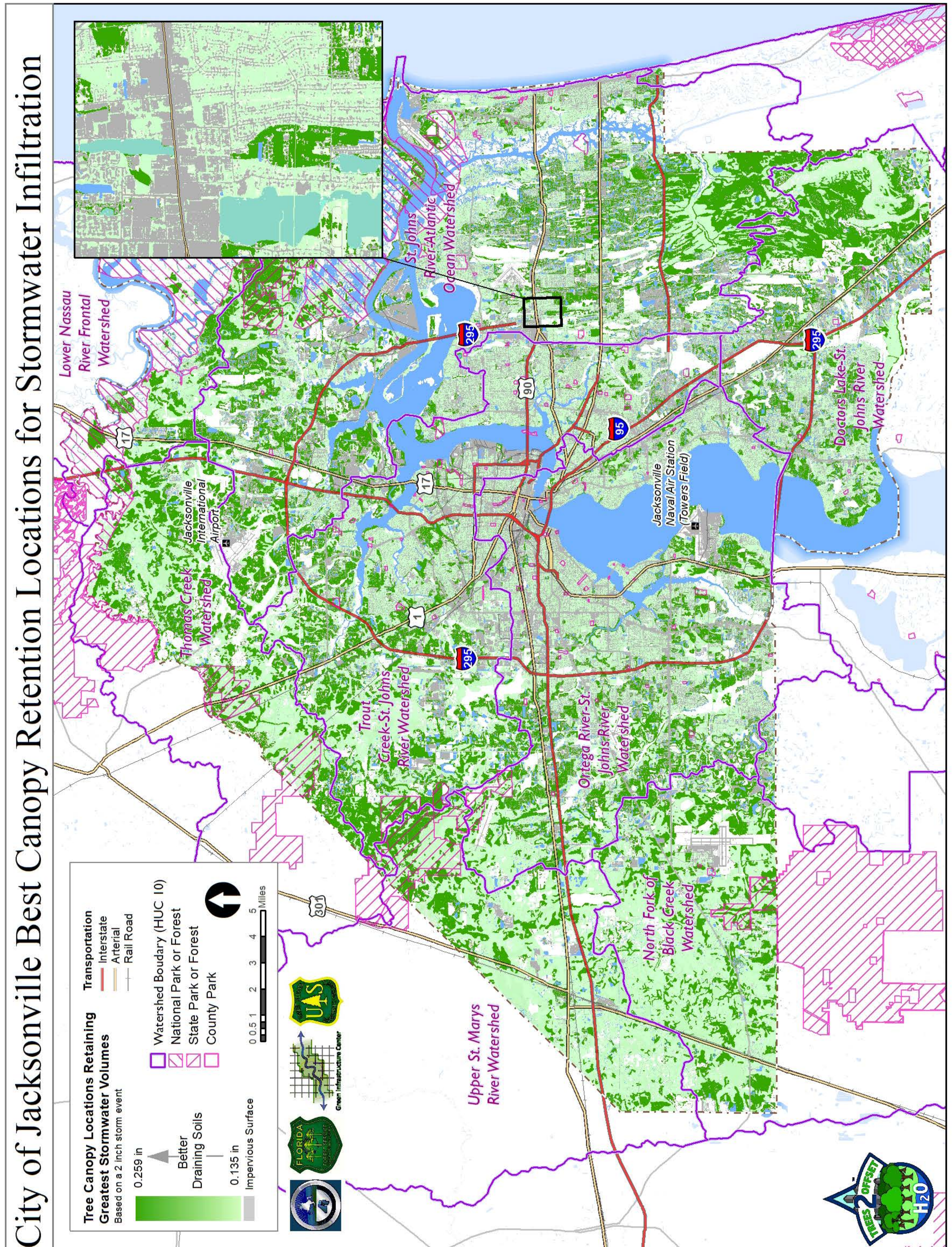
*Street trees provide welcome shade and beautify the city's neighborhoods.*




The street trees map shows which streets have the most canopy (dark green) and which have the least (red). Streets lacking good coverage can be targeted for planting to facilitate uses, such as safe routes to school or beautifying a shopping district.




This map shows where tree planting will yield the greatest benefits for stormwater interception and filtration (darkest orange).




This map shows where tree retention will yield the greatest benefits for stormwater interception and infiltration (darkest green).

See Methods Appendix for more details on mapping methodology.

# CODES, ORDINANCES AND PRACTICES REVIEW

This review is designed to determine which practices make the city more impervious (e.g. too much parking required) and which make it more pervious (e.g. conserving trees or requiring open spaces). Documents reviewed during the codes, ordinances and practices analysis for the project include relevant sections of the city's current code that influence runoff or infiltration. Data were gathered through analysis of city codes and policies, as well as interviews with city staff, whose input was incorporated directly on the spreadsheet summary prepared by the GIC. The spreadsheet provided to the city lists all the codes reviewed, interviews held and relevant findings. A more detailed memo submitted to the city by GIC, also provides additional ideas for improvement.


*Greenscape members are dedicated to community tree planting and education.*

## EVALUATION AND RECOMMENDATIONS

Points were assigned to indicate what percentage of urban forestry and planning best practices have been adopted to date by the city. The spreadsheet tool created for city codes can also serve as a tracking tool and to determine other practices or policies the city may want to adopt in the future to strengthen the urban forestry program or to reduce impervious land cover. A final report comparing all studied localities will be issued by GIC in 2019.

*Jacksonville just celebrated its twenty-third year of being recognized as a 'Tree City USA' by the Arbor Day Foundation.*

Jacksonville invests staff time and funds to manage its urban forest. The city has an Urban Forestry Program that is in charge of protecting the urban canopy through building permit reviews and inspections conducted across the city. The Public Works Department's Mowing and Landscape Division conducts maintenance on the trees in the public right-of-way.

The city just celebrated its twenty-third year of being recognized as a 'Tree City USA' by the Arbor Day Foundation, which means that it spends adequate funds per capita on tree care, it has a tree ordinance, and it practices tree management. Greenspace, a local nonprofit in Jacksonville and JEA, the electric authority, also hold tree giveaways to help residents plant and care for trees on private property.

The recommendations provided in this report are a way to increase the protections for, and size of, the forest in Jacksonville. As noted earlier, although the city's canopy is about 55.5 percent, it is not distributed equally citywide. Jacksonville is one of 12 localities in a six-state area of the Southeastern U.S. to be studied and the final city to be completed. A final report will compare Jacksonville to other cities and vice versa.

*Trees donated for community planting are key to reforestation.*

## Top recommendations to improve forest care and coverage in Jacksonville listed in priority order include the following:

1. **Link the city's urban trees to stormwater infrastructure through city documents including the Comprehensive Plan, Land Development Procedures Manual, and Stormwater Design Manual.** These documents should discuss the role of urban forests in stormwater management. They should also credit trees as best management practices (BMPs) for stormwater management.

2. **Apply for aid when cleaning up and replanting trees post-storm.** The Federal Emergency Management Agency (FEMA) offers aid for not just storm clean up, but also for replanting, as long as the urban forest is clearly identified as a part of green stormwater infrastructure. The Florida Forest Service (FFS) Urban and Community Forestry staff is an excellent resource for more information on this topic. They are currently working with FEMA to develop the standards for how to account for tree loss.

3. **Use the GIC's stormwater uptake calculator to determine the benefits of maintaining or increasing tree canopy goals by watershed.** The calculator provided to Jacksonville allows the city to determine the stormwater benefits or detriments (changes in runoff) from adding or losing trees and calculates the pollution loading reductions for nitrogen, phosphorus and sediment.

4. **Discourage the practice of clear-cutting development sites in the City of Jacksonville.** Total loss of tree canopy on a site results in excess runoff and excess nutrient loading. In addition, housing developments that include green space and natural areas in their plans sell faster and for higher profits (Benedict and McMahon 2006). Higher profits result in increased tax revenue for a city. One way to avoid clear-cutting lots is by setting tree canopy coverage requirements or preventing clear cutting prior to submission of an approved site plan for a development. These requirements can be set as percentages by land use or by tree density requirements per land use/area.

5. **Remove the single-family dwelling exemption from tree removal permit ordinances.** The City of Jacksonville requires tree removal permits for most land uses but exempts single family dwellings. A significant portion of the city's land area is made up of single family dwellings. As such, a large portion of tree canopy can be lost. Having a permit requirement would allow the urban forester to educate the landowner and determine if there are alternatives to tree removal. This recommendation will require more staff for review, enforcement and education.

*Total loss of tree canopy on a site that has been clear cut results in excess runoff and additional nutrient loading.*

6. **Conduct a land cover assessment every four years to determine current canopy coverage and allow for comparison of tree canopy coverage change over time.** Keeping tree canopy coverages at levels that promote public health, walkability, and groundwater recharge is vital for livability and for meeting state water quality standards. Regular updates to land cover maps allow for this analysis and planning to take place. In addition, regular updates to an urban tree canopy accompanied by stormwater uptake calculations can be used to show FEMA that tree canopy is being used as green stormwater infrastructure.

7. **Require 600, 1,000 and 1,500 cubic feet soil volume planting requirements for small, medium, and large trees respectively for all tree plantings.** At a minimum, canopy trees require 1000 cubic feet of soil volume to thrive as recommended by the Environmental Protection Agency (Stormwater to Street Trees 2013). The City of Jacksonville currently does not require a minimum root zone volume. Instead, tree planting areas are specified. A lack of minimum root zone volume requirement can lead to inadequate soil volume for newly planted trees, contributing to suboptimal growth and health.

8. **Consult urban forestry staff at the beginning of development projects for city-owned and privately-owned land.** Urban forestry staff in most cities are consulted when tree survival has already been compromised. The city should involve urban forestry staff at the beginning of projects during preliminary design discussions so forestry staff can identify trees that should be preserved on-site along with tree preservation mechanisms.

9. **Inspect tree protection mechanisms prior to the beginning of construction.** In many cities, staff either do not inspect tree protection mechanisms or those who conduct inspections lack training in tree protection mechanisms, such as fencing, and arboriculture. City staff should be trained to inspect tree protection mechanisms and inspections should be required before construction can begin.

10. **Set clear measurable goals with actionable steps for the conserving the urban forest.** The city should create urban forestry goals by neighborhood, watershed, or community zone. Having a canopy goal allows cities to recognize when canopy is too low or and make a plan for how to bring the canopy up to desired levels or to prevent excessive tree loss. Having a goal also inspires community tree planting campaigns.

11. **Use the urban forestry budget calculator to determine funds needed to reach planting goals.** Planting and maintaining trees costs additional money, but is well worth the outcomes for ecosystem services that trees provide. The city should determine the goal for its tree canopy coverage level and allocate funds to achieve it over time. Most importantly, the city should encourage more planting on private property since most city land is in private ownership.

12. **Use the new infiltration maps to prioritize tree planting and tree retention areas.** GIC created infiltration maps to show where trees should be planted and retained for maximum stormwater benefit. Distribute these maps to community groups and use them within municipal government processes to guide tree planting efforts and encourage tree preservation.

13. **Plant trees around stormwater ponds.** Trees take up stormwater and do not threaten the structural integrity of stormwater ponds as long as they are not placed on the embankment. Trees also beautify a landscape and can allow a stormwater pond to function as an amenity and a stormwater management device. Tree roots also work to cleanse groundwater and can add shade to a stormwater pond to reduce algal growth.

14. **Incentivize LID and constructed green infrastructure (green roofs, bioswales, recessed planting beds etc.).** Most developers in Jacksonville are not utilizing LID (Low Impact Development) strategy BMPs, though the regulatory framework exists for them to do so. One way to encourage the use of LID BMPs is to green light – faster approval processes -- the development process when substantial LID methods are employed on-site.

15. **Develop a complete green streets policy.** Complete green streets allow for integration of stormwater management and aesthetic goals. By incorporating vegetation as an integral part of the design, green streets create and connect habitat, reduce urban heat island effect, help remove air pollutants, and promote walking and biking. The city should develop a green streets policy that includes the following elements: green infrastructure (trees and other vegetation), pedestrian space, bicycle lanes, and stormwater management.

16. **Develop an Urban Forest Management Plan (UFMP) for the city.** The city should include the current condition of the urban forest, the current maintenance costs, and options to achieve the urban tree canopy coverage goals in a citywide UMFP. A UFMP details a vision for urban tree canopy. It meshes local government and community interests to proactively manage the urban canopy and provide long term benefits. The city should develop an UFMP which describes the condition of the urban forest, the current maintenance costs, and the urban tree canopy coverage goals and methods to achieve them.

17. **Develop a Forestry Emergency Response Plan (FERP) for the city.** Forestry Emergency Response Plans (FERPs) are essential parts of any municipality's hazard mitigation and emergency management plans. Elements of FERPs should be given the same thought and attention paid to other aspects of emergency response management. FERPS should include the following sections: tree benefits, risk management and pre-disaster response, and post-disaster response and FEMA reimbursement processes for tree loss.

18. **Re-use urban waste wood.** Re-use of urban waste wood is an excellent way to engage the community, get them excited about urban forestry, and make a positive impact on the local economy. The USFS Southern Region funded the Southeast Urban Wood Exchange which connects urban wood producers and processors. Urban wood in Jacksonville can be posted to this site and used by locals. Access the website at: http://www.urbanwoodexchange.org/index.php.

## BEST PRACTICES FOR CONSERVING TREES DURING DEVELOPMENT

Tree planting or preservation opportunities can be realized throughout the development process. A first step is to engage in constructive collaboration with developers. The city should hold predevelopment meetings for large sites that may disturb extensive acreage of urban forest. For example, mandate a pre-development conference for all sites that are three acres or more in size and require review by the urban forester. This allows conversations about options for tree preservation, arranging development so as to avoid large trees and tree clusters or shrinking impervious areas to avoid excessive land clearing.

It is necessary to actively promote the implementation of development designs that minimize the loss of urban forest canopy and habitat. The city should actively encourage site layouts that conserve trees. The GIC has found that economic arguments (real estate values for treed lots, access to open spaces, and rate of sales) are usually the most compelling way to motivate developers to take the extra effort and care to design sites and manage construction activities to manage tree conservation. This will facilitate site designs which save more trees and thereby require less constructed stormwater mitigation. Many developers are willing to cooperate in such ventures, as houses often sell for a premium in a well-treed development.

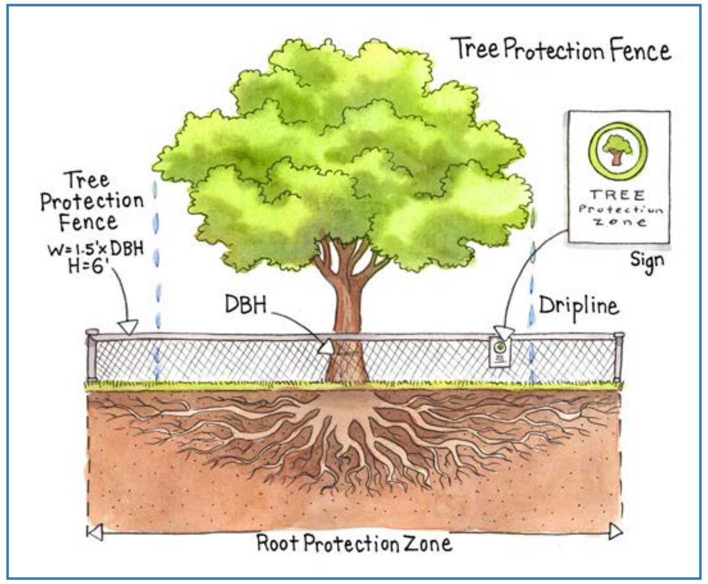
### Tree Protection Fencing and Signage

The most common form of tree protection is tree protection fencing. It is a physical barrier that keeps people and machines out of tree's critical root zones during construction. However, some municipalities only require plastic orange fencing and wooden stakes. This type of fencing can be removed or trampled easily and makes tree protection efforts less effective. Trees slated for protection may suffer development impacts such as root compaction and trunk damage.

Small roots at the radial extents of the tree root area uptake water and absorb nutrients. Protection of these roots is critical for the optimal health of a tree. Jacksonville only requires fencing to protect the trunk and roots from 6' from the base of the tree and 50% of the land area under the dripline, which is inadequate for protecting tree roots. Instead, the city should require placement of tree protection fencing at a distance 1.5' times the tree's diameter at breast height (DBH) from the tree.

In high risk areas, such as trees near construction entrances, the city should require sturdy metal chain link fencing and use orange plastic fencing in lower risk areas such as along the tree line at the edge of a development property.

The city does not require tree protection signage. Tree protection signage provides information about what can and cannot occur in tree protection zones. Tree protection signage communicates how work crews should understand and follow tree protection requirements. It also informs construction crews and citizens about the consequences of violating city code. Construction crew members may not understand that building materials may not be placed in tree protection zones and that moving the protective fencing around the tree is never permitted. The city should design a standard tree protection sign which summarizes the do's and don'ts of working near and around tree protection zones. Additional training may be helpful to ensure that developers comply with the city's tree ordinances and understand how to protect trees during construction.



*Tree Protection Fence and Signage*


*This downtown tree does not have enough room underground to support its roots and the tree is not healthy. The city can invest in better tree wells to ensure long term survival.*

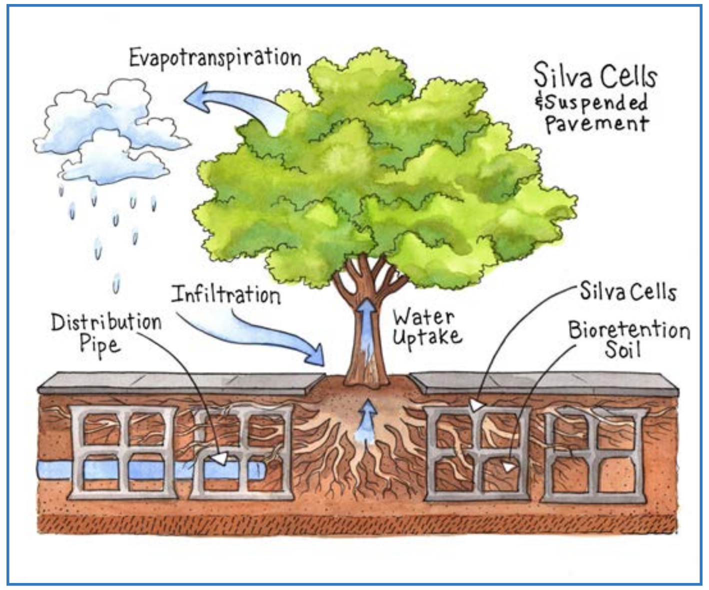


## TREE PLANTING

In urban environments, many trees do not survive to their full potential life span. Factors such as lack of watering or insufficient soil volume and limited planting space put stresses on trees, stunt their growth and reduce their lifespans. For every 100 street trees planted, only 50 will survive 13-20 years (Roman et al 2014). This means that adequate tree well sizing standards are a critical factor in realizing the advantages of a healthy urban forest. At a minimum, large canopy trees require 1000 cubic feet of soil volume to thrive. In areas where space is tighter or where heavy uses occur above, 'Silva cells' can be used to stabilize and direct tree roots towards areas with less conflicts (e.g. away from pipes). Permeable pavers above ground also allow more water to reach tree roots and they also reduce runoff.

In addition, large trees should not be planted where they may interfere with overhead lines. These and other practices, implemented to provide long term care, protection and best planting practices for the urban forest, will help ensure that investments in city trees will pay dividends for reducing stormwater runoff, as well as cleaner air and water, lower energy bills, higher property values and natural beauty long into the future.


*Too large a tree was planted under a powerline.*



*Silva Cells and Suspended Pavement*


Photo: Cummer Museum

*Cummer Museum's permeable parking spots.*


Photo: Cummer Museum

*Permeable pavers in the Cummer Museum's parking lot allow water to infiltrate to the soil and reduce runoff while watering tree roots.*

The city's trees are our green infrastructure!

## CONCLUSION

Adapting codes, ordinances and municipality practices to use trees and other native vegetation for greener stormwater management will allow Jacksonville to treat stormwater more effectively. Implementing these recommendations will significantly reduce the impact of stormwater sources (impervious cover) and benefit the local ecology by using native vegetation (trees and other shrubs) to uptake and clean stormwater. It will also lower costs of tree cleanup from storm damages, since proper pruning or removal of trees deemed to be 'at risk' can be done before storms occur.

Jacksonville should use the canopy map and updates to track change over time and to set goals for increasing canopy by neighborhood and by planning area. Jacksonville now has the data and tools to plant trees in the most strategic locations and to preserve those trees that are doing the best work for stormwater management. The city can also consider investing more of its tree fund for increasing the size of tree wells and providing better structural support for trees in difficult places. The city can use the canopy data, analysis and recommendations and stormwater calculator tool to continue to create a safer, cleaner, cost-effective and more attractive environment for all.

*Jacksonville's 337 parks covering 80,000 acres offer abundant opportunities to enjoy the outdoors and support wildlife.*

*The Jacksonville Arboretum offers residents a peaceful setting to appreciate the city's trees.*

# APPENDIXES

## APPENDIX A: TECHNICAL DOCUMENTATION

This section provides technical documentation for the methodology and results of the land cover classification used to produce both the land cover map and potential planting scenarios for Jacksonville.

Land cover classifications are an affordable method for using 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 (i.e. the images) are turned into information about land cover types of interest, e.g. what is pavement, 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?

### Land Cover Classification

The National Agricultural Imagery Project (NAIP) creates new aerial imagery for Florida every few years. Urban areas for this project were mapped using the 2015 NAIP imagery (completed by Plan-It Geo). The NAIP 2017 Leaf-on imagery (4 band, 1-meter resolution) was used for the land cover classification of areas outside of city limits. In addition, the 2015 data were updated using a land cover classification from 2017 NAIP image to replace areas identified as significantly changed. For example, construction sites and large clearing that appear to be changing from plantation forest to something else were re-examined and reclassified. The full set of NAIP data were acquired through the Earth Resources Observation and Science (EROS) Center of the U.S. Geological Survey.

### Pre-Processing

The NAIP image tiles were first re-projected into the coordinate system used by the city.

NAD_1983_2011_StatePlane_Florida_East_FIPS_0901_Ft_US
WKID: 6438 Authority: EPSG

Projection: Transverse_Mercator
False_Easting: 656166.6666666665
False_Northing: 0.0
Central_Meridian: -81.0
Scale_Factor: 0.9999411764705882
Latitude_Of_Origin: 24.33333333333333
Linear Unit: Foot_US (0.3048006096012192)

Geographic Coordinate System: GCS_NAD_1983_2011
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_NAD_1983_2011
Spheroid: GRS_1980
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314140356
Inverse Flattening: 298.257222101

### Supervised Classification

The imagery was classified using an object based supervised classification approach. The ArcGIS extension Feature Analyst was used to perform the primary classification with a "bull's eye" object recognition configuration to identify features based on their surrounding features. Feature Analyst software is an automated feature extraction extension that enables a GIS analyst to rapidly and accurately collect vector feature data from high-resolution satellite and aerial imagery. Feature Analyst uses a model-based approach for extracting features based on their shape and spectral signature.

For better distinction between classes, an NDVI image was created. The NDVI image along with the source NAIP bands (primarily 4, 1 and 2) were used to identify various features where they visually matched the imagery most accurately.

### Post-Processing

The raw classifications from Feature Analyst then went through a series of post-processing operations. Planimetric data were also used at this point to improve the classification. Roads, sidewalks, and trails were "burned in" to the raw classification (converted vector data to raster data, which then replaced the values in the raw classification). The 'tree canopy' class was not affected by the burn-in process, however, because tree canopy can overhang streets. These data layers were also used to make logic-based assumptions to improve the accuracy of the classification. For example, if a pixel was classified as 'tree canopy,' but that pixel overlaps with the roads layer, then it was converted to 'Tree Cover over Impervious.'

The final step was a manual check of the classification. There was confusion in the industrial plantation/agriculture areas; since many are in transition from agriculture to other land uses, data from various sources including the Florida Cooperative Land Cover Map (CLC) were used to verify and edit. National Land cover data were used for reference in defining swamp and water bodies. Wooded wetlands where identified using Lidar data (where vegetation above 12-ft feature height then the area was considered Wooded Wetland if over Wetland in the NHD dataset).



### Potential Planting Area Dataset

The Potential Planting Area dataset has three components. These three data layers are created using the land cover layer and relevant data in order to exclude unsuitable tree planting locations or where it would interfere with existing infrastructure.

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

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
  - Bare earth
- **Excluded Land Cover Features**
  - Existing tree cover
  - Water
  - Wetlands
  - Impervious surfaces
  - Ball fields (i.e.: baseball, soccer, football) where visually identifiable from NAIP imagery. Digitized by GIC.
- **Exclusion Features:** (buffer distance)
  - Roads areas (10 ft.)
  - Driveways (10ft)
  - Railroads (10ft)
  - Structures (10ft)
  - Storm pipes (10ft)
  - Waterlines (10ft)
  - Sewer lines (10ft)
  - Power lines and other identifiable utilities (10ft)

### Potential Planting Spots

The Potential Planting Spots (PPS) are created from the PPA. The potential planting areas (PPA) is run through a GIS model that selects spots a tree can be planted depending on the size tree's that are desired. Tree planting scenario was based on a 20 ft. and 40 ft. mature tree canopy with a 30 percent overlap.

### Potential Canopy Area

The Potential Canopy Area (PCA) is created from the PPS. Once the possible planting spots are given a buffer around each point, this represents a tree's mature canopy. For this analysis, they are given a buffer radius of 10 or 20 ft. that results in 20 and 40 ft. tree canopy.

*NAIP Image 2016*

*Potential Planting Area (PPA)*

*Potential Planting Spots (PPS)*

*Potential Canopy Area (PCA)*

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## TREE PLANTING

Planting the next generation of trees is very important – put a big emphasis on this!

Show the percent of public versus private land. {Note: this is too difficult to show on a map of this scale but the city has this information}

The Right of Way on Main Street has a faulty irrigation system and the trees are suffering. The tree planting boxes are 4' x 4' and are too small. [City staff noted that it is difficult to keep a poorly designed project functioning when the tree wells are inadequately sized.] Another resident stated this was also a problem at State and Union streets.

Look at the option to convert more empty lots into parks or pocket parks (especially treed lots). For example, Balis Park in San Marcos was donated.

Compensate the city for the loss of removed trees.

Planted buffer legislation is coming. Different widths of buffers require planting standards (e.g. 20')

Greenscape has a tree giveaway option. Coordinate with them to plant in key areas.

Focus on planting trees along creeks.

Get away from using stormwater ponds as they take up a lot of land! (Use other infiltration methods = trees)

## REDUCE IMPERVIOUSNESS

The Bartrum area is losing trees rapidly

Look at the problem of 'total lot clearing' (removing all land on a site prior to development)

In Springfield, new driveways have to be ribbon drives (two strips of concrete rather than paving the entire thing) but that is only for the historic district.

Impervious lot coverage in the city is restricted but the regulations cover only the house or other built structures but not patios or driveways.

Eliminate downtown minimum parking statutes (requires too much impervious area).

The Cummer Museum has a permeable parking lot – highlight this!

## EDUCATION

There is a fear of falling trees from storms. Teach residents how to care for trees to minimize risk.

Share information on the values of trees with the average homeowner.

There are other values of native plants such as for pollinators.

Why were non-native plants installed under the Acosta Bridge?

The city should hold bi-annual sessions to discuss tree management with the community and focus on 'How are we doing? What could we do better?'