TREES TO OFFSET STORMWATER

Case Study 04: Charleston, South Carolina

CITY OF CHARLESTON

Green Infrastructure Center

August 2018

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CONTENTS

Project Overview 1
Project Funders and Partners 1
Outcomes 1
Community Engagement 2

Summary of Findings 3

Why Protect Our Urban Forests? 6
Additional Urban Forest Benefits 9
Quality of Life Benefits 9
Economic Benefits 11
Meeting Regulatory Requirements 11

Natural Ecology in Urban Conditions – Changing Landscapes 12
Historic Land Cover 12
Charleston Growth and Development Challenges 13
Sea Level Rise 14
Charleston's Green Future 16

Analysis Performed 16
Method to Determine Water Interception, Uptake and Infiltration 17
Land Cover, Possible Planting Area, Possible Canopy Area Analysis 19

Codes, Ordinances and Practice Review 29
Evaluation and Recommendations 29
Best Practices for Conserving Trees During Development 32
Tree Planting 33
Conclusion 34

Appendixes 36
Appendix A: Methods Appendix – Technical Documentation 36
Appendix B: Community Comments 38
Appendix C: Bibliography 40

Project Overview

This project, called Trees to Offset Stormwater, is a study of the City of Charleston's forest canopy and the role that trees play in up taking, storing and releasing water. This study was undertaken to assist the City of Charleston 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 ways in which the city can benefit from tree conservation and replanting. It also evaluated ways for the city to improve forest management as the city develops.

PROJECT FUNDERS AND PARTNERS

This is a pilot project for a new approach to estimate the role of trees in stormwater uptake. South Carolina is one of six southern states that received funding from the USDA Forest Service to study how trees can be utilized to meet municipal goals for stormwater management. The project was developed by the nonprofit Green Infrastructure Center Inc. (GIC) in partnership with the states of South Carolina, North Carolina, Alabama, Georgia, Florida and Virginia. The South Carolina Forestry Commission is administering the pilot study in South Carolina. Charleston was selected as the test case for South Carolina.

The GIC created the data and analysis for the project. 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 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, the City of Charleston now has baseline data against which to monitor canopy protection progress, measures of the stormwater uptake by its trees and water quality benefits provided by the urban forest, as well as a way to prioritize restoration of canopy where it is needed.

The Angel Oak is one of the city's oldest trees.

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 citizen input and recommendations for the future of the City of Charleston's urban forest. 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,
- Two community forums to provide outreach and education,
- Presentation of the results of the pilot studies as a case study at the National Partners in Community Forestry Conference, and
- A case booklet and PowerPoint presentation detailing the pilot study methodology, as well as lessons learned and best practices.

The project began in October 2016 and the City of Charleston staff members have participated in project review, analysis and evaluation. The following city departments and divisions were involved in the project review committee: Information Technology and Geographic Information Services; Parks and Urban Forestry; Planning, Preservation and Sustainability, and Zoning; and Public Service and Stormwater. Staff advised the GIC and coordinated Charleston community engagement events.

Two community meetings were held. The first meeting held in June 2017 provided an overview of the project and an opportunity to gather community input and concerns regarding tree conservation and to review the canopy cover maps. The second meeting, held in November 2017, provided recommendations for the city (see the list following) and elicited feedback on priorities for selected actions.

All individual comments from both meetings were provided to the city and are listed in Appendix B. Residents asked that pine trees (*Pinus sp.*) and sweetgum trees (*Liquidambar styraciflua*) be included in tree preservation requirements. They suggested the city incentivize preservation of groups of trees over individual specimens and felt that 10-foot tree buffers were inadequate in size for achieving tree preservation. They also wanted more proactive city tree pruning to lessen storm damages and to have more ways for citizens to learn about proper tree planting and management. Residents wanted more incentives for developers to save trees and help with messaging to developers about the importance of trees to meet desires for a 'livable Charleston.'

Residents called for more trees in areas such as the northern, eastern and western parts of the Peninsula, as well as shopping centers in Byrnes Downs and in South Windermere, older neighborhoods in West Ashley, and the DuPont/Wappoo Community Plan area. There were both concerns about tree loss from new development and for tree protection and replacement, which were considered central to preserving the city's character and historic identity. Several residents expressed concern about tree removals on Johns Island from current and pending development. See the Appendix B for a full list of comments.

Residents learned how the tree canopy was mapped and then provided ideas for tree conservation or planting.

Community members were presented with eight specific code/ordinances or process changes which GIC recommended to the City of Charleston (in addition to others already recommended in a longer memo provided to the city). Meeting attendees were asked to choose the top three changes that would most benefit the urban forest. The policy or code changes are listed below in priority order (most to least popular).

1) Increase funds for forest management (pruning, planting, watering etc.).
2) Tighten the development footprint to conserve trees/forests/connections.
3) Protect trees in wetlands by avoiding fill dirt placement around existing trees (whenever possible).
4) Develop a goal of no net loss of canopy. Plant in areas with older canopy, lowest canopy, and flood prone areas.
5) Preserve pine trees (they hold a lot of water)!
6) Expand tree protection fence out to 1.5' per inch Diameter at Breast Height (DBH) (protect trees better during construction).
7) Create tree canopy requirements by zoning type.
8) Fund and implement tree risk assessments and care to minimize storm damage and harm.

The City of Charleston 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.*
- *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 protect their trees.*
- *Support grant applications for tree conservation projects.*

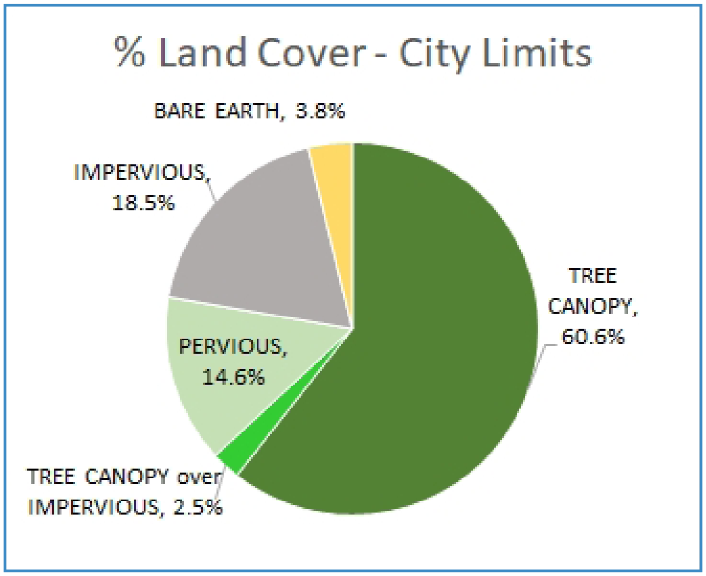
Summary of Findings

Satellite imagery was used to classify the types of land cover in the City of Charleston (for more on methods see Appendix A). This shows the locations for areas with vegetative cover that allow for the uptake of water and areas that are impervious and more likely to have stormwater runoff. High-resolution tree canopy mapping provides a baseline of tree canopy cover that is used to assess current tree cover and to evaluate future progress in tree preservation and planting. The City of Charleston has been provided with an ArcGIS geodatabase with all digital shapefiles produced during the study.

Trees can reduce residential cooling costs by 30 percent or more.

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. Tree canopy serves as 'green infrastructure' that can provide more capacity for the city to support 'grey infrastructure' (i.e. stormwater drainage systems) in the future. It also can be used to show how the city can reduce potential pollution of its surface waters, which can have an impact on impaired waters and associated Total Maximum Daily Load (TMDL) requirements.

This project created a detailed land cover analysis to evaluate 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 within a forest, a lawn setting, a forested wetland or over pavement, such as streets or sidewalks. 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 by the GIC (see Appendix A for a technical summary of the methods used).



City tree canopy is 63 percent and impervious land cover is 8.5 percent.

During an average high volume rainfall (a 10-year storm) in the City of Charleston, over 24 hours the city's trees uptake an average of 569 million gallons of water.

That's enough water to fill nearly 861 Olympic-size swimming pools!

City of Charleston: Fast Facts & Key Stats

- **Counties: Charleston County, Berkeley County**
- **Port town in southeastern South Carolina.**
- **2017 Census Population Estimate: 134,875 People**

Total Study Area: 200.95
(includes county land within the city area)*

Total Area of Charleston: 133.61 sq. mi. area

** All study area calculations determined by GIC's high resolution land cover analysis using 2015 and 2016 data.*

Land: 81.4 sq. mi.

Wetlands: 29.42 sq. mi.

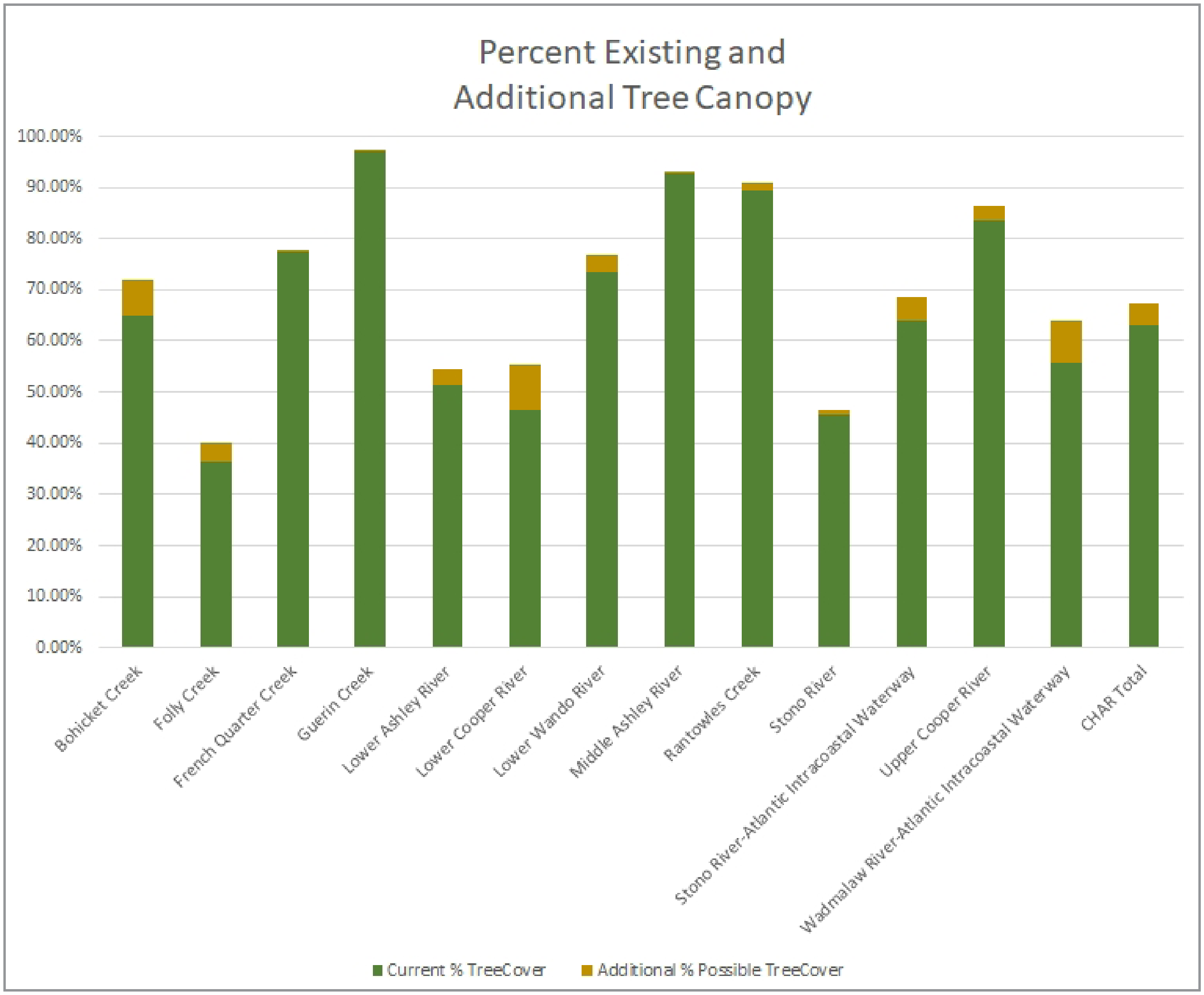
Water: 22.75 sq. mi.

Miles of Stream: 297 miles

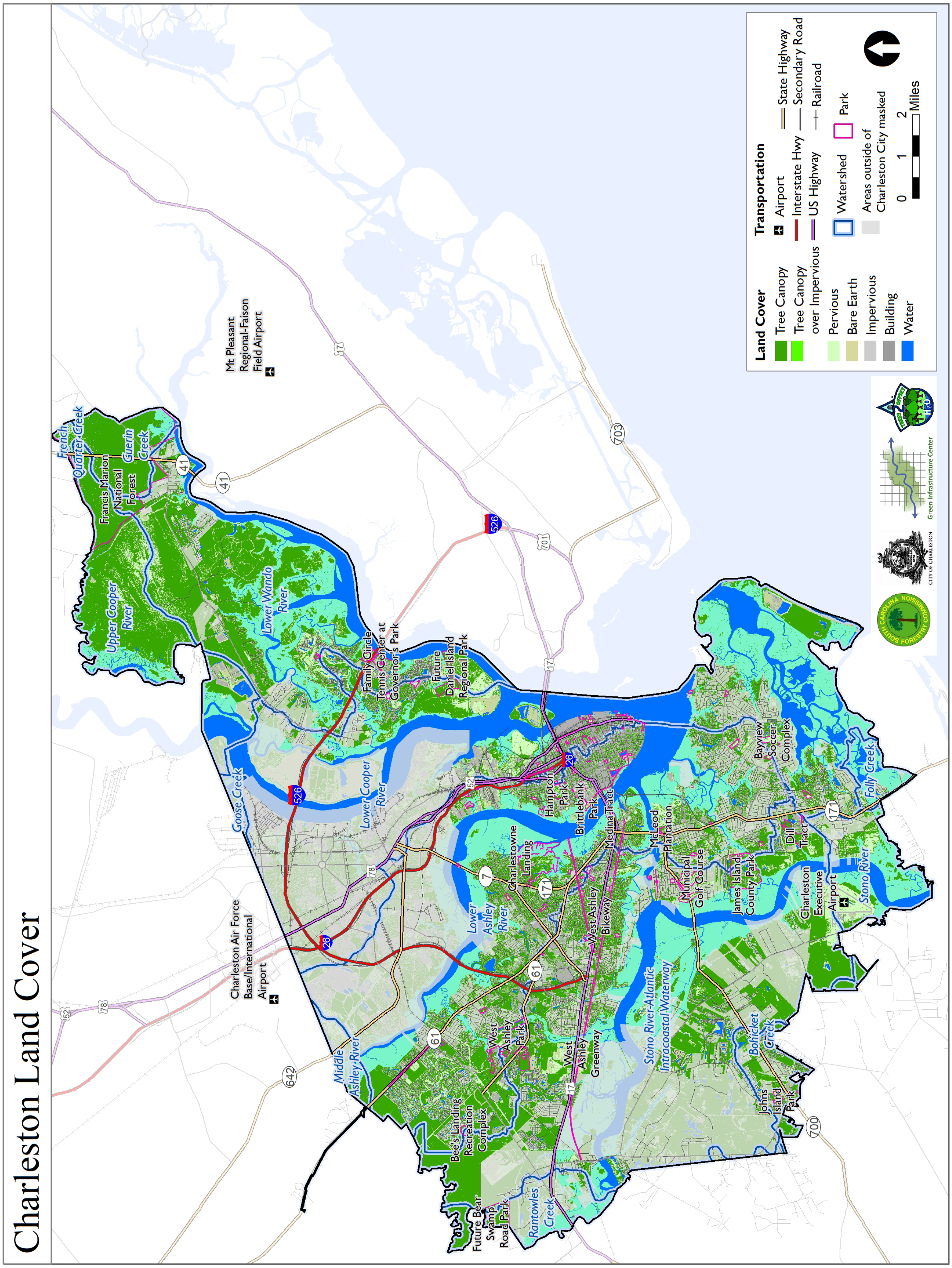
Acres of Lakes/Ponds: 376.32 acres
(National Hydrography Data)

Acres of Wetlands: 18,829 acres
(estimated not surveyed)

Tree Canopy: 32,896 acres



Percent Tree Cover and Possible Planting Area by Watershed



This map shows the study area and includes lands that are not within the incorporated area. The entire study area was analyzed because some county lands may be annexed one day. Total canopy coverage within the City of Charleston is 63 percent.

Why Protect Our Urban Forests?

As areas develop, natural land cover changes to urban land cover and forested land cover decreases. 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 with it pressures for land conversion for 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).

Cities such as Charleston, have lost both natural forest cover and wetlands as land has been cleared or filled to make room for development. While citywide canopy is high at 63 percent coverage, tree distribution is not uniform. Densely developed areas such as neighborhoods in the downtown Peninsula have canopies ranging from 30 to 8 percent.

The City of Charleston has addressed the need for conserving forests as it develops by requiring a significant forest buffer around developments to avoid clearing entire sites. For more on this and other related tree protection ordinances, see the Codes and Ordinances section of this report.

The purpose of this report is not to seek a limit on the City of Charleston's growth, but rather to help the city better utilize its tree canopy to manage its stormwater. Ancillary 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; increased wildlife habitat; fostering walkability and multimodal transportation; and encouraging both tourism and retail sales.

As forested and open land are converted to impervious surfaces, stormwater runoff increases, causing temperature spikes, increased potential for pollution of surface and ground waters and increased potential for flooding. According to the U.S. Environmental Protection Agency (EPA), excessive stormwater runoff accounts for more than half of the pollution in the nation's surface waters and causes increased flooding and property damages, as well as public safety hazards from standing water. As land becomes more impervious, rates of infiltration decrease, while runoff rates and volumes increase (EPA Watershed Academy). The EPA recommends a number of ways to use trees to manage stormwater in the book *Stormwater to Street Trees*.

Waterfowl, such as this snowy egret in Charleston, depend on clean water.

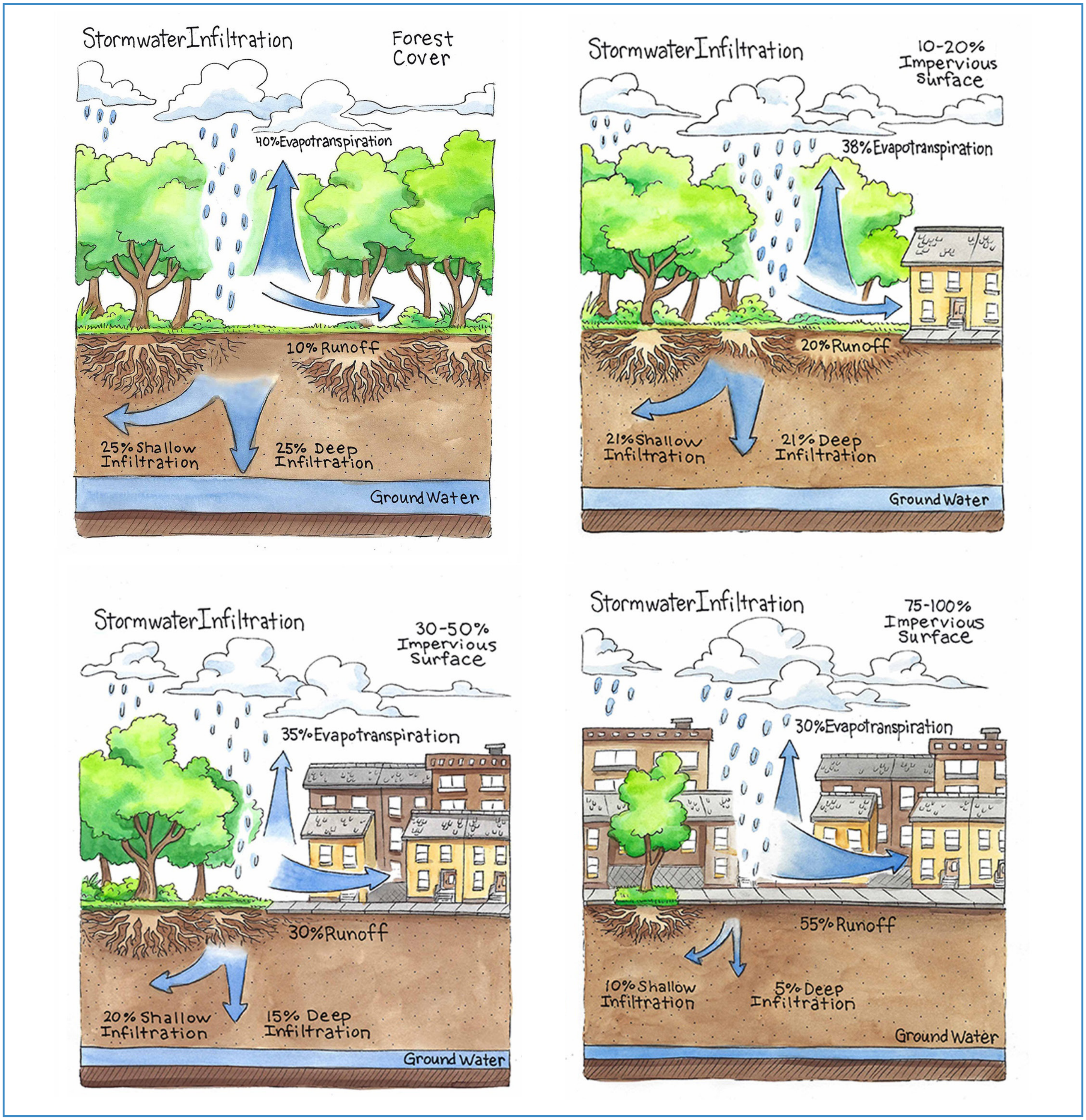
Assessment and inventory of trees is key to ensuring a healthy forest.

Imperviousness is one consideration; another concerns the degree and type of forested land cover, since vegetation helps absorb stormwater and reduces the harmful effects of runoff. Unfortunately, many cities and counties did not have a baseline to assess the damage or strategies to replace lost trees. This project is the first high resolution tree canopy mapping project created for the city.

In the past several years, many powerful storms have affected the Southeastern United States leading to a great deal of tree loss. This study was funded to address this problem 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 to attrition 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. Trees planted improperly (wrong site), poorly maintained (inadequate care), or planted inappropriately (wrong tree for the site or climate) can also 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 they provide tremendous



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

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 the City of Charleston are very old and may lack quantity or quality-based stormwater management practices that are now required for new developments.

Trees filter stormwater and reduce overall flows. So planting and managing trees is a natural way to mitigate stormwater. Estimates from 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

Excess impervious areas cause hot temperatures and runoff.

Newly Planted Tree in Charleston

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 sewer storm systems and also reduces flooding.

Each tree plays an important role in stormwater management. 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 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 annually. This means reduced flooding in neighborhoods and reduced stress on waste water treatment plants as well as less runoff into the city's stormwater drainage systems, rivers and estuaries.

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. By retaining trees and forests, it is possible to reduce the likelihood or severity of flooding.

In urban areas, tree canopy should be assessed and realistic goals established to maintain or expand it. Geographic Information Systems (GIS) are 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 page 24).

Buffering surface waters from pollution

Urban forests are also critical to buffering surface waters from pollution. However, at certain levels of urban development and related imperviousness, aquatic life begins to decline. The rate of decline is affected by factors such as land cover, lot sizes and types of land use, as well as the locations of imperviousness within the watershed. Excessive urban runoff results in pollutants such as oil, metals, lawn chemicals (e.g., fertilizer and herbicides), pet waste and other pollutants reaching surface waters. High stormwater flows result in channel and bank scouring, releasing sediments that smother aquatic life and sedimentation reduces stream depth and clogs ditches, and as channel capacity, there is yet more bank scouring and flooding.

ADDITIONAL URBAN FOREST BENEFITS

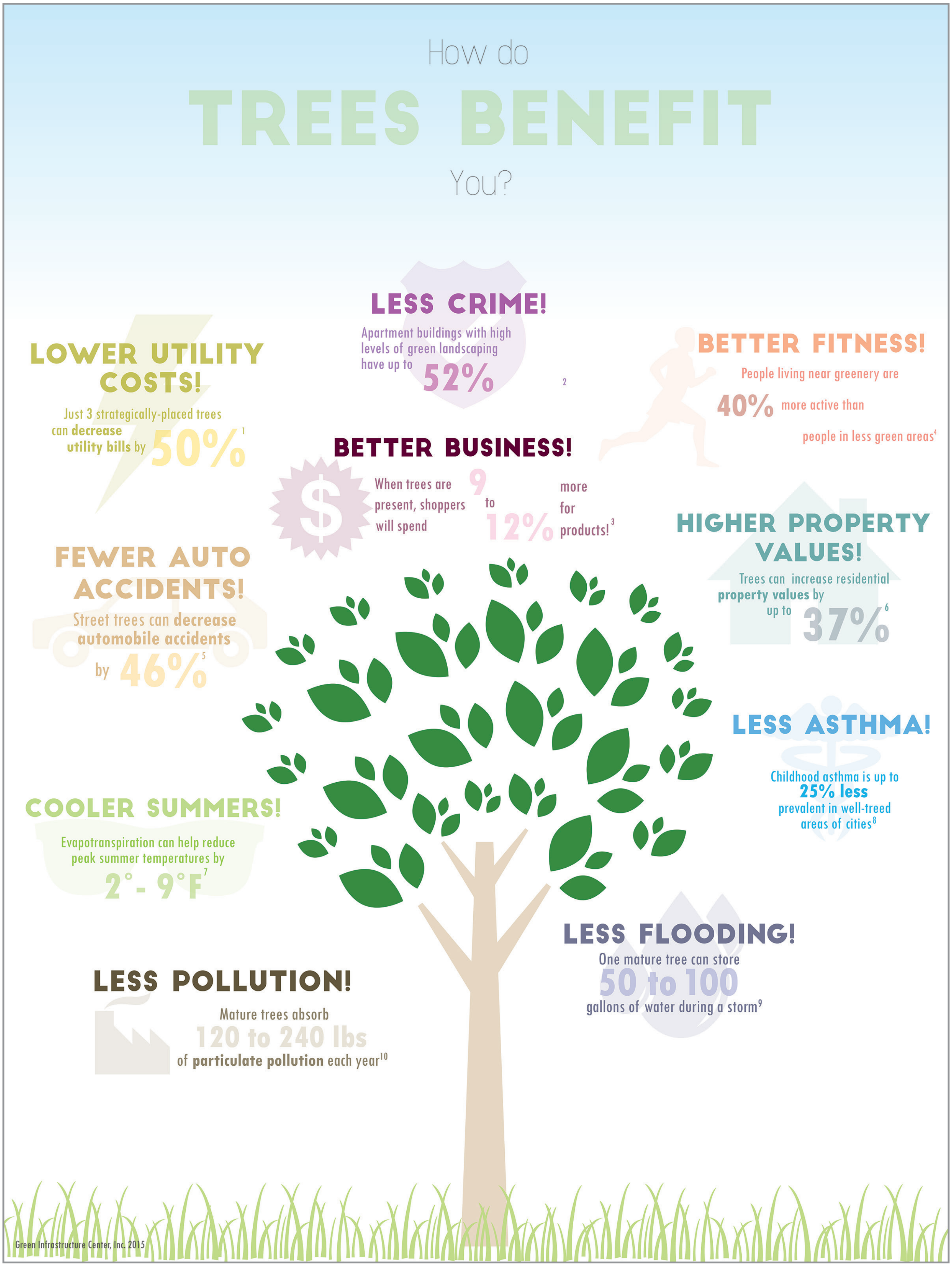
Quality of Life Benefits

During South Carolina'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. Multiple studies have found significant cooling (2-7 degrees) and energy savings from having shade trees in cities (McPherson et al 1997, Akbari et al 2001). In addition, trees absorb volatile organic compounds and particulate matter from the air, thereby improving air quality, and reducing asthma rates. Shaded pavement also has a longer lifespan so maintenance costs associated with roadways and sidewalks are less (McPherson and Muchnick 2005).

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).

One tree can absorb thousands of gallons of water annually.

Well treed areas encourage people to walk and bike.


How do
TREES BENEFIT
You?
LESS CRIME!
Apartment buildings with high levels of green landscaping have up to 52%[2]
LOWER UTILITY COSTS!
Just 3 strategically-placed trees can decrease utility bills by 50%[1]
BETTER FITNESS!
People living near greenery are 40% more active than people in less green areas[4]
BETTER BUSINESS!
When trees are present, shoppers will spend 9 to 12% more for products![3]
FEWER AUTO ACCIDENTS!
Street trees can decrease automobile accidents by 46%[5]
HIGHER PROPERTY VALUES!
Trees can increase residential property values by up to 37%[6]
LESS ASTHMA!
Childhood asthma is up to 25% less prevalent in well-treed areas of cities[8]
COOLER SUMMERS!
Evapotranspiration can help reduce peak summer temperatures by 2°- 9°F[7]
LESS FLOODING!
One mature tree can store 50 to 100 gallons of water during a storm[9]
LESS POLLUTION!
Mature trees absorb 120 to 240 lbs of particulate pollution each year[10]
Green Infrastructure Center, Inc. 2015

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).

A study by the National Association of Realtors found that 57 percent of voters surveyed were more likely to purchase a home near green space and 50 percent were more willing to pay 10 percent more for a home located near a park or other protected area.

Meeting Regulatory Requirements

Trees also help meet the requirements of the Clean Water Act. The Clean Water Act requires South Carolina to have standards for water quality. When waters are impaired they may require establishment of a TMDL standard and a clean-up 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. Forest cover also reduces the cost of drinking water treatment. The American Water Works Association found a 10 percent increase in forest cover reduced chemical and treatment costs for drinking water by 20 percent (Ernst et al. 2004).

Trees could be added for shade and beauty. As trees are lost to age or illness, they should be replaced with new trees.

A stork appreciates the habitat of Charleston, SC

Natural Ecology in Urban Conditions – Changing Landscapes

Natural history, even of an urbanized location, informs planting and other land-management decisions. Prior to conversion from natural or agricultural land cover to urban, it was Charleston's climate and geographic location that determined its flora and fauna.

Charleston is located in the Southern Coastal Plain province of South Carolina, characterized by a relatively flat landscape of sand and clay sediment types. The Southern Coastal Plain extends from South Carolina and Georgia, through much of central Florida, and along the Gulf Coast lowlands of the Florida Panhandle, Alabama, and Mississippi. It is a heterogeneous landscape containing barrier islands, coastal lagoons, marshes, and swampy lowlands along the Atlantic coast.

HISTORIC LAND COVER

Prior to European settlement, longleaf pine, wiregrass, and bluegrass plant communities dominated the area in and around what is now the City of Charleston. After settlement, plant communities shifted away from longleaf pines to hardwood trees and large shrubs as a result of fire exclusion.

The natural ecology of the Southern Coastal Plain area includes longleaf pines.

Anhinga in Charleston

Marsh in the city

As the population of Charleston started to rise, agriculture became the dominant economy and land use was primarily made up of rice, cotton, and indigo fields. This altered the existing hydrology by converting forest land to crop land with drainage alterations enacted to facilitate agricultural uses. Removal of existing trees, alteration of hydrologic and fire regimes, and subsequent urbanization and impervious surface expansion mean that more stormwater runoff is generated today than in the past.

CHARLESTON GROWTH AND DEVELOPMENT CHALLENGES

Founded in 1670 as Charles Town, to honor King Charles II of England, the city's initial location at Albemarle Point on the west bank of the Ashley River (now Charles Towne Landing) was abandoned in 1680 for its present site. The City of Charleston eventually became the fifth-largest city in North America. Today the city supports South Carolina's largest population, surpassing the City of Columbia. Since 2010, Charleston has increased by nearly 14,000 people.

Despite the changes to the landscape, the City of Charleston's low lying elevation and surrounding hydrology, leave a significant portion of the city's land as fresh and saltwater wetlands (18,829 acres).

The City of Charleston is a cultural landmark and development pressure on the city will continue, including in wetland areas. Development and fill of forested wetlands can significantly alter the city's hydrology and increase downstream flooding. Growth and densification of the city will be challenged by the large amount of existing wetlands and also by rising sea levels. Great care is needed to design developments that minimize impacts to forested wetlands. Denser and taller developments can reduce the demands of growth to avoid the clearing of additional wetlands.

This parking lot in Charleston has both a permeable parking area and also a bioswale that captures and cleans the runoff.

Downtown welcomes walkers with treed paths.

Demands for space to meet the needs for housing, commercial, business, industrial uses and transportation have strained both the city's grey and green infrastructure. As an older city, there are areas that pre-date the 1987 Clean Water Act Amendments and which were not subject to subsequent rules requiring first large and then smaller localities to treat stormwater runoff. Treating stormwater within an already developed landscape, is achieved by 'retrofitting' stormwater best management practices into existing areas, such as by adding bioswales to sidewalk areas or restoring wetlands. Of course, new developments do have to follow the city's stormwater regulations, so as areas develop or re-develop stormwater management practices are added. Recommendations for improvements to better utilize trees to manage stormwater and to reduce imperviousness are found in the Codes, Ordinances and Practices section on page 29.

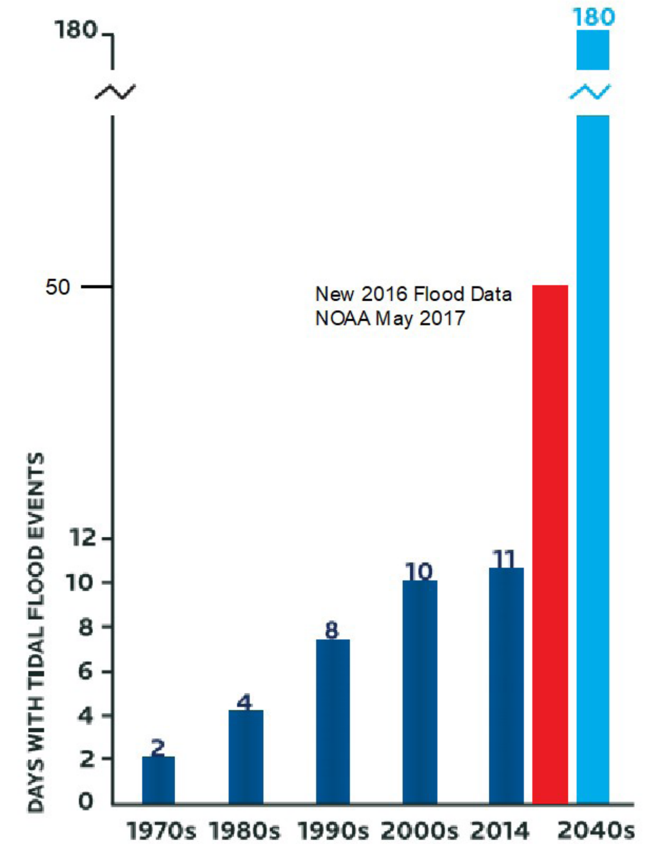


Figure 1. Days with tidal Flooding Events, Charleston, SC

180 days of tidal flooding are predicted by the year 2045 according to NOAA data released May 2017.

SEA LEVEL RISE

With many marshes, rivers and creeks present throughout the city, flooding has long been a consideration in the City of Charleston. However, recent problems such as sea level rise, heavier storm events, wetland draining and conversions have increased standing water and flooding as the capacity of existing drainage systems have declined. As sea level rises, drainage pipes are partially full even when it is not raining because water tables have also risen and land has subsided. Increased imperviousness has also led to less water storage and increased downstream flooding. Studies now project 180 days of tidal flooding per year by the year 2045. Compared to the 1970s when there was an average of just two days per year, tidal flooding is increasing at an alarming rate. It is clear that rising sea levels will continue to shape the city's growth and redevelopment.

Thanks to the city's foresight, the City of Charleston's first Sea Level Rise Strategy was developed and adopted by City Council in April of 2016. As of this publication (August 2018), the strategy recommended planning for 1.5 to 2.5 feet of sea level rise. It also encouraged best practices for hardscape and landscape features that absorb, sustain, cleanse and release water, revising maximum percent impervious space standards, and encouraging open space connectivity to marshes and creeks.

King tides, the highest seasonal tides that occur each year, flood Charleston's streets.

This street tree has been overwhelmed by salt water and will need to be removed. As the city floods, some trees will need to be replaced with those that are more tolerant of flooding and salts.

The city can plan for sea level rise by mapping forested areas that may be permanently flooded (changing from forest to marsh) as well as areas where frequent inundation will put trees at risk. For areas that are flooded frequently, the city can choose to plant trees that can withstand frequent inundation and also choose not to plant trees in areas where storm surges and flooding will significantly shorten their lifespans. A key next step is to prepare the city's urban forest to become more resilient by creating a list of salt-tolerant tree species that can thrive under more frequent inundation.

As this photo from August 2017 shows, even usual afternoon showers cause streets to flood.

CHARLESTON'S GREEN FUTURE

Charleston is working to develop in ways that support a quality lifestyle for residents and visitors alike, while also meeting state and federal mandates for protecting air and water. The city boasts approximately 120 parks and other open spaces comprising 1,809 acres. Charleston hopes to connect the upper and lower peninsula downtown with a new linear park called the Lowline that would stretch through the heart of the peninsula along an unused rail corridor. Other new parks and protected open spaces are also anticipated through the Greenbelt Program, which was renewed by voters in 2016 as part of a county-wide half-cent sales tax referendum.

Charleston will also maintain its Tree City USA status, a recognition of commitment to four core standards of sound urban forestry that have been in place for over 35 years, (this is discussed more in a later section.) These trees also support pollinators and John's Island is home to the state's first incubator farm for pollinators, located just outside the city. City residents can plant trees that are pollinator friendly such as oaks (Quercus), which support 534 species of moths and butterflies. To support a robust urban forest, a diversity of trees should be planted to ensure that disease does not wipe out the selected trees of one species.

This oak can support up to 534 species of moths and butterflies.

Trees support pollinators too!

Analysis Performed

This project evaluated how to calculate stormwater 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 18. However, new tools created for the project will also allow the stormwater benefits of tree conservation or additions to be calculated at the site scale.

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 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 following.

METHOD TO DETERMINE WATER INTERCEPTION, UPTAKE AND INFILTRATION

Currently, the city uses TR-55 curve numbers (CN) developed by the Natural Resources Conservation Service (NRCS) to generate expected runoff amounts for different land covers and soils. The city could choose to use the modified TR-55 CNs for this study that include a factor for canopy interception. 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.

This study used modified TR-55 CNs to calculate stormwater uptake for different land covers, since they are widely recognized and understood by stormwater engineers. Curve numbers produced by this study can be utilized in the city's modeling and design reviews. The provided spreadsheet calculator tool provided makes it very easy for the city to change the CNs if they so choose. What is new about the calculator tool is that it generates a more realistic curve number by applying the area specific land cover conditions in which the trees are found. A canopy interception factor is added to account for the role trees play in interception of rainfall based on their locations and planting conditions (e.g. trees over pavement versus trees over a lawn or in a forest).

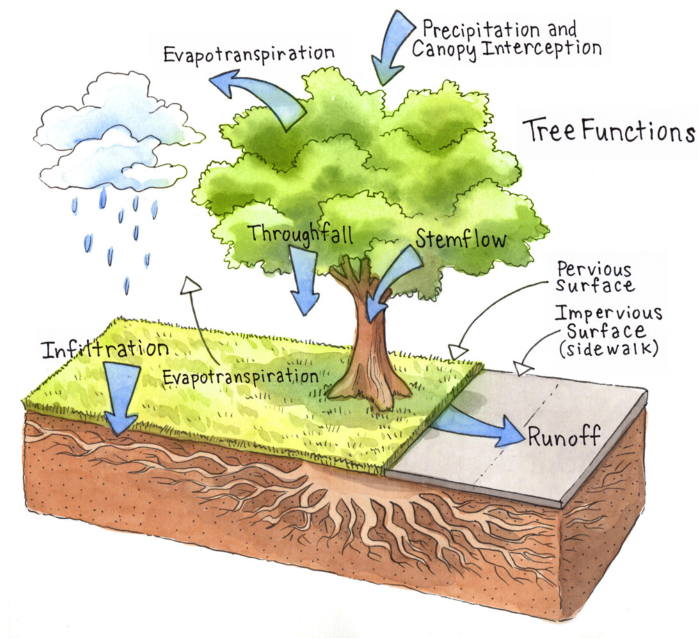
Tree canopy reduces the proportion of precipitation that becomes stream and surface flow, also known as water yield. A study by Hynicka and Divers (2016) modified the water yield equation of the NRCS model by adding a canopy interception term (Ci) to account for the role that canopy plays in capturing 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
- Soil compaction
- Hydrologic condition – density of vegetative cover, surface texture, seasonal variations
- Treatment – design or management practices that affect runoff

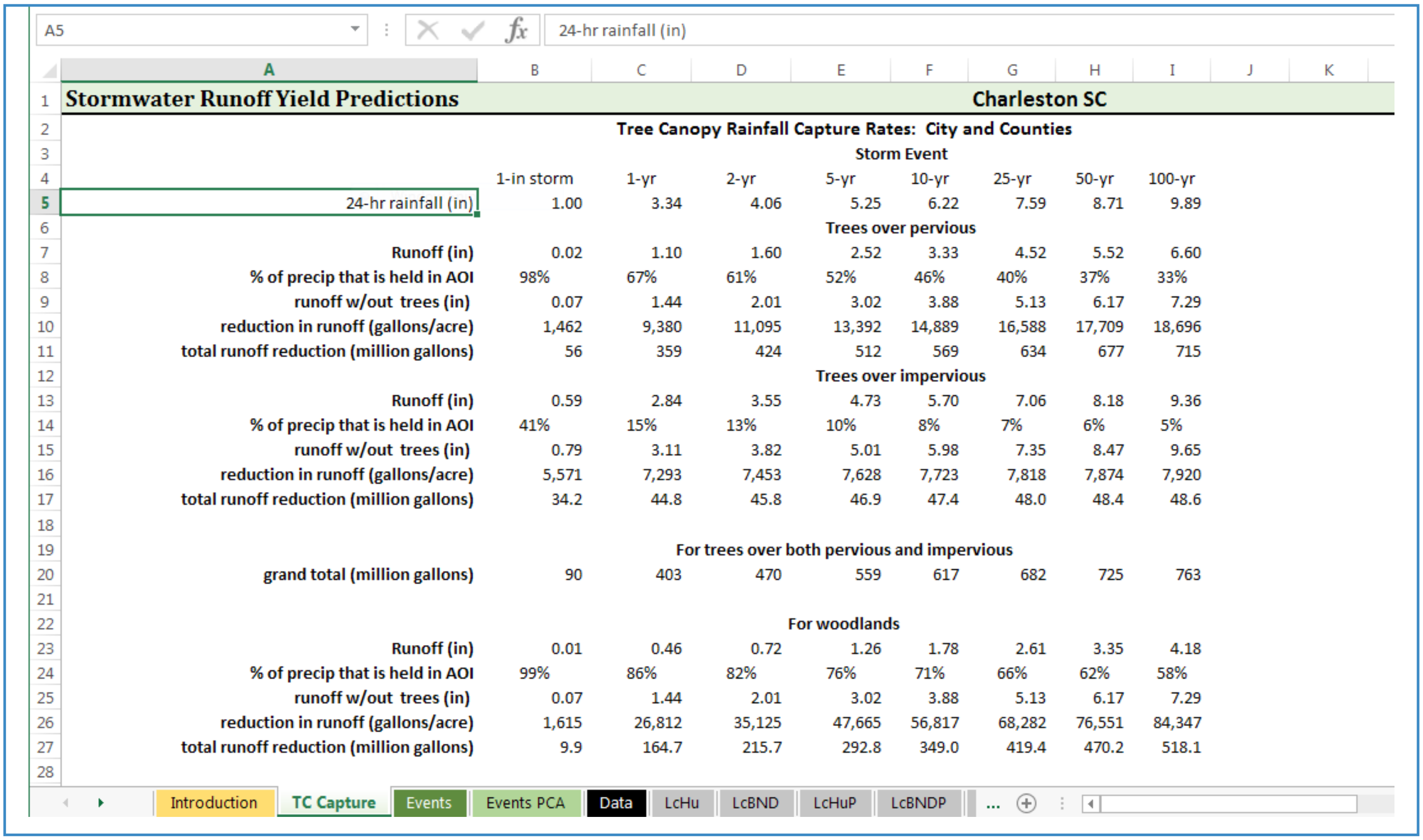
In order to use the equation and model scenarios for future tree canopy and water uptake, the project team first developed a highly detailed land cover analysis and an estimation of potential future planting areas, as described following. These new land cover analyses can be used for many other projects, such as looking at urban cooling, walkability (see map of street tree coverage on following pages), trail planning and for updating the comprehensive plan.



Trees and the Water Cycle

An example of how this modeling tool can be used for watershed-scale forest planning is indicated below. The actual model spreadsheet was provided to the City of Charleston for their use. It links to the land cover statistics for each type of planting area. It also allows the city to add trees or to reduce trees and to see what are the effects for stormwater capture or runoff. The key finding from this work is that removal of mature trees and existing forests generate the greatest impacts. As more land is developed, the city should seek to 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.

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. It can 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 will make the tool available to developers for modeling purposes.



Stormwater Runoff Yield Predictions						**Charleston SC**		
			Tree Canopy Rainfall Capture Rates: City and Counties					
				Storm Event				
	1-in storm	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
24-hr rainfall (in)	1.00	3.34	4.06	5.25	6.22	7.59	8.71	9.89
				Trees over pervious				
Runoff (in)	0.02	1.10	1.60	2.52	3.33	4.52	5.52	6.60
% of precip that is held in AOI	98%	67%	61%	52%	46%	40%	37%	33%
runoff w/out trees (in)	0.07	1.44	2.01	3.02	3.88	5.13	6.17	7.29
reduction in runoff (gallons/acre)	1,462	9,380	11,095	13,392	14,889	16,588	17,709	18,696
total runoff reduction (million gallons)	56	359	424	512	569	634	677	715
				Trees over impervious				
Runoff (in)	0.59	2.84	3.55	4.73	5.70	7.06	8.18	9.36
% of precip that is held in AOI	41%	15%	13%	10%	8%	7%	6%	5%
runoff w/out trees (in)	0.79	3.11	3.82	5.01	5.98	7.35	8.47	9.65
reduction in runoff (gallons/acre)	5,571	7,293	7,453	7,628	7,723	7,818	7,874	7,920
total runoff reduction (million gallons)	34.2	44.8	45.8	46.9	47.4	48.0	48.4	48.6
				For trees over both pervious and impervious				
grand total (million gallons)	90	403	470	559	617	682	725	763
				For woodlands				
Runoff (in)	0.01	0.46	0.72	1.26	1.78	2.61	3.35	4.18
% of precip that is held in AOI	99%	86%	82%	76%	71%	66%	62%	58%
runoff w/out trees (in)	0.07	1.44	2.01	3.02	3.88	5.13	6.17	7.29
reduction in runoff (gallons/acre)	1,615	26,812	35,125	47,665	56,817	68,282	76,551	84,347
total runoff reduction (million gallons)	9.9	164.7	215.7	292.8	349.0	419.4	470.2	518.1

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). Planting 25% of the PPA would capture an additional 22 million gallons during a mean annual 24-hr storm (66 Olympic swimming pools).

Trees could be added here for shade and beauty.

In the graphic of the calculator tool, the model is used to estimate that a hypothetical 10 percent loss of tree canopy for Charleston, would result in increased runoff yield for a mean annual 24-hr storm by 208 million gallons (313 Olympic swimming pools).

The calculator tool shows if planting efforts were to increase the canopy from 63 percent to 67 percent, the model shows a decrease in stormwater runoff (or increase in capture) of 88 million gallons. The model is a tool for seeing the results of adding or losing tree canopy.

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. 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.

LAND COVER, POSSIBLE PLANTING AREA, POSSIBLE CANOPY AREA ANALYSIS

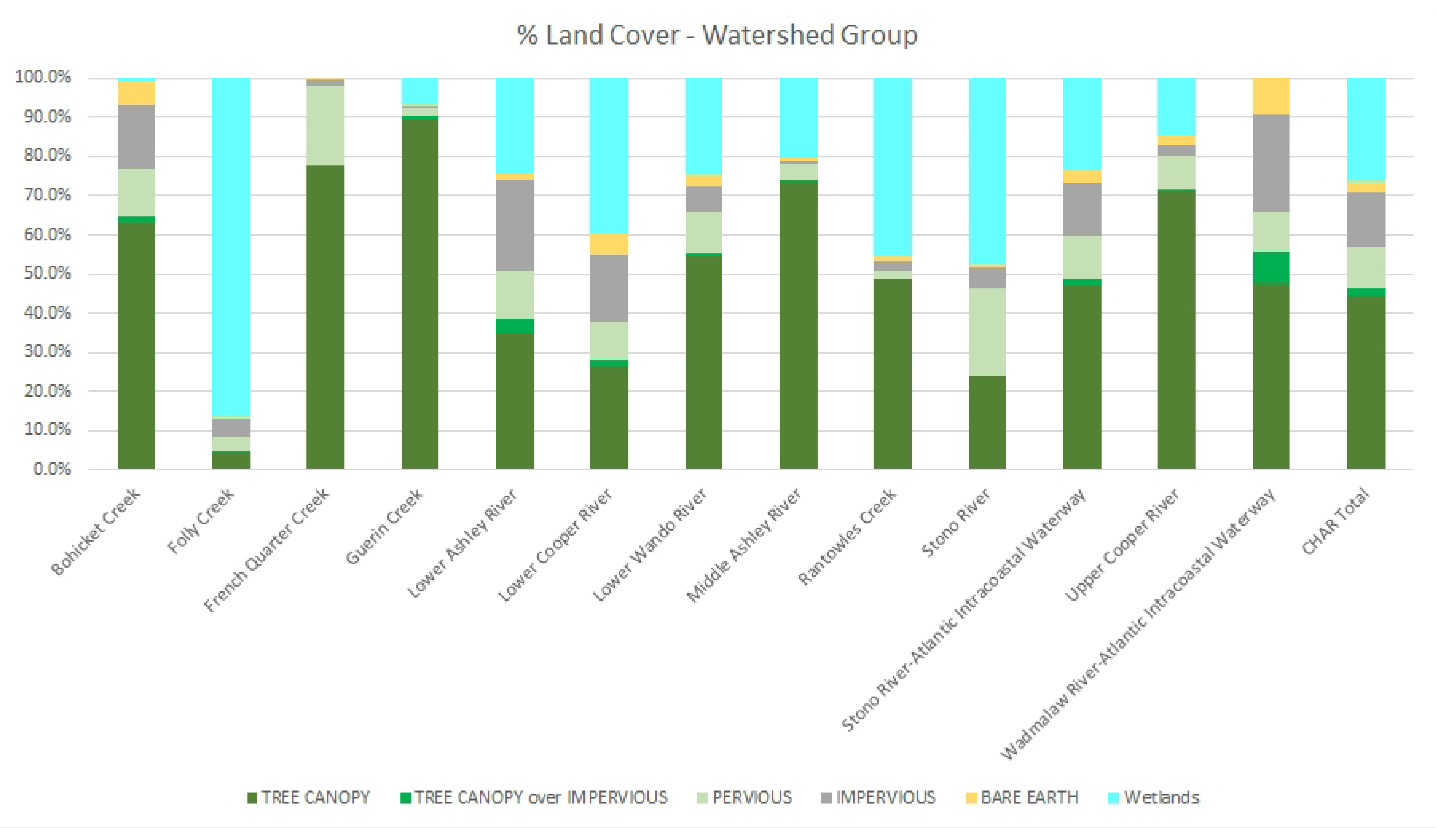
The land cover data were created using 2015 leaf-on imagery from the National Agriculture Imagery Program (NAIP) distributed by the USDA Farm Service Agency. Ancillary data for roads (from the City of Charleston Government), and hydrology (from National Wetlands Database) were used to incorporate:

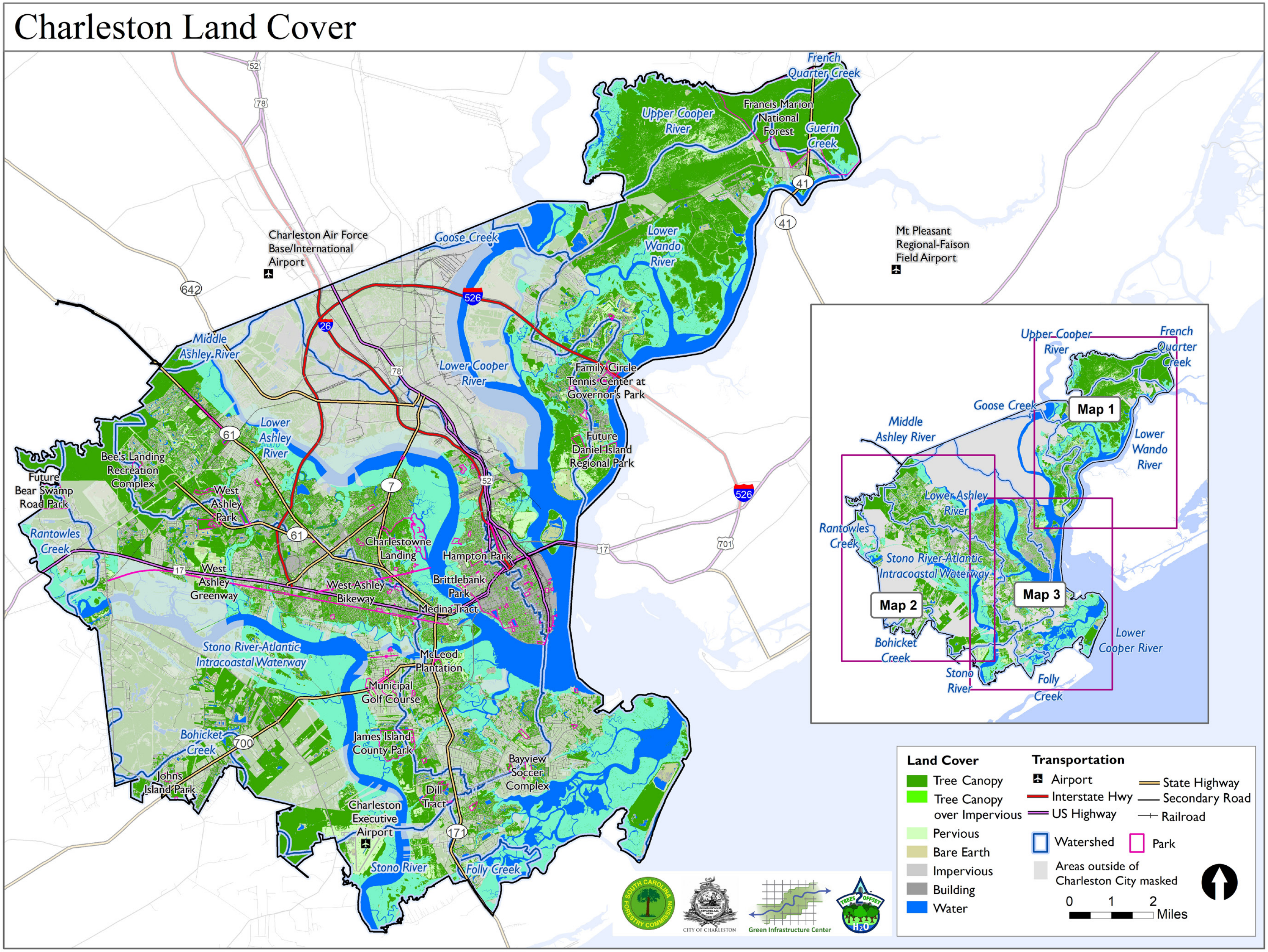
1) Tree Cover Over Impervious Surfaces class, which otherwise could not be seen due to these features being covered by tree canopy; and,

2) Wetland classes not distinguishable using spectral/feature-based image classification tools.

Forested open space was identified as areas of compact, continuous tree canopy greater than one acre, not intersected by buildings or paved surfaces.

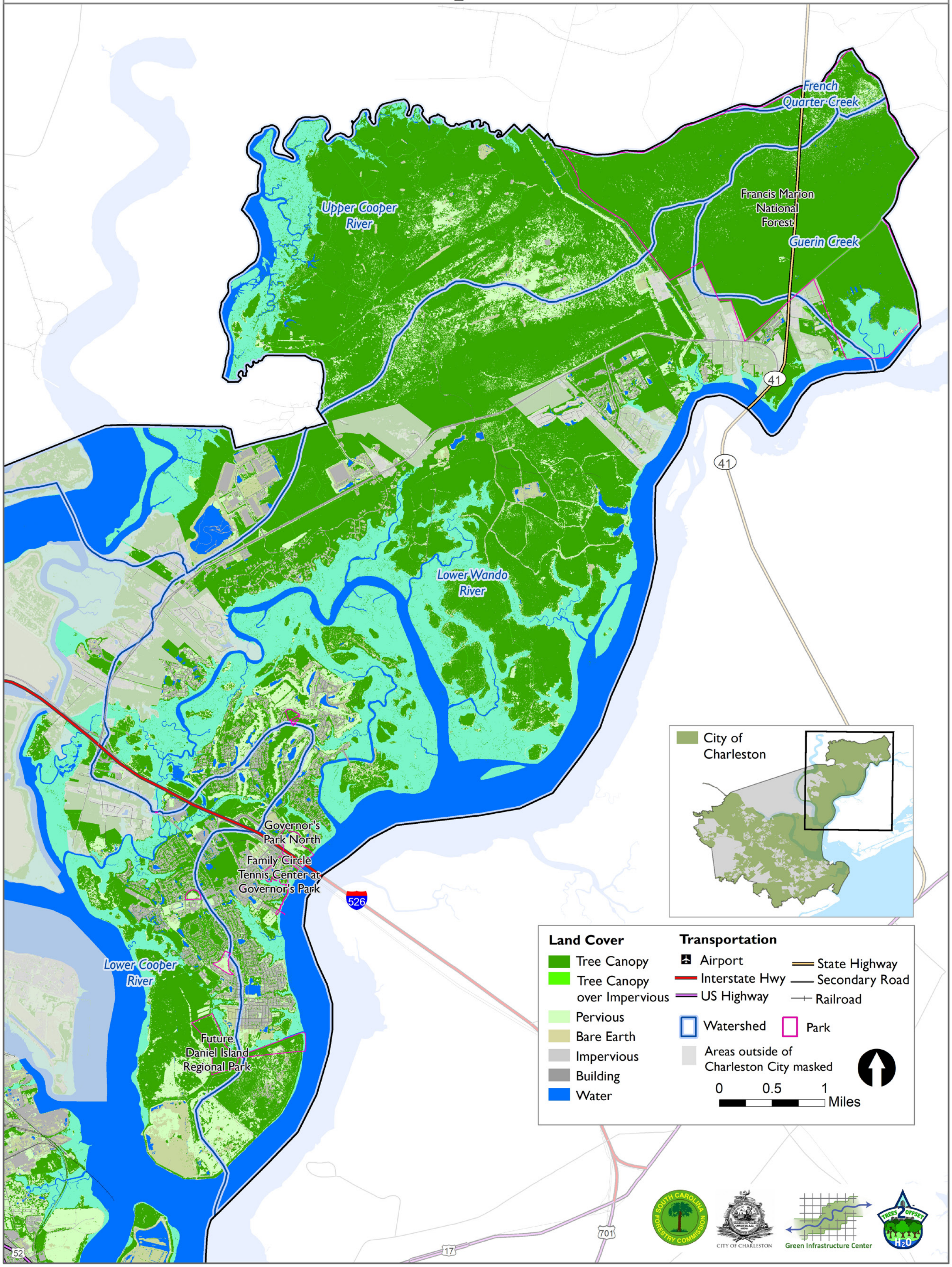
Downtown cemetery and garden provides places to enjoy serenity and to soak up rainfall.



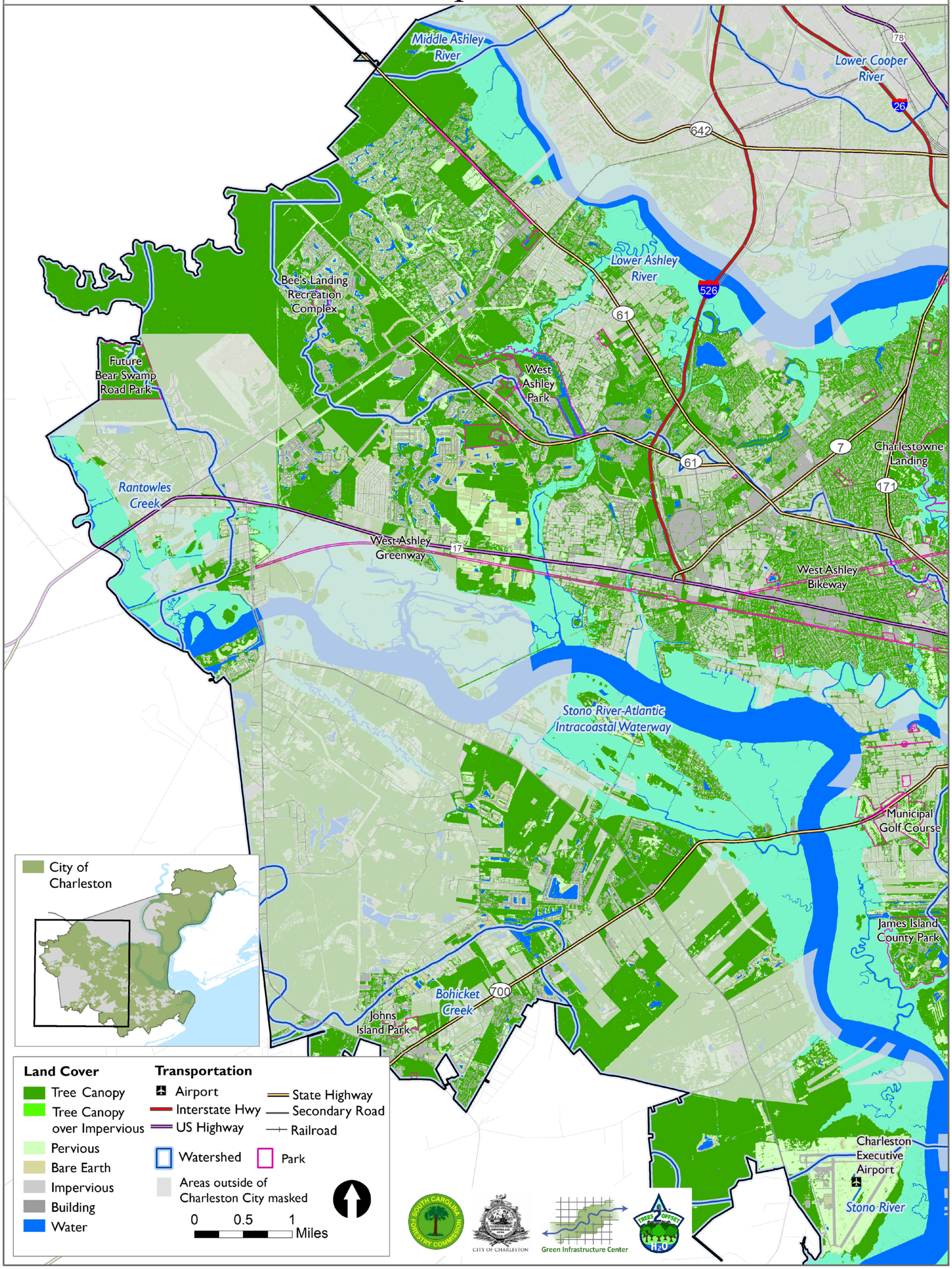


This shows what is currently treed. As the city is so large, tree canopy is also shown in the with zoom in maps for greater detail on the following pages.

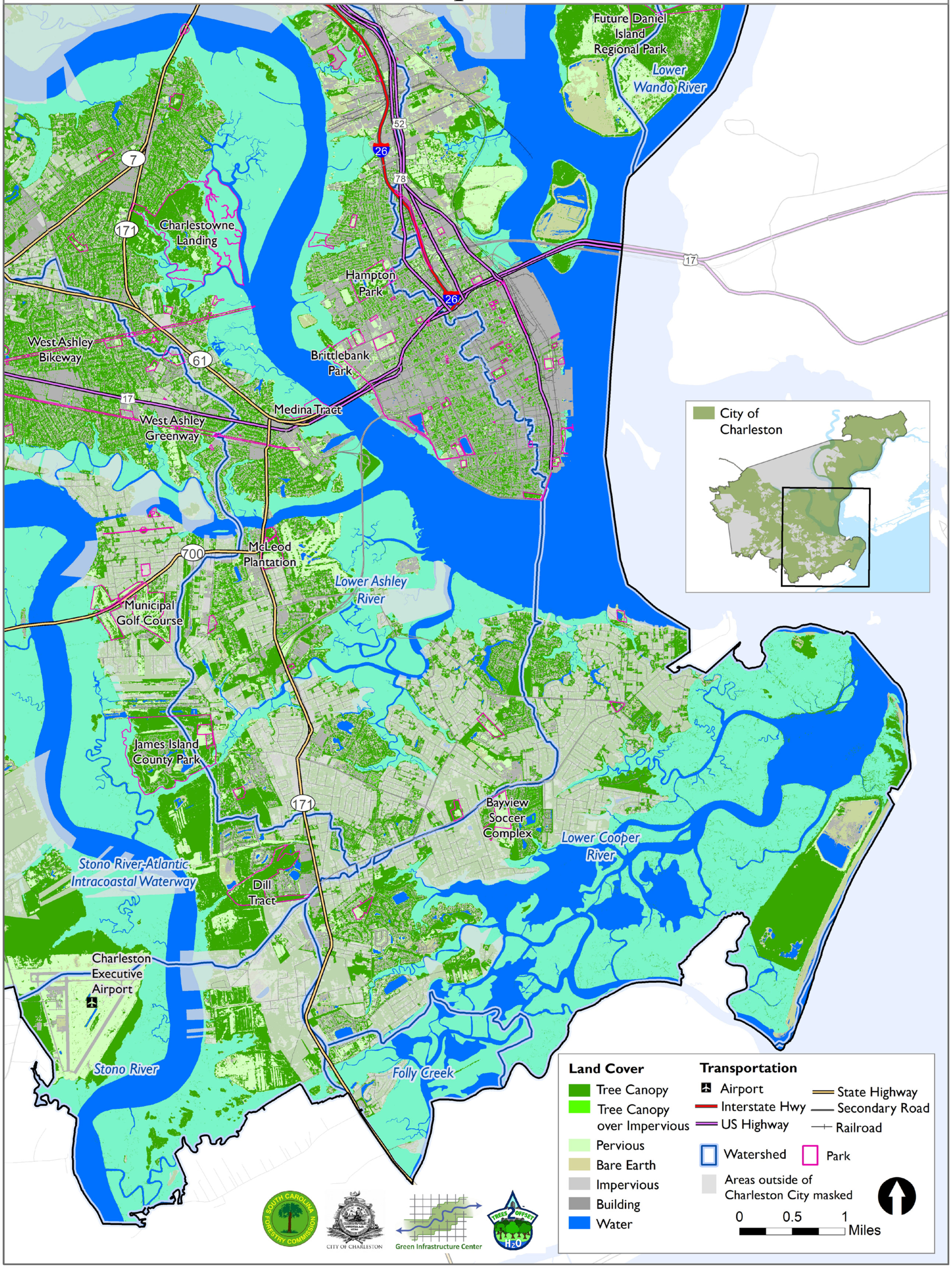
Charleston Land Cover - Map 1



Charleston Land Cover - Map 2



Charleston Land Cover - Map 3



The final classification consists of nine classes (types of land cover). The Potential Planting Area (PPA) is created by selecting the land cover features that have space available for planting trees. Of the nine land cover classes, only pervious, turf, and bare earth are considered for PPA.

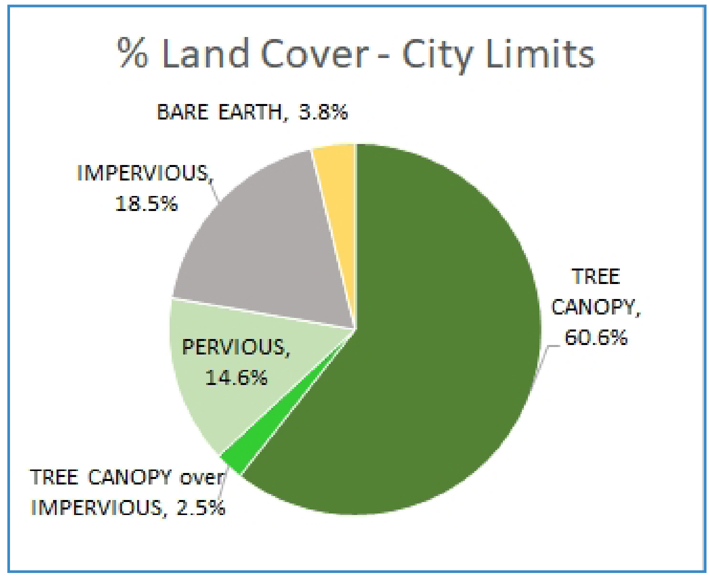
Next, these eligible planting areas are limited based on their proximity to features that might either interfere with a tree's natural growth (such as buildings) or places a tree might affect the feature itself such as power lines, sidewalks or roads. Playing fields, cemeteries and other known land uses that would not be appropriate for tree cover are also avoided. However, there may be some existing land uses (e.g., golf courses, agricultural lands that are expected to remain in agricultural use, etc.) that are unlikely to be used for tree planting areas that were not 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 area for potential places trees can be planted and grow to full size.

Tree over street

Trees over forested wetland

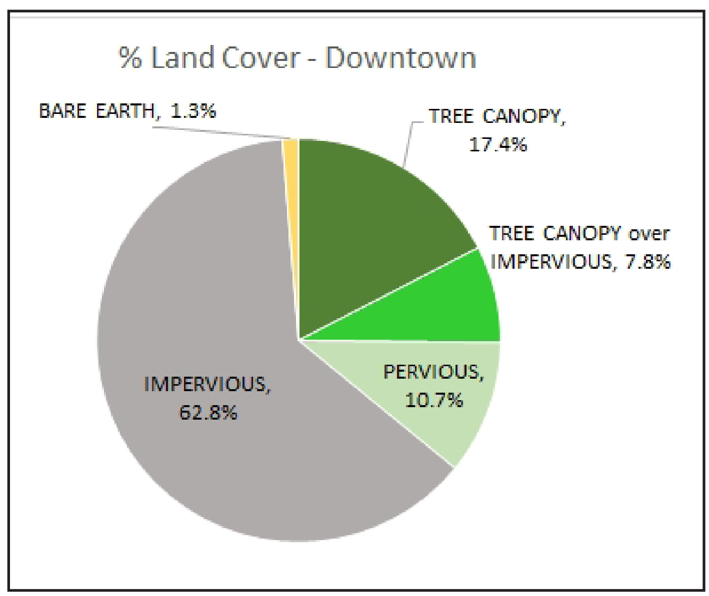
Tree over lawn

Tree over parking lot

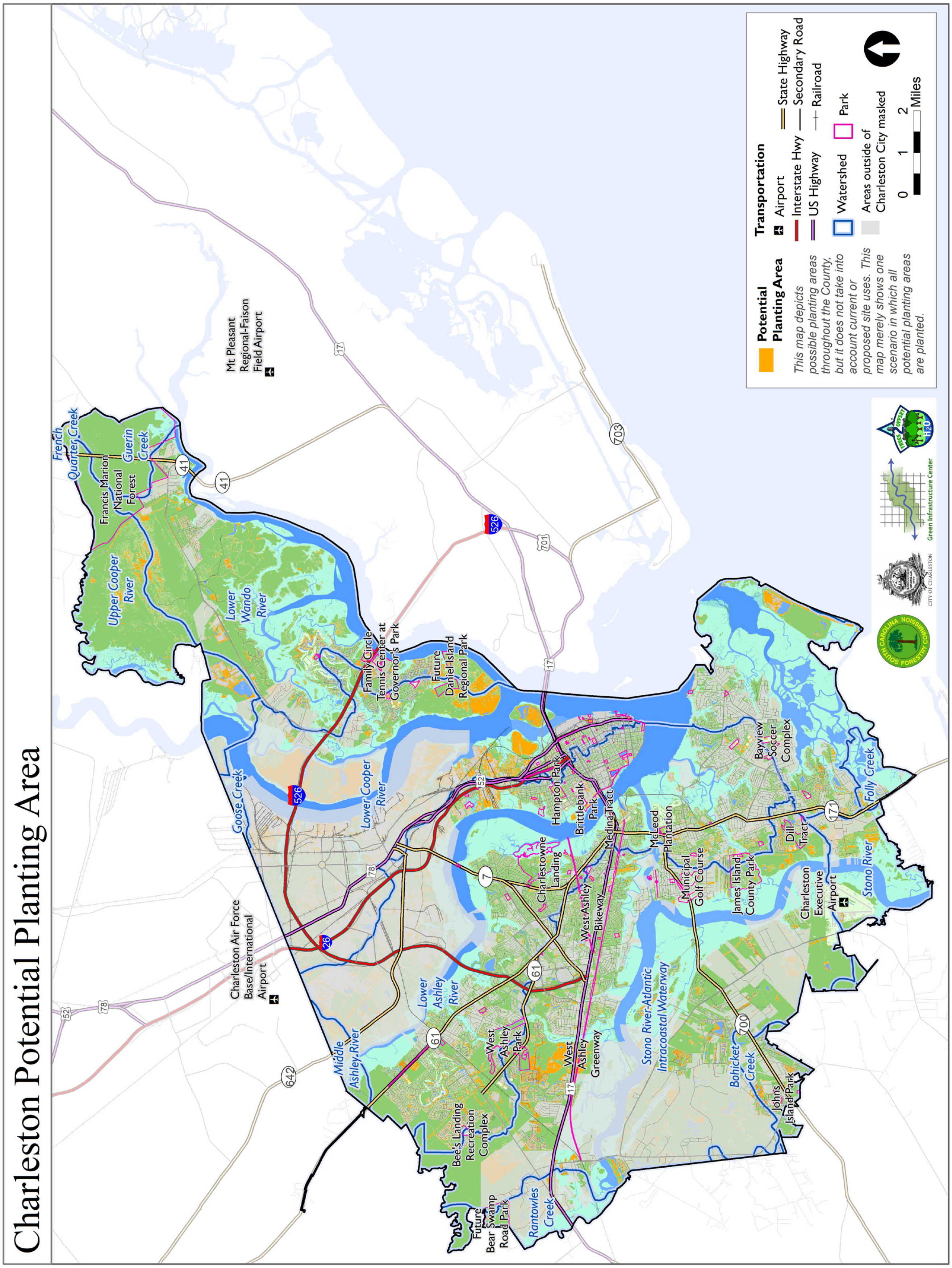


This pie chart shows the canopy based on its planting condition and these data inform analysis for how well water being captured and infiltrated.

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

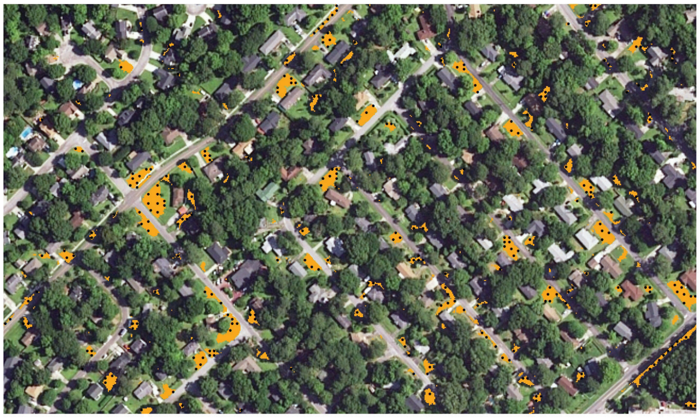


This pie chart show the difference between the downtown which is older and more densely developed and has less canopy overall than the rest of the city.



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.

Increasing the Charleston tree canopy from 63% to 67% could decrease stormwater runoff by 88 million gallons.



Potential Planting Spots (PPS)

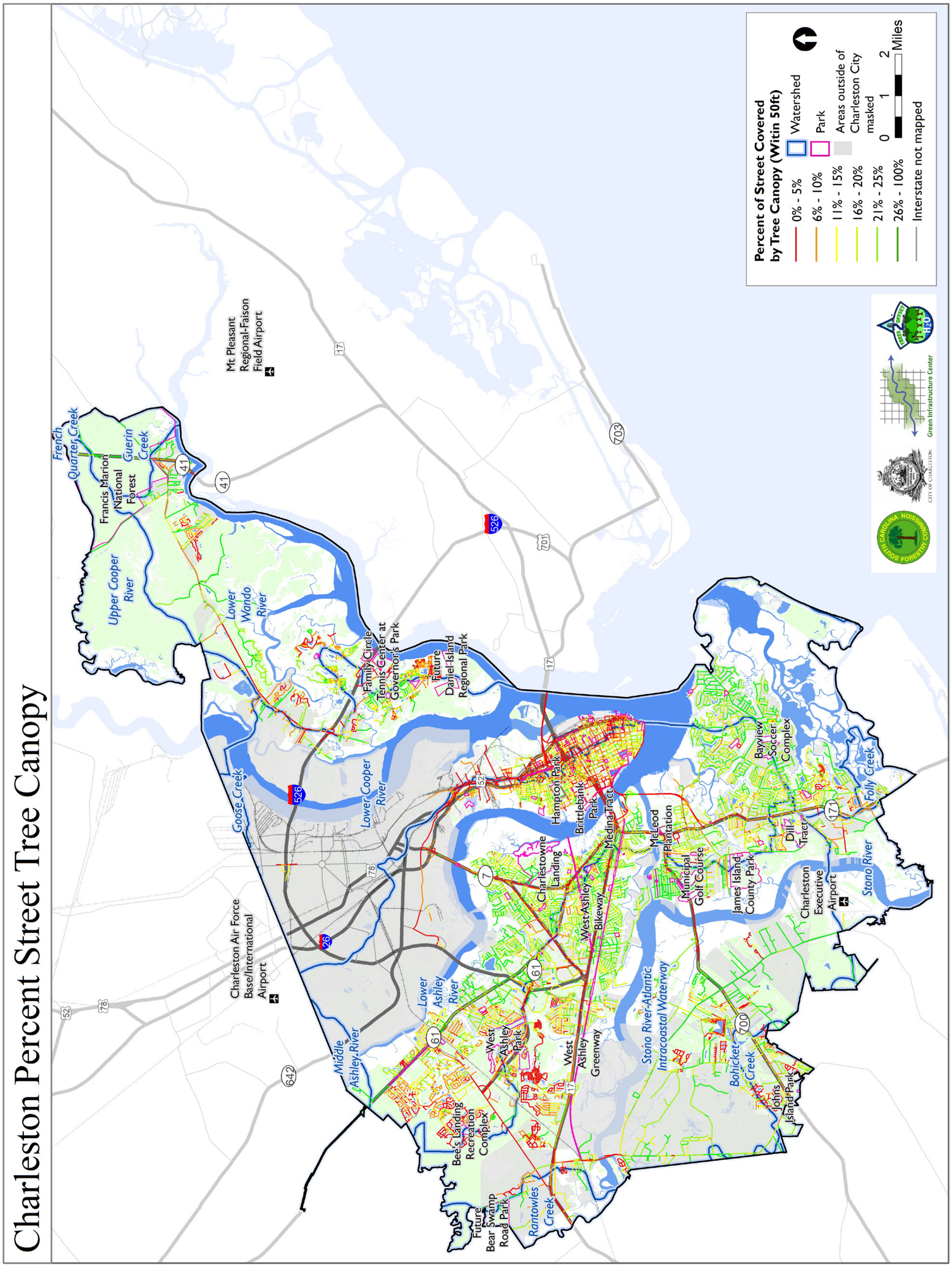
Potential Canopy Area (PCA) shows the overlap of canopy trees

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. For this analysis, that buffer radius is either 10 ft. or 20 ft., which result in either a 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.

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.

The GIC recommends that the canopy data be updated every five years. This requires use of remote sensing to translate aerial 'leaf-on' imagery to spatial data using the infrared bands that are reflected by different surfaces. National Agricultural Imagery Project (NAIP) data are available for free download. There are also 'off-the-shelf' software packages for analyzing imagery data. To perform this work, city staff should be well trained in analysis of remotely sensed data. If not, then the update of the data may require an outside consultant to provide the analysis, or the city may want to dedicate time to training in-house GIS staff. Once a new tree canopy map is created, it can be compared to past maps to determine whether the canopy is increasing or decreasing and compared against any established canopy goals. See the Methods Appendix for more details on mapping methodology.



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.

Codes, Ordinances and Practices Review

This review is designed to determine which practices make the town 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 portion of 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 more ideas for improvements.

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 localities progress across the south will be issued in 2019.

Charleston invests staff time and funds for managing its urban forest. In fact, the city just celebrated its 36th 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, that it has a tree ordinance, and practices tree management.

The recommendations provided in this report are a way to increase the protections for, and size of, the forest in Charleston. As other places are studied, they will be compared to the city, and vice versa. These recommendations will require additional funds to implement. Funds for care of urban street and park trees will need to be funded by the city. Expanding tree canopy requires participation and cooperation with the private sector.

As this raised walkway shows, Charleston often makes significant efforts to allow large trees and sidewalks to co-exist.

Top recommendations for the City of Charleston listed in priority order include the following:

1. **Use the GIC's stormwater uptake calculator to determine the benefits of maintaining or increasing tree canopy goals by watershed.** The calculator provided to Charleston 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.

2. **Update the 2000 Urban Forestry Management Plan (UFMP) to add statistics on the community values of trees, measurable and achievable urban forestry goals, action steps required to achieve them, and a detailed list of maintenance items and frequencies (see # 3 below).** Although the city has an UFMP, at 18 years old it lacks up-to-date statistics, goals or current needs assessments. These components can be divided into several sections including documentation of the community values of trees, outlining urban forestry goals and developing a maintenance item schedule.

3. **Develop a goal for the number of tree plantings per year to ensure urban tree canopy maintenance. Ask for additional funds to meet the tree planting goals.** Tree plantings are necessary to keep the tree canopy at its current level. Ensure adequate funding by requesting funds specific to tree planting. Unless new trees are planted, the city will see a decline in forest canopy in the coming decades.

4. **Conduct a land cover assessment every four years to determine 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 for watershed health is vital for livability and meeting state water quality standards. Regular updates to land cover maps allow for this analysis and planning to take place and to spot and address negative trends and take preventative actions.

5. **Develop a forestry emergency response plan as well as strengthen pro-active pruning.** The city does not have a plan for replacing trees lost to natural disasters such as hurricanes or other storms. This means that if no new trees are planted, canopy will decrease over time. Given the many benefits that trees provide (increased groundwater infiltration, soil stability, and reduced runoff and flooding, shade and better air quality), the city should plan for funding and replacement tree plantings following natural disasters. The city also needs to engage in proactive pruning of the urban forest. Charleston should budget for and schedule consistent pruning of urban trees for those areas of the city that are most at risk for storm impacts. Proactive pruning may result in less cleanup after large storms. The city should prune more frequently in highly trafficked areas of the city.

The city has expert staff who are qualified to take care of the canopy but they do not have enough staff to meet the demand for such a large city.

6. **Increase the standard tree protection zone to 1.5' per 1" DBH of the tree.** Larger tree protection zones protect the fibrous roots involved in water uptake and nutrient absorption. The city should protect these roots and increase the likelihood of post construction tree survival.

7. **Work with developers to shrink the development footprint to minimize impervious surfaces.** Holding a pre-development conference allows all parties to explore ideas for tree conservation before extensive funds are spent on land planning.

8. **Hire a position to manage spatial urban forest data within the Parks Department.** Urban forestry data can be used interdepartmentally for planning purposes if it is kept up to date.

9. Require tree canopy coverage percentages by land use. To assure quality of life for all in a community, add a requirement in Charleston codes and ordinances for minimum tree canopy coverage by land use. For example, 50 percent low density residential, 40 percent high density residential, 30 percent mixed use and 20 percent commercial.

10. Remove the pine tree exclusion from tree inventory requirements. Native pine trees provide great ecological benefit and stormwater uptake (due to the high leaf area index of the pine needles). Protect clusters of pine trees during construction, especially in areas where they do not threaten current or future structures.

11. Require 600, 1,000 and 1,500 cubic feet soil volume planting requirements for small, medium, and large trees respectively. 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 arborist should be consulted to recommend soil volumes based on species. While live oaks can survive with less soil volume, the city needs to have a diversity of tree species in place to avoid losses from disease and to provide other values, such as wildlife and pollinator habitat.

12. Do not pile soil in critical root zones of trees in fill conditions. Tree roots require gas exchange to survive. Filling in critical root zones of trees drastically reduces tree survival rates.

When trees do not have enough room to begin with, they may create their own spaces and cause damage to other infrastructure.

13. Ensure avoidance of direct discharge of high volumes of untreated or lightly treated stormwater into wetlands. Stormwater is required to be fully treated through stormwater ponds, bioswales, Filterra boxes or other best management practices before being discharged into natural wetlands. However, allowing excessive stormwater volumes to be discharged into natural wetlands can kill trees and other vegetation by altering the water levels (drowning existing vegetation). It is better to discharge water into constructed wetlands that are built specifically for this purpose to handle varying water levels.

14. Develop a contingency budget and work toward city approval of the budget. Establish minimum budget requirements to ensure maintenance of the urban forest during economic hardship.

15. Develop a mechanism for receiving stormwater utility fee reductions for planting trees or other creative incentives to subsidize community tree planting. Stormwater utility fees are a mechanism for funding stormwater management based on the amount of impervious surfaces generated for land cover by parcel. The city should provide an incentive for reducing impervious areas to lessen the fee, with extra credits for tree planting.

16. Set minimum and maximum parking requirements. Developers may desire more parking spaces than are necessary. Excessive parking spaces add unnecessary impervious area and result in more stormwater runoff. The city should consider setting parking maximums in areas where transit systems and public parking are adequate to support demand.

Many of the oaks in the historic downtown grow well despite restrictive planting areas. In this image, the sidewalk has been re-designed to allow for both the oak tree's roots and pedestrians.

17. Protect heritage, witness, and champion trees. Protection of heritage and witness trees adds a cultural and aesthetic component to urban forestry while also protecting more trees. Heritage and witness trees can commemorate historical events which hold great significance to a community.

The Angel Oak is hundreds of years old and protected from development, but there are many other city trees that may need additional attention and protective measures.

Although cabbage-palms are native to South Carolina, as they are planted here (widely spaced), they do little to capture stormwater because they have small canopy area and shallow roots.

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. Holding a pre-development conference which allows all parties to explore ideas for tree conservation before extensive funds are spent on land planning. This could be a great addition to currently held pre-application meetings with the Technical Review Committee. Many developers are willing to cooperate in such ventures, as houses often sell for a premium on a well-treed development.

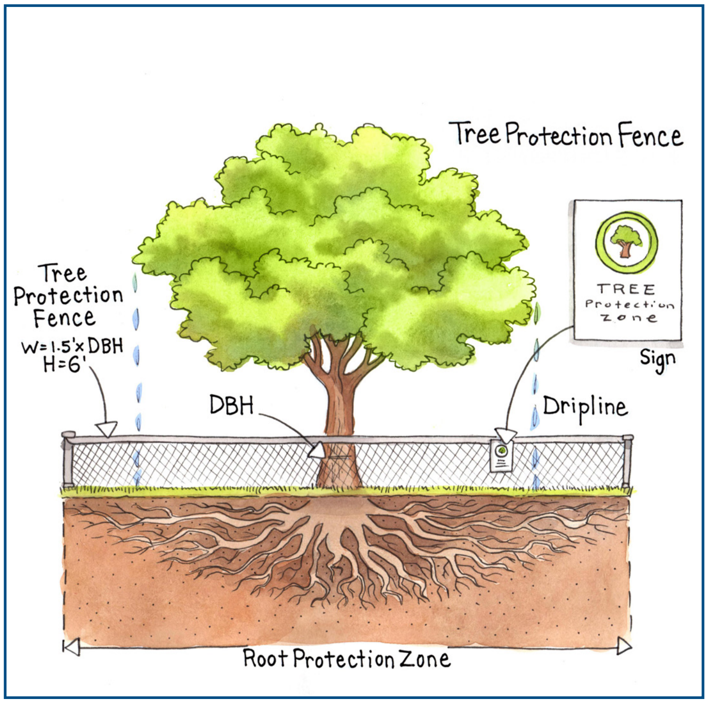
However, it will also be necessary to actively promote the implementation of development designs that minimize the loss of urban forest canopy and habitat. Without additional prodding, developers may not consider alternative site layout options to find the one that removes the least amount of natural resources. 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.

Tree Protection Fencing

The most common form of tree protection is tree protection fencing. It is a physical barrier that keeps people and machines out of a 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. Instead, sturdy metal chain link fencing can be required in high risk areas (such as near heavy construction equipment and active site grading) and orange plastic fencing can be used in lower risk areas (such as along woodland at the edge of a development property).

Small roots at the radial extents of the tree root area uptake water and absorb nutrients. Protection of the small fibrous roots is critical for the optimal health of a tree. Tree protection fencing is recommended to be placed at a distance of 1.5' from the tree trunk per DBH inch of the tree and encroachment on the critical root zone should be highly discouraged in order to best protect tree health and functions.

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.

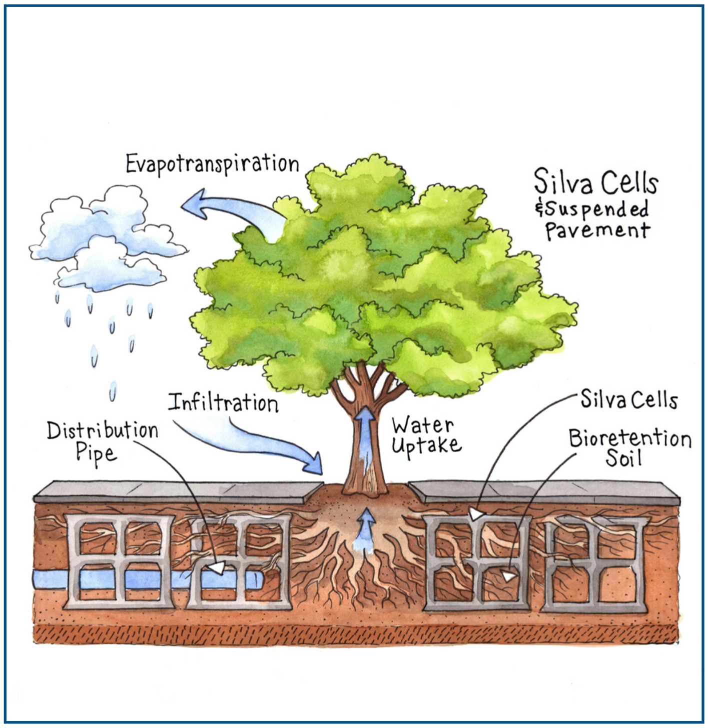


Tree Protection Fence and Signage

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, stunts their growth and reduces their lifespans. Some trees, such as live oaks survive in extremely difficult conditions, although even live oaks appreciate some support for soil volume and rainfall access. This means that adequate tree well sizing standards are a critical factor in realizing the advantages of a healthy urban forest. At a minimum, 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.

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 the city's 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.



Silva Cells and Suspended Pavement

CONCLUSION

Adapting codes, ordinances and municipal practices to use trees and other native vegetation for greener stormwater management will allow the City of Charleston to treat stormwater more effectively. Implementing these recommendations will significantly reduce the impact of stormwater sources (impervious cover) and use better ecologically sound methods (trees and vegetation) 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.

The City of Charleston should use the canopy map and updates to it, to track change over time. 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.

Citizens, private businesses and institutions also play a key role in tree planting and care. Since most land in the city is privately owned, volunteer efforts are vital to maintaining a healthy urban canopy for all to enjoy.


NO PARKING
PASSENGER LOADING

Appendixes

APPENDIX A: METHODS — 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 (PPA maps) for the City of Charleston.
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 or development?

Land cover classification

NAIP 2015 Leaf-on imagery (4 band, 1-meter resolution) was used for the Landcover classification. The full set of NAIP data was 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

Projection: Transverse_Mercator

False_Easting: 656166.6666666665

False_Northing: 0.0

Central_Meridian: -81.0

Scale_Factor: 0.99994117 https://www.dropbox.com/s/4mpprkcxq6bji3l/ReportMap_09_MarshMigration_201800426.jpg?dl=064705882

Latitude_Of_Origin: 24.33333333333333

Linear Unit: Foot_US (0.3048006096012192)

Geographic Coordinate System: GCS_North_American_1983

Angular Unit: Degree (0.0174532925199433)

Prime Meridian: Greenwich (0.0)

Datum: D_North_American_1983

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 "bulls eye" object recognition configuration and was used to identify features based on their surrounding features. Feature Analyst software is an automated feature extraction extension that enables 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 using Raster Calculator instead of ArcGIS' Imagery Analyst menu for consistency. 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. Several ArcGIS tools were built to automate this process. For example, the ability to draw a circle on the map and have all pixels classified as 'tree canopy' to 'non-tree vegetation,' a process usually requiring several steps, is now only a single step.

Potential Planting Area Dataset

The Potential Planting Area dataset has 3 components. These three data layers are created using the landcover 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

Exclusion Features (buffer distance)

- Excluded landcover features
  - Existing tree cover
  - Water
  - Wetlands
  - Imperious surfaces
  - Ball Fields (i.e.: Baseball, Soccer, Football) where visually identifiable from NAIP imagery. (Digitized by GIC)
- Impervious surfaces setback
  - Roads (based on road width estimate from centerlines) (5ft)
  - Sidewalks (5ft)
  - Park Trails (5ft)
  - Railroads (10ft)
  - Buildings (15ft)
  - Wetlands (10ft)
  - Stormwater pipes (10ft)

Potential Planting Spots

The Potential Planting Spots (PPS) are created from the PPA. The potential planting area (PPA) is run through a GIS model that selects spots a tree can be planted depending on the size trees 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 spread.

Power Lines

Note that planting under power lines is not generally recommended (although many live oaks co-exist in such situations). Since the locations for overhead transmission lines was not provided as part of this study (it is always requested), a planting site will still need to be evaluated for the presence of overhead lines and what types of trees may be suitable there. For example, a shorter tree may still be planted under a power line.

NAIP Image 2015

Potential Planting Area (PPA)

Potential Planting Spots (PPS)

Potential Canopy Area (PCA)

Public Comments Community Meeting One:

Comments/Questions about the Trees and Stormwater Grant and Maps:

1. Are the pervious areas on Morris Island undeveloped?
2. Inset maps may be required for West Ashley neighborhoods.
3. West Ashley Circle is a road and is built out already
4. The map representation of the Medical University of South Carolina (MUSC) has four buildings missing and the urban farm missing.
5. There is a large parcel about to be developed in the Peninsula that needs to be accounted for in the tree canopy and PPA maps.
6. West Edge is being redeveloped and is under construction.
7. Colonial Lake has been redeveloped and this should be reflected on the maps.
8. Development plans are in the review process for Bolton's Landing.
9. Is the data and information being generated in this grant going to be shared with West Ashley Plan consultants?

Stormwater Practices:

1. Plantings around ponds and other stormwater structures are generally discouraged.
2. Tiger Swamp needs more trees to help uptake stormwater.
3. Be aware of leaf litter in certain tree species.
4. Keep storm drains clean. The city, county and homeowners need to be more aware.
5. Landscape companies should not blow leaves into road ways because it clogs drains.

Charleston Codes, Ordinances and Practices:

1. Make the Parks Department more dynamic. Make the Parks Department more robust. Add more staff to work and maintain trees.

Pedestrians and Bikes:

1. Make pedestrian and bike bridges like other progressive cities.
2. Holy City Treks will help as volunteers to 'safer the bike' to provide safety for bikers, walkers and people that take the bus.

Tree Plantings and Care:

1. New developments need to preserve and plant more trees.
2. Retrofit city streets with trees.
3. There is a neighborhood match program in which every two trees that a neighborhood buys, the nonprofit group Charleston Trees will buy one.
4. The northern, eastern and western part of the Peninsula should have more trees.
5. Some parts of the city (Burns Downs for example) has older trees. It is necessary to start replacing trees.
6. Shopping centers throughout the city need more trees.
7. South Windemere needs more trees.
8. Older neighborhoods in West Ashley need more trees.
9. All of Dupont/Wappoo area needs more trees.
10. Sandhurst lost 50% of its canopy. It needs more canopy and tree plantings.
11. Beautify the city with trees. Continue the plantings across the Ashley River Bridge.
12. Bees Ferry Road has planted street and median trees.
13. The north side of Singleton Park needs trees.
14. There are potentials for fruit tree planting in Hampton Park.
15. Street trees are needed along key corridors (i.e. Highway 17 and Sam Rittenberg Boulevard) but this would require SCDOT and SCE&G to get on board. Trees along these corridors would help calm traffic and offer shade while people are sitting in traffic.
16. Incentivize places like Citadel Mall for redevelopment and tree planting.
17. There is an opportunity for more tree plantings in light of the Shadowmoss Church Creek FEMA buyout.
18. The intersection of Highway 61 and Frontage Road has a median and is a good place for a small or medium tree.

Community Engagement and Education:

1. The group 'Charleston Trees' is expanding from planting public lands only to also providing plantings for private lands.

Flooding:

1. There is general flooding through Tiger Swamp. This is due to the way the site was developed – through fill.
2. There is a huge increase in flooding in WestEdge. Is this high tide related? A lot of big rain events have caused workers there to be released early in the last three weeks.
3. Confederate Circle is flooding along William Ackerman Drive. A citizen has been in the neighborhood for four years and each year flooding seems to increase.
4. There is flooding at the West Ashley library.
5. There are more floods during rain events. Ditches remain full for days after the event.
6. Developments seem to do a lot of fill and set up drainage onto existing properties. This causes flooding on Pebble, Risher and Sarah Roads.
7. There is serious flooding near Harmon Field. Could add trees there.

Other:

1. One citizen loves the treed portion of the greenway. They are appreciative of the shade because of the heat and asphalt pavement conditions.
2. Underground power lines should be used due to potential aboveground utility and tree conflicts.
3. One location in the city took all the understory/brush, built an office and an oil change business and provided no sound or visual buffer.
4. There is a greenway and children's hospital planned for the Medical University of SC (MUSC) campus.
5. There is greenspace and traffic calming planned near the MUSC campus.
6. In one area of the Peninsula, the soil may need to be dredged to allow trees to grow.
7. East Central Lofts are being constructed in the Peninsula.
8. There are several large parking lots that could be better utilized or landscaped.
9. The vegetated buffers along Glenn McConnell Parkway are good and should be replicated and required elsewhere.

Community Urban Forestry Approaches:

1. Consider trees an infrastructure asset. Funding for care should include assessment and pruning for health and to minimize storm damage.
2. Do not plant trees adjacent to critical infrastructure.
3. Prune for trees months before the storm and not the day before.
4. Citizens on John's Island do not want clear cutting on the island.

Information/Materials for Citizen Led Tree Plantings:

1. Provide a place where citizens can obtain native trees for planting.
2. The city website of South Carolina Cooperative Extension should provide information for homeowners for identifying and planting native trees.
3. Provide more information for private property owners about tree value and care.
4. Encourage residents to plant a tree (city should not have to pay).

Trees and Stormwater Study Methodology:

1. Along with storm water drains and pipes to avoid in PPA, please be mindful of overhead and underground electric lines and other utilities when considering canopy as well.

Further Questions:

1. How do we get builders/developers to care?
2. How do we get adjoining property owners to collaborate on creating greenways? unity Meeting Two

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