Urban Tree Canopy Assessment
of Lake Charles, Louisiana

October 2022

An Analysis of Forest Cover and Benefits

Prepared by the
Green Infrastructure Center Inc.

This report and urban tree analysis were funded by the U.S. Forest Service and Louisiana Community Forests through a grant to the Green Infrastructure Center Inc. The mention of trade names, commercial productions, services or organizations does not imply endorsement by the U.S. Forest Service, Louisiana Community Forests or the City of Lake Charles.

Prepared by the Green Infrastructure Center Inc.
Publication Date: October 2022

Report by the
Green Infrastructure Center Inc.

Lake Charles, Louisiana
Urban Tree Canopy Assessment

An Analysis of Forest Cover and Benefits

October 2022

Prepared by the
Green Infrastructure Center Inc.

Table of Contents

Project Overview and Executive Summary

This report describes the tree canopy and associated benefits for Lake Charles, Louisiana. The tree canopy assessment was funded by Louisiana Community Forests. The Green Infrastructure Center Inc. (GIC) was hired to conduct the evaluation for Lake Charles. GIC evaluated the city's tree canopy extent, plantable areas, and determined the environmental benefits provided by the city's trees.

This assessment is helping the city meet its goal of recovering tree canopy lost during four federally declared natural disasters that occurred between the fall of 2020 and spring of 2021. The severity of these events decimated the city's tree canopy with losses of 33% between pre-storms (2019) and post-storms (2022). The city, local nonprofit groups, businesses, foundations and community groups are developing a recovery plan for the region. The "Just Imagine" campaign is envisioning a new 50-year master resilience plan for Calcasieu and Cameron Parishes through catalytic projects that will spur economic growth and create more resilient infrastructure, both natural and constructed. The urban tree canopy assessment compliments and supports this effort. The new land cover data and an accompanying assessment of Lake Charles' urban forest codes and policies can be used to strengthen management of the city's urban forest. These tools also can inform the city's application of green infrastructure to mitigate environmental impacts such as urban heat and stormwater runoff.

In summary Lake Charles can use the results of this report to:

- Support the recovery efforts to replace tree canopy lost from recent natural disasters.
- Build capacity for the City's tree planting campaign #ReTreeLC
- Document the many environmental and social benefits provided by city trees
- Determine the strategic locations for retaining or planting trees to realize environmental and social equity benefits
- Inform management of the city's urban forest and support investments in tree care and planting
- Prioritize policy and code updates to support more tree plantings and tree retention
- Use new data to support regional catalytic projects in the Just Imagine Plan

Hurricane Laura damaged many homes and properties. Lake Charles is still working to recover from storm damages.

Lake Charles' tree canopy was severely damaged during four federally-declared natural disasters in 2020 and 2021, resulting in extensive tree losses.

Why Map Urban Canopy?

Trees are declining throughout the southern United States. Causes for this decline arise from multiple sources including land conversion for development, storm damage, hurricanes, and lack of tree replacement as older trees die. Many communities in Louisiana have now mapped their tree canopies and are looking for ways to protect or expand their urban forests. Data about the City of Lake Charles' trees are needed to track trends, assess losses or set goals to retain or restore canopy. The City of Lake Charles now has baseline data to set canopy goals, monitor canopy protection progress, measure environmental benefits of city trees and prioritize strategic restoration of canopy locations.

Trees are the city's 'green infrastructure.' Just as we manage our grey infrastructure (roads, sidewalks, bridges and pipes), we also need to manage our 'green infrastructure' (trees and other vegetation). The city's green infrastructure provides many values that support a vibrant, safe and healthful city. Trees add to the city's historic coastal character, and they enhance its livability by filtering storm water and reducing runoff, cleaning the air, providing oxygen, shading, and natural beauty and enhanced property values. As the City of Lake Charles recovers from natural disasters and continues to grow, it should also manage and expand the urban forest. This will help the city meet its goal to be "a regionally vibrant cultural center with plenty of access to outdoor amenities."

Fast Facts & Key Stats Lake Charles

Parish: Calcasieu

2021 Population Estimate: 81,097 people

Total City Area: 51.1 sq. miles

Land: 44.7 sq. miles; 17,856 acres

Acres of lakes/ponds: 1,912

Acres of swamp & marsh: 910

Miles of stream/canals: 103

Acres of tree canopy: 2,951

Gray vs Green

Image at left shows Lake Charles' gray infrastructure including buildings and roads. Classified high-resolution satellite imagery (at right) adds Lake Charles' green infrastructure data layer (trees and other vegetation). The green infrastructure provides cleaner air, water, energy savings and natural beauty.

Summary Outcomes

Canopy

Lake Charles has a tree canopy of 10.6%. This relatively low canopy resulted from damages by several devastating hurricanes during the fall of 2020 which resulted in a 5% canopy loss (33% of the existing canopy). Fortunately, the City of Lake Charles has room to add significantly more tree cover that would provide many benefits to the city for shade, air quality, urban cooling and habitat and natural beauty. These benefits trees provide for Lake Charles' citizens are called 'ecosystem services' or benefits nature provides relatively for free. In fact, the city could achieve a far greater canopy coverage that is higher than the pre-storm coverage of 15% and thus provide even more benefits to the Lake Charles' community.

Air Quality

Trees play a critical role in not only providing oxygen, but also cleaning the air of particulate matter and ground level ozone (O_3), which can harm human health. Trees also sequester greenhouse gases such as sulfur dioxide and carbon dioxide, and as these gasses are trapped by trees, the severity of climate change is reduced. Trees also store carbon and prevent its release, further helping to ameliorate possible climate change impacts. Each year, the tree canopy of Lake Charles removes 1,337,534 lbs. of CO_2, 142,274 lbs. of ground-level ozone (O_3) and 47,647 lbs. of airborne particulate matter that can cause respiratory distress.

Heat Island

Similar to most southern cities, Lake Charles suffers from urban heating and stormwater runoff impacts from too much impervious surface coupled with a lack of vegetative cover. Excessive pavement and lack of shade lead to increased temperatures known as *urban heat islands*. The lower the tree canopy cover, the higher the surface temperatures and the hotter the city.

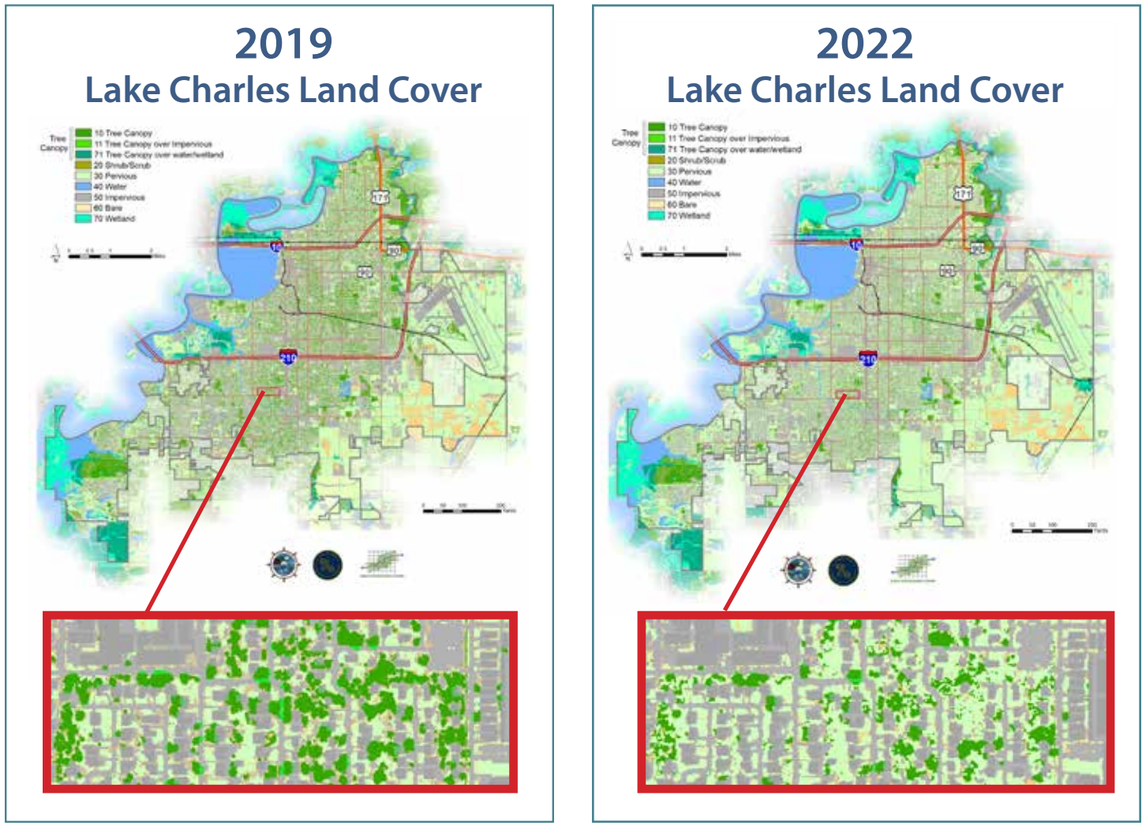
Stormwater Uptake

The city's trees also help mitigate stormwater as they capture rainfall in their canopy, trunk and roots and surrounding soils and then release some of that water back to the atmosphere through evapotranspiration. One mature large tree can absorb thousands of gallons of water per year. During a one-year/24-hour rainfall event (4.63 inches), the city's trees soak up 31.2 million gallons of water! This means less flooding of streets. During that same rainfall, the city's trees reduce runoff pollution loads for nitrogen by 3%, phosphorus by 4%, and sediment by 2%, thereby reducing water pollution.

Canopy Trends and Goals

Maintaining canopy while keeping up with losses as older trees age and die, are lost to storms, or are cleared for development, requires the city to continually plant trees. As the city recovers from past storms and continues to grow and develop, it will be important to maintain existing coverage and to plant replacement trees to overcome losses. Based on analysis of change in canopy over two years (2019-22) the city lost 33% of its tree canopy to several natural disasters; equal to about 100,000 trees lost. If this trend were to continue, without further investment and planting efforts, the city's canopy could disappear in a relatively short amount of time. Although a complete loss is unlikely since residents will continue to replant, the city needs to *increase the rate of planting to prepare for and to recover from natural disasters*.

Lake Charles has adopted a citywide goal to increase tree canopy to pre-Laura (2020) levels of 15% to be achieved over the next ten years. This requires planting more than 103,700 trees in total or 10,370 trees annually across the city. The city can reassess progress and adapt its canopy goal over time to achieve a higher overall canopy coverage.



The City of Lake Charles lost significant canopy in the last few years due to storms. There is opportunity to recover lost canopy though accelerated tree planting. More trees equate to better air quality, shade and energy savings, more stormwater uptake and improved water quality too!

Introduction

The city of Lake Charles is a 51.1 square-mile community in Calcasieu Parish in Southwestern Louisiana and is the sixth largest city in Louisiana, with an estimated 2021 population of 81,097 persons. The city is racially and ethnically diverse with 43.9% non-Hispanic Whites, 47.9% Black/African Americans, and 3.4% Latino residents[1].

Lake Charles (French: Lac Charles) is a brackish water body located alongside the Calcasieu River in Southwest Louisiana, United States, situated almost entirely within the Lake Charles city limits. The border adjoins 5.8 miles of Lake Charles' shoreline and 1.43 miles of the Calcasieu Riverfront. Lake Charles' mission is to be "united for progress prosperity" and its vision is to be "a vibrant art, cultural and dining scene with parks scattered throughout the city and easy access to shimmering Lake Charles, via the beautiful Lakefront Promenade." With 198.5 acres of municipal parks, beach and conservation lands, the city is rich in natural amenities that contribute to its high-quality lifestyle.

The Canopy Assessment

This report describes the city's current canopy coverage, the canopy assessment method, an analysis of the canopy's environmental benefits and city strategies to sustain and expand the urban forest. Products created include:

- 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
- Calculation of the environmental benefits and pollution removal by city trees
- Analysis of city's codes, ordinances and practices for their ability to conserve or protect the urban forest
- A public survey concerning where the city should prioritize tree planting efforts and the top strategies for increasing tree canopy
- Tree canopy community outreach and educational materials

The city can utilize the tree canopy to maximize environmental and social benefits including:

- Community health and vibrancy.
- Aesthetic values and natural beauty.
- Decreased urban heat island and reduced heating and cooling costs.
- Abundant bird and wildlife habitat.
- Expanded walkability and multimodal transit support.
- Revenue from tourism and retail sales.

1 https://www.census.gov/quickfacts/lakecharlescitylouisiana

Lake Charles has many older street trees that need continual care to ensure they remain healthy.

How the Urban Forest Benefits Lake Charles

Reducing Stormwater Runoff and Filtering Pollutants

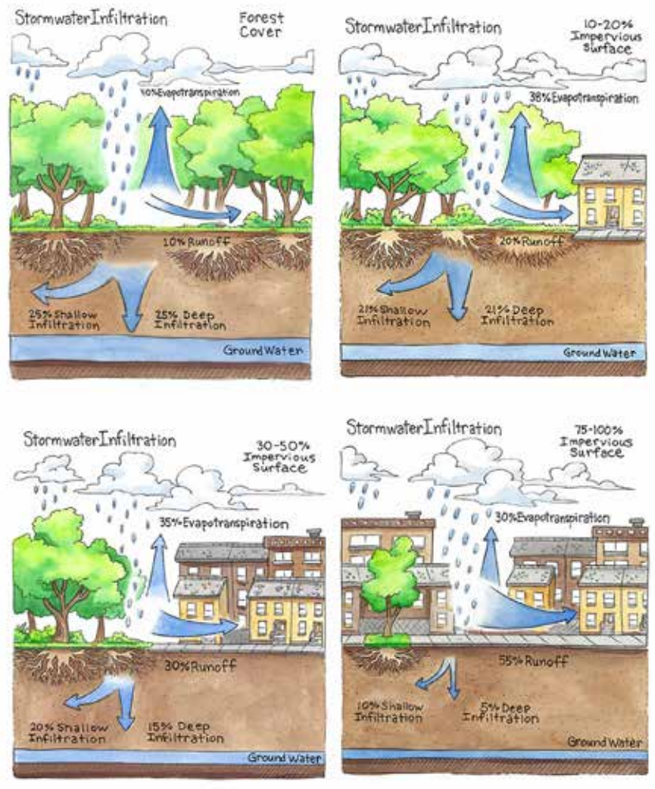
Trees protect cities from problems associated with stormwater runoff. However, as forested land is converted to impervious surfaces, runoff increases. Excess stormwater runoff can cause temperature spikes in receiving waters, increased pollution of surface and ground waters, and greater potential for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

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

The average annual precipitation in Lake Charles is 57.49 inches (146 cm), some of which runs off carrying surface pollutants. Large, paved areas contribute significant volumes of this runoff. During a one-inch rainfall event, a one-acre paved area such as a mall parking lot, will release 27,000 gallons of runoff compared to an acre of forest, where only 750 gallons of water run off. While stormwater ponds and other best management practices are designed to mimic rainfall release by detaining and filtering runoff, they do not fully replicate pre-development hydrology. In addition, older parts of the city may lack stormwater management practices that are required for new developments, so not all runoff is captured or treated before it flows to open waterways.

Since trees filter stormwater and reduce overall flows, planting or conserving trees is a natural way to mitigate stormwater. Each tree plays an important role in stormwater management. Based on the GIC's review of multiple studies of canopy rainfall interception, a typical street tree's crown can intercept between 760 gallons to 4000 gallons of water per tree per year, depending on the species and age. During a 1-year/24-hour rainfall event (4.63 inches) in the City of Lake Charles, the trees take up 31.2 million gallons of runoff, or about 47 Olympic swimming pools of water. In a larger rainfall event similar to Hurricane Laura in 2020 (up to 8 inches of rain), the trees take up 44 million gallons.

Runoff increases as land is developed.



Data Source: Federal Stream Corridor Restoration Handbook (1998)

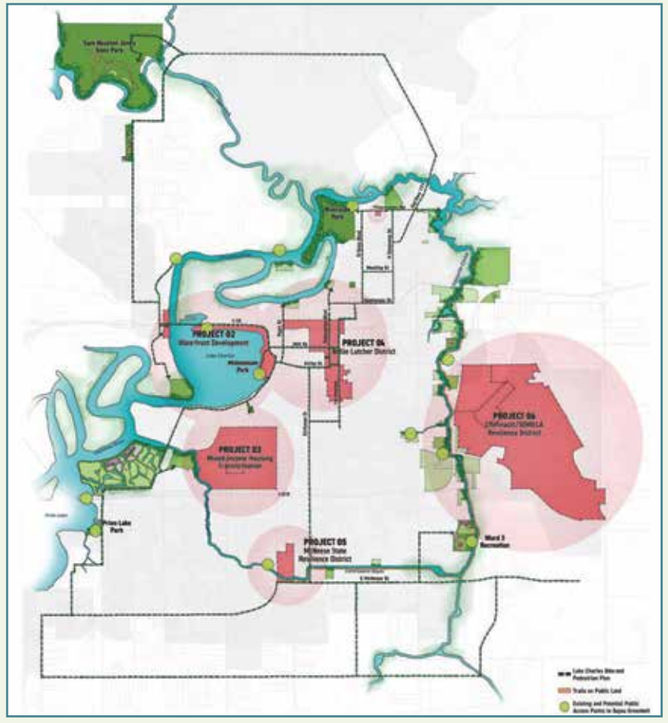
Planting trees strategically along the coulees can reduce nonpoint source pollution from entering into the local waterways.

Buffering Storms and Flooding

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

Excessive stormwater runoff accounts for more than half of the pollution in the nation's surface waters.

Retaining trees and forests along coasts also provides a wind break and helps to evaporate and reduce standing water. In addition, utilizing trees as 'green infrastructure' can provide a basis for reimbursement from FEMA if trees are damaged during storms. To qualify, trees must be inventoried and specifically utilized for stormwater management, erosion and sediment control, buffers or other green infrastructure functions.



The Bayou Green Greenbelt is a proposed network of greenways and trails that will connect residents to public greenspaces and natural landscapes.

Lake Charles participates in the National Flood Insurance Program's Community Rating System (CRS). The CRS is a voluntary incentive system that allows local governments to earn flood insurance premium discounts for policyholders in the community. Local governments receive points for actions or policies that reduce flooding and flood damage; these points earn premium discounts as high as 45%. The City of Lake Charles is currently rated as Class 9 in the CRS program, saving residents and businesses within its special flood hazard areas on average about $200,000 per year.

Additionally, communities can earn credit for adopted management plans that protect the critical natural functions of floodplains and native species, while implementing habitat restoration projects. CRS requirements include an inventory of all species in the plan's geographic purview, action items for protecting one or more of the identified species of interest, restoring natural floodplain functions, and the review and update of the plan every 10 years. If a green infrastructure plan is created using the canopy data, this can also be tied to the city's effort to earn additional points in the CRS to further reduce flood insurance premiums. Multiple objectives can be achieved by combining canopy data with the planning efforts to identify green infrastructure networks. For example, the Bayou Greenbelt, a planning and technical support effort by the National Park Services' Rivers and Trails Conservation Assistance Program would connect a series of greenways and corridors along the coulee system to provide recreational opportunities for the community, while at the same time, enhancing the functionality of the drainage systems. Sites along the Bayou Greenbelt can be identified for further tree plantings and restoration using the tree canopy and potential planting areas (PPA), while also helping to lower the city's CRS rating.

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

As tree cover is lost and impervious areas expand, excessive urban runoff results in pollutants such as oil, metals, lawn chemicals (e.g., fertilizer and herbicides), pet waste, trash, and other contaminants flowing into surface waters. Trees help capture and filter that urban runoff. According to GIC's stormwater model, during a 1-year/24hour rainfall event (4.63 inches) in Lake Charles the trees capture:

- 14,249 lbs. nitrogen,
- 1,152 lbs. of phosphorus and
- 1,079 tons of sediment.

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

Trees help reduce stormwater runoff from residential areas.

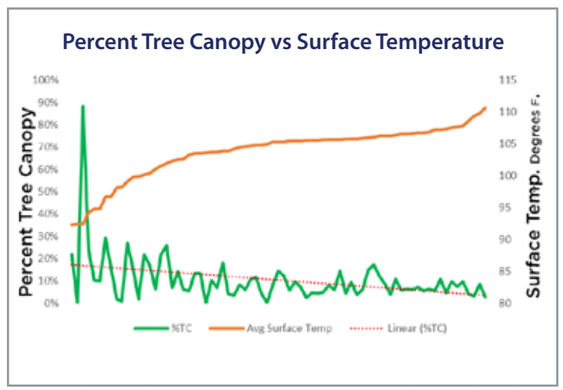
There are many spaces in existing parking lots where trees can be planted or replaced.

Air Quality and Surface Heating

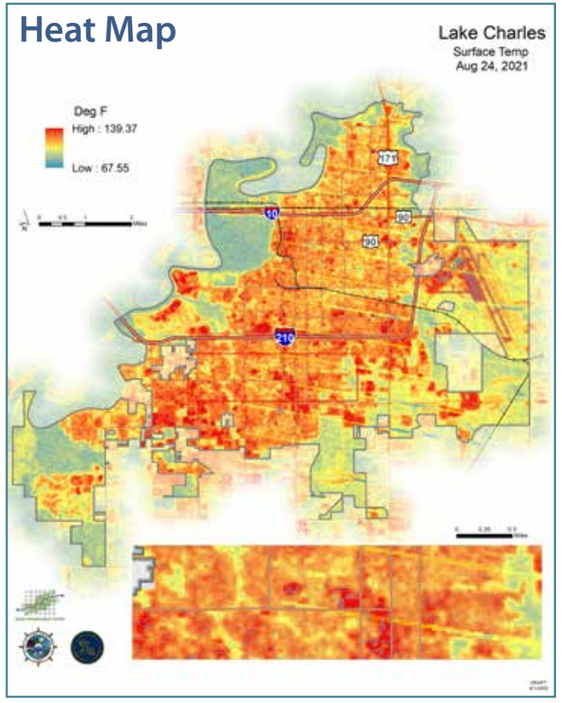
Trees Cool the City

During Louisiana's hot summers greater shade is always appreciated. Excessive heat can lead to heat stress which especially affects infants and children up to four years of age, those 65+ years of age and older, those with underlying medical issues, and those on some medications (Centers for Disease Control 2020).

Tree cover shades streets, sidewalks, parking lots, and homes, making southern urban locations cooler, and more pleasant for walking or biking. Multiple studies have found significant cooling (2-7 degrees Fahrenheit) and energy savings from having shade trees in cities (McPherson et al 1997, Hashed et al 2001). Shaded pavement also has a longer lifespan, so maintenance costs associated with roadways and sidewalks are less (McPherson and Muchnick, 2005).



Higher surface temperatures are positively correlated with reductions in tree canopy coverage.



Trees Clean the Air

In addition to cooling surfaces, trees absorb volatile organic compounds and particulate matter from the air, improving air quality, and thereby reducing asthma rates. Trees play a critical role in not only providing oxygen but also cleaning the air of particulate matter and ground level ozone (O_3), which can harm human health. Trees also sequester greenhouse gases such as sulfur dioxide and carbon dioxide. As these gasses are trapped by trees, the severity of climate change is reduced. Trees also store carbon and prevent its release, further helping to ameliorate possible climate change impacts. Even at the neighborhood level, trees reduce pollutants. Trees clean the air and well treed neighborhoods suffer less respiratory illnesses, such as asthma. (Rao et al, 2014),

More trees could be planted on North Enterprise Boulevard adjacent to industrial sites, thereby reducing noise and air pollution.

Social Values

Trees Improve Cognitive Function

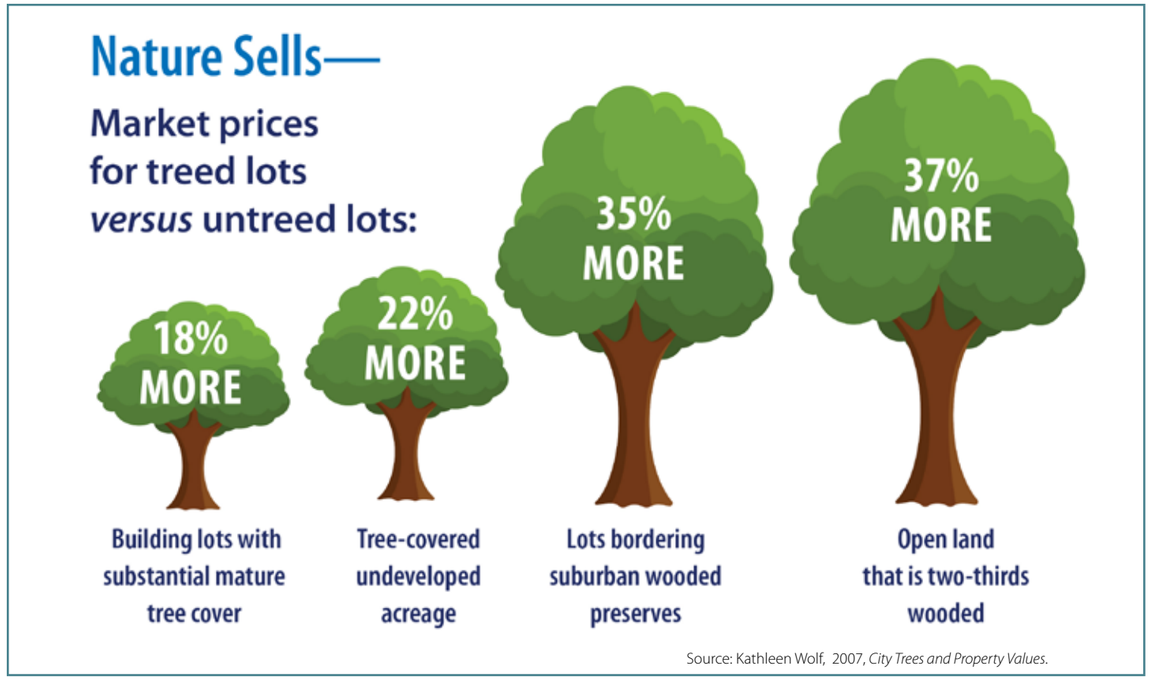
Children who suffer from Attention Deficit Hyperactivity Disorder (ADHD) benefit from living near forests and other natural areas. One study showed that children who moved closer to green areas have the highest level of improved cognitive function after the move, regardless of level of affluence (Wells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

Children who moved closer to green areas had the highest level of improved cognitive function after the move.

Trees Improve Walkability

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 are well treed (Tilt, Unfried and Roca 2007).

Well treed areas encourage people to walk and bike.



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

Trees Increase Property Values and Sales

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

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

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

Urban Tree Loss – Reversing the Trend

Lake Charles now has baseline data to monitor canopy increases from plantings, measure the stormwater and water quality benefits of its urban forest, and can prioritize restoration of canopy where it is most needed. Currently the city's canopy coverage is 10.6%, but it could be expanded.

The city's near-term canopy trend is downward. Over three years (2019-22), the city lost 33% of its relative tree canopy. This equates to nearly 100,000 trees lost (net) or around 58,000 small trees and 41,000 large shade trees. If this trend were to continue, the city's canopy could disappear in a few decades. While this is unlikely, new actions are needed to stem the losses and grow the canopy.

To change the loss trajectory, the city needs to actively plant trees to replace those lost to natural mortality (old age), storms, development, pests, and neglect or poor care. As older trees die (or before they die), younger trees need to be planted to restore the older canopy. While the city has been planting trees, more trees need to be planted by both the public and private sectors at greater numbers to achieve the goal of a 5% citywide canopy increase. The data from this report can inform the city's tree canopy recovery strategy and planting plan and can be shared with the public to encourage them to plant trees. This strategy can also be used to secure grants and donations to help fund the recovery effort.

Newly planted tree.

Why Are Urban Trees Declining?

Tree loss is not a problem that is unique to Lake Charles. Trees are declining throughout the southern United States. 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).

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. Choosing the wrong tree for a site or climate, planting it incorrectly, or caring for it poorly can all lead to tree canopy loss. For every 100 street trees planted, only 50 will survive 13-20 years largely due to poor planting conditions and care (Roman et al, 2014). Even in older developed areas with a well-established tree canopy, redevelopment projects may remove trees. It is 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.

A well-treed neighborhood of today may not have good coverage in the future unless young trees — the next generation — are planted.

Current and Potential Canopy and Ecosystem Services Modeling

In order to determine the current tree canopy, model scenarios for future tree coverage, and quantify their ecosystem services, a highly detailed land cover analysis and an estimation of potential future planting areas were developed (see Appendix A for details). In addition to urban forest planning, the new land cover data can be used for other purposes such as analyzing urban cooling, walkability, street tree plantings, inform area plans, or the city's comprehensive plan.

Method

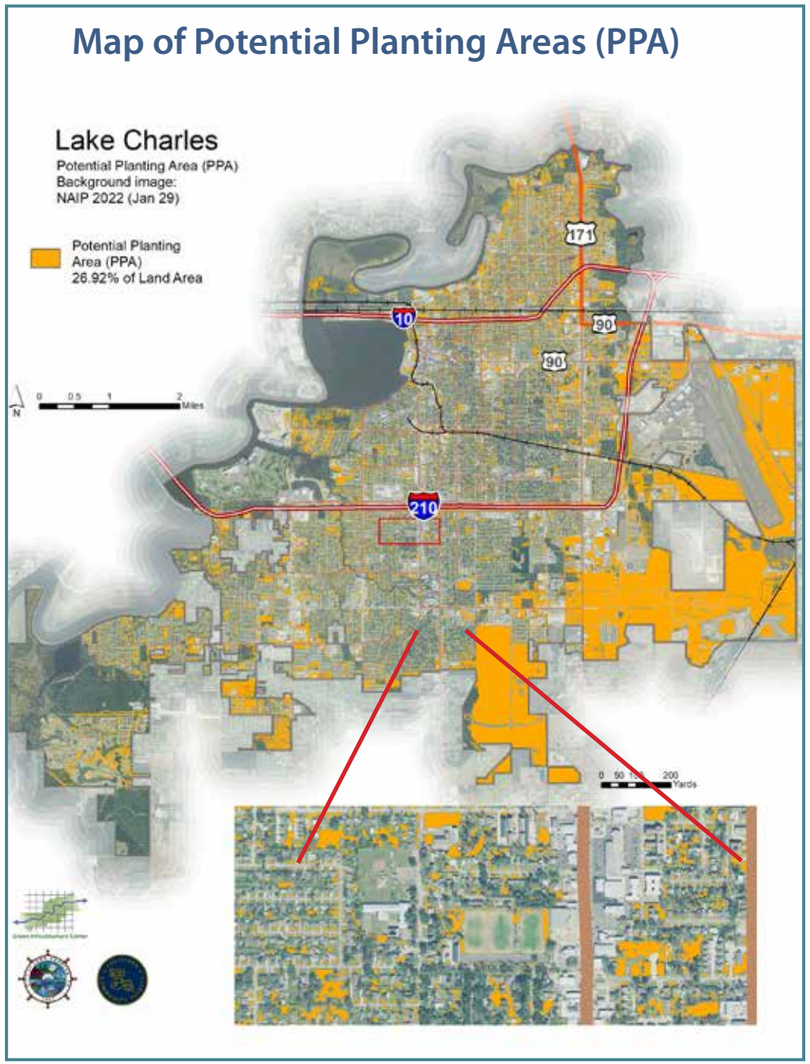
Satellite imagery from the National Agricultural Imagery Program (NAIP) distributed by the USDA Farm Service Agency was classified based on 4 infrared bands to determine the types and extent of different land covers in Lake Charles. Two canopy maps were created using NAIP imagery data – one from 2019 and one from 2022 data. Additional data from the City of Lake Charles, the National Wetlands Inventory, and National Hydrography Dataset were also used to determine:

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

The final classification for land cover consists of nine classes (types of land cover).

Tree canopy includes woody vegetation over 10 feet in height. LiDAR was used to determine height, which allows distinctions between large shrubs versus trees.[2] This allows the analysis to separate bushes from trees and other vegetation. This is very important when modeling tree benefits since the modeled pollution removal benefits are based on trees and do not necessarily translate to smaller, non-woody vegetation.

Map of Potential Planting Areas (PPA)



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

NAIP Image 2022

Potential Planting Areas (PPA)

In urban areas, realistic goals for expanding urban canopy depend on an accurate assessment of plantable open acreage. A Potential Planting Area (PPA) map estimates areas that may be feasible to plant trees. The PPA is created by selecting the land cover features that have space available for planting trees and accounts for the overlap of canopy (e.g., canopy that is intermingled or a large canopy tree that partially covers an understory tree). Of the nine land cover classes, only pervious/turf were considered for PPA. However, some paved areas could be removed or reduced, soils conditioned, and then used to plant new canopy.

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, such as golf courses and airports were also avoided in calculating plantable areas. The resulting PPA represent the maximum potential places trees can be planted and grow to full size. The GIC recommends no more than half the available PPA is realistic to plant, since many uses such as tomato gardens or sunbathing by the pool require full sun.

Potential Planting Spots (PPS)

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

Potential Canopy Area (PCA)

The Potential Canopy Area (PCA) is created from the PPS. Once 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 represents a 20 ft. or 40 ft. diameter canopy. These individual tree canopies are then dissolved together to form the potential overall canopy area. For Lake Charles 30% more canopy could be added to the city.

Maps and Findings

The tree canopy map should be used to plan for tree conservation and as a benchmark to gauge future progress in tree preservation and planting. An ArcGIS geodatabase with all GIS shape files produced during the study was provided to the city.

Tree Canopy Goal for the City of Lake Charles

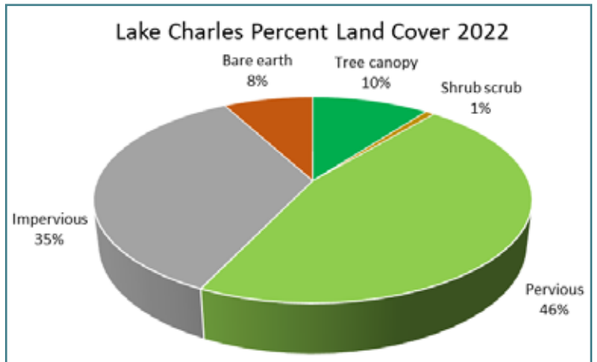
The city developed a tree planting campaign slogan called #ReTreeLC to restore canopy lost from recent major tropical storms and other disasters. Using tree canopy and land cover data, this plan's consultants mapped the maximum potential tree canopy for planting 100% of the available planting areas which equates to a potential canopy cover of 40%. However, planting 100% of the PPA is not a realistic goal because property owners have other uses for their land such as vegetable and ornamental gardens, or lawns. A more realistic goal for the maximum potential tree canopy is to plant only 50% of the PPA, resulting in a maximum desired goal of 25% tree canopy.

Using this information and other tools, such as GIC's Canopy Budget Calculator Tool which estimates the financial cost of increasing canopy to a certain percentage, the city decided to recover tree canopy lost to recent storms and floods, to a pre-2019 tree coverage of 15.6%. This will increase the canopy from the current low level to 10.6% to 15%, approximately 5% more canopy planted over the next 10 years. This will require planting an additional 103,700 trees; approximately 60,808 large shade trees and 42,891 small trees at a rate of or 10,370 trees planted annually.

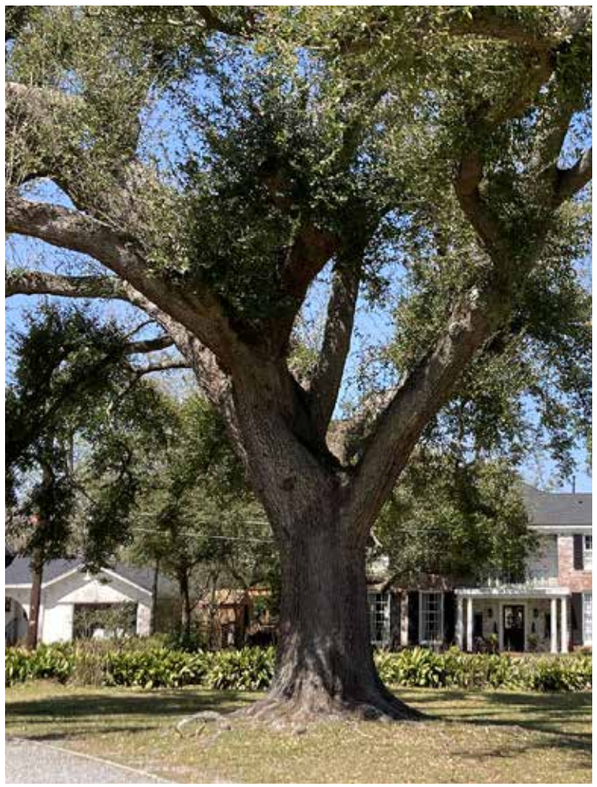
The city also requested statistics for canopy by the following geographies:

- Streets
- Watersheds
- Floodplains
- Census Block Groups
- Parks
- Schools
- Zoning
- Parcels
- City-owned properties

The canopy data and the possible planting area map can inform tree planting decisions to meet many goals such as walkability, stormwater mitigation, energy savings or economic revitalization. Knowing the distribution of canopy for different types of properties allows the city to craft more specific strategies for achieving their canopy goal of 15% and ensuring that canopy is distributed equitably across the landscape. The following maps can be used to prioritize where to start planting and for public awareness of such planting needs.

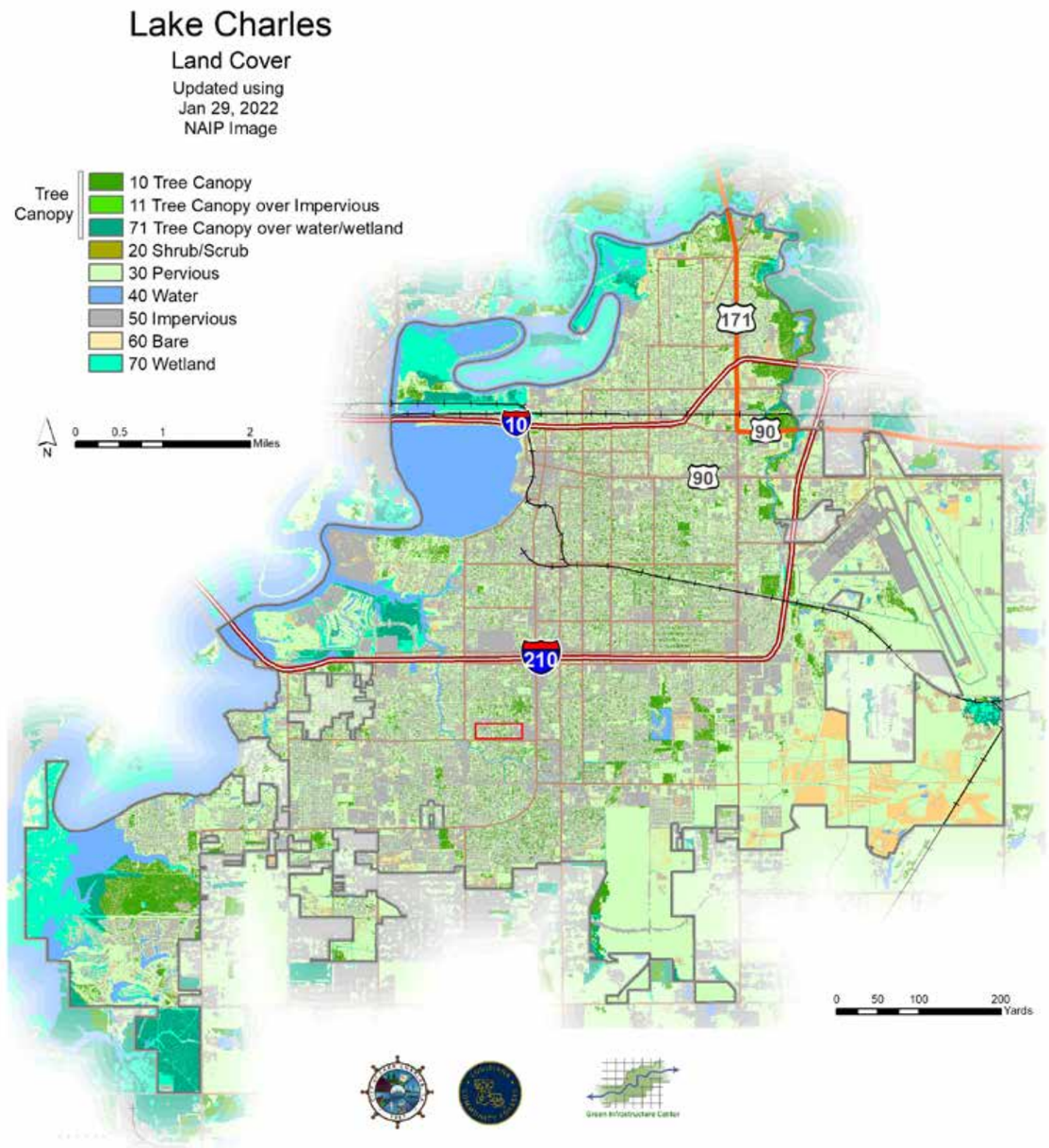


Citywide forest cover is 10.6%.



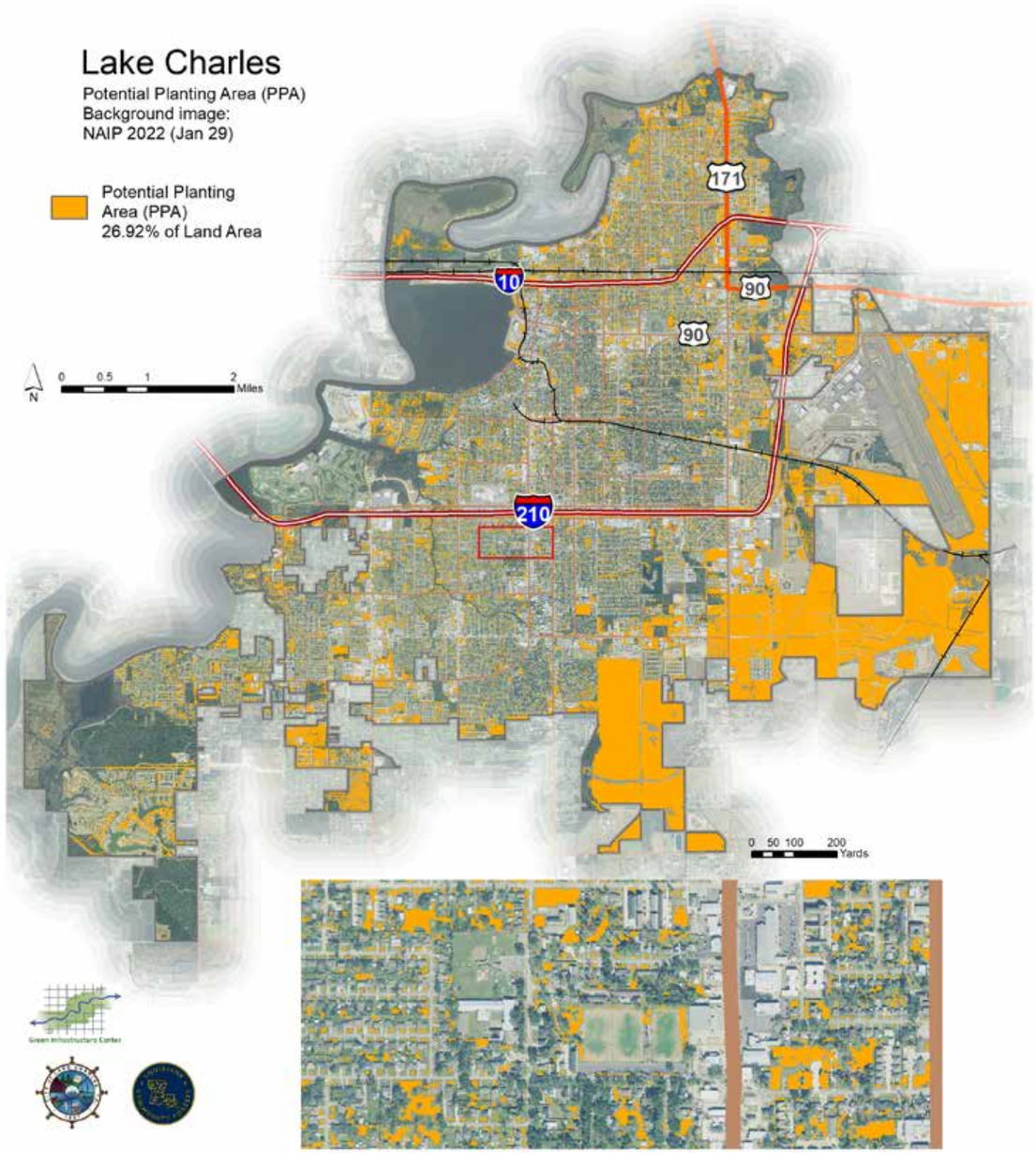
One mature tree can absorb thousands of gallons of water per year.

Map of City Land Cover and Tree Canopy



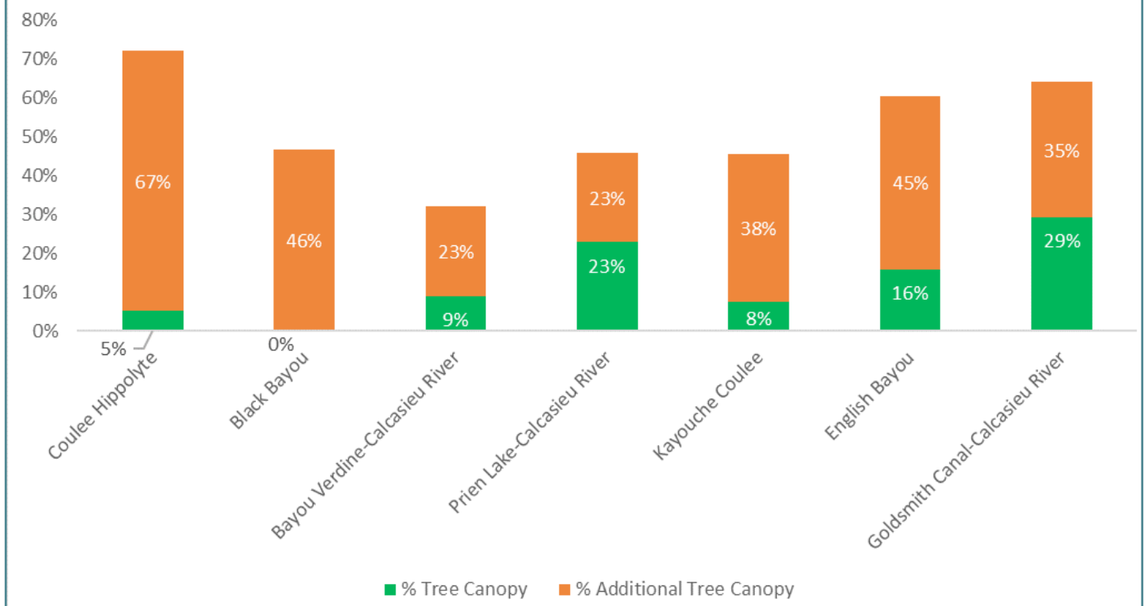
This map shows the tree canopy of the city which covers 10.6% of the area.

Map of Potential Planting Areas (PPA)



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.

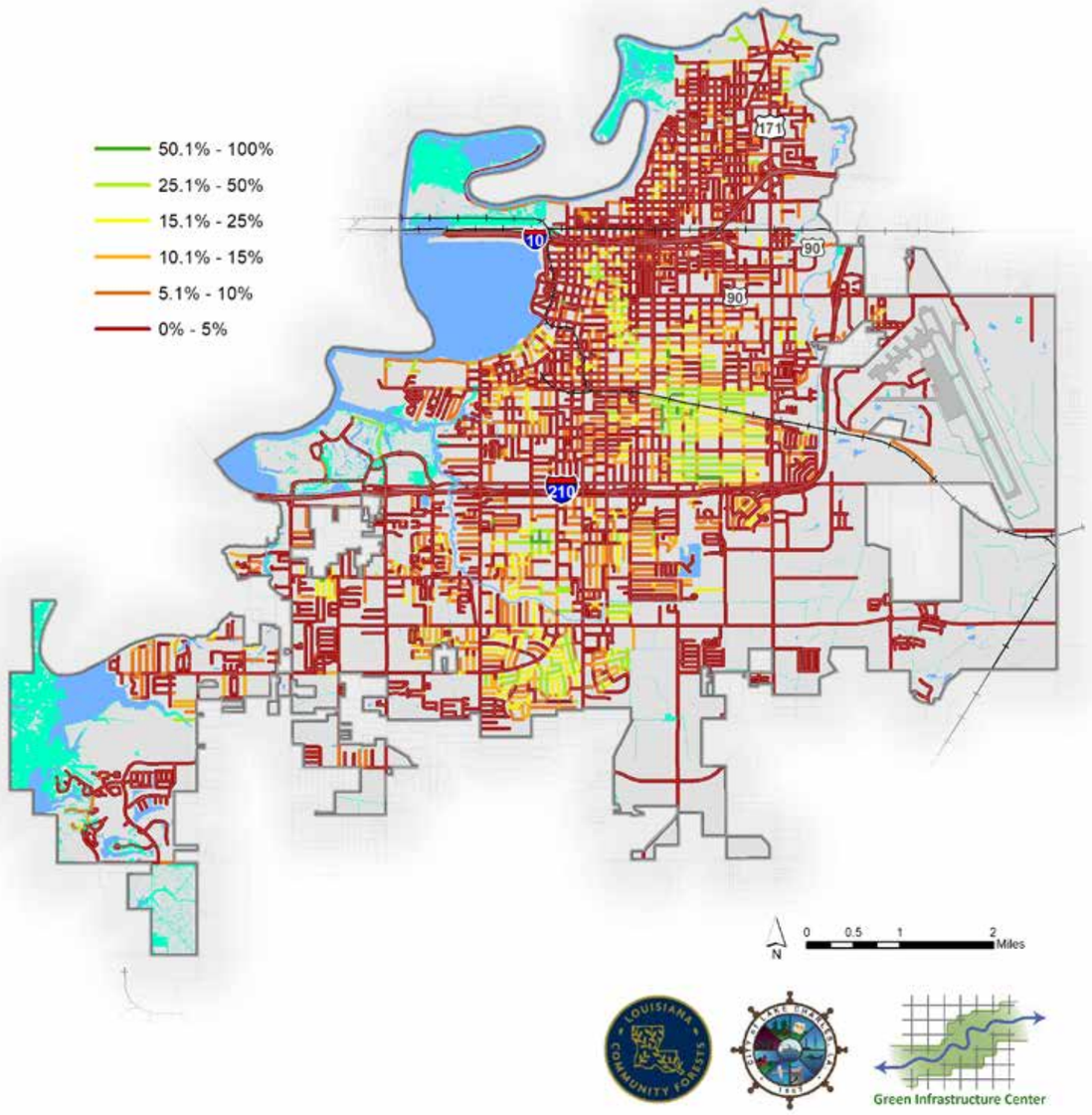
Percent Tree Cover and Potential Additional Canopy by Watershed



Map of Street Tree Coverage

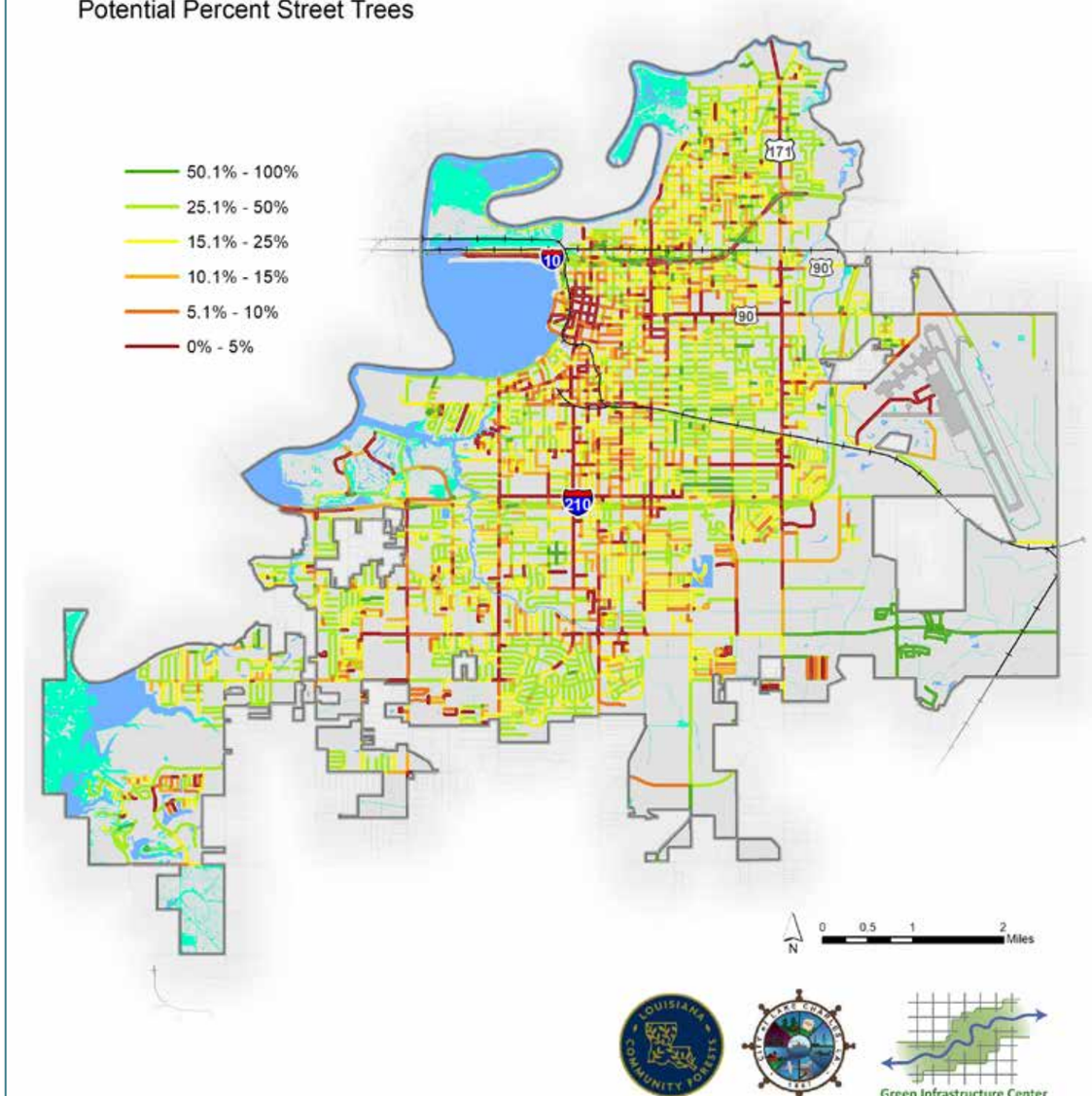
Percent Street Trees is calculated using the Land Cover Tree Canopy and road centerlines, which are buffered to 50 ft. outward from each road segment's centerline. The percent value represented is the percentage of tree cover within that 50 ft. buffer. See maps on the following 2 pages.

Map of Street Tree Coverage



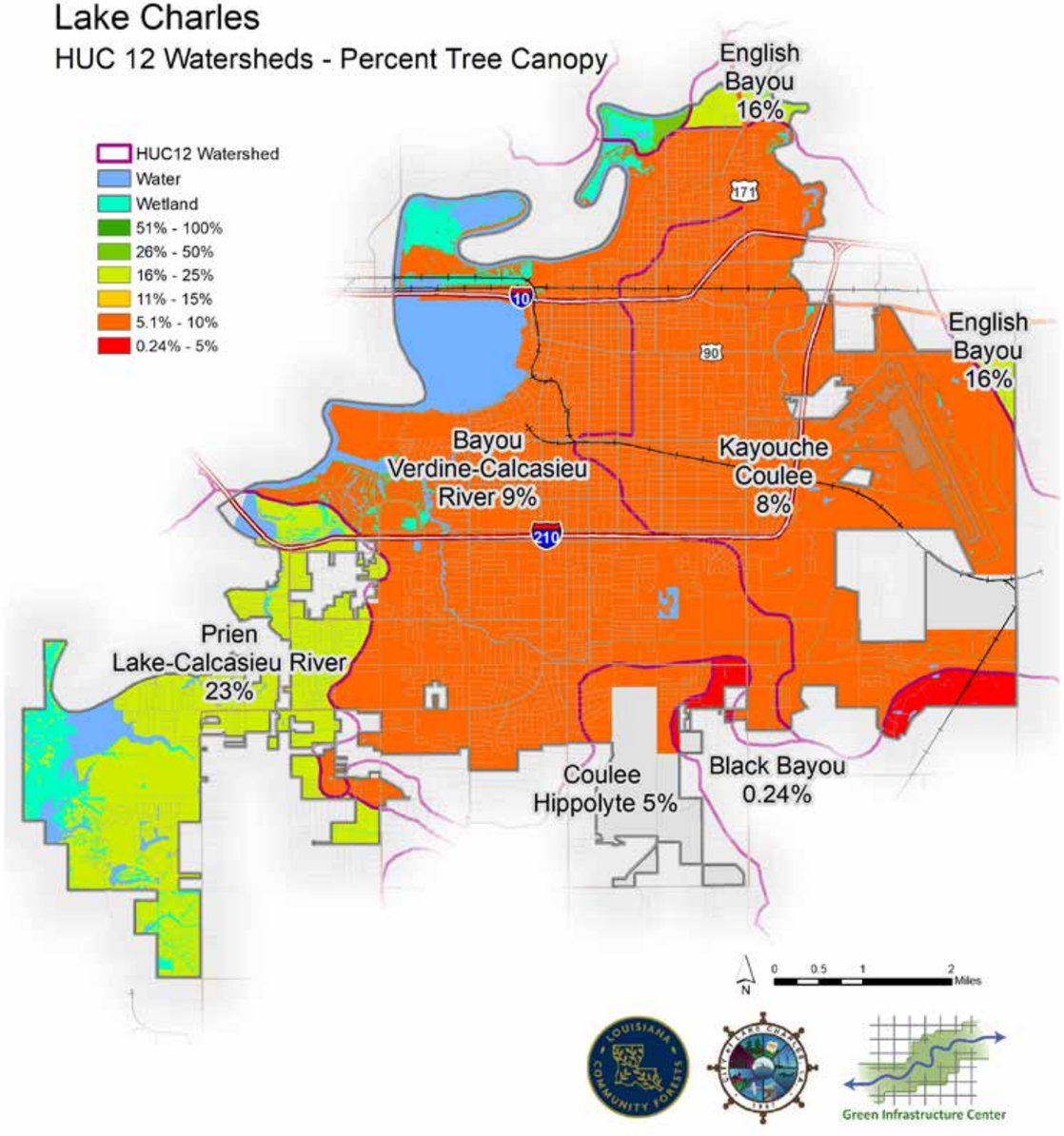
This map shows which streets have the most canopy (dark green) and which have the least (red). Streets lacking good coverage can be prioritized for tree plantings to facilitate uses, such as Safe Routes to School or beautifying a shopping district.

Map of Potential Street Tree Coverage



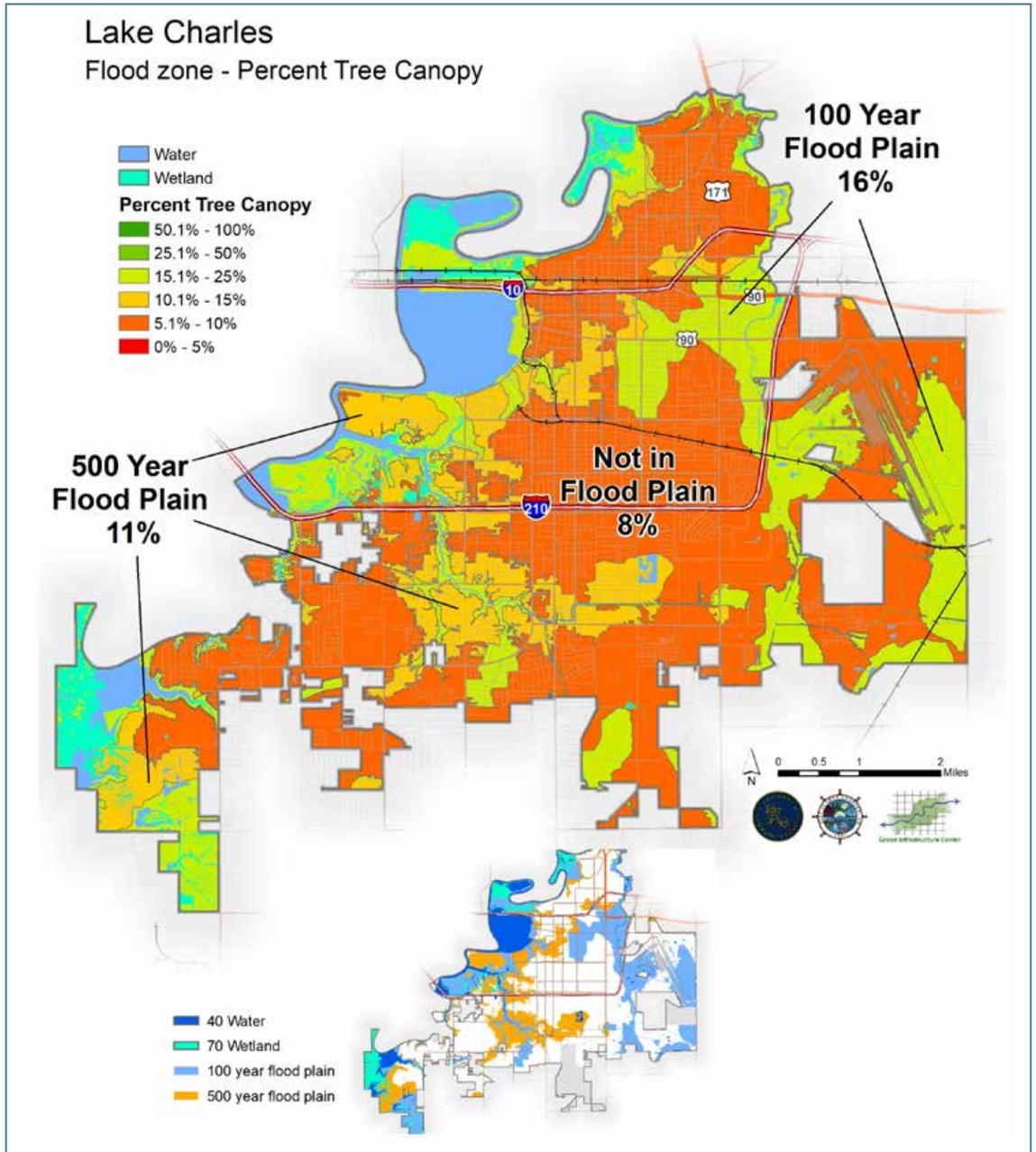
The potential street trees map shows which streets could support additional tree canopy if planted with more trees. Greater canopy coverage along streets and sidewalks can keep neighborhoods cooler.

Map of Watershed Coverage



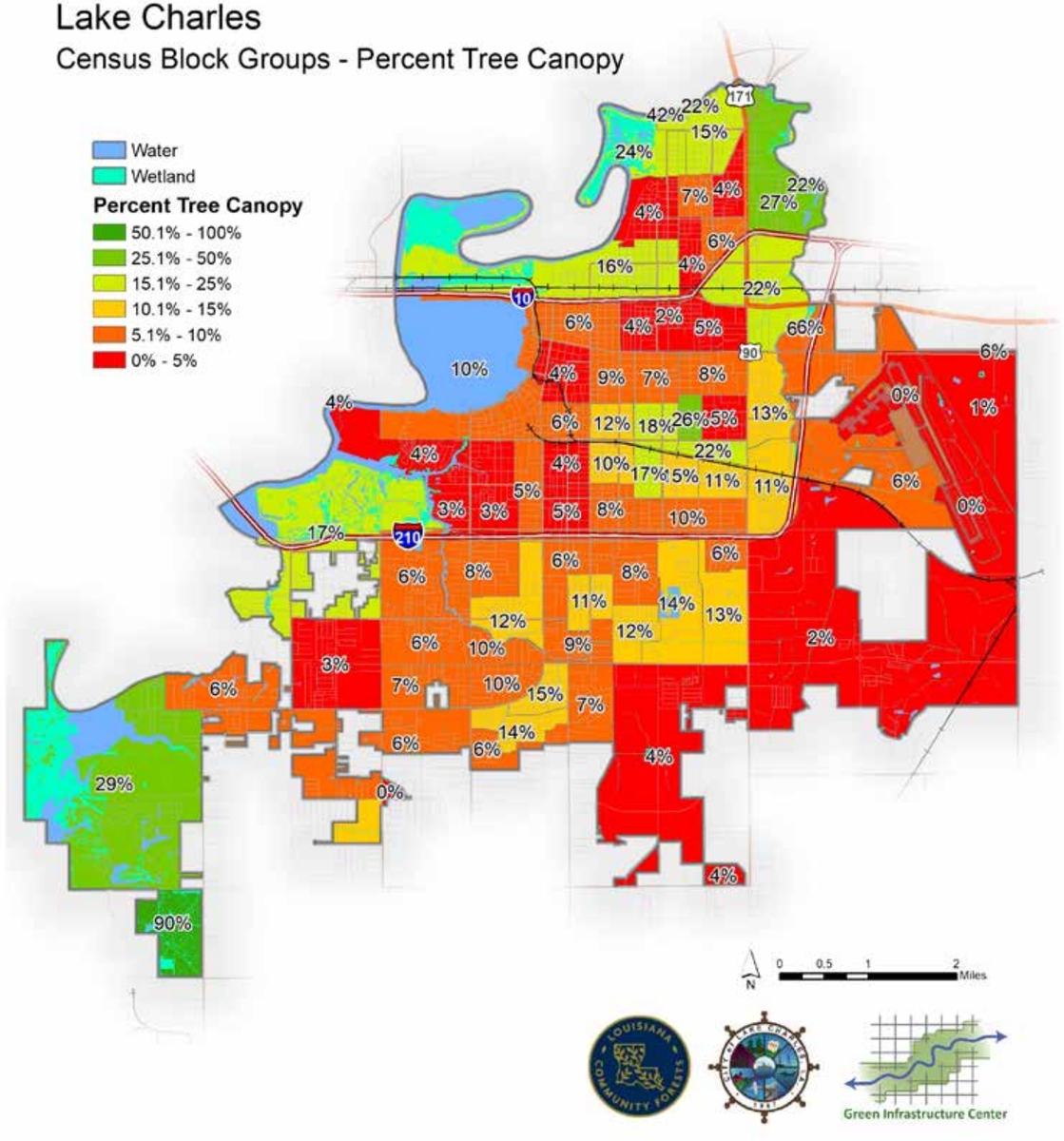
Each watershed in the city's jurisdiction was analyzed for tree canopy. Tree canopy can reduce the amount of stormwater runoff which carries trash, nutrients, pesticides, sediment and other pollutants into nearby waterways, lowering water quality.

Map of Floodplain Coverage



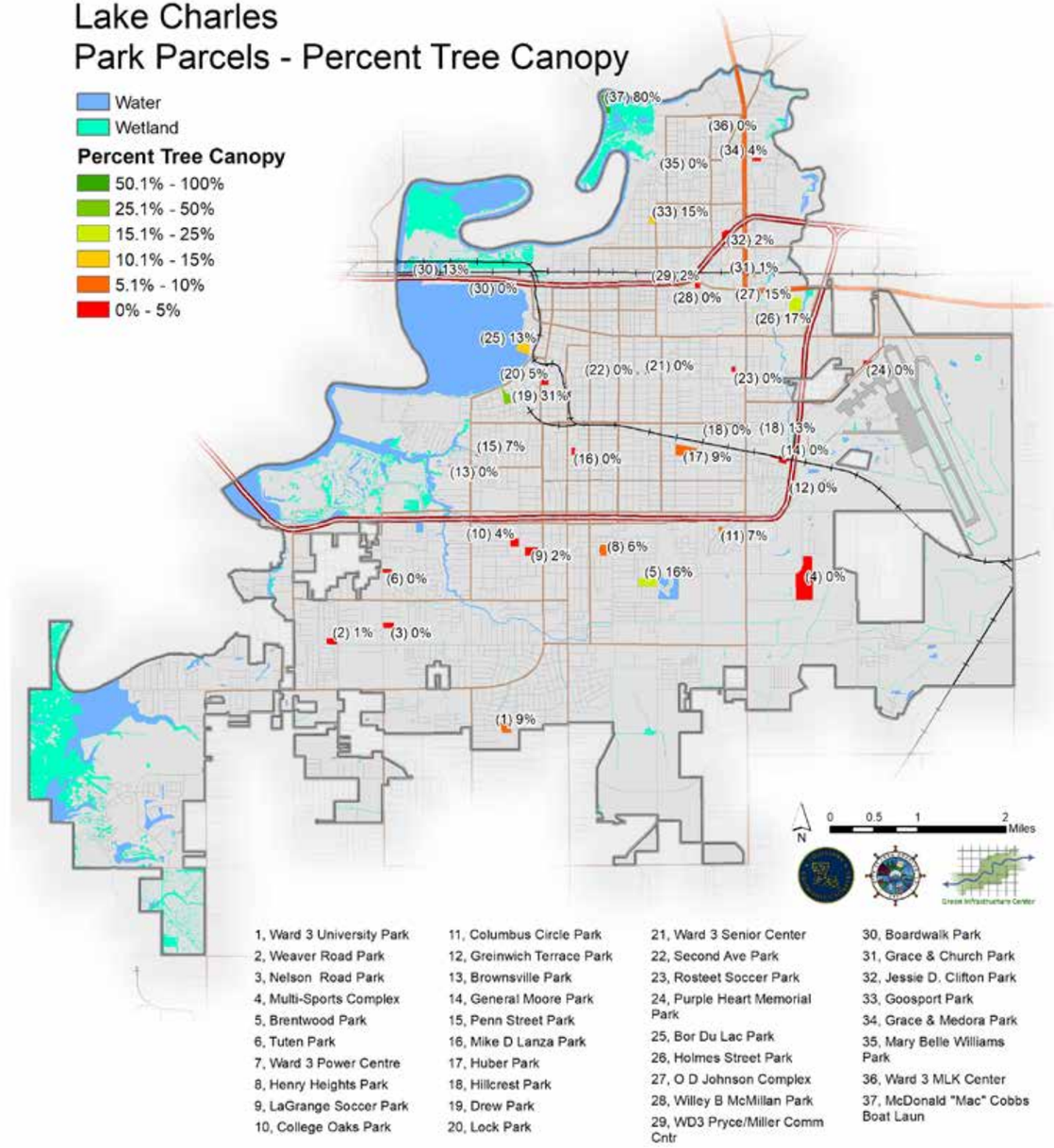
Flood zones are areas of the city more prone to flooding. Trees play a vital role in capturing rainfall and soaking up stormwater which can reduce the amount of flooding in the city.

Map of Census Block Group (CBG) Coverage



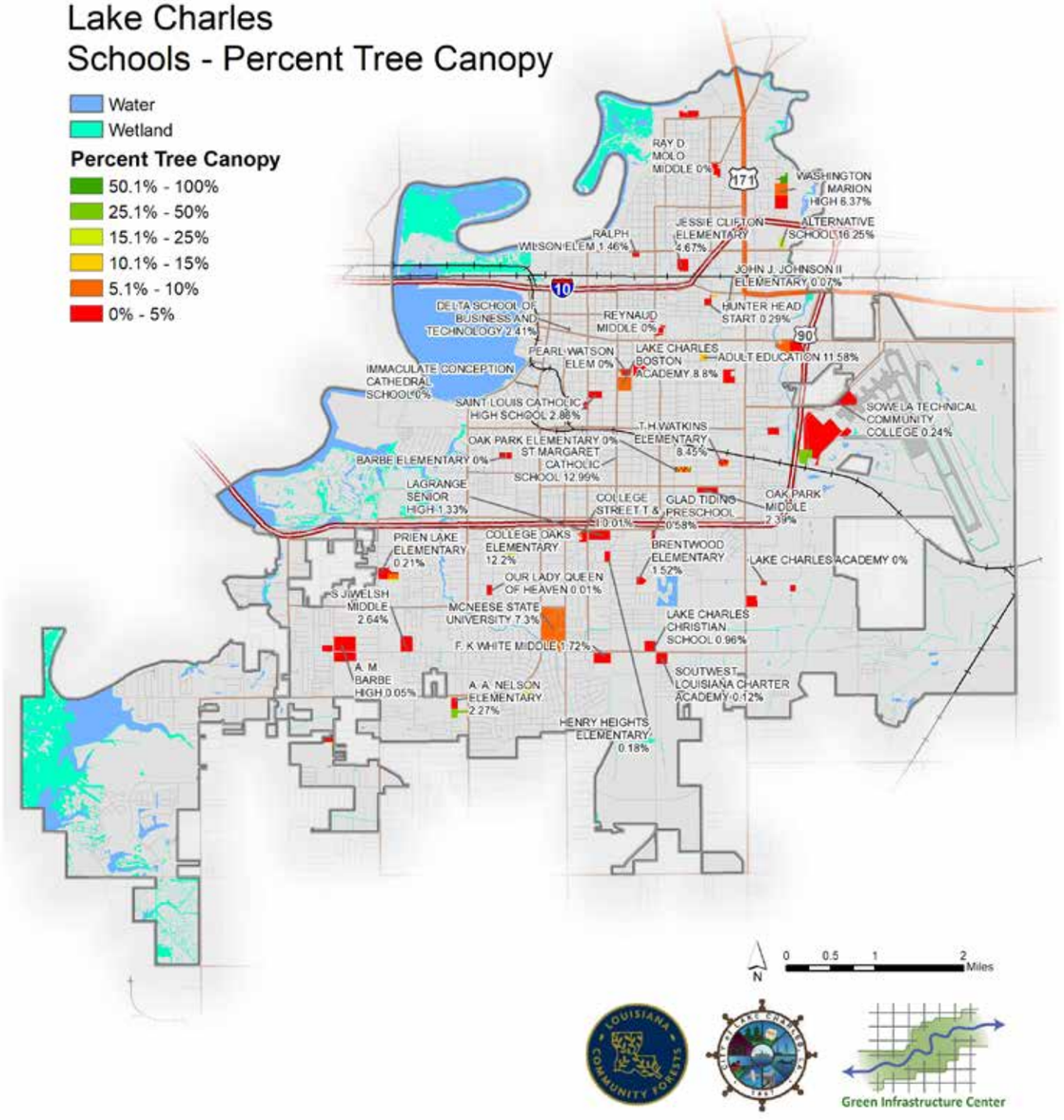
This map show that not all tree canopy is not evenly distributed across neighborhoods in Lake Charles. The city can use this data to prioritize low-income and minority neighborhoods for more tree plantings and future tree giveaways.

Map of Park Coverage



This map shows which parks are well-treed and which parks are not. Many parks have room for more trees and the city has prioritized park tree planting in the last few years.

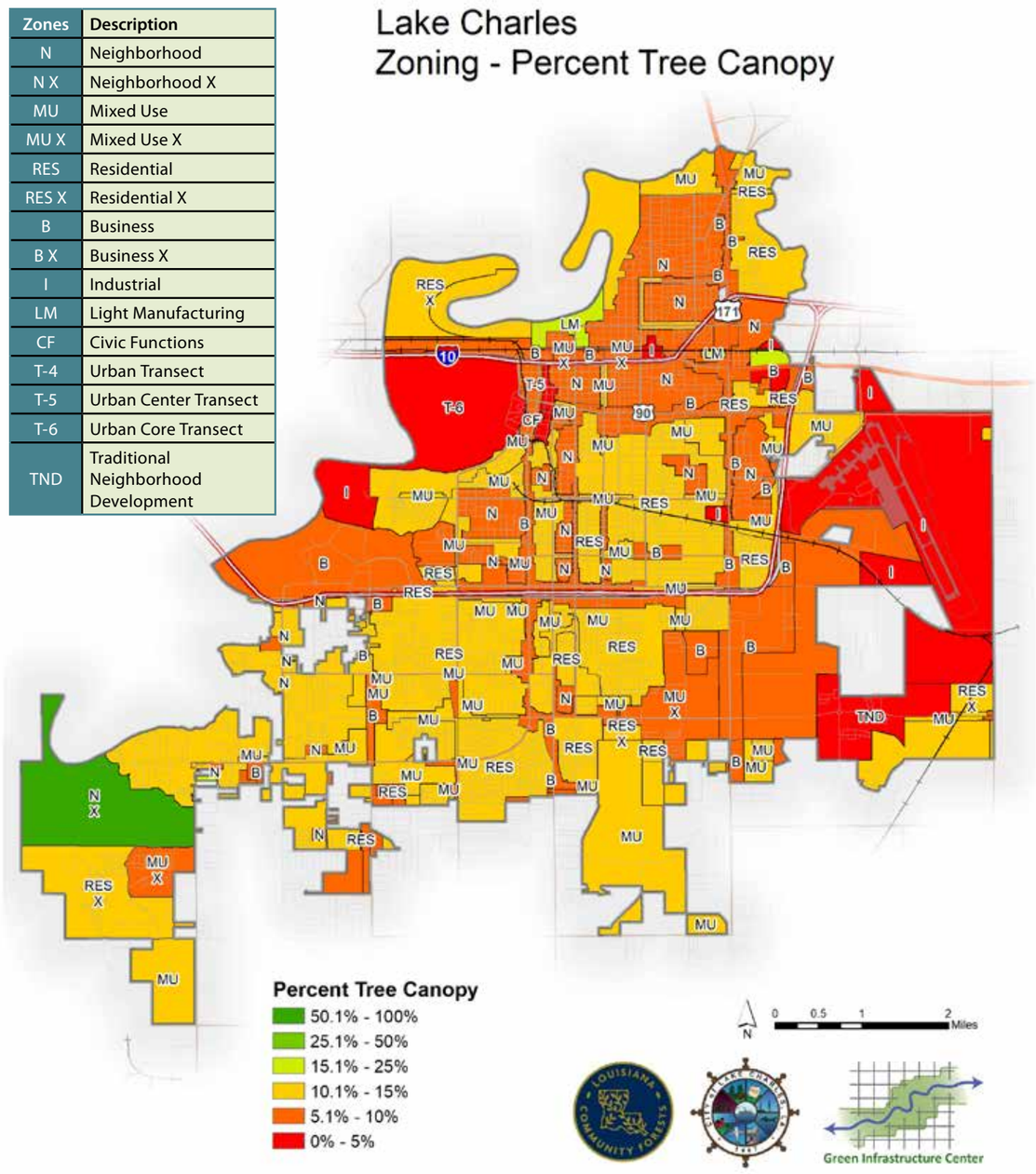
Map of School Coverage



Partnering with schools and students to increase tree canopy on campuses is a great way to educate the families about tree planting while also providing greater mental and physical health for students.

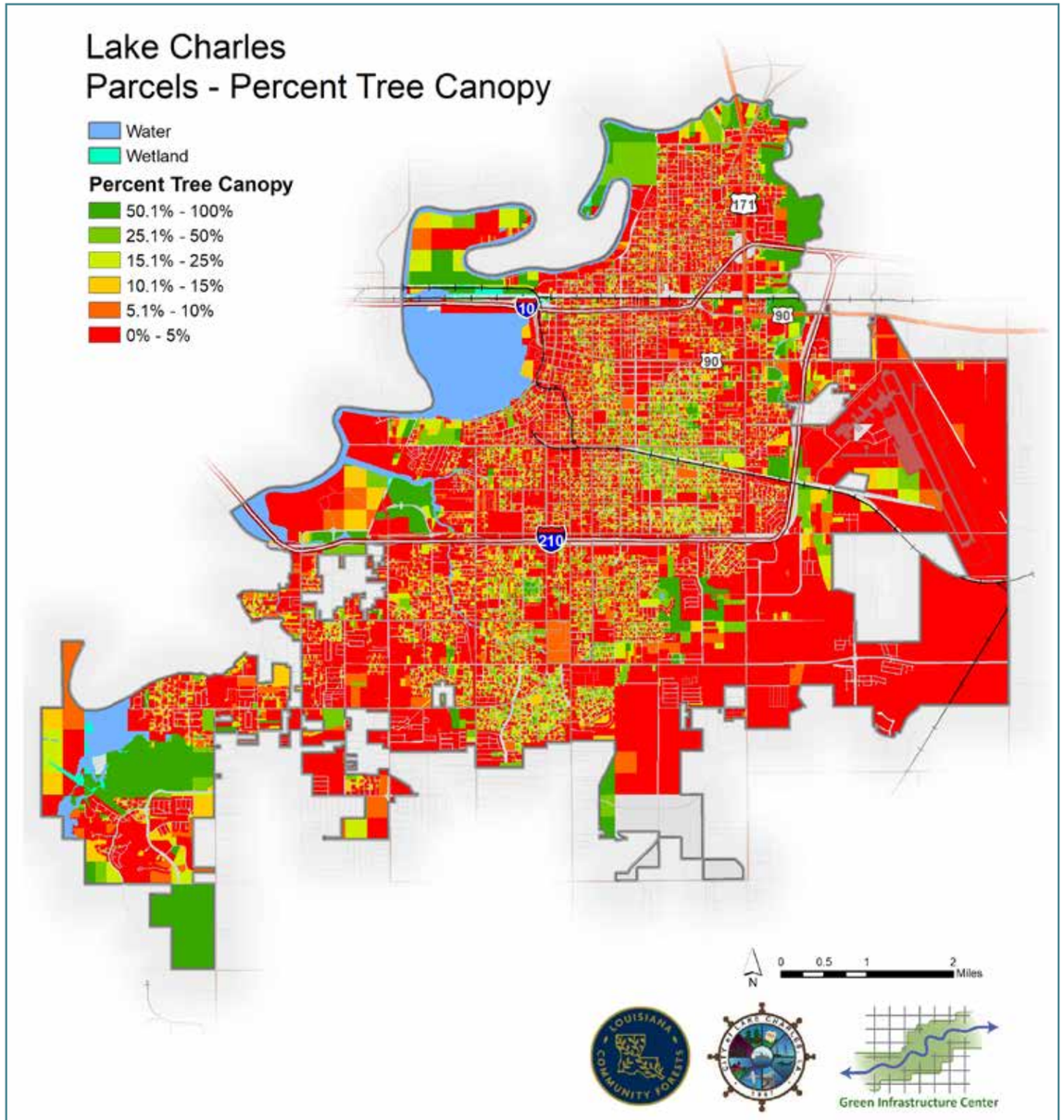
Map of Zoning Coverage

Zones	Description
N	Neighborhood
N X	Neighborhood X
MU	Mixed Use
MU X	Mixed Use X
RES	Residential
RES X	Residential X
B	Business
B X	Business X
I	Industrial
LM	Light Manufacturing
CF	Civic Functions
T-4	Urban Transect
T-5	Urban Center Transect
T-6	Urban Core Transect
TND	Traditional Neighborhood Development



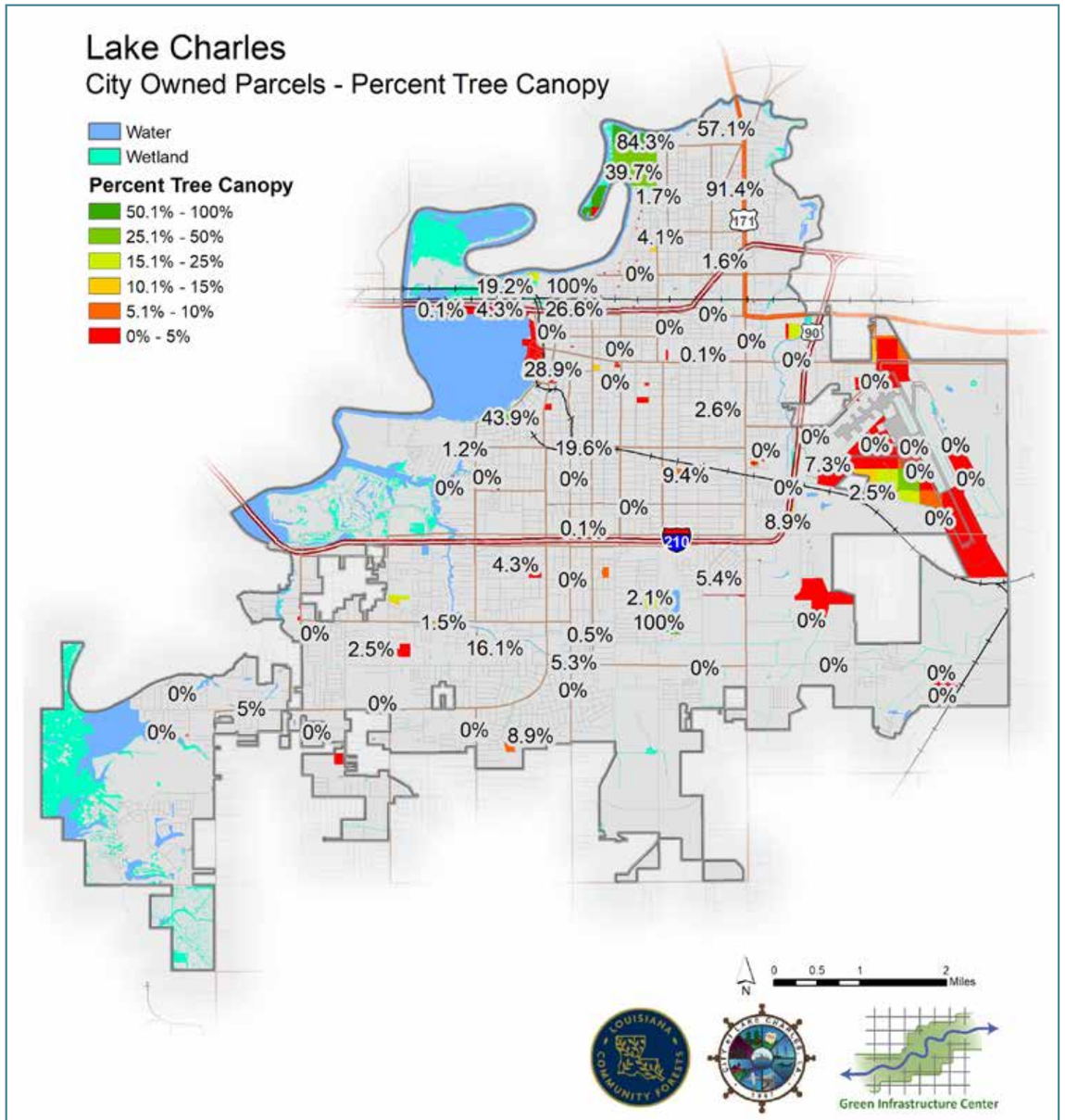
This map depicts canopy by zoning classes. On average, lower impact zoning classes such as residential zones have greater tree canopy and potential planting areas than do higher intensity classes such as commercial or industrial.

Map of Parcel Coverage



Every city parcel was analyzed for tree canopy cover. The data show that many residential properties lack sufficient canopy and have potential for more trees, particularly in neighborhoods of North Lake Charles.

Map of City-owned Properties Coverage



This map shows where the city can plant additional public trees. The city can lead by example by planting more trees on land it manages.

Methods to Calculate Tree Benefits

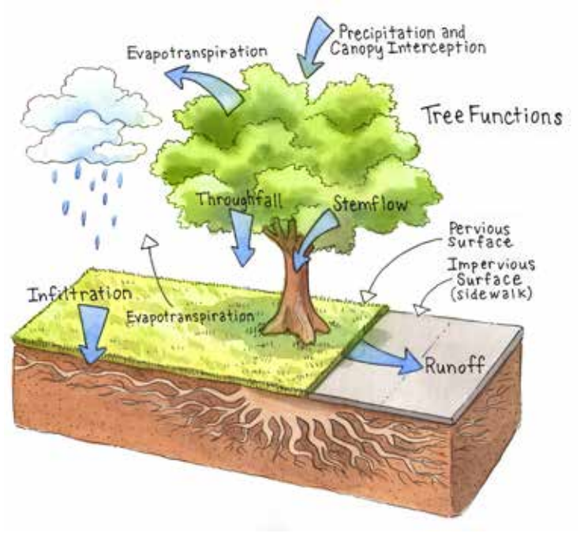
Stormwater Uptake

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

Trees intercept, take up and slow the rate of stormwater runoff. Canopy interception varies from 100 percent at the beginning of a rainfall event to about three percent at 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 recognize that trees have important stormwater benefits (Kuehler 2017, 2016). See diagram of tree water flow at right.

The amount and type of open space under and around the tree and the condition of surface soils affect the infiltration of water. The TSW tool developed for Lake Charles has a data field to hypothetically add trees to determine stormwater uptake from new tree planting. The TSW tool applies the PPA data to determine how many more trees could be planted. The tool also calculates the amount of nitrogen, phosphorus and sediment the trees and their surrounding soils take up. For more about the stormwater calculator tool, see Appendix B.

The TSW model is a tool for seeing the results of adding or losing tree canopy and the resulting pollution increases or decreases (nitrogen, phosphorus, sediment). For example, the model shows that for a



hypothetical 5% loss of tree canopy for the city, during a 10-year storm event, an additional 700,000 gallons of rainfall runoff would occur: that's more than an Olympic swimming pool's water volume. Conversely, if half of each plantable area were covered with new trees – increasing tree canopy – the TSW model shows that trees could capture an additional 49 million gallons of water during the same storm; or about 74 Olympic pools' volume of water.

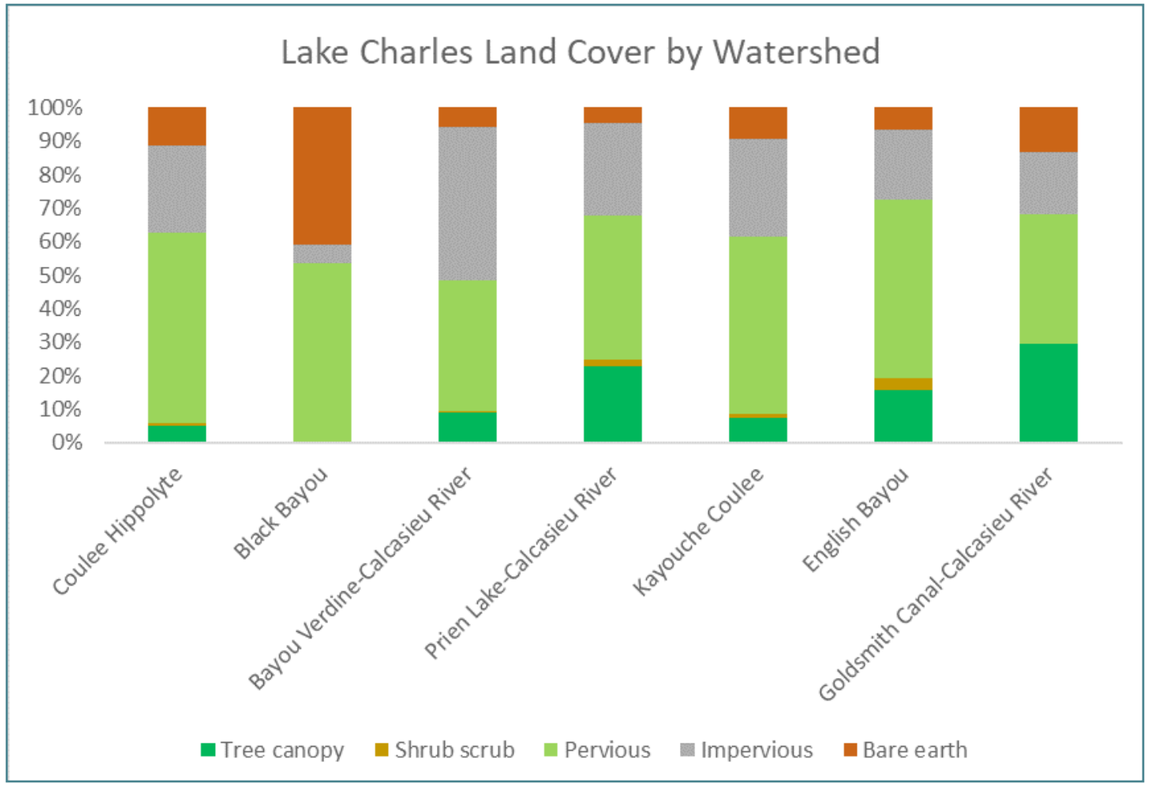
Combining the stormwater calculator with the canopy budget calculator tool, the city can estimate the cost-effectiveness of planting

Name: Lake Charles, Louisiana, USA* — Urban Tree Canopy Stormwater Model — version May 8, 2017

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.

				million gallons										
	TOTALS	10.8%	30.5%	31.2	-	8.7	15.7%							
	Statistics by Drainage Basin (current settings)							Variable						Variable
	Area	Current Tree Cover	Current Impervious Cover	Tree H20 Capture	Increased H2O w/xx% tree loss	Added H2O Capture w/xx% PCA	Adjusted Tree Cover from loss and gain scenarios	Pick an Event	Pick a loss scenario		Converted Land		Canopy Added	Enter % canopy to add
		%		million gallons			%	Event	% UTC loss	% FOS Loss	% Imperv	Max TC Possible	% Canopy Added	% of PCA achieved
1	Bayou Verdine-Calcasieu River	9.1%	45.8%	11.0	-	2.68	13.4%	1 yr / 24	0%	0%	0%	57.4%	4.3%	15%
2	Black Bayou	0.2%	5.0%	0.01	-	0.29	6.0%	1 yr / 24	0%	0%	0%	39.0%	5.8%	15%
3	Coulee Hippolyte	5.1%	22.2%	0.4	-	0.20	7.9%	1 yr / 24	0%	0%	0%	23.2%	2.7%	15%
4	English Bayou	15.8%	21.4%	0.9	-	0.23	22.7%	1 yr / 24	0%	0%	0%	61.4%	6.8%	15%

The Trees to Offset Stormwater Tool allows the city to see the water uptake by existing canopy and model impacts from changes, whether positive (adding trees) or negative (removing trees and adding impervious surfaces).

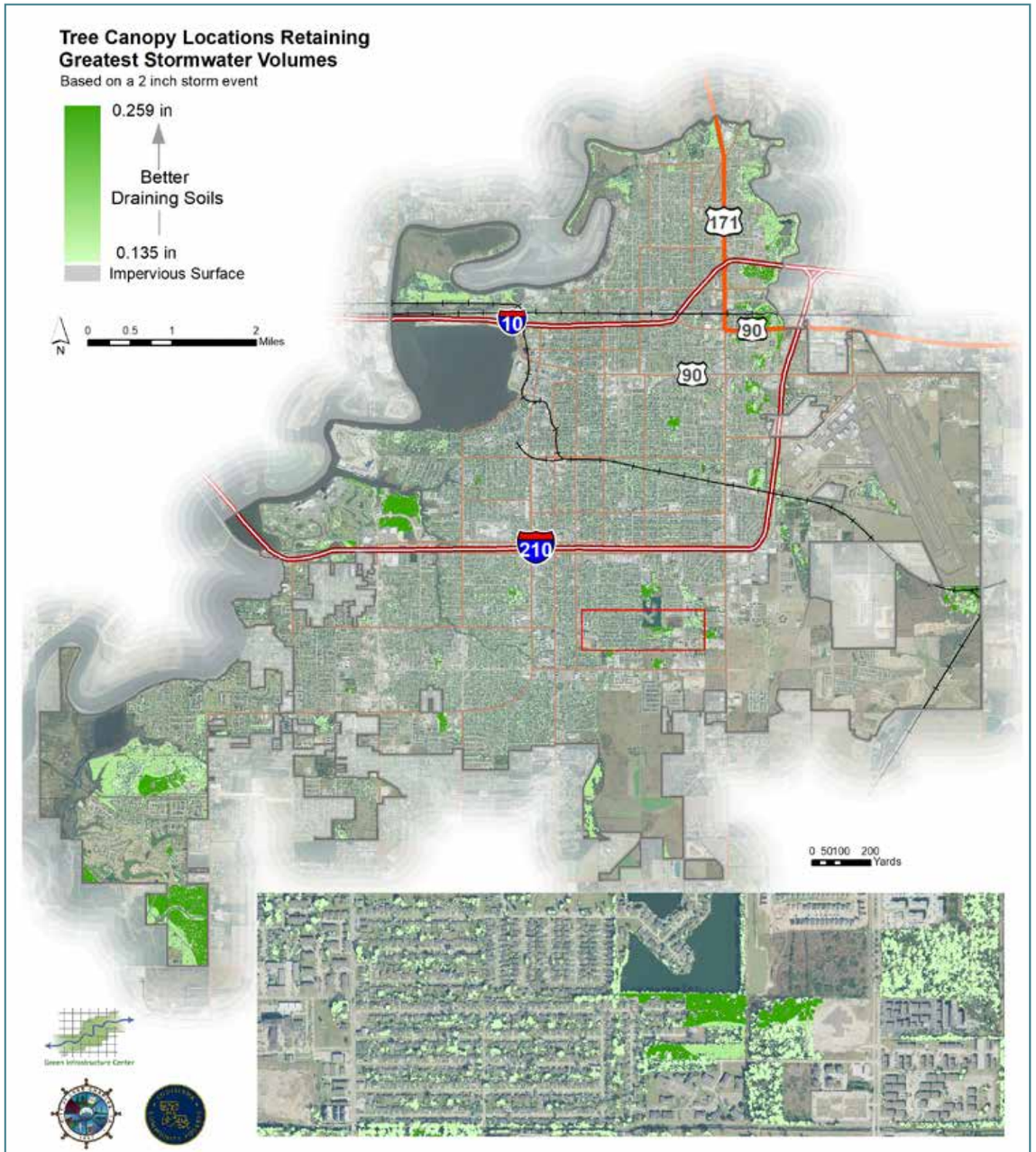


Combining the stormwater calculator with the canopy budget calculator tool, the city can estimate the cost-effectiveness of planting trees to mitigate stormwater runoff.

trees to mitigate stormwater runoff. Hypothetically if the city assumes a flat cost of $230 for the purchase and labor of planting a tree, then a 5% canopy increase (covering 20% of the total costs) would capture nearly 9 million additional gallons of stormwater during a 1-year/24-hour rainfall event (4.63 inches) at an average cost of $0.63 per gallon. These estimates illustrate the cost-effectiveness of using trees as a stormwater mitigation strategy in the community, in addition to realizing the other ecosystem service benefits trees provide.

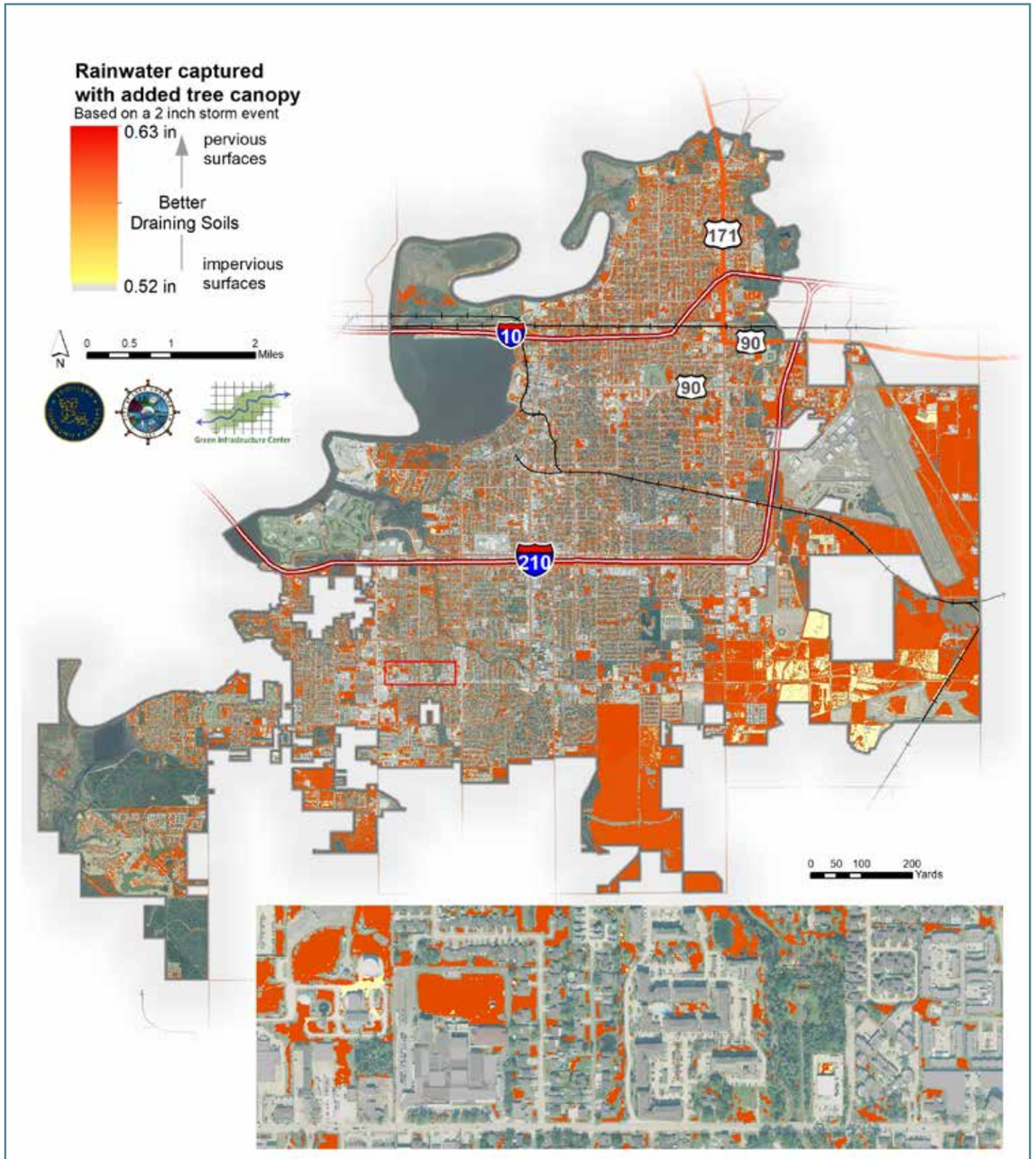
Removal of mature trees and existing forests generates the greatest impacts for increasing stormwater runoff. As more land is developed, the city should seek to maximize tree conservation for maintenance of surface water quality and groundwater recharge. The following maps show areas that are the most important to retain trees for stormwater uptake and those areas where tree planting will have the most benefits for stormwater uptake. This is based on the types of soils present.

Impacts of Tree Loss



This map identifies existing mature tree canopy that is in the best location (in dark green) for retaining stormwater on site.

Added Tree Benefits



This map identifies the best planting areas to plant trees to infiltrate stormwater into the soil.

Air Quality Pollution Removal Values

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

Carbon monoxide (CO) affects how quickly greenhouse gases such as methane breakdown, which are linked to climate change and global warming. Carbon is another element that contributes to climate change mainly in the form of carbon dioxide. Trees sequester carbon from carbon dioxide in their leaves, trunk, and roots, and prevent it from being released into the atmosphere where it can contribute to climate change.

Ground level ozone O_3 can cause the muscles in people's airways to constrict, trapping air in the alveoli, leading to wheezing and shortness of breath, which is particularly harmful to those with respiratory diseases or chronic conditions, such as asthma. Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2)also irritate airways in the respiratory system and aggravate respiratory conditions such as asthma.

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

Well-treed neighborhoods suffer less respiratory illnesses, such as asthma (Rao et al, 2014). This means that investments in canopy at the neighborhood scale can increase the health of residents.

Air Quality Multipliers

Pollutant (Abbrev.)	Benefit Description	Removal rate (lbs/acres/year)	Removal rate (lbs/year)
CO	Carbon monoxide removed annually	1.13	3,335
NO_2	Nitrogen dioxide removed annually	6.241	18,417
O_3	Ozone removed annually	48.212	142,274
PM_{10}	Particulate matter greater than 2.5 microns and less than 10 microns removed annually	13.683	40,379
$PM_{2.5}$	Particulate matter less than 2.5 microns removed annually	2.463	7,268
SO_2	Sulfur dioxide removed annually	3.068	9,054
CO_2 seq	Carbon dioxide sequestered annually in trees	509.90	1,504,726
CO_2 stor	Carbon dioxide stored in trees (note: this benefit is not an annual rate)	38,081.24	100,573,574

Codes, Ordinances and Practice Review

This review determined 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 urban forest practices, 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.

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 for determining 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. The less city land that is paved, the more room there is to add trees.

Categories the city scored best in were "Tree Care and Protection," "Implementation Capacity," and "Reducing Impervious Surfaces", while "Monitoring Progress," "Plans and Goals," and "Emergency Response" all had room for improvement. Best practices the city follows under "Implementation Capacity" include training staff to manage the urban forest. While the city does not have a dedicated city arborist or urban forester, it does have several staff that have taken the International Society of Arboriculture's Certified Arborist certification training. The city also plans to train its code enforcement staff in arboriculture to identify tree health issues when enforcing city code. The city contracts with private arborists to meet tree care demand when staff do not have capacity or the required expertise. Best practice examples under "Tree Care and Protection" are city processes to plant and manage street trees and required street tree plantings every 40 ft. within rights-of-way (ROW) in new subdivisions.

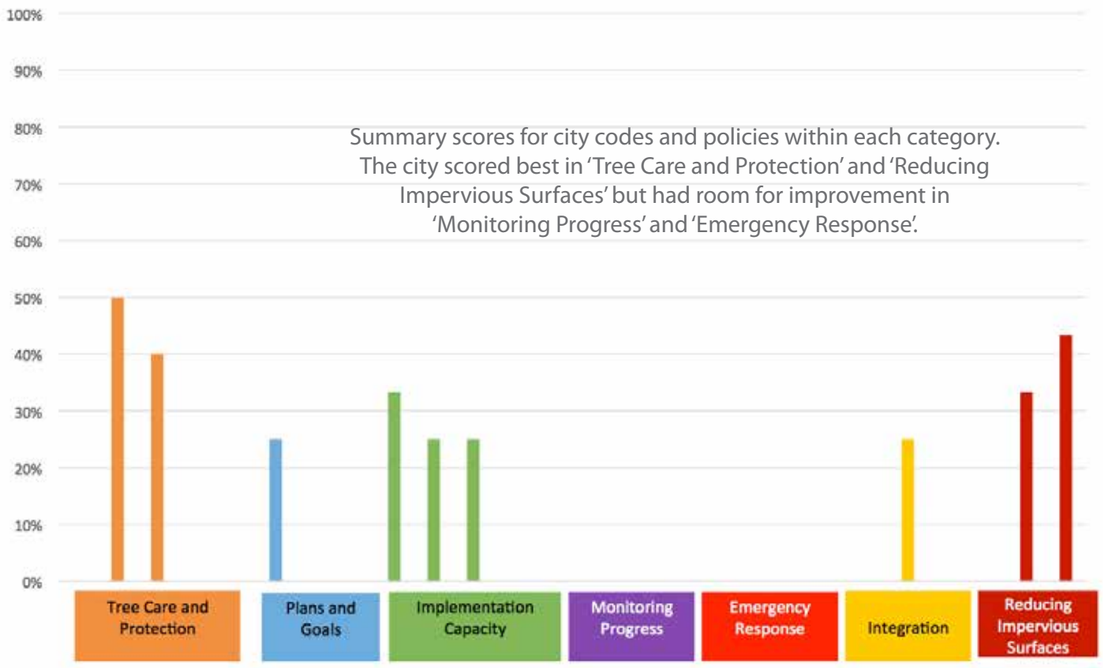
IMPLEMENTATION CAPACITY

Codes and ordinances that specify tree planting and care are great but without property resources, implementation of codes and goal achievement will be almost impossible. Implementation capacity includes well-trained

			Presentunicipality Commen	viewer Commen	Source	What to Look For	Score	Potential Score
Advisory Boards/Groups								
	Is there a Tree Commission/Urban Forestry Commission/Tree Board?	N				Tree Commissions can organize and guide tree planting and conservation efforts. Members typically have more time devoted to specific tree initiatives than the average municipality staff member can. Members also typically have different perspectives, resources, and scopes of influence than the average municipality staff member. Having a Tree Commission can expand the reach of urban forestry. Municipalities with an active Tree Commission/Urban	0	3
	Do the members of the Tree Commission/Urban Forestry Commission/Tree Board include representative from various occupations and areas of the municipality?	N				Ensure demographic and geographic representation of municipalities by the Tree Commission. Tree Commissions representing geographic and demographic variations in the municipality score one	0	1
Staff								
	Is a certified arborist on staff?	Y	The city sent a public works staff member to get certified as an arborist.			A certified arborist on staff aids municipalities in making informed decisions regarding tree health and tree placement. Municipalities with at least one certified arborist on staff or a consultant hired via	3	3
	Is at least half of one staff member's job duties devoted to managing grants?	Y	Grant administration is spread out across departments and special projects.			Grants are a viable and creative way to achieve targeted missions in a municipality. However, grant management and the paperwork that accompanies most grants is time consuming. Municipalities with at least half of one staff member's job duties devoted to managing grants or other funding sources score one	1	1
	Is there a full time regular staff member that has authority over day-to-day urban forestry	N				Urban forest management is a full time job even in a relatively small municipality. Municipalities employing at least one full time staff member with authority over	0	3

A snapshot of the types of questions or sections of code evaluated.

Trees and Stormwater Codes, Ordinances, and Practices —Audit Summary



Recommended areas of improvement for "Plans and Goals" were an urban tree canopy assessment with clear goals and strategies outlined, which the city has now achieved with this report, developed in partnership with the Green Infrastructure Center and Louisiana Community Forests. In addition, the city would benefit from creating an urban forest management plan to support the long-term care and maintenance of the city's urban forest and to ensure it is adequately funded in annual budgets. Recommendations under "Monitoring Progress" includes collecting public tree inventory data to support city decision-making, plans, policies and budget needs for the urban forest, as well as creating systems for residents to request street tree plantings or removals. Having a system in place for residents to request tree plantings can identify streets to plant, while a removal request process can limit unnecessary removals by professionally certifying the tree needs be removed while also increasing the efficiency of identifying and potentially mitigating hazardous trees.

Other recommendations for the city include becoming recognized as a "Tree City USA" by the Arbor Day Foundation. The city meets half of the requirements (see box at right) through current spending and community events. To fully meet the criteria, the city needs to establish a Tree Board and re-work some of its tree protection elements across multiple codes into a singular public tree ordinance. The Tree City USA membership demonstrates that the city has the requisite foundational programmatic and policy elements to support urban forest management. In addition, Tree City USA member cities have access to corporate sponsorships and grant opportunities through the Arbor Day Foundation.

TREE CITY USA®

To be recognized as a "Tree City USA" the City of Lake Charles needs to:

1. spend at least $2 per capita on tree care, planting or maintenance,
2. have a public tree ordinance
3. establish a Tree Board, and
4. hold an annual Arbor Day Celebration in the community.

Community Engagement

Public Survey and Input

The Green Infrastructure Center created a public survey to inform this assessment. The survey was open for six weeks from June 1st to July 15th 2022. Links to the survey were shared through the city's social media, sent directly to community groups and shared with attendees at city meetings. It also was shared at community engagement open houses held for a larger regional resiliency planning effort called Just Imagine. This effort was led by a coalition of local partners, including the City of Lake Charles. Three days of open houses were held for the public to review top-rated economic and environmental resiliency projects. GIC shared the results of the urban tree canopy analysis and gathered additional input from attendees. Thirty-one residents filled out the survey. The city will continue to gather more additional community input concerning the urban forest, tree planting efforts and opportunities to get involved.

Following are highlights from the public survey.

Tree values

The community overwhelmingly ranked shade (84%) as the number one community value trees provide. As extreme heatwaves become more common in Louisiana and across the southern U.S., the ability of trees to mitigate urban heat island impacts, reduce energy costs and protect public health are becoming increasingly important.

Tree concerns

Based on recent storm events, respondents ranked falling trees and resultant property damage as their top concerns. Selecting proper tree planting siting and selection of species can mitigate some of those risks as well as doing tree risk assessments around critical public infrastructure to identify hazards and mitigate risk.

Tree planting locations

The top places residents wanted to see trees planted in the community (in order) were along streets, in parks, stormwater mitigation sites and hot areas. Urban tree canopy data from this assessment can guide city efforts to identify specific sites or neighborhoods for these tree plantings or tree giveaways.

Strategies to increase canopy

The public thought the best three strategies were: city tree giveaways for residents, requiring developers to plant more trees and city tree planting in public spaces and ROWs.

Informing the "Just Imagine" Campaign

"Just Imagine" is a regional vision and community plan to revitalize and create a more resilient Southwest Louisiana. This report's data can be used to support the use of trees and green infrastructure to achieve many of the Just Imagine's goals as the city and the region prepare for major investments in infrastructure and economic development.

JUST IMAGINE SWLA
A 50-Year Resilience Master Plan for Calcasieu and Cameron Parishes

Some examples of how the city can apply canopy assessment data to inform the Just Imagine projects include:

Bayou Greenbelt

- Use this assessment's data to identify areas lacking tree canopy along proposed sections of the Bayou Greenbelt and implement tree plantings along the trail to shade users and provide stormwater benefits.

Strong Downtowns

- Re-design streetscapes as complete green streets which includes adequately sized tree wells and soil volumes for large canopy shade trees. Any installed stormwater facilities, such as bioswales should include spaces for trees to increase stormwater uptake.

Streetscape trees need adequately sized tree wells.

Photo Credit: Lindsey Janies, courtesy of Lake Charles Southwest Louisiana CVB

Chennault/SOWELA Area Resilience Districts

- Update city ordinances to increase tree canopy requirements in parking lots and require the planting of large canopy trees to shade surfaces and uptake stormwater. This would support the goal for green infrastructure parking lot improvements that also enhance walkability in these districts.

McNeese Area Resilience District

- Plant street trees along routes leading to the university to create healthier paths for students attending classes and mitigate urban heat and reduce stormwater impacts.
- Add tree plantings along the Contraband Bayou route extensions to the east and west of the university will help protect water quality, mitigate stormwater volumes, provide riparian habitat for wildlife and increase the recreational value for users of the greenway.

Nellie Lutcher District

- Add additional trees along the trail on First Avenue. While the city and its partners have begun tree planting, there is additional space for future tree plantings.
- Install complete green streets which contain adequately sized tree wells and soil volumes, along with treed bioswales to mitigate stormwater impacts and create a more vibrant and healthier district to attract cultural tourists.

The city and its partners have started planting the First Ave trail segments with trees.

Mid-City Neighborhood Transformation

- Continue to prioritize tree equity in the community by partnering with the regional housing authority to replace lost canopy in the large public housing development.
- Partner with Barbe Elementary School to plant trees with students and use the tree canopy and potential planting area (PPA) data to inform planting locations. This can be used as an annual Arbor Day Celebration activity.
- Use street tree canopy data and overlay with Safe Routes to school for students to increase canopy along their walking routes.

Waterfront Development

- Plant trees at the waterfront park and parking lots. Many parking lot islands are lacking any trees and can easily be planted.
- Plant strategic tree buffers and living shorelines to protect waterfront developments from storms. Buffers can be designed to avoid overly limiting views and waterfront access.

The waterfront has lots of room for more tree plantings.

Photo Credit: Lindsey Janies, courtesy of Lake Charles Southwest Louisiana CVB

Evaluation and Recommendations

The recommendations provided in this report are based on the land cover and ecosystem service modeling, analysis of the tree canopy and potential planting areas and the codes, ordinances and policy review. As noted earlier, the 10.6% tree canopy cover is unevenly distributed across the city. Top recommendations to improve forest cover in Lake Charles listed in priority order include:

1 **Continue to hold public tree giveaways**. To realize its goal of 15% canopy cover, the city will need to replace canopy lost from storms over the last several years. The city will need to plant thousands of trees and foster active participation from the community to plant trees on private property. Tree giveaways are one of the most popular and cost-effective ways to get trees planted on private property. The city gave away 2000 1-gallon trees at its spring 2022 tree giveaway. Since the city lost such a significant amount of canopy (33% relative loss pre-2020) it needs to hold frequent tree giveaways (2-3 per year at least in the first 5 years post-storm) to maximize tree planting and establishment for the long-term recovery of the urban forest. The city should also prioritize low-income and majority people of color neighborhoods such as north Lake Charles for outreach and tree giveaways.

Tree giveaways are popular and cost-effective ways to get trees planted onto private property. The city has held several tree giveaways for residents.

2 **Codify the role of trees as green infrastructure within the Hazard Mitigation Plan**. The Federal Emergency Management Agency's (FEMA), Public Assistance grants support "*Plantings (such as trees, shrubs, and other vegetation) are eligible [for funding] when they are part of the restoration of an eligible facility for the purpose of erosion control, to minimize sediment runoff, or to stabilize slopes, including dunes on eligible improved beaches. Plantings required to mitigate environmental impacts, … are only eligible if required by a Federal, State, Territorial, Tribal, or local code or standard permit that meets the criteria described in Chapter 2:VII.B.7.*" (FEMA, 2020). In order for trees to be eligible by FEMA under the Public Assistance Grants for reimbursement, documentation on the role those trees play in mitigating stormwater or erosion is necessary. Adopting trees as a hazard mitigation strategy and policy can establish precedent for the role of trees as green infrastructure (note: additional documentation steps are required). Adding trees as green infrastructure can also be used to justify funding tree planting as green infrastructure under FEMA's Hazard Mitigation and Building Resilient Infrastructure and Communities (BRIC) grant programs.

3 **Continue tree plantings in parks and rights-of-way and for key streets where green infrastructure and shade are needed.** The city has planted over 370 trees in various parks in partnership with local businesses and volunteers since last December. The city in partnership with the Louisiana Department of Transportation has planted 770 trees along the interstate in three phases between 2017 and 2020. The public identified streets and the hottest areas of the city as a top priority for tree planting efforts. Use the street tree coverage map developed by GIC to target streets with low tree canopy coverage and higher than average surface temperatures to increase shade along city streets.

The city planted trees in cooperation with the Louisiana Department of Transportation to beautify the I-10 corridor.

4 **Establish a tree board or commission**. A Tree Board or Commission comprised of community stakeholders will increase advocacy for Lake Charles's urban forest. Typical responsibilities for a tree board include grant writing, planning the Arbor Day celebration and other tree events, serving as ambassadors for the urban forest, and acting as an advisory body for tree related issues. A Tree Board is also required for designation as a Tree City USA which opens up financial opportunities for the city. The Tree Board should be made up of a diverse group of stakeholders (age, interest, expertise, etc.) and meet at least quarterly. Lake Charles has already developed a coalition of businesses, foundations, nonprofits, and community members interested in seeing more trees planted. Some of these individuals could be appointed to a future tree board.

5 **Establish a stormwater utility fee**. The management of stormwater facilities and infrastructure needs to be sustainably funded over the long-term. Having a dedicated fee that residents and businesses pay into annually can support the necessary investments in green infrastructure. It can also incentivize residents, developers and property owners to incorporate green infrastructure best management practices into new projects, or through retrofits. Allow developers and property owners to use tree plantings to offset the amount of the fee. Ensure that utility fee revenues are used to support public tree plantings.

6 **Develop a stormwater best management practice design manual for Lake Charles which includes both tree planting and constructed green infrastructure as best management practices (BMPs)**. Without standards, innovative stormwater techniques such as green roofs, suspended pavement systems, vegetated swales and tree pits cannot be credited toward stormwater requirements. The city should develop stormwater best management practice standards, along with incentives for developers and homeowners to install green stormwater technology. The city should continue to install these practices on city-owned buildings and properties to serve as educational demonstrations. A good example of such applications are the recent flood and stormwater resiliency enhancements installed at Hillcrest Park.

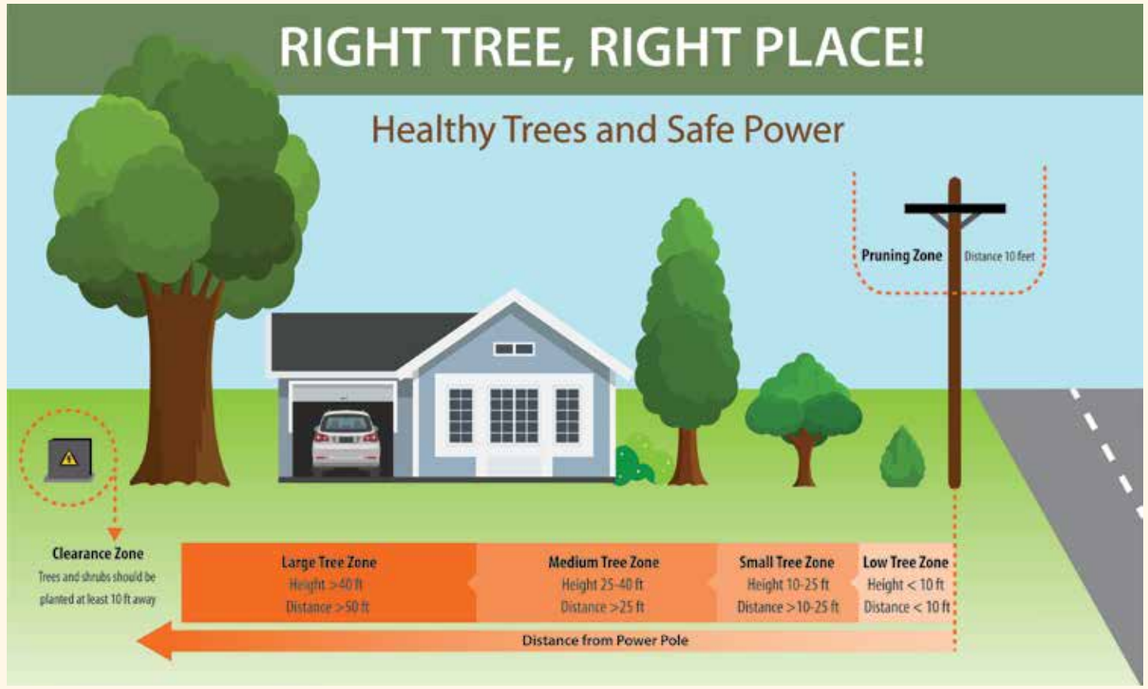
The city installed a demonstration green infrastructure project at Hillcrest Park featuring trees and bioswales to mitigate stormwater runoff and flood hazards.

7 **Consolidate tree related protections and standards into a single tree protection ordinance.** The city has several statutory elements for protecting trees found within other codes, such as the city's landscaping standards. These tree-related codes should be consolidated into a single ordinance that also includes new protections and processes for the management and removal of public trees. Example elements in a tree protection ordinance include standards of care for public trees and trees in rights-of-way (ROW), a removal process for removing public trees and trees in the ROWs, and guidelines to protect mature trees on site during the development or redevelopment process. Model tree ordinances are available for the city to reference in crafting its own tree protection ordinance.

8 **Establish a process for the public to request and remove street trees**. Create a system for the public to request that a street tree be planted in their right-of-way (ROW) or that they be allowed to plant a tree themselves. A formal process makes sure that the tree will not be in conflict with surrounding uses or other infrastructure present such as overhead utilities. It also helps the city control what species are planted in the public ROWs. Ensure those trees are protected from unnecessary removals by also developing a legal process for requesting tree removals. This will help the city track how many trees are lost annually through removals.

There is plenty of space available along streets for more tree canopy.

9 **Develop more information for citizens about supporting the city's urban canopy**. Community engagement is a challenge for many municipalities. However, as most of the city's urban forest is in private ownership, the community should be engaged in urban forestry management and tree planting. Educate the public about the loss of tree canopy that occurred over the last two years and show them how much planting space is available to replant trees. The public survey revealed most respondents don't think they have room for more trees on their properties despite what the data show. Survey respondents also did not know what species to plant. Sharing the tree list GIC developed for the city can educate the public about which species should be planted and where. Include infographics with social media posts and tree giveaways, such as "Right Tree, Right Place" (*see following page*) and planting brochures to aid in proper siting and planting of trees on private property.



10 **Determine urban forestry data needs and appropriate software for collecting urban tree data and determining forest management needs**. Monitoring urban forest composition and health is necessary for maintaining a thriving urban forest that serves both people and wildlife. Recent advancements in public tree inventory technologies have made data collection far less arduous. Use of these software systems allows managers to make informed decisions. The city can partner with McNeese State University professors and students to support data collection. Students are already documenting large historic oaks on campus and in the community. As a first step to make the inventory process achievable, the city could focus inventory in areas with critical infrastructure, at public facilities, or highly trafficked evacuation routes.

McNeese professors and students are collecting tree inventory data on large oaks. The city could partner with the university to collect new data for trees near critical infrastructure to flag trees that may need to be managed better for safety.

11 **Use public tree inventory data to track city assets**. Integrate public tree data into the city's asset management tracking software. This will allow the city to track and monitor its assets for tree locations, condition and maintenance needs. These data are critical for securing future FEMA reimbursement to replace trees under its Public Assistance grants available after federally-declared disasters.

12 **Conduct annual proactive tree risk assessments in highly trafficked areas of the city**. Tree risk assessments can be used to determine and develop plans to mitigate tree risks, such as diseased limbs that may fall. In highly trafficked areas, these assessments should be done annually. Implementing proactive tree risk assessments will reduce risks and potential losses. The city should send ISA-certified arborists on staff to additional Tree Risk Assessment Qualification (TRAQ) trainings. The city should have someone on staff trained in tree risk assessment to allow for a more rapid evaluation of tree risk in the event of emergency, immediately following a storm.

13 **Develop an urban forest management plan for the city**. An urban forest management plan (UFMP) details the vision and the process for managing the city's urban tree canopy. It is used to achieve local government and community goals to proactively manage the city's urban canopy and achieve long term benefits. A UFMP also informs budgeting for urban forest maintenance or planting.

14 **Prioritize forestry activities and develop a contingency budget for the urban forest to allow critical urban forestry maintenance items to continue through economic downturns.** Establish minimum budget requirements to ensure maintenance of the urban forest. Also establish a tree fund to help mitigate future tree losses from new development or storms.

15 **Require and enforce 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 1,000 cubic feet of soil volume to thrive, as recommended by the Environmental Protection Agency (Stormwater to Street Trees, 2013). Greater soil volume and soil areas will also decrease a tree's risk of failure during a storm by providing adequate area for root anchoring.

16 **Update the zoning code to establish higher minimum tree canopy percentages or a minimum number of additional trees for new developments**. Current standards require two trees be planted per single-family residential lot and one tree per 40 linear feet in nonresidential and multi-family lots. The city can increase these standards to require developers to plant more trees on site. For example, establish a minimum percentage of 20% tree canopy for residential zones or increase the number of required trees on single-family lots to four trees per lot. Another avenue to achieving greater canopy onsite is by updating canopy standards for parking lots. Currently, the city code allows for small trees to be planted at a higher density versus the planting of fewer larger shade producing trees. The city could require only the planting of large shade canopy trees in parking lots (Class A trees) and prohibit smaller trees (Class B trees) from these sites in order to maximize shade and stormwater benefits. Smaller trees could be allowed only where planting strips are constrained by other factors such as underground utilities. The city could also increase the number of required trees to be planted based on either the number of parking spaces (one tree island for every eight parking spaces) or by reducing the distance from one tree every 65 feet (current code) to one tree for every 45 feet or less.

17 **Incentivize developers to incorporate and retain mature trees on sites and protect those trees during construction.** Large mature trees provide greater and more immediate ecosystem service benefits than newly planted trees used for mitigation. The city's code can be amended to incentivize retention of mature trees for meeting stormwater requirements. Other types of incentives include faster permitting for preserved trees or patches of forest. The tree preservation code should also provide specific protections for mature trees during the construction process such as require fencing a distance of 1.5' times the tree's diameter at breast height (DBH) from the tree, exclude storage and staging of materials near the tree, place clearly visible signage and avoid trenching utilities that would impact tree roots. Existing large trees should be indicated on site plans along with tree protection measures.

This tree is not adequately protected from ongoing construction. Heavy machinery can compact the soil, damage roots and lead to decline in tree health or mortality.

18 **Enforce penalties if preserved trees die post-construction.** Too often, poorly planted and maintained trees die years after a development project is complete. During the establishment period (around two years), make sure landscaping survives by requiring inspections and bonding landscape materials at 180% of the cost. This incentivizes the developer to maintain landscaping and to replace required landscaping that doesn't survive. While the city code does require landscape materials that die be replaced or else suffer penalties, the penalties are not defined, and enforcement is inconsistent. The city is currently sending code enforcement staff to be trained in arboriculture to aid in identifying tree health-related problems

19 **Continue the integration of planning for trees in all planning and pre-development activities**. Holding pre-development conferences before sites are designed allows for creative solutions for tree retention to be considered as well as to calculate potential stormwater impacts from tree removal or planting. Sketching these site design ideas to protect trees early on allows for exploration of ideas for tree conservation before extensive funds are spent on site planning.

20 **Obtain Tree City USA membership status through the Arbor Day Foundation**. The city already meets multiple requirements for Tree City USA designation including spending more than $2 per capita on tree care and maintenance and holding tree planting celebrations. The city also has elements of the last two remaining requirements, the Tree Board and a Tree Protection Ordinance, but further work is needed to either establish them or formalize them in the code (see recommendations four and seven for more information).

21 **Conduct a land cover assessment every four to six years to compare tree canopy coverage change over time.** Tree canopy coverage should be expanded and maintained to promote public health, walkability, water quality and groundwater recharge. Regular updates to land cover maps also track trends (losses or gains) in the canopy over time and support adaptive management for prioritizing planting strategies

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 of Lake Charles holds planning concept reviews, but they are not mandatory. Someone from the city knowledgeable in tree health and care should attend all scheduled reviews. Greater encouragement for these meetings and funding for additional staffing within the city's urban forestry program could expand the frequency of trees conserved and benefits derived from these meetings.

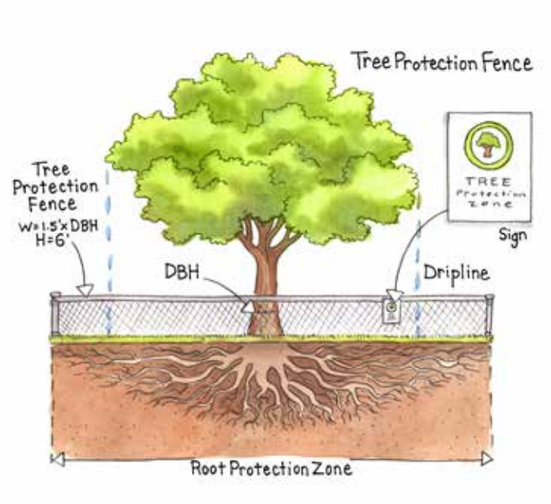
Actively promoting development designs that minimize the loss of urban forest canopy and habitat is key to continued progress in expanding city canopy cover. While the city actively encourages site layouts that conserve trees, developers may not always agree to implement staff suggestions. The GIC has 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 fencing. It is a physical barrier that keeps people and machines out of a tree's critical root zone during construction. However, some municipalities only require plastic orange fencing and wooden stakes. This type of fencing can be removed or trampled easily and reduces protection effectiveness. Without effective barriers, even trees designated to be saved may suffer development impacts such as root compaction and trunk damage. The city should require sturdy metal chain link fencing in high-risk areas (e.g., near heavy construction equipment and active site grading) and use orange plastic fencing in lower risk areas (e.g. along the tree line 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 these roots is critical for the optimal health of a tree. Many cities request that tree protection fences be placed at the dripline. While protection at the dripline is an accepted practice, it does not adequately protect the 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.

The city currently does not require tree protection signage. Tree protection signage communicates how work crews should 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

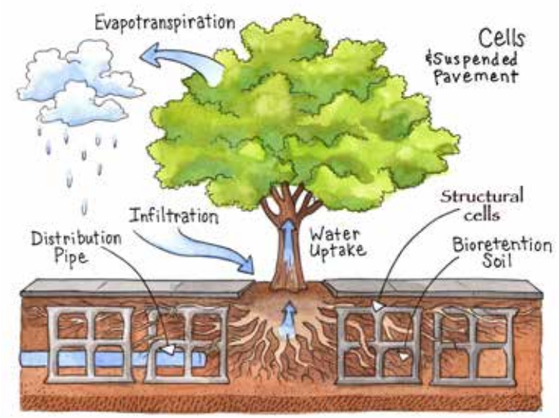


Tree Protection Fence and Signage

a standard tree protection sign which summarizes the dos 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. If the work crews are of different nationalities, consider signage that has multi-lingual instructions.

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



Structural Cells and Suspended Pavement

Planting trees in the right place away from power lines can avoid harmful over pruning.

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 tight or where heavy uses occur above, underground tree support cells can be used to stabilize and direct tree roots towards areas with less conflicts (e.g., away from pipes). *See diagram on page 44.*

In addition, large trees should not be planted where they may interfere with overhead lines. GIC updated the city's preferred tree species list that includes details for which species can be planted where. Having an updated, preferred tree species list allows the city to set standards for tree placement and siting within its jurisdiction. For example, some trees thrive in a backyard but not in a parking lot due to heat sensitivity. These and other practices, implemented to provide long term care, protection and best planting practices for the urban forest, will ensure that investments in city trees will pay dividends for reducing stormwater runoff, as well as cleaner air and water, lower energy bills, higher property values and natural beauty long into the future.

Photo credit: City of Lake Charles

Conclusion

Adapting codes, ordinances and municipality practices to use trees and other native vegetation for greener stormwater management will allow Lake Charles 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 species (trees and other vegetation) to uptake and clean stormwater. It will also lower costs of tree cleanup after storms since proper pruning or removal of trees deemed to be at risk can be done before storms occur.

Lake Charles should use the canopy map and updates to track canopy change over time and prioritize increasing canopy by neighborhoods to restore lost canopy. 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.

Photo credit: City of Lake Charles

Photo credit: City of Lake Charles

The Lake Charles community is working hard to recover the city's lost tree canopy.

Next Steps

An urban forest management plan is another key plan the city should develop to ensure that it has detailed and actionable processes to care for and manage its trees. Grant funding is available from the Louisiana Community Forests for such activities. A key aspect of urban forest management is integrating urban forestry within its emergency response plan. This should be coordinated with Calcasieu Parish and adjacent communities who share similar concerns about storm debris and removal or repurposing. 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. Codifying trees as green infrastructure to mitigate stormwater, erosion and urban heat will make them eligible for replacement under FEMA's Public Assistance grants. Collecting tree inventory data (location, species, trunk diameter, photo) will support the documentation necessary to claim a tree as eligible for reimbursement if lost or damaged by a storm or other natural disaster. Including tree maintenance records and expenditures as part of the city's asset management system will demonstrate the role trees play as critical green infrastructure.

Lastly, it is recommended that the city conduct a land cover assessment every four years to compare tree canopy change over time and progress towards the 15% coverage goal. Keeping tree canopy coverages at levels that promote public health, walkability, and clean water 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 and to identify and address negative trends as well. 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 clean air and water, lower energy bills, higher property values and natural beauty long into the future.

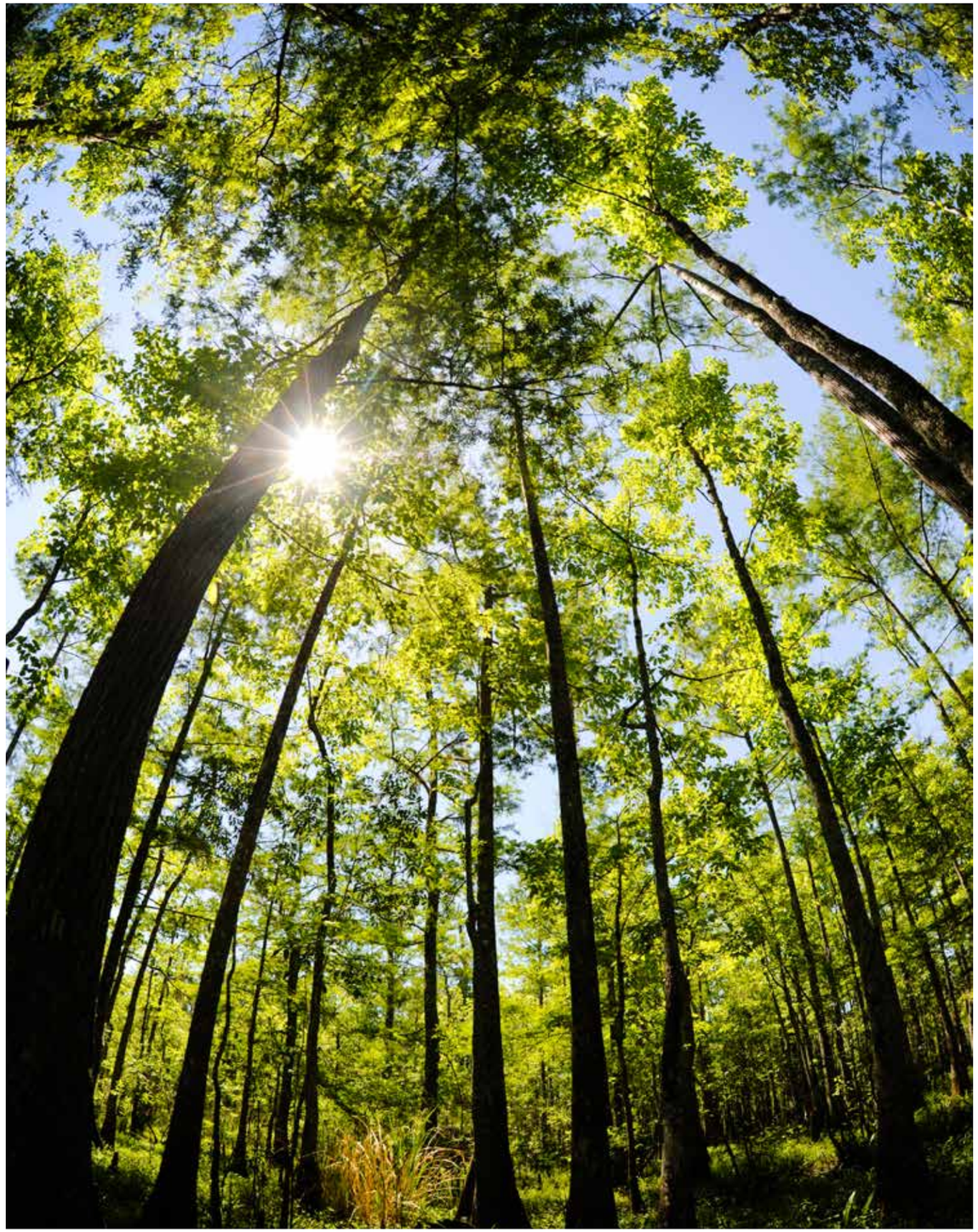


Photo Credit: Lindsey Janies, courtesy of Lake Charles Southwest Louisiana CVB

Appendixes

Appendix A: Land Cover Analysis Methods

This section provides technical documentation for the methodology used to classify land cover and create Potential Planting Spots (PPS) and Potential Canopy Area (PCA) scenarios for the city. 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 (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?

Method

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

Two canopy maps were created using the NAIP imagery– one from October 30, 2019 at 1-meter resolution and one from January 20, 2022 at 1-m resolution. Feature height data were derived from LiDAR 2018 (Light/Laser Detection And Ranging, high resolution elevation data) from US Geologic Survey and hydrologic and infrastructure data provided by the City of Lake Charles. These data were used to determine seven land feature classes using the following method.

1. Tree Canopy. Features identified as "green" or typically above 0 in NDVI (Normalized Differential Vegetation index) that have a feature height above 10 feet were classified as Tree Canopy.
2. Tree Canopy over impervious are features that overlapped impervious surfaces primarily created from existing vector data where available.
3. Wooded wetlands were identified based on where NDVI is above 0 OR feature height is above 10 ft and intersects NHD water/wetland.
4. Scrub/Shrub. Spectrally these features appear very similar to tree canopy but do not meet the height requirement to be considered a tree and are above 1 meter in height.
5. Turf/Pervious are features identified as "green" or typically above 0 in NDVI but have a feature height less than 1 meter.
6. Impervious surfaces were created using an object-based recognition tool ArcGIS add-on called Feature Analyst and existing vector data such as road edge and building polygons. These features are typically below 0 on an NDVI.
7. Bare earth and Sand were easily confused with impervious surfaces but typical had a NDVI value closer to 0.

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

Note: Bare earth is easily mis identified with impervious surfaces. Curve numbers in the TSW Calculator are similar and this does not affect analysis. In some places, sidewalks or golf cart paths were identified as bare earth under canopy. There are few places like this, and the overall area of the class is small – so the percentage may appear high.

The NAIP 2019 image was originally used as the primary input. However, during the course of the project, the 2022 NAIP imagery became available. Therefore the 2019 classification was created using an NDVI image to show where tree canopy had changed (i.e., it went from being 2019 tree canopy to an NDVI value of less than 0, indicating that it had become an impervious feature).

A Confusion matrix was run to test the accuracy of the canopy data which resulted in ....

Land Cover for Cape Charles	C_10	C_30	C_50	Total	Urban Canopy Accuracy
Tree canopy and wooded wetlands	26	0	0	26	100.0%
Pervious and bare earth	2	130	3	137	95.9%
Impervious surfaces	0	2	86	88	97.7%
Total	28	132	89	251	
Percent Accuracy	92.9%	98.5%	96.6%		96.4%

Potential Planting Area Dataset

The Potential Planting Area dataset has three 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.

- Potential Planting Area (PPA)
- Potential Planting Spots (PPS)
- Potential Canopy Area (PCA)

The **Potential Planting Area (PPA)** is created by selecting the landcover features that have space available for planting trees, then eliminating areas that would interfere with existing infrastructure.

Initial Inclusion selected from GIC-created land cover pervious surfaces class.

Exclusion features applied:

- The pervious surfaces were then buffered in 10 ft. from all impervious surfaces including buildings and roads.
- Playing fields (i.e.: baseball, soccer, football) as well as golf courses, cemeteries, airports and other incompatible land uses were then identified where visually possible. (Digitized by GIC)
- Once this initial phase was completed, the Potential Planting Area data were reviewed by the city and manually edited to best represent city expectations of where planting was allowed (e.g., not on play fields). In addition, areas that were known to be planned for development were removed.

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

The **Potential Planting Spots** (PPS) are created from the PPA. The potential planting areas (PPA) are run through a GIS model that selects spots a tree can be planted depending on the size tree's that are desired.

- Tree planting scenarios were based on a 20 ft. and 40 ft. mature tree canopy with a 30% overlap. Therefore, the planting spots are 16 ft. and 32 ft. apart respectively.

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

NAIP Image 2022

Appendix B: Trees and Stormwater Calculator

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

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

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

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

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

Major factors determining CN are:

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

Tree over street

Trees over forest

Tree over lawn

Tree over parking lot

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

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

Photo Credit: Lindsey Janies, courtesy of Lake Charles Southwest Louisiana CVB

Photo Credit Chad Moreno, Killer Photography, Courtesy of Lake Charles CVB

Appendix C: Bibliography

_____ Appendix: Hynicka, Justin, and Marion Divers. “Relative reductions in non-point source pollution loads by urban trees.” in Cappiella, Karen, Sally Claggett, Keith Cline, Susan Day, Michael Galvin, Peter MacDonagh, Jessica Sanders, Thomas Whitlow, and Qingfu Xiao. "Recommendations of the Expert Panel to Define BMP Effectiveness for Urban Tree Canopy Expansion." (2016).

_____Runoff and infiltration graphic. EPA Watershed Academy Website. Accessed September 01, 2022: https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=170

_____“Complete Green Streets. Smart Growth America.” Website accessed September 01, 2022: https://smartgrowthamerica.org/what-are-complete-streets/

_____ Penn State Extension, Trees and Stormwater: https://extension.psu.edu/the-role-of-trees-and-forests-in-healthy-watersheds

_____“Stormwater to Street Trees.” U.S. Environmental Protection Agency, September 2013. EPA report # EPA 841-B-13-001.Web site accessed September 01, 2022: https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf

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

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

Benedict, Mark A. and Edward T. McMahon, “*Green Infrastructure: Smart Conservation for the 21st Century*.” Washington, D.C., Sprawl Watch Clearing House, May 2002. Accessed September 01, 2022: http://www.sprawlwatch.org/greeninfrastructure.pdf

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

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

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

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

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

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

Federal Emergency Management Agency (FEMA), 2020, Public Assistance Program and Policy Guide, Version 4, Effective June 1, 2020.

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

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

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

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

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

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

Nowak, David John, E. Robert III, Daniel E. Crane, Jack C. Stevens, and Jeffrey T. Walton. *Assessing urban forest effects and values: Washington, DC’s Urban Forest*. Vol. 1. United States Department of Agriculture, Forest Service, Northern Research Station, 2006.

Nowak, D.J., and Greenfield, E.J., “Tree and impervious cover change in U.S. cities.” in *Urban Forestry & Urban Greening*, Vol. 11 (2012); pp21-30. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1239&context=usdafsfacpub

Nowak, et al, (2010). *Sustaining America’s Urban Trees and Forests*. https://www.fs.usda.gov/nrs/pubs/gtr/gtr_nrs62.pdf

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

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

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

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

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

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

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