CITY GREENPRINT 1.0

Charlottesville's Green Infrastructure Guide

CITY OF CHARLOTTESVILLE, VA

This project was conducted in partnership with the Green Infrastructure Center Inc. Funding is provided by the Virginia Department of Forestry's Urban and Community Forestry Program and the USDA Forest Service.

July 2018

To learn more about the Virginia Department of Forestry visit:
http://www.dof.virginia.gov/forestry/community/index.htm

To learn more about the GIC visit: www.gicinc.org.

NOTE: This document was formally completed and released in August 2020 with limited relevant updates made to the July 2018 version.

Full size versions of the maps contained in this document can be found and downloaded at www.charlottesville.gov/greeninfrastructure or requested via email from greencity@charlottesville.gov.

Contents

1. City GreenPrint: Charlottesville's Green Infrastructure Guide

1.1 Introduction: How Green Infrastructure (GI) Supports a Green City

The City of Charlottesville ('City') has set a clear vision to be clean, green, connected, and healthful. Charlottesville's recently adopted Strategic Plan sets a goal for "A Beautiful and Sustainable Natural and Built Environment" with an objective to "Be responsible stewards of natural resources." Assessing the extent and condition of the city's green assets – known as 'green infrastructure' – is key to achieving this vision. Green infrastructure is also central to the City's 2014 Complete Streets Policy, which includes a focus on natural resources as elements of the built environment that support ecosystem health and integrity and livable communities.

Green infrastructure encompasses natural elements such as trees, rivers, and good soils, which are considered 'infrastructure' because they provide key functions to support communities. For instance, the Rivanna River provides Charlottesville with drinking water, while the city's trees provide clean air, shade, stormwater runoff treatment, and beauty. Just as the City plans for sidewalks, roads, or storm drains – *grey* infrastructure – it also needs to plan for and maintain its *green* infrastructure. Although the term green infrastructure was first used in 1994 to describe natural features that support people and wildlife, in 2006 EPA expanded the term to include constructed green infrastructure, such as the green roof on City Hall or the rain garden at Greenleaf Park, which both treat stormwater and clean the air.

Charlottesville's maturing Green Infrastructure (GI) Program is based on strategically integrating nature into the urban environment to enhance environmental values and create a more healthful city. Weaving natural processes into the built environment provides the benefits of stormwater management, flood mitigation, air quality management, habitat, and improved aesthetics, just to name a few.

This document supports the conservation and restoration of the City of Charlottesville's green infrastructure. It provides an introduction to what green infrastructure is and an overview of how it can support a community with setting greener goals. It presents the current green infrastructure baseline to build upon as well as a summary of planning/analysis tools developed specifically around the topic of tree planting potential. The City project team landed on the term "GreenPrint" for this document since it can serve much as a blueprint to guide development of the city's green network – habitat patches and their connections. As the City grows its Green Infrastructure Program, so too will the guidance provided. This Green Print as version 1.0 conveys the City team's commitment to program evolution.

Key City Strategies Addressed by the Green Print

2019 Strategic Plan Goal 3 (2018-2020)

GOAL 3: A Beautiful and Sustainable Natural and Built Environment
3.1 Engage in robust and context sensitive urban planning and implementation 3.2 Provide reliable and high quality infrastructure 3.3 Provide a variety of transportation and mobility options 3.4 Be responsible stewards of natural resources 3.5 Protect historic and cultural resources

Charlottesville's 2025 Vision (excerpt):
2025 vision for a Green City:
Charlottesville citizens live in a community with a vibrant urban forest, tree-lined streets, and lush green neighborhoods. We have an extensive natural trail system, along with healthy rivers and streams. We have clean air and water, we emphasize recycling and reuse, and we minimize stormwater runoff. Our homes and buildings are sustainably designed and energy efficient.

As such, the GreenPrint contains:

- A compilation of green infrastructure assets
- Key facts and statistics about the city's green infrastructure
- Maps of key green resources and tips for how to use them
- An analysis of tree-specific planting opportunities
- Resources for implementation

Intended users include City staff and decision makers, developers, citizens and anyone who wants to

support the City's goals to be green, healthful, and connected (see sidebar on previous page).
One of the critical GI focal themes is the urban tree canopy. With funding support from the Virginia Department of Forestry (VADOF), the City has assessed its urban canopy over two intervals. The City's 2007 Comprehensive Plan established a goal of 40% tree canopy cover and the canopy cover map published in 2009 found canopy coverage to be 47%. The City then re-assessed its Urban Tree Canopy in 2015, using 2014 aerial imagery and established the urban tree canopy cover to be at 45%; a loss of two percent.

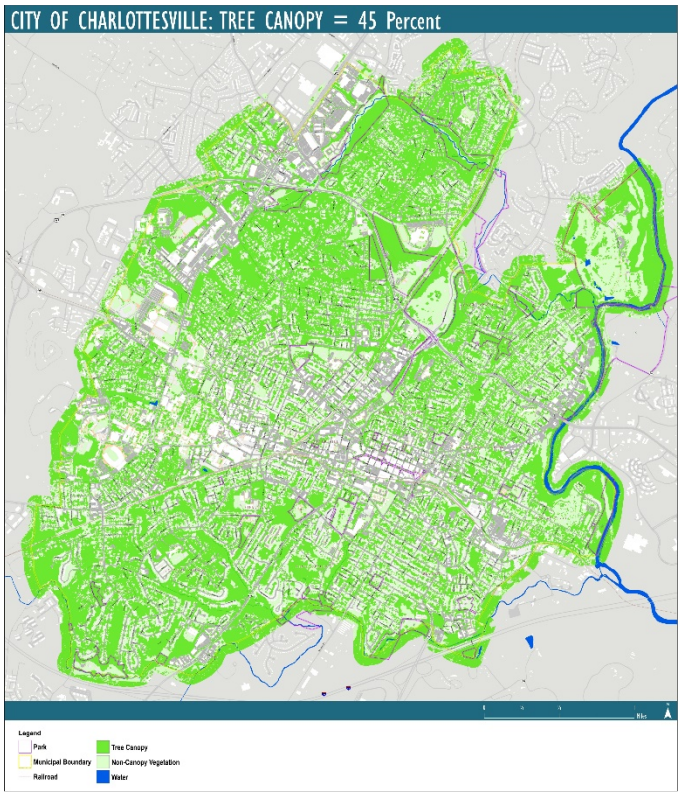
Subsequently, the City obtained a technical assistance grant from VADOF and the Green Infrastructure Center (GIC) to assess the city's green infrastructure assets as a connected network. The Charlottesville Department of Public Works served as the lead agency for the assessment effort and collaborated with multiple agencies and committees to complete the project. The proposed outcome of the project was to provide tools and strategies to promote GI through mapping, assessment and analysis, narrative and graphics.

City Asset Maps created for this project consist of numerous maps available for online viewing, including:

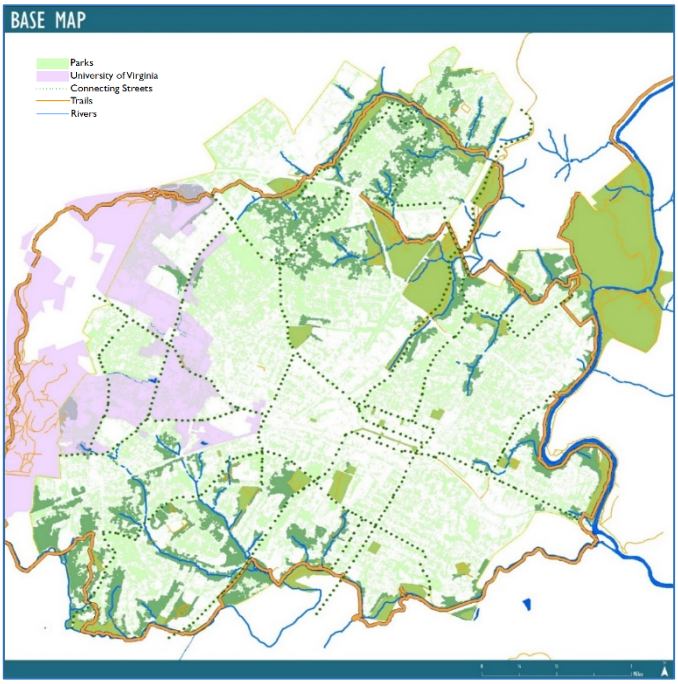
- Base Network
- Forest Patch Analysis
- Historic-Cultural
- Recreation
- Tree Canopy Overview
- Treed Streets
- Water
- Water-Riparian Buffers

http://www.charlottesville.gov/greeninfrastructure

The Base Map (Map 2) provides a snapshot of the city's green resources – primarily tree canopy, parks and streams – that support both wildlife and people. This modified base map shows the components that form a connective network for green infrastructure to facilitate the movement and health of people, pollinators and wildlife across the city (it is discussed later in this report).



Map 1: Tree Canopy



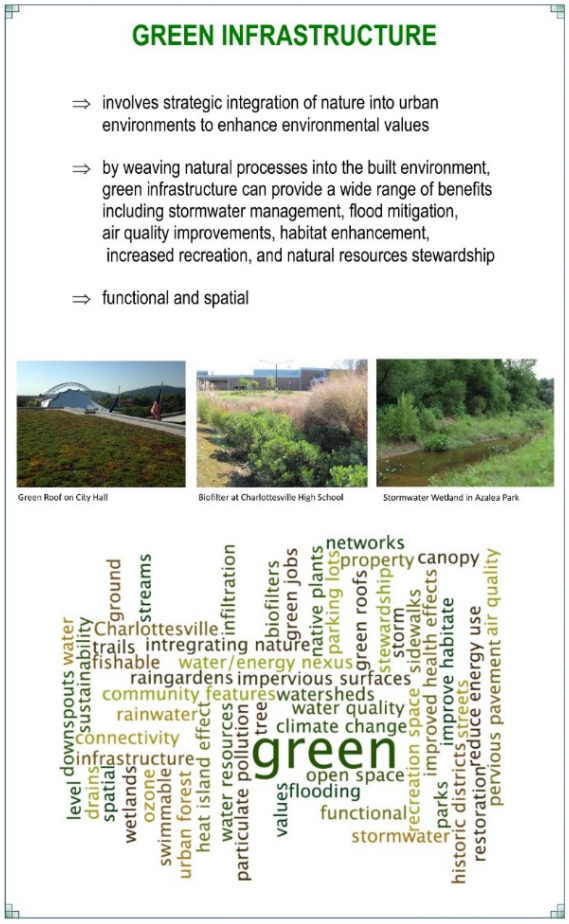
Map 2: Base Map

The maps and data created for this project will be used to inform the Comprehensive Plan update, zoning decisions, and standards or locations for tree planting. They will help build new connections and strengthen others and will inspire progress towards the "Green City" vision.

A series of maps were created to understand the city's green infrastructure extent, location and how it supports important goals such as clean water, livable neighborhoods, settings for cultural sites, recreation, and also social equity in terms of how assets are distributed citywide. Maps are described throughout this report and can be used to achieve goals within the Comprehensive Plan.

1.2 Green Infrastructure Defined

In urban areas, the term 'green infrastructure' can be applied to the wide range of natural assets and strategies that exist or are installed in the built environment to improve the quality of our natural resources and that contribute to healthier natural habitat, increase recreational opportunities, and improve aesthetics.



Working at several scales (municipal, neighborhood, and site), green infrastructure is the strategic integration of nature into urban environments, in order to enhance environmental function. Thinking of Charlottesville's natural elements as our 'green infrastructure' helps to ensure they are managed just as the City manages its grey infrastructure of roads, sidewalks, bridges, and buildings. *Green Infrastructure* is a term the Florida Greenways Commission coined in 1994 to explain that nature is part of our 'infrastructure' because it also provides functions that support our existence.

Newly planted tree in Riverview Park

They developed a state model to assess Florida's best areas for wildlife, recreational uses, scenic views, and other benefits. Following on Florida's work, Virginia also developed a green infrastructure model, as did several other states, and now there is even a national model. In 2006, the U.S. Environmental Protection Agency expanded the definition of green infrastructure from natural elements to also include *constructed stormwater best management practices* using green features, including green rooftops, rain gardens and biofilters, permeable pavers and rainwater harvesting cisterns.

In this guide, we refer to two terms: *natural green infrastructure*, such as trees, water, or soils; and

green stormwater infrastructure, which are the engineered systems that utilize natural elements to treat stormwater, and in some cases, provide habitat. This guide focuses primarily on the city's natural green infrastructure – its trees, parks, streams, and other open spaces.

By weaving natural processes into the built environment, green infrastructure provides a range of benefits, including:

- stormwater management
- flood mitigation
- air quality improvements
- mitigation of the urban heat-island effect
- reduced water and energy use
- habitat enhancement
- facilitation of walking and biking
- increased recreational opportunities
- improved aesthetics

Understanding the many benefits that natural elements provide in urban settings is an evolving science, and the expectations for protecting, managing, and enhancing them are increasing. As a historic city founded in 1762, most of the city's development took place before the enactment of regulations concerning clean water. As a result, much of the city's stormwater runoff is not captured or treated; instead, it flows through storm drains and pipes directly into local waterways – notably, the Rivanna River.

Furthermore, many of the city's roadways have only sparse 'green' features. This is, in part, because of the lack of available planting opportunities in public rights-of-way. Conflicts with roots and branches have to be minimized, so both underground and overhead utilities impose severe limitations on tree planting along the city's streets. Also, with most of the city's land under private control, available public spaces to plant additional trees are limited.

Despite these challenges, having a clean and green city requires the re-introduction of both natural and constructed green infrastructure. In other words, we need to *retrofit* (redesign) much of the city's existing infrastructure with natural elements to meet today's expectations for clean water, clean air and healthful lifestyles.

Another consideration for many older cities is that open spaces, trails, and trees need continual attention to make sure they are green and thriving. Just as one would renovate older housing stock over time, trees in older neighborhoods also need attention. Long established neighborhoods often have larger and older trees, and as they age they die and need replacement. Unless the City and its citizens plant replacement trees, canopy will be lost over time.

Also, it's not just the age of a tree that determines its longevity. When compared to trees in natural

Bioswale at Riverbluff Circle slows and cleans runoff

settings, urban trees are subjected to many additional stresses that shorten their life spans. Inadequate planting areas that can't hold enough soil volume, or damage from laying underground utilities can cause life-shortening stress. This means that replacement of trees may require improving planting areas, and that areas that have already been planted may now be deemed unsuitable for large or long-lived trees. Additionally, robust and effective green

infrastructure requires maintenance and improvement to ensure that Charlottesville can, for example, reap the benefits of its trees into the future.

It is challenging to set strategic tree planting or canopy coverage goals without information to help determine which goals may be realistic or feasible. The analysis done in this project will help the City determine where new trees can be planted to maintain its canopy, re-green areas, or to replace trees that will be lost because of old age, utility damage, or development.

1.3 Why Manage Green Infrastructure?

A key to making Charlottesville green, healthy, and connected is to first protect as much of the *current* natural green infrastructure – trees, wetlands, parks – as possible, and add them where they have been lost or compromised. Preserving well-functioning and linked natural assets provides an effective starting point for further establishing a robust natural landscape that provides a range of services including:

- Helping the city's landscape function as a sponge and a filter – soaking in and cleaning large volumes of stormwater runoff and removing air pollutants through plant processes.
- Creating enjoyable and functional corridors for movement of people and animals.
- Serving as a healthful and aesthetic background for urban life.

When space to replant native vegetation is lacking, or when intensive treatment is needed in small spaces, such as high-density developed areas, the City can use smaller-scale best management practices, such as bioswales, to mitigate impacts from the already constructed landscape.

As part of a successful green infrastructure strategy, the City needs to understand the physical distribution of its natural green infrastructure. This information provides a valuable tool for planning, strategizing, and management. Establishing a baseline, identifying gaps in the network, and finding opportunities to make connections between green infrastructure assets helps to build a more robust natural system in the city. The green infrastructure assessment conducted by the City and GIC utilized data to do just that - it mapped the current green infrastructure and its *connectivity* across the city.

A well-connected green landscape is healthier than one that is highly fragmented. Connectivity facilitates recreational activities and the movement of pollinators, birds, butterflies and other animals. Smaller urban spaces, such as linear stream valleys, or even pocket parks, contribute to the connected green landscape and make the city more walkable. The city's tree canopy map provided a starting point for looking at how green the city is, how green its streets are, and for considering how to re-green areas to facilitate pedestrian movement.

Habitat Patches

Taken together, clusters of trees, along with other vegetation such as shrubs, native grasses, and flowers provide important habitats for wildlife. Even in a city, smaller habitats add up and provide critical benefits for animals, such as amphibians, birds, bees and other beneficial insects. While some residents may have limited experience with or appreciation for urban wildlife, providing education about green infrastructure can raise awareness of its benefits, such as supporting pollinators to support agriculture or habitat for migrating birds, and contributing to clean air and water.

Habitat patches provide benefits to wildlife and absorb more water than trees in lawns.

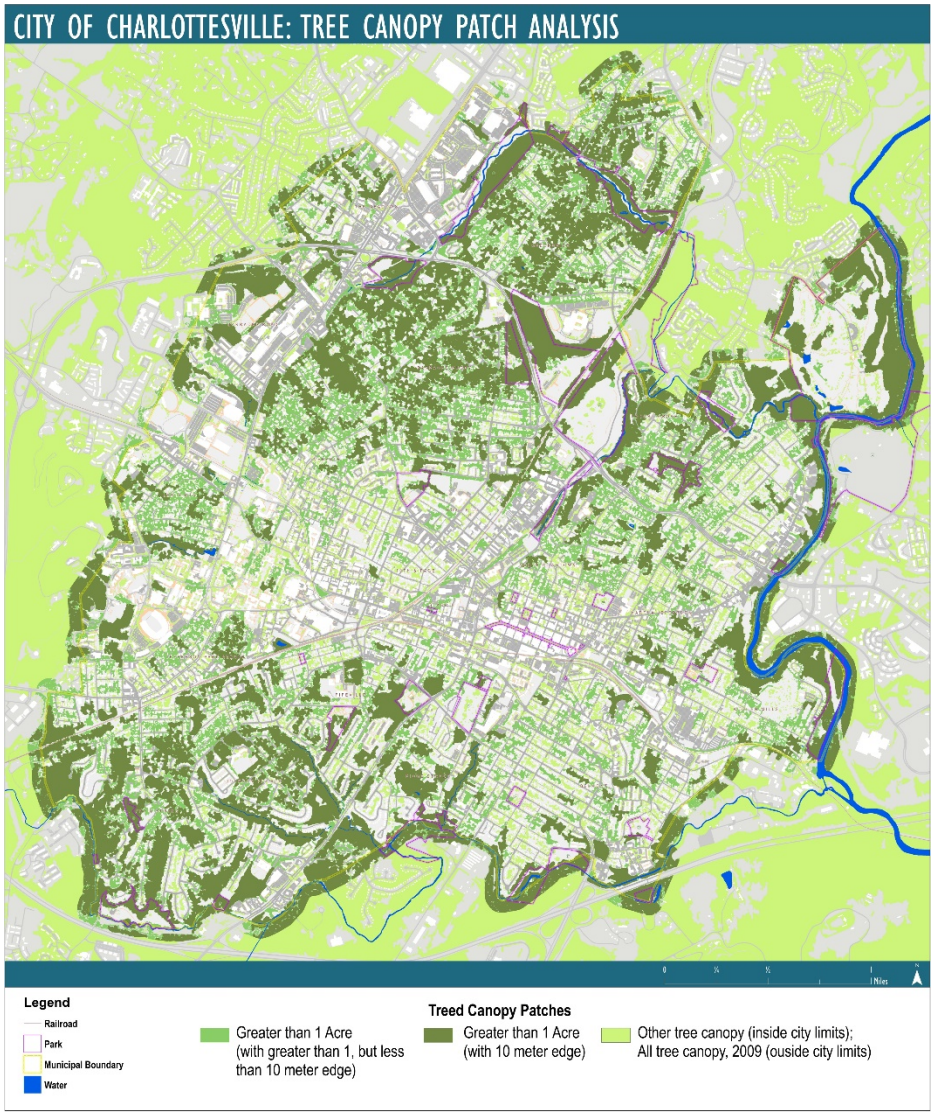
Trees grouped together, especially those with native ground cover of shrubs and plants, function as a forest ecosystem and provide more infiltration of stormwater and ecological benefits. Leaves and other decaying vegetation also can build up to create a duff layer that supports key soil microbes and acts as a sponge to hold water and protect trees in times of drought. This is why a cluster of trees is better than separated individual trees, as habitat patches provide more benefits than isolated trees.

Trees grouped together are also better protected from wind damage. The Tree Canopy Patch Analysis in Map 3 on this page shows a distribution of patches meeting certain adjacency criteria.

In summary, a green infrastructure program first identifies current natural features; second, protects those natural features; third, restores and enhances treed areas and other natural features where they have been lost; and, fourth, mitigates unavoidable impacts.

Stormwater Reduction from Trees and Other Vegetation

Charlottesville drains to the Rivanna River, which sits in the middle of the James River Watershed – a major tributary to the Chesapeake Bay. Excessive urban runoff results in pollutants such as oil, metals, lawn chemicals, pet waste and sediment reaching surface waters. High stormwater flows result in stream channel and bank erosion, releasing sediments that smoother aquatic habitat. Stream health is affected by factors such as land cover, lot sizes and land use types, as well as the location and extent of impervious surfaces within the watershed. There is a demonstrated pattern between increasing levels of imperviousness and decreasing abundance and diversity of aquatic life (macroinvertebrates, fish, salamanders and other aquatic-dependent species) in surface waters). Improving runoff in the city will help local streams and the Rivanna River as well as downstream waterways, including the James River and Chesapeake Bay.



Map 3: Patch Analysis

The Clean Water Act requires cities such as Charlottesville to manage their urban stormwater and make water quality improvements. Charlottesville is working to reduce its inputs of bacteria, nitrogen, phosphorus, and sediment, the key pollutants impacting the Rivanna River and the Chesapeake Bay. The City has to comply with requirements under its Municipal Separate Storm Sewer System (MS4) Permit, issued by the Virginia Department of Environmental Quality to prevent surface waters from becoming impaired and to improve water quality. The City's permit includes requirements to educate and engage its citizens and take actions to reduce the amount of pollutants reaching waterways.

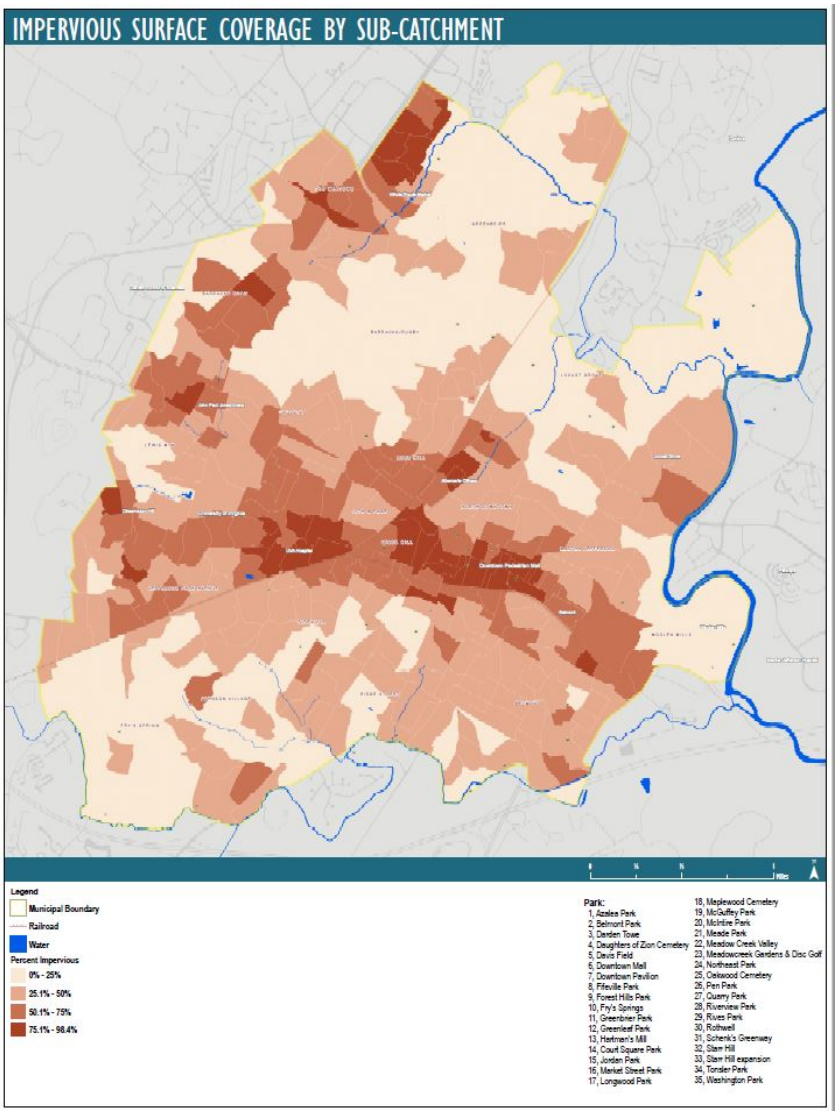
Studies have shown that a robust urban tree canopy can reduce a city's stormwater runoff by anywhere from two to seven percent (Fazio 2010). During a rainfall event of one inch, one acre of forest will release 750 gallons of runoff, while a one-acre parking lot will release 27,000 gallons – 36 times more runoff (Penn State Extension). According to the City, there are roughly 99 million square feet, or

2,273 acres, of impervious surfaces in Charlottesville. During a one-inch rain, those impervious surfaces produce 61,371,000 gallons of stormwater runoff. Since the city receives an average of 43" of rain per year, those 2,273 acres of impervious area release 2.6 billion gallons of runoff per year.

Converting impervious areas in the city to green space, or diverting runoff away from city streams benefits the Rivanna and James River and Chesapeake Bay. For more information on stormwater management and best practices, see the City's website at www.charlottesville.gov/stormwater.

Parks and Trails

Trees can also benefit the city's open spaces, such as parks, schools, and trails. The City's list of parks includes all the properties managed by Charlottesville's Parks and Recreation Department including parks, cemeteries, and golf courses. There are many opportunities to add trees, remove invasive vegetation, and restore native plants on these properties. In urban areas, even small patches of green space become important to consider because together they make a large cumulative difference.



Map 4: Impervious Surface Coverage

In addition to having parks for recreation, the amount of well-shaded and protected bike lanes and sidewalks affect whether or not children can enjoyably walk to school. The City runs a Safe Routes to School initiative that offers opportunities to incorporate green infrastructure – trees and other landscaping – along the route. Children who walk to school arrive more awake and ready to learn and just 20 minutes of exposure to green spaces dramatically improves cognitive functioning.

Residents enjoy the shade at Riverview Park

Small Shrubs and Micro Habitats

While a mature tree will usually absorb more water than a small shrub, trees are not always the best fit for a particular location. In areas where there is not room to plant them or where sunlight is desired to support a vegetable garden, other shrubs and native groundcovers can be planted. Shrubs and plants also reduce stormwater runoff, feed birds and pollinators, and add natural beauty. If a lawn is necessary, such as for providing a place for kids to play, aerating that lawn can help it absorb more water.

Small shrubs also provide habitat

Patches of vegetation all add up to provide more habitat for pollinators – which we need to protect our food supply. Farmers markets and resident's backyard vegetable gardens would not be possible without bees. Wild bees (versus commercially-raised bees) are less susceptible to disease and can travel to more areas, so it's important to support their needs. Even in a city such as Charlottesville, improving the habitat of citizen's backyards can make a huge difference (see the Resources Section for ideas). Since eating fresh, local food has become more popular, protecting pollinators is something most people can support.

1.4 Overview of City Efforts to Date

This project builds on a number of initiatives already underway to create a Green City, including installation of multiple green stormwater infrastructure projects such as rain gardens, a green rooftop, stormwater wetlands, stream restorations, rainwater harvesting, and permeable pavements. The City also has an urban forest management program; a focus on sustainable and healthful transportation options through trails and bikeways, buses and trolleys, and electric vehicle charging stations; has invested in sustainable agriculture through schoolyard gardens, community gardens, and the City Markets; practices sustainable waste management through recycling and composting; and is involved in improving energy performance through green buildings and renewable energy generation.

The City is committed to the stewardship of its natural assets. Since 2006, the City of Charlottesville has been recognized by the National Arbor Day Foundation as a Tree City USA, which means it manages its urban forest and allocates funds for continued tree planting and care. Charlottesville has also advanced from Bronze to Silver Bike Friendly Community status and from a Silver to Gold Walk Friendly Community rating. What's more, recently the City received designation as a SolSmart Silver City, which gives recognition for adopting a program and practices that lower barriers to solar energy development.

In 2016, the City published an online, interactive map named CityGreen (www.charlottesville.gov/CityGreenMap) to showcase projects and resources around Charlottesville that contributing to its status as 'A Green City'. The map includes numerous themes, with icons linked to specific project/site details, and offers several base maps that users can toggle between, including:

- Green Stormwater Infrastructure: Green stormwater infrastructure utilizes plants, trees, and other measures to mimic natural processes that control and treat stormwater before it enters surface waters. It includes practices such as vegetated roofs, bioretention, tree planting, permeable pavement, and rainwater harvesting. These practices intercept, evaporate, transpire, filter, infiltrate, capture, and reuse stormwater.

- Sustainable Buildings & Energy: Green buildings increase the efficient use of energy, water, and materials while reducing building impacts on human health and the environment. Renewable energy systems also can reduce operating costs and greenhouse gas emissions. The City encourages sustainable building practices

and has completed several projects to demonstrate this commitment, such as the Downtown Transit Center, which is a LEED Silver building.

- **Natural Resources:** Stewardship of natural resources in an urban environment can lead to clean air and water, diverse forests and plant communities, healthy habitats, access to outdoor recreation and natural beauty, and management of the city's historic landscape.

- **Sustainable Agriculture**: Local farmers markets and community gardens showcase local produce, options to grow fruits and vegetables, and how to access community gardens.

- **Sustainable "Getting Around"**: Charlottesville encourages sustainable options for getting around town, including public transit, bike and pedestrian infrastructure, ride sharing, and alternative fueling locations.

- **Sustainable Waste Management**: Reduce, reuse, recycle (or compost)! The most effective way to reduce waste is not to create it in the first place. The City promotes reducing, reusing, and recycling/composting items to save natural resources, reduce costs, and protect the environment.

2. How Green Is Charlottesville?

The most direct way to determine how green a city is entails mapping its green assets to catalog their location and extent. This project created asset maps of green features in Charlottesville. Using the city's tree canopy data and other data, the GIC and the City developed new maps to demonstrate how to improve connectivity, walkability, and greening of the city's landscapes.

The maps and data analysis will help the City:

- Recognize overlap between different types of natural and cultural assets, and how they support one another.
- Plan for a strategic network of green infrastructure and maximize co-benefits by planning for related goals, such as re-greening an area for environmental health while also restoring a commercial area.
- Analyze scenarios by using GIS to visualize how new plans and proposals might affect the city's green infrastructure.

The maps show how GI supports important goals such as clean water, livable neighborhoods, settings for cultural sites, recreation, and also social equity in terms of how assets are distributed citywide. As digital files, the maps created for this project are 'living' maps that can be updated as the city changes. New data can be added and new projects planned by using the maps to inform where there are gaps in green infrastructure assets or where there are important resources that need protection or restoration.

2.1 Tree Canopy

When evaluating the ecological health of an urban area, tree canopy is a common metric. Urban tree canopy (UTC) is a measure of how much of the city is covered by trees. In 2015, the City conducted a canopy assessment which established that 45% of Charlottesville is covered by tree canopy (including both public and privately owned land).

However, while 45% is a good canopy coverage, the citywide percentage does not tell the whole story. The majority of the city's tree canopy (72%) is on private land, with only about 21% under control of the City (this includes public facilities, parks, and road rights-of-way). This means that most opportunities to add or care for trees are on private property. The key take-away is that taking care of trees in the city will require efforts from *both the private and public sector.* Additionally, the coverage percentage does not take into consideration the condition, age, or type of the trees; nor does the percent of canopy coverage alone provide insight into distribution, connectivity, or how the canopy can be integrated into future planning efforts.

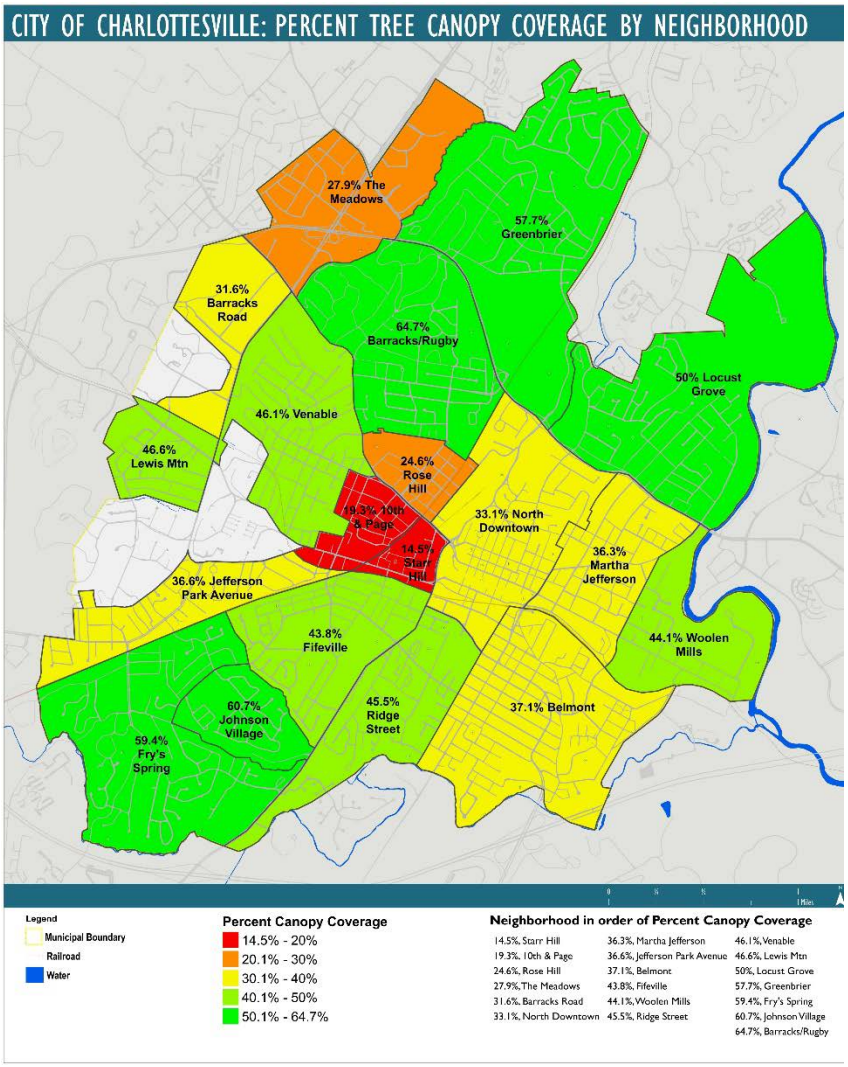
The Urban Forest

In urban areas, it is useful to identify the largest remaining patches of tree canopy. As explained earlier, large patches of canopy can serve as green nodes in the city's green infrastructure network, and have the potential to generate benefits greater than the same number of dispersed individual trees. In terms of retaining tree canopy, it is often simpler and more cost-effective to conserve existing tree canopy than to plant new canopy. For example, to replace

the number of trees in one acre of forested land would require planting approximately 4,500 linear feet of trees (about 2.5 times the length of the pedestrian Charlottesville Downtown Mall). Larger groupings of trees can provide additional benefits that individual trees cannot, such as habitat and stormwater treatment when understory and pervious ground cover are considered. Map 5 shows the overall canopy for neighborhoods of the city for comparison.

Neighborhood	% Canopy
Starr Hill	14.5
10th and Page	19.3
Rose Hill	24.6
The Meadows	27.9
Barracks Road	31.6
North Downtown	33.1
Martha Jefferson	36.3
Jefferson Park Avenue	36.6
Belmont	37.1
Fifeville	43.8
Woolen Mills	44.1
Ridge Street	45.5
Venable	46.1
Lewis Mountain	46.6
Locust Grove	50
Greenbrier	57.7
Fry's Springs	59.4
Johnson Village	60.7
Barracks/Rugby	64.7

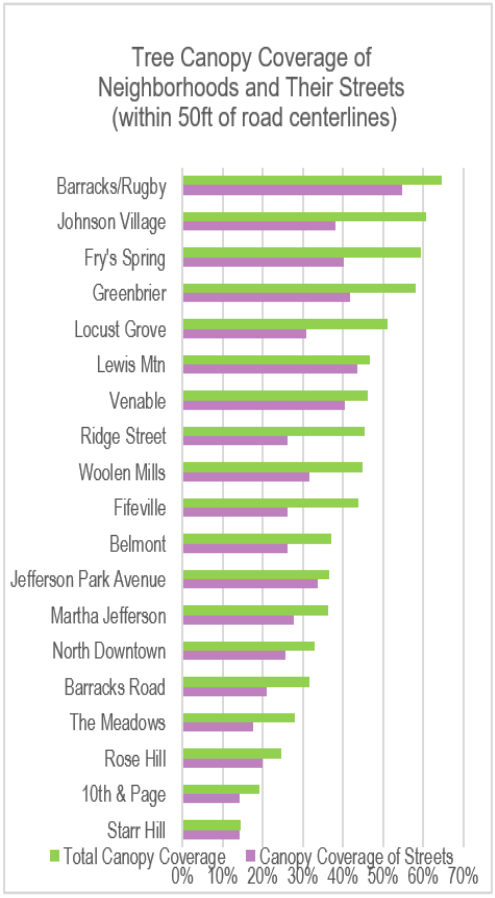
This buffer protects the Rivanna River from runoff and provides habitat at Riverview Park.

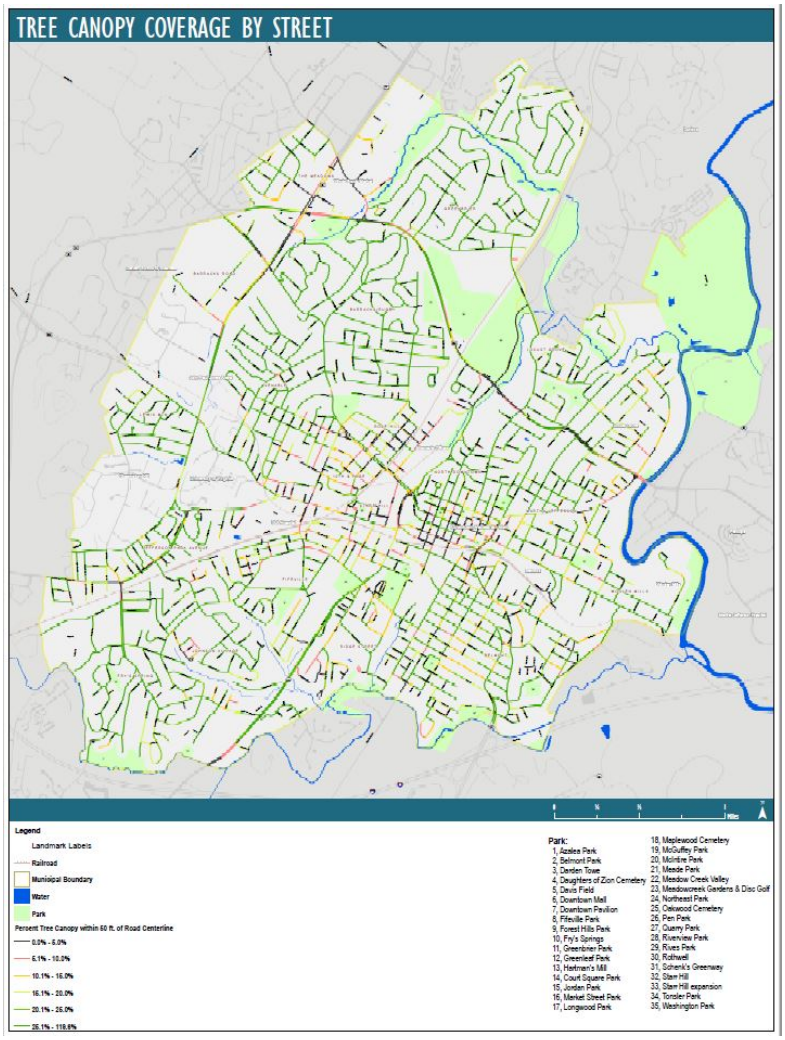


Map 5: Tree Canopy by Neighborhood

Trees provide beauty, cooling and add to property values.

This newly planted oak in Belmont Park will ensure that the lovely oaks that shade this park will be there in the future.



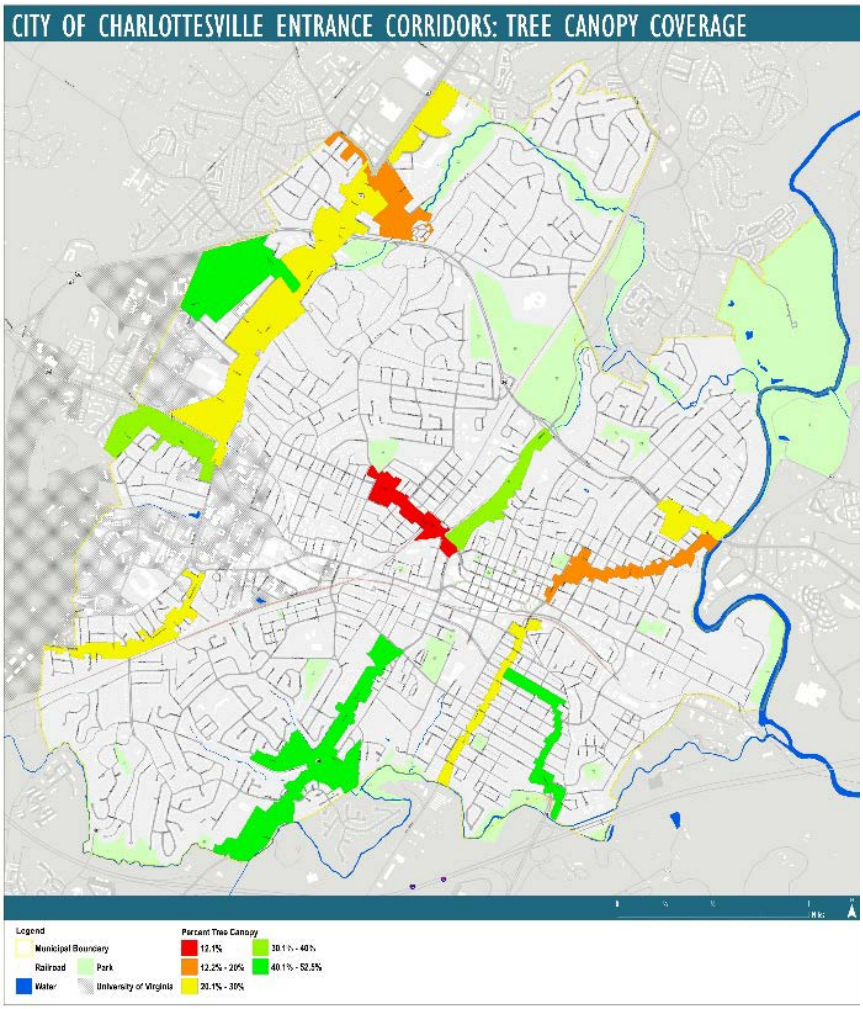


Map 6: Canopy Coverage of Streets

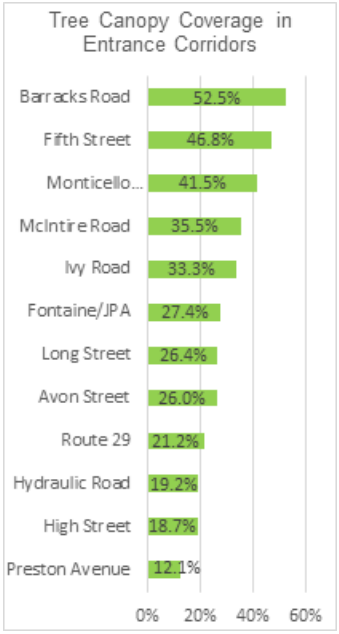
Map 6 shows the total length of roadways within the city in canopy coverage categories with green colors indicating highest levels canopy and red colors indicating the lowest. Well-treed streets feel 'greener' and create a more bike- and pedestrian-friendly environment. When trees are not present, distances are perceived to be longer and destinations farther away, making people less inclined to walk or bike than if streets and walkways are well treed (Tilt, Unfried and Roca 2007). However, the tree coverage of neighborhoods is not necessarily reflective of the coverage of the neighborhood's streets. The results of a comparative analysis are presented in the table on this page. For example, Johnson Village has the largest difference between overall canopy coverage and tree canopy along streets (a 23% difference). Trees along streets provide a great deal of benefits, since streets are often the most visible public spaces in a city. Tree canopy coverage along streets varies considerably in Charlottesville. Map 7 shows the percent tree canopy within 50 feet of road centerlines for each entrance corridor in the city (this 50-foot zone includes both public and private lands, since trees on either contribute to the streetscape).

Why Trees Need Continual Replacement

In urban environments, many trees do not survive to their full potential lifespan. Factors such as lack of watering or insufficient soil volume stress urban trees, stunt their growth or reduce their lifespans. For every 100 street trees planted, only 50 will survive 13-20 years (Roman 2014). Survival rates vary greatly due to differences in planting conditions, species, and other factors such as susceptibility to storms. This requires planting more trees than are necessary to account for future mortality. Whenever possible, existing trees should be conserved since a small replanted tree will take many years to deliver the ecosystem functions of a large tree.



Map 7: Canopy Coverage In Entrance Corridors



Even today's well-treed neighborhoods may not have good coverage in the future if they are comprised of mainly older trees that will soon need replacing. For example, the Locust Grove neighborhood has more than 50 percent canopy coverage, but it may need more new trees planted in the near future to ensure that its high canopy coverage is maintained.

Tree diversity is also a consideration. Cities often plant only one species along a street, which is not only species-limited, but may not even be native or appropriate. If a disease strikes, as happened with Dutch elm disease, it can be totally devastating. That disease killed many of the street trees in American cities in the 1960s and continues to kill elms. It was particularly devastating where whole areas were planted with the same single species. In Charlottesville, Bradford pears and Norway maples are examples of species that are non-native and do not fare well in the Piedmont landscape; Ash trees are projected to be decimated by the invasive Emerald Ash Borer.

Our Urban Forest: Fast Facts & Key Stats

NATURAL ELEMENTS

Tree Canopy in Floodplain: 473 acres, 15% of the city's UTC, 62.5% of the floodplain is forested

Tree Canopy within 50 ft. of Streams: 293 acres, 9% of the city's UTC, 50ft buffers are 78% forested

Tree Canopy within 100 ft. of Streams: 545 acres, 17% of the city's UTC, 100ft buffers are 71% forested

Largest Distinct Tree Canopy Patches (> 1 acre, 10 m edge): 1,709 acres, 54% of city's UTC

Tree Canopy on Steep Slopes: 542 acres, 17% of city's UTC

HUMAN ELEMENTS

Tree Canopy within 50ft of Trails (Existing): 175 acres, 6% of city's UTC

Tree Canopy within 50ft of Trails (Proposed): 146 acres, 5% of city's UTC

Tree Canopy within 50ft of Bike Corridors (Primary): 44 acres, 1% of city's UTC

Tree Canopy within 50ft of Bike Corridors (Secondary): 56 acres, 2% of city's UTC

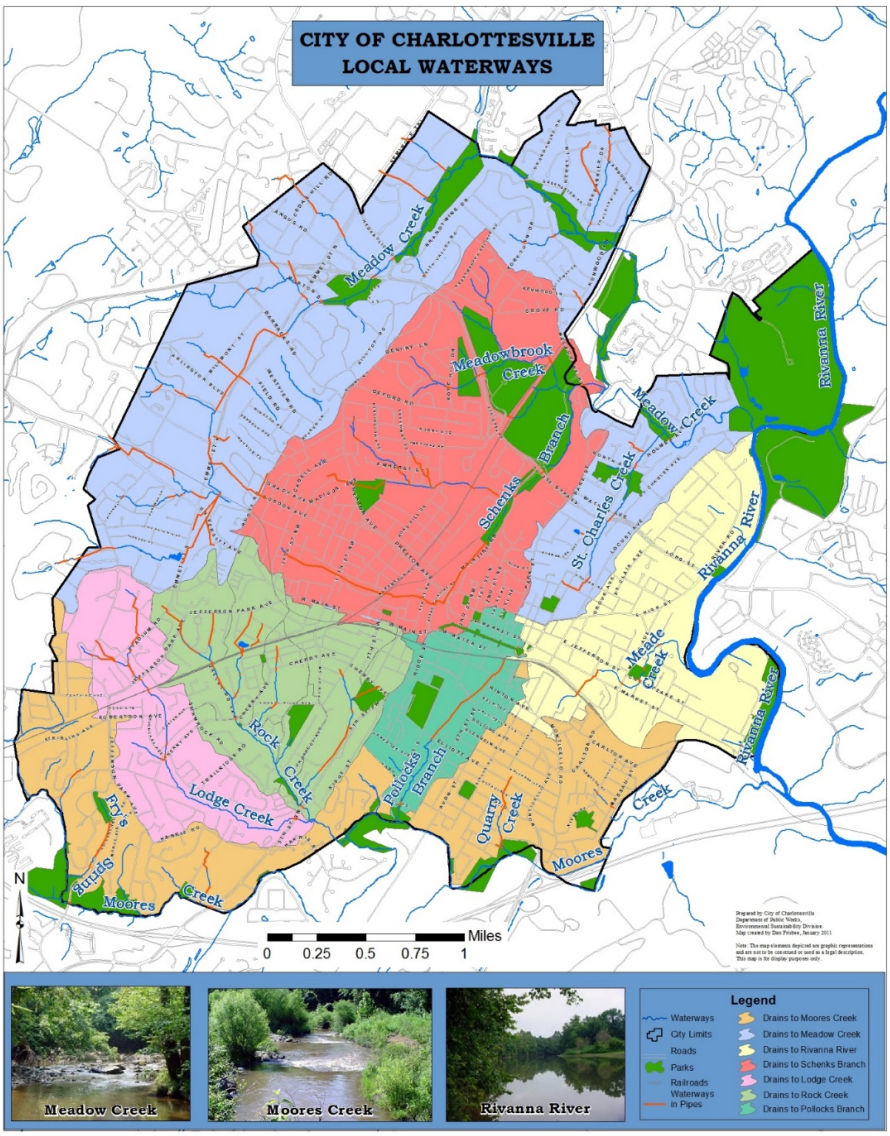
Tree Canopy within 50ft of Bike Corridors (Neighborhood): 167 acres, 5% of city's UTC

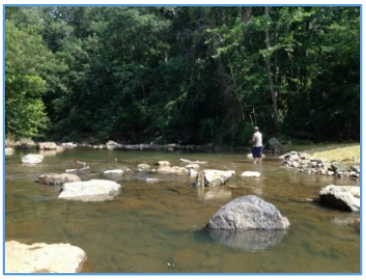
Tree Canopy in Parks: 413 acres, 13% of city's UTC

2.2 Rivers and Streams

A key driver for making Charlottesville as green as possible is supporting the health of local streams. The Rivanna River is the city's major waterway and flows along the city's eastern border. It is fed by two major tributaries in the city; Moores Creek along the city's southern border and Meadow Creek in the northern part of the city. Translated loosely the origin of its name is rive-anna or "River of Anne", named for Queen Anne of England.

Many efforts have unfolded in recent years to celebrate and restore the river. Several groups, such as the Rivanna Conservation Alliance, focus their efforts on education and stewardship of the river. The Rivanna River and many of its tributaries are impaired, requiring attention to restore them to better health. The river is also valued for its role in shaping the city. The watershed was first inhabited by Monacan Indians and later inspired Thomas Jefferson to locate his home along the Rivanna. Jefferson ran for the state legislature on a platform of making the river navigable and many of these structures are visible today.

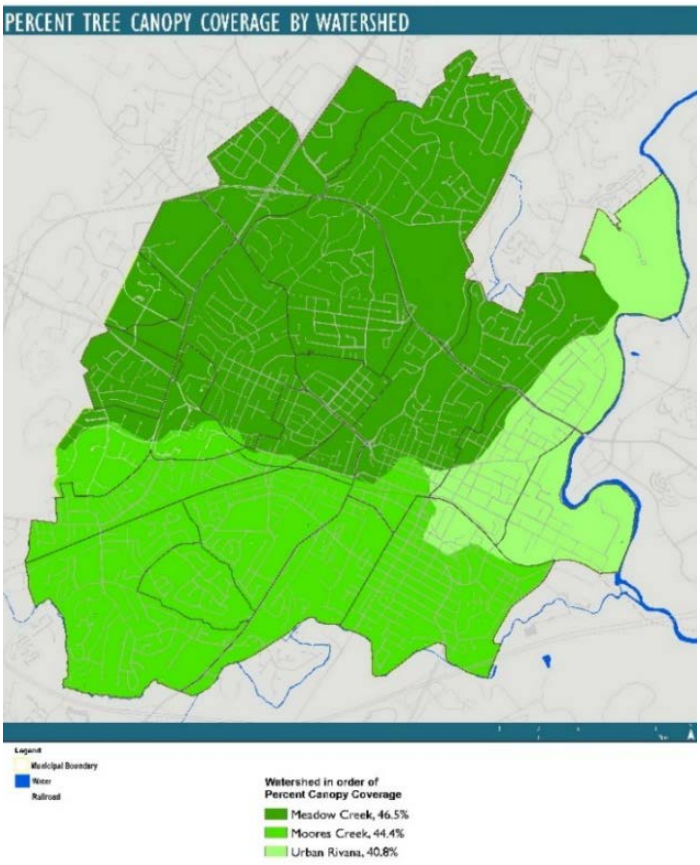




A stream crossing was removed along Moores Creek to restore fish passage and eliminate debris jams.

Stream flow has been interrupted in the city as creeks were piped in the past to make way for development and to accommodate sanitation challenges. While piping streams puts them out of sight and opens land for development, it causes water quality to decline as streams lose oxygen and receive more stormwater from streets, buildings, and parking lots that can contain pollutants such as oil, metals, pet waste, dirt, and lawn chemicals. Charlottesville has taken notable steps in the past decade to improve its stream network. For example, in 2012, a major stream restoration and habitat improvement project was conducted on Meadow Creek and its associated parkland. More recently, from 2014-17, four man-made obstructions in Moores Creek were removed and stream improvements were made. The pictures to the left show an obstruction (low water bridge) near Jordan Park that was removed by the City to allow for better water flow and fish passage.

A key determinant of the health of a stream is how forested its watershed is, not just along the stream, but overall, throughout its entire drainage area. The map of tree canopy by watershed (Map 8) shows which watersheds are well treed and which could benefit from more tree planting. In urban areas, vacant and underutilized parcels often provide opportunities for revegetation and filtration of stormwater.

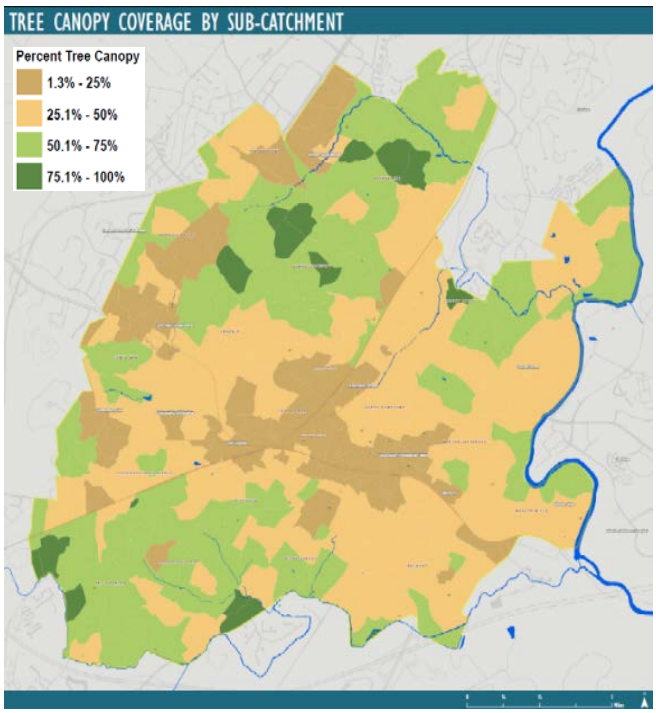


Map 8: Major Watersheds and Canopy Cover

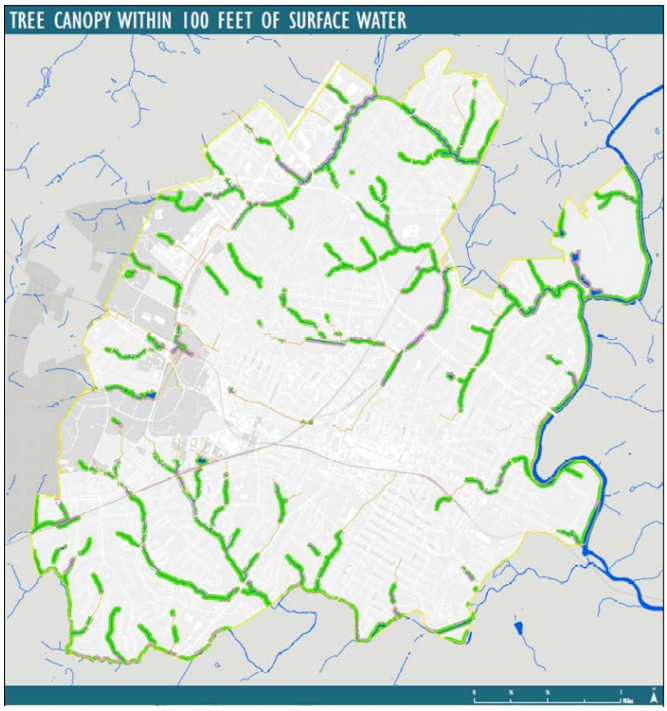
At an even smaller scale, tree canopy by sub-catchments (subsets of the watersheds) can be useful for planning and management, as shown in Map 9.

Stream buffers are very important to stream health. Charlottesville requires protection of 100-foot vegetative buffers on the Rivanna River, Moores Creek, and Meadow Creek. Research shows that a 100-foot vegetated buffer can remove more than 90 percent of the nitrogen, phosphorus, and sediment entering the stream. Nitrogen and phosphorus are nutrients for plants, but in excess cause algae growth that uses up stream oxygen when the algae die and decay. Sediment clogs the gills of fish, smothers aquatic habitat, and carries other pollutants attached to soil particles into the water.

Map 10 shows tree canopy coverage within the riparian buffer zone (defined here as 100 feet) in the city. Overall, these riparian buffer zones have tree canopy coverage of 71.4 percent. The three stream buffer zones that are protected in the city along the Rivanna, Moores Creek, and Meadow Creek have a tree canopy coverage of 71.7 percent. About half (52.6 percent) of all 100-foot stream buffers in the city are protected in some form, through either the stream buffer ordinance, steep slope ordinance, a conservation easement, or are within a City park.



Map 9: Canopy Coverage by Subcatchment



Map 10: Stream Buffers

Fast Facts About Stream Buffers

For protected buffers along Meadow and Moores Creeks and the Rivanna River:

71.7% of stream buffers are covered by tree canopy

71.4% are in private ownership

24.7% are in City ownership

1.7% are on school grounds

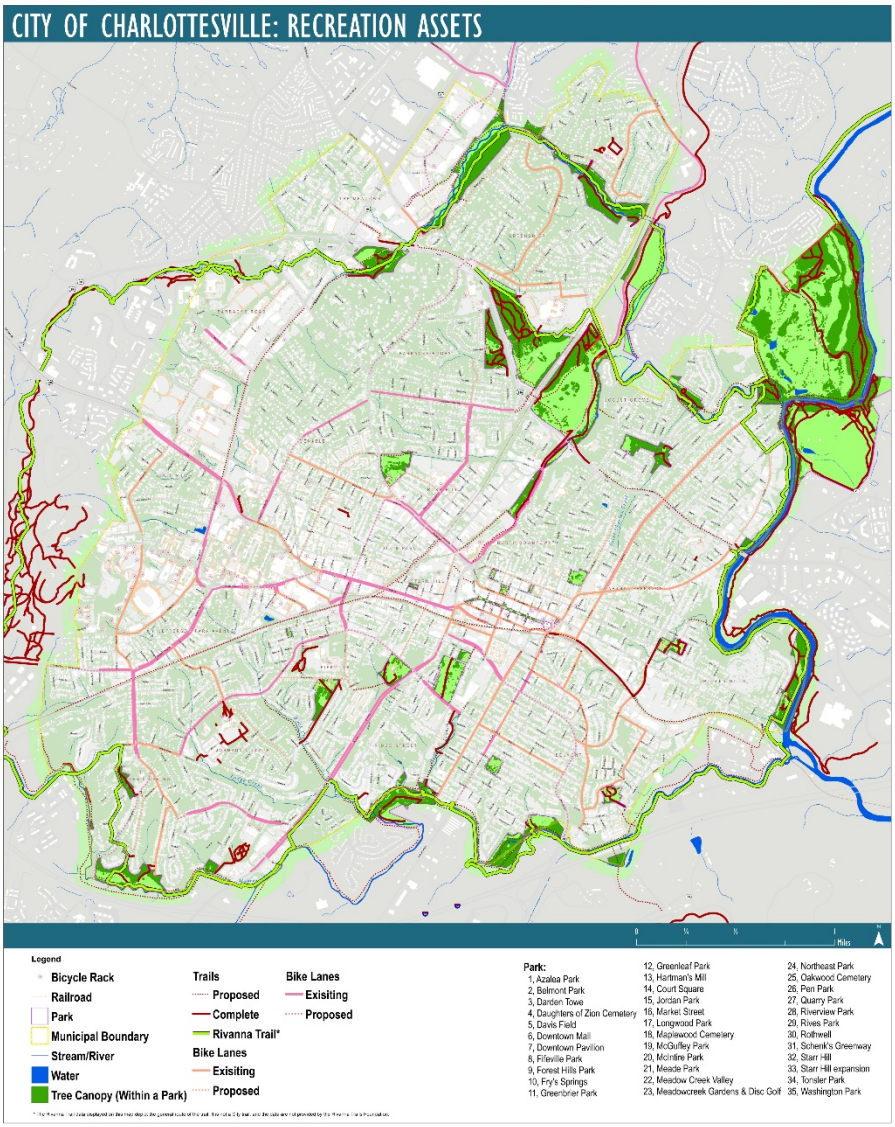
7.1% are on UVA (state) land

For all 100 foot zones along city waterways (both protected by ordinance or not):

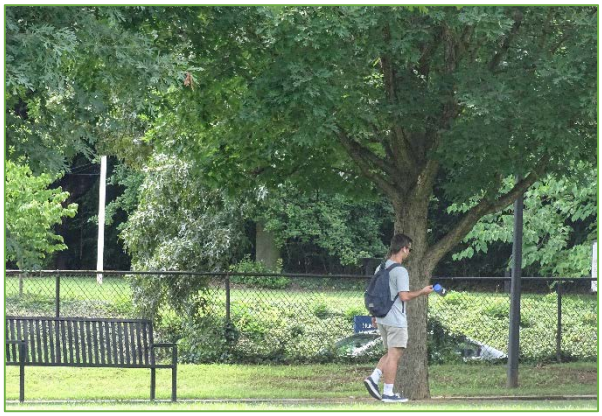
52% are protected by being within the designated stream buffer zone (Rivanna River, Moores Creek, and Meadow Creek), on a steep slope, under easement, or on City park land.

2.3 Parks and Other Open Spaces

Today, the City supports 26 parks, which together offer a wide diversity of uses, from baseball, hiking, swimming, gardening, boating and biking, to enjoying a stroll along a greenway. The green infrastructure of the city supports its trails both by buffering them from urban settings and by providing some truly special nature experiences within and just outside of the city.

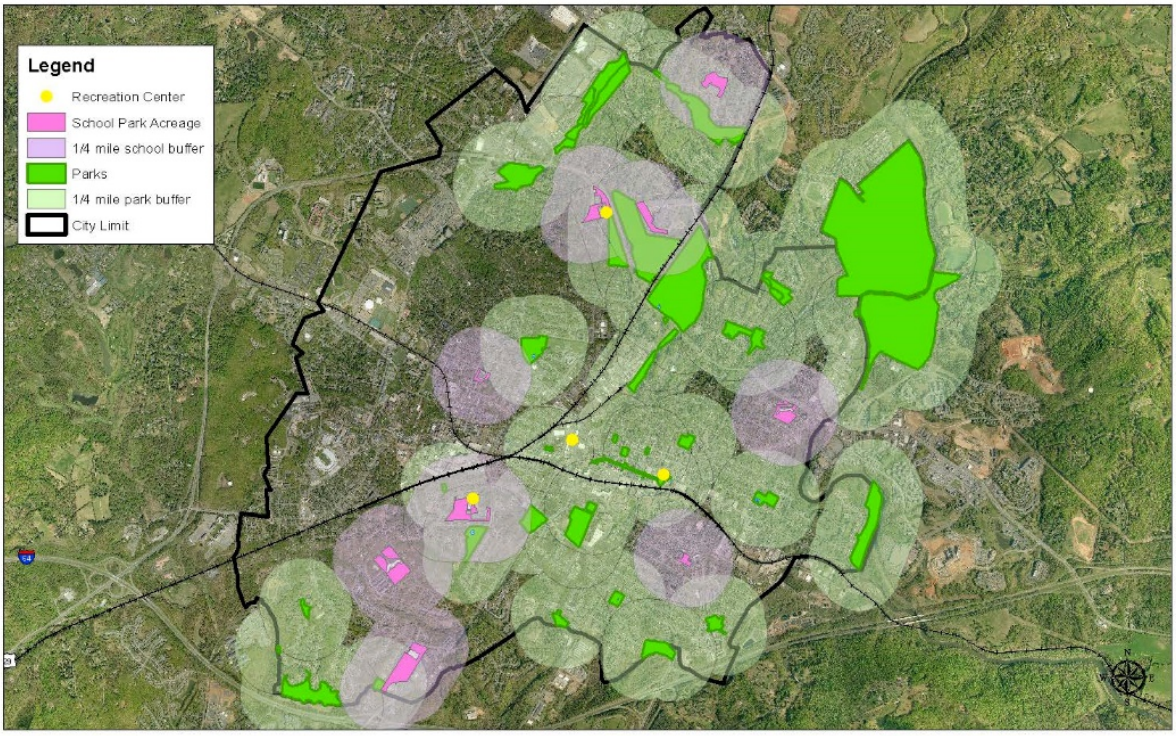


Map 11: Recreation Assets



Trails in City parks are a valuable amenity and allow residents to enjoy the city's green infrastructure.

1/4 mile buffer on parks and schools



Park	% Canopy
Northeast	92
Longwood	90
Jordan	90
Greenleaf	82
Greenbrier	76
Meadow Creek Gardens	76
Starr Hill	75
Riverview	71
Schenks Greenway	70
Quarry	70
Meadow Creek Valley	67
Starr Hill (expansion)	66
Darden Towe	65
Court Square Park	58
Forest Hills	55
Market Street Park	54
Azalea	53
Pen	50
McIntire	44
Downtown Mall	43
Fifeville	41
McGuffey	39
Belmont	39
Washington	35
Tonsler	35
Meade	28
Rives	22

Residents need access to parks and trails where they live. As populations age in place, people look for walks they can take within their neighborhoods, as do young families who desire parks that don't require a car trip to access them.

Not all pedestrians can walk to a park, but as demonstrated by the image above, much of the city is within 1/4 mile of a park or school campus. A key consideration is also how well the City parks function both ecologically and aesthetically. Nature-based recreation is a key component of Charlottesville's green infrastructure network. The chart shows the percent canopy coverage in each park in the city.

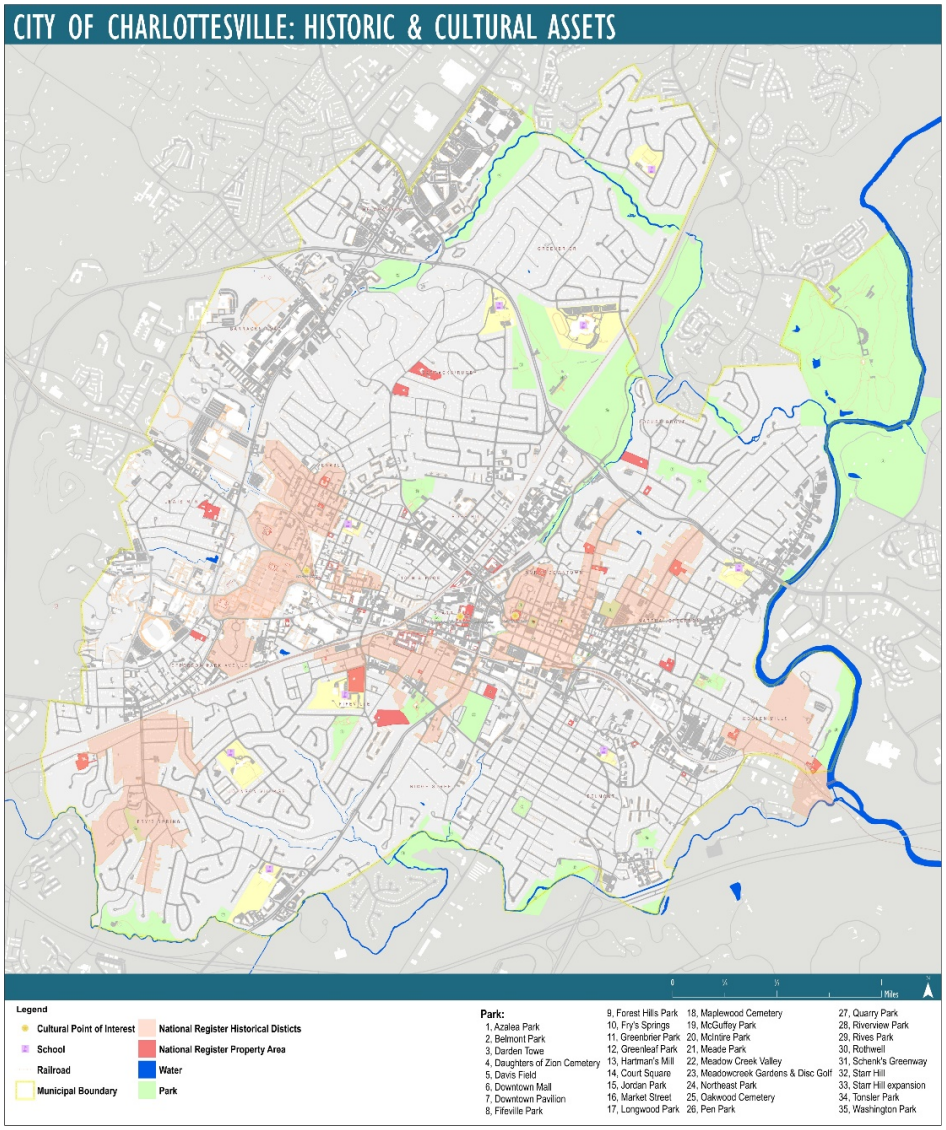
Riverview Park connects to a broader trail network and is easily accessible from adjacent neighborhoods.

2.4 Historic and Cultural Assets

Trees provide the setting and context for many historic buildings and sites in the city. The images below show how trees frame these sites and add to the natural beauty and cultural context, as well as to aesthetic values.

The trees are part of the historical context. For example, Thomas Jefferson led the planting of many of the trees at the University of Virginia. Protecting large historic trees can also meet goals for protecting the city's culture.

The trees on the downtown mall have become part of the fabric of Charlottesville's historic downtown.



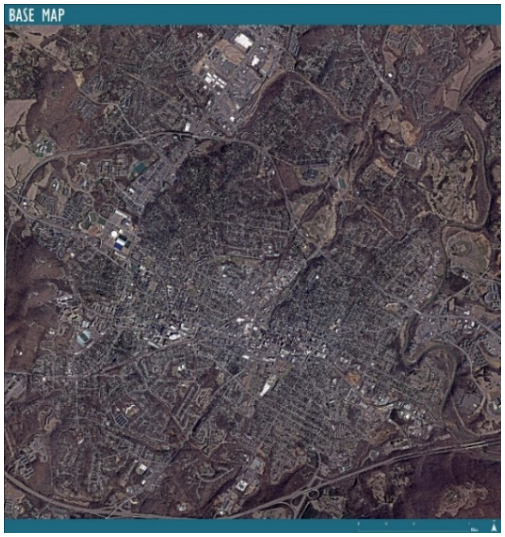
Map 12: Historic and Cultural Assets

2.5 Mapping Connectivity – Creating a City GreenPrint

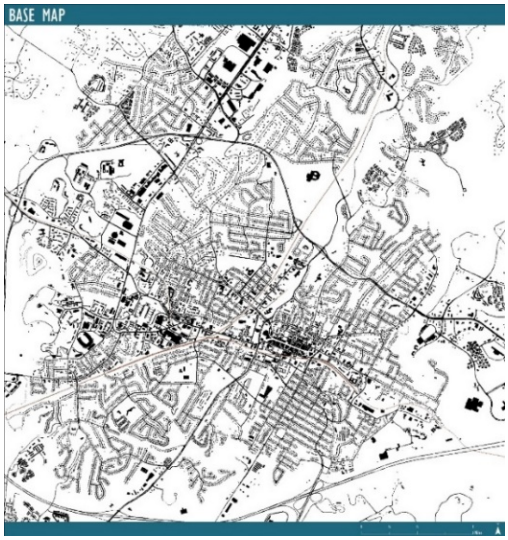
Connected landscapes are more ecologically resilient and also more walkable. When landscapes are connected, if there is a disturbance that damages species in one area, they can repopulate species from adjacent areas. The most obvious connections are streams that flow across the landscape as water carves pathways through the land and provides drainage, migration routes for fish, aquatic insects, amphibians, birds, and people. Much of the city's trail network also follows stream valleys.

As noted earlier, the greener the street, the more likely people are to walk along it. This project used the City's framework streets established through the recently completed Streets That Work initiative and other walkability goals to inform the green asset maps. In addition, trees can make streets safer because they have been shown to 'calm' traffic. They do this by creating visual stimuli – cues that cause the driver to observe additional obstacles and slow down. The opposite of this is a wide, straight road without vegetation – roads that cause people to drive faster and are less safe.

The following map series shows how the city's green network – habitat patches and their connections – was created to form a city 'GreenPrint.' Some connections may be green streets (primarily people connections) while other areas are larger and provide additional benefits for wildlife, water filtration, and cleaning the air. Areas that are protected are noted (e.g. parks, easements, and other open spaces). As the city continues to grow, develop, and redevelop, citizens, builders, and City agencies need to pay attention to protecting and restoring green spaces. The map serves as a GreenPrint (a blueprint, but for habitats) of connections that should be maintained, restored, or expanded. Nodes serve as important points for wildlife, habitat clusters, or gathering spaces for people, while connectors help join them together. This series of nodes and connectors make up the green network map.

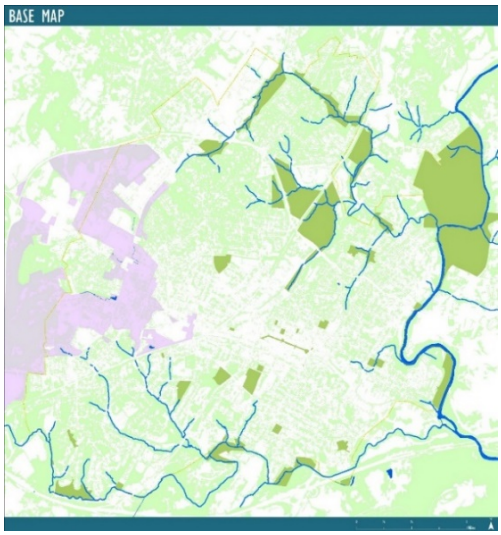


Aerial Map

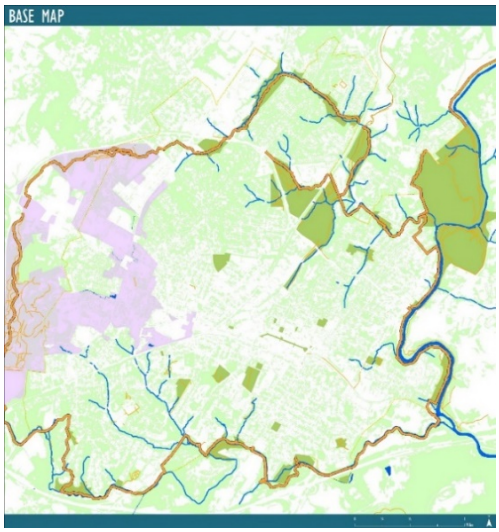


Roads

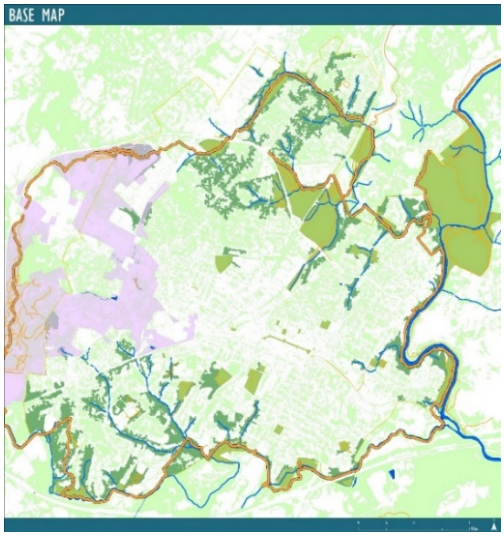
Tree Canopy



Stream Network & Protected Open Space



Trail Network

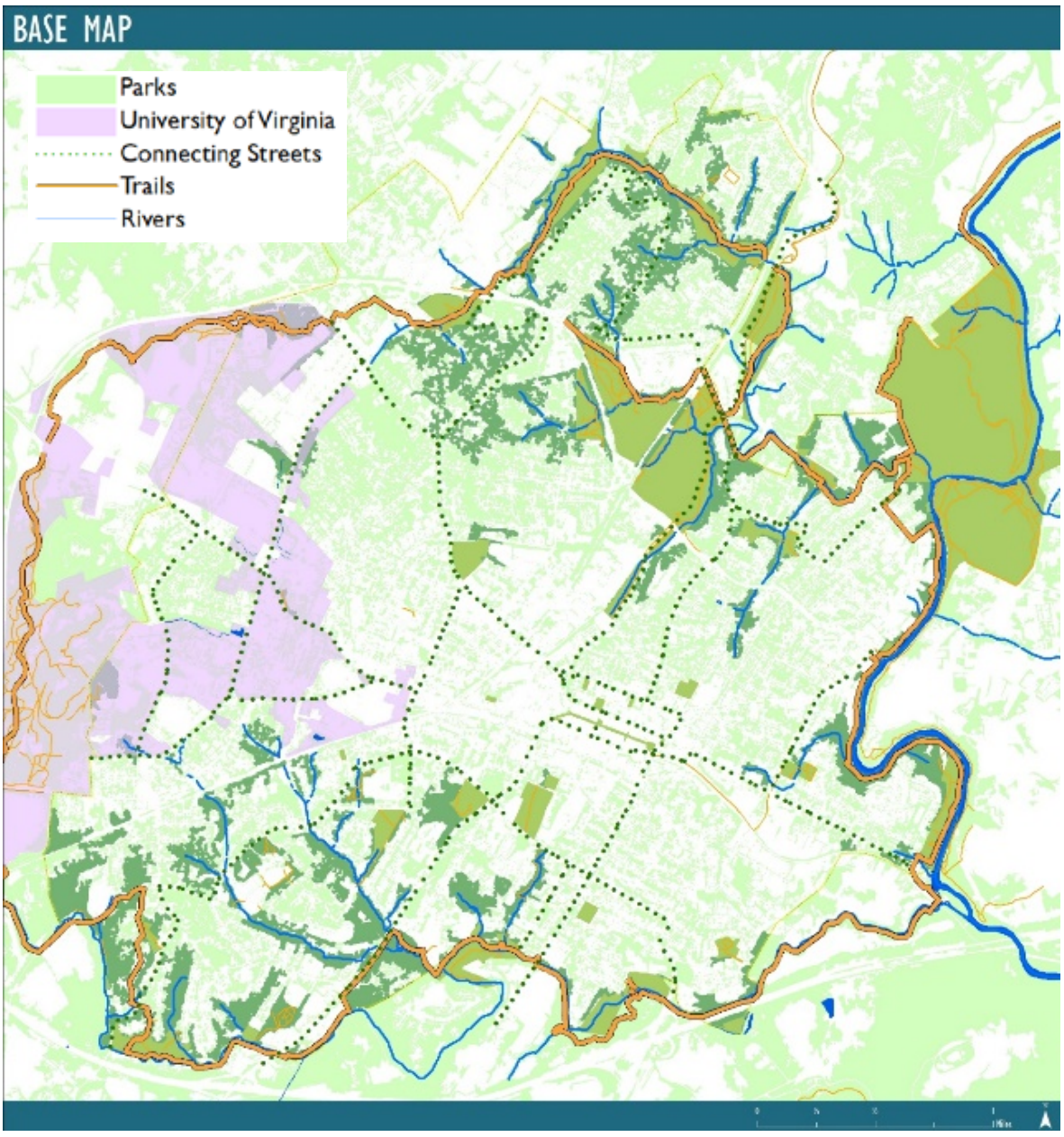


Large Supporting Canopy Patches

All of these maps were combined together to form the city's green infrastructure network. The green network map shows several key elements that contribute to the 'green network' in Charlottesville:

- ✓ Large tree canopy patches (nodes)
- ✓ Vegetated stream buffers and floodplains (connectors)
- ✓ Parks and University of Virginia (nodes)
- ✓ Framework streets that connect nodes
- ✓ Bicycle lane corridors

This is a combination of assets, both natural and constructed, that meet the City's planning priorities (framework streets, trail plans, sidewalk plans) for connecting people across the city. Adding framework streets as green threads forms the final connective green tissue to create a network.



Map 13: Combined Map of Assets and Pathways Creates a City 'Green Print'

2.6 Smaller Scale Opportunities

In addition to meeting local aspirations for robust green infrastructure for a variety of local benefits, Charlottesville is in the path of a major monarch butterfly migration. The monarch has declined to historically low levels and in 2017 fell 30% below its long-term population average. There are several causes for this decline, but the chief one is habitat loss along the monarch's migration route. Even areas within the city contribute to habitat for butterflies and other pollinators. To learn more about the monarch and what plants help them see the *Resources* section.

Since most of the city's land is residential, perhaps the greatest gains in small habitat patches can be made one yard at a time. Pollinators such as birds, bees, and butterflies can take advantage of smaller patches of habitat across yards. There are increasing reports that with bees threatened by habitat loss, pesticides, and climate change, healthy diverse urban green spaces may provide critical resources to these essential pollinators.

Given a growing understanding of the value of biodiversity conservation and urban ecosystems, habitats of all scales play an important role.

3. Informing City Decision-Making: Possible Planting Areas

The City can use the green asset data collected and analyzed by this project to inform zoning decisions, as well as to update its Comprehensive Plan. When meeting with prospective land developers, the GreenPrint maps can be used to show where green space is desired or key connections could be kept open across multiple parcels to preserve current corridors or allow for future trails or pollinator, bird, mammal, and amphibian pathways. City staff can also use the maps to prioritize where trees should be planted or to form the basis for grant proposals and funding applications.

3.1 Using the Data to Analyze and Evaluate Benefits and Opportunities

The City held a workshop in summer 2016 that included members of various City bodies and committees, including the City Council, Planning Commission, Tree Commission, and the PLACE and Streets That Work task forces. The group was oriented to key concepts in green infrastructure planning and was invited to review maps of city assets in specific focus areas. The purpose was to test ideas for how to use the data for on-going City planning efforts.

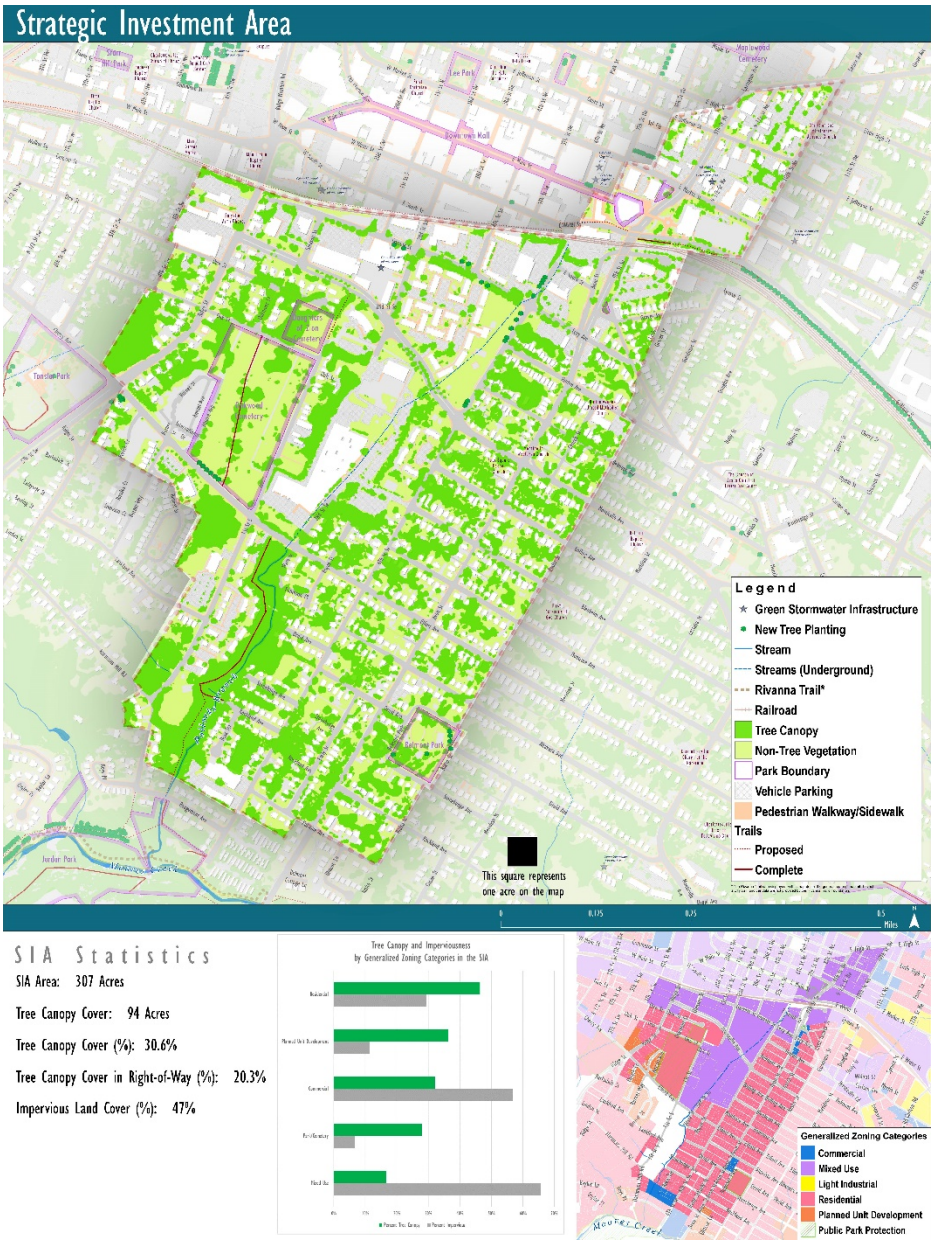
Participants at a City workshop reviewed ideas for how to grow the green network and meet City goals.

The maps on the following pages are an example of scenarios in which the data can be utilized. Application of this data process was demonstrated at three scales:

- ☐ **Small Area Planning:** Strategic Investment Area
- ☐ **Streets that Work, Framework Streets:** Upcoming Right of Way (ROW) Project Opportunities
- ☐ **Neighborhood Scale:** Areas with Limited Green Infrastructure

As participants worked with the maps, they were able to understand what areas were candidates for tree planting versus those that had too many constraints caused by utilities.

Workshop discussions included how to use other green features, such as green walls, where trees are not appropriate because of vertical constraints. Places that are highly impervious, such as plazas, might be made more infiltrative with permeable pavements and collection tanks, which could be placed under the pavement to hold and store water.
Most participants agreed that anytime new developments are considered, the question should be asked, "Is there a green connection that can be made here?". Others suggested that trees should be considered as a utility, since they function to store, detain, clean, and transpire stormwater. Collaborating more carefully with utility placement was another suggestion, as was a rebate program to those who plant trees to offset the City's stormwater utility fee.



The maps helped to show which parcels could best lend themselves to tree planting. Participants also noted that many of the best options to plant trees were in yards, where there are more consistently good planting areas, rather than along streets.

In the Strategic Investment Area, trees were noted as an important consideration in planning efforts. For example, trees have been shown to reduce vacancy rates of building rentals and increase money spent on shopping. Participants suggested that in small-area plans, such as the Strategic Investment Area, planning for trees should be a key consideration.

A compilation of comments collected at the workshop is included in Appendix A. Members of the City Tree Commission appreciated the ability to use the planting area analysis to consider realistic milestones for meeting canopy goals and for replanting areas

downtown. They also noted the importance of focusing on neighborhoods where trees are older and stated that the next generation of trees should be planted now, in order to maintain future canopy levels.

Parcel-Based Metrics for Multiple Benefits: Environmental, Economic, Social Benefits

Parcel-based metrics (using parcels as the geographic unit of measurement) help estimate where green infrastructure currently provides, or may in the future provide, benefits. For example, if the City is deciding which parcels to recommend for green infrastructure when it is working with a developer to preserve trees or is trying to meet its goals to protect a local creek, it may want to flag those parcels that had high environmental weightings.

The following chart lists the benefit metrics that were used and those measurement variables used to rank the parcels.

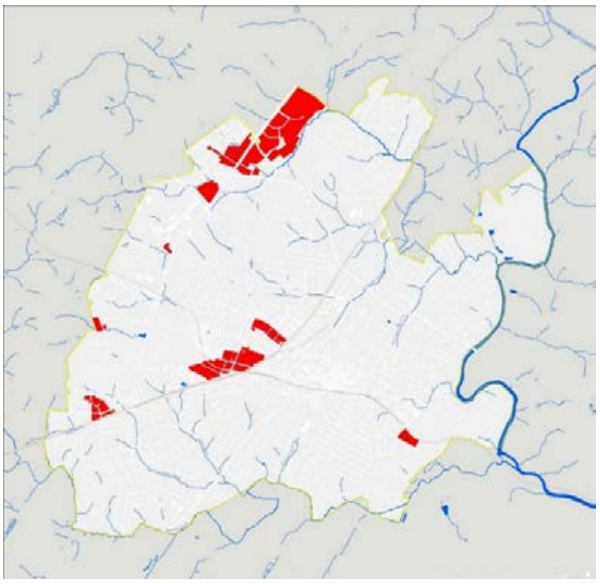
Benefit	Measurement Variable
Air Quality	Proximity to high-traffic roads
Cooling (Heat Island)	Daytime Thermal Radiation
Aesthetics/Beautification	Entrance Corridors
Commercial Enhancement	Commercial Zones
Water	Steep Slopes (>25%)
	Impervious Surfaces (Non-Building)
	Flood Prone Areas (Flood Zones)
Population	Population Density
Sociodemographic	Median Household Income
Public Health/Walkable Neighborhoods	Current & Future Trails/Sidewalks
	5-minutes walk zones to schools
	Current and Future Bike Lanes

Data Use Strategies

Three main ways the City could use these data are:

1. **To determine details about sites of interest:** For example, any site in the city can be queried individually to see which benefits may be associated with the site. If a parcel is proposed for a rezoning, the City can use the database to see if that parcel has particular benefits (economic, environmental, or social) and whether those benefits will be preserved or lost under a new use.

2. **To create city-wide parcel filters (to find all parcels meeting specific goals):** These data can be easily filtered to find parcels that meet a specific set of criteria.



Parcels in highly impervious subcatchments and in certain census block groups

For example, trees provide air quality benefits by removing pollutants from the air. High-traffic roads were mapped, and parcels that were adjacent to these roads were flagged as locations that have potential for generating significant air quality benefits. Thus, these parcels could be targeted for outreach to private landowners to encourage them to protect or replant trees on these properties.

The parcel data can be queried easily to quickly find parcels that meet multiple criteria. For example, it is possible to query which parcels are within entrance corridors, in commercial zoning districts, and within a 5-minute walk zone of a school. This quickly identifies areas where additional trees (or other green infrastructure assets) may have beautification, economic, and public health/walkability benefits all at the same time. This can be used to justify budgeting for more tree planting in areas that will have multiple benefits.

3. **To create city-wide overlays (to find parcels that meet multiple goals):** Weighted rankings can be used to create a single 'score' that takes into account multiple criteria. For example, parcels can be ranked by how many 'environmental' benefits are associated with the parcel (air quality, water quality, *etc.*)

Example parcel filter (see map on previous page): Parcels in red are those that are in highly impervious sub-catchments (>50%) **and** in census block groups with less than $40,000 median household income.

Possible Planting Areas and Sites

In addition to knowing what tree canopy the city has currently, it's important to learn where new trees could be planted. This project provides the City with a tool to see whether and where there may be areas to plant trees. The City's project to map its tree canopy also included a Possible Planting Area Analysis.

While the Possible Planting Area (PPA) map estimates areas where it is feasible to plant trees, it is not a planting suitability map. In this analysis, the map of refined PPA excluded areas with extensive underground utilities (such as large pipes) to ensure that sites indicated for planting would not require extensive relocation of utilities or end up being undersized planting areas. This provides a more realistic map of where trees can actually be planted to survive and thrive.

The PPA was originally created by mapping several types of land cover, including turf grass and bare soil, while excluding land cover types where trees cannot be planted, such as buildings and roads. This analysis only considers pervious PPA and does not include impervious PPA, such as parking lots, even though it may be possible to plant trees in these areas by removing asphalt. Additional exclusion factors (places where trees cannot be planted) were applied to refine the PPA:

- The Meadow Creek Restoration area (an area that was replanted, but not captured in land cover data)
- Railroad rights-of-way
- A 10-foot buffer around existing trees
- A 10-foot buffer around existing buildings
- A 15-foot buffer around recent tree plantings
- A 10-foot buffer around underground utilities
- Sidewalks
- Private alleyways (alleyways that do not receive public maintenance, but must remain clear for vehicles)
- Un-addressable buildings – ranging from sheds to parking decks

Additionally, points were given a 40-foot separation distance. A 15-foot buffer was used around the available dataset of overhead utilities, but points that fell within this buffer were not removed, only flagged as constrained. Trees can still be planted in these locations; they are simply not ideal for larger trees. These final two constraints were chosen because they are consistent with codes and best practices for tree planting and maintenance in Charlottesville.

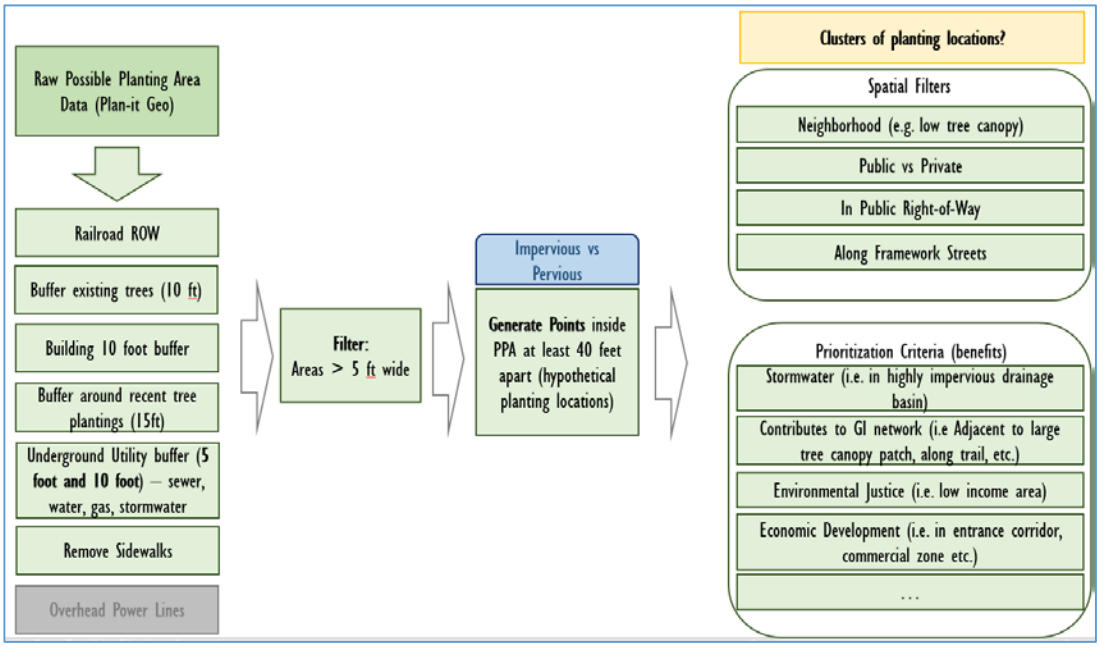


Diagram illustrating the process of refining the original PPA data

The above image series highlights the difference between possible planting areas and possible tree canopy. Possible planting areas (highlighted in yellow in the center image) estimate area in which a tree could be planted. This is different than potential tree canopy (highlighted in orange in the image on the right), which can overhang areas in which it is not possible to plant a tree (like a road). This means that resultant canopy – after planting – is greater than the PPA due to the overhang by the canopy.

Method to Calculate PPA

The basic outline of this process was to first update the provided 'possible planting area' (PPA), then create tree points within the final PPA, calculate a variety of metrics to attach to each point, and finally create map books to guide future tree plantings. These data have been provided to the City's GIS staff.

A variety of datasets were used to complete this analysis. The primary data source had already been created for the City of Charlottesville by consultants who had developed a full land-cover classification and derived the PPA from that land-cover dataset. However, their product was derived from 2014 aerial imagery, which has some major limitations. For example, its analysis only includes trees planted prior to 2014, unless a tree's specific location has since been tracked by the City.

Many of the datasets used as both exclusion factors and point metrics are updated on a regular basis by City staff. This will allow the City to update this analysis in the future and prevent it from becoming outdated.

Potential tree planting locations are semi-random points that have been placed to maximize the number of trees that can be planted in the PPA.

Before planting, the PPA still needs to be field-checked and compared against unseen barriers, such as unmapped overhead utilities, other potential uses of the area, and any development plans. For example, it may not be desirable to plant trees alongside an avenue that is due to be widened, or in an open area that is used for active recreation.

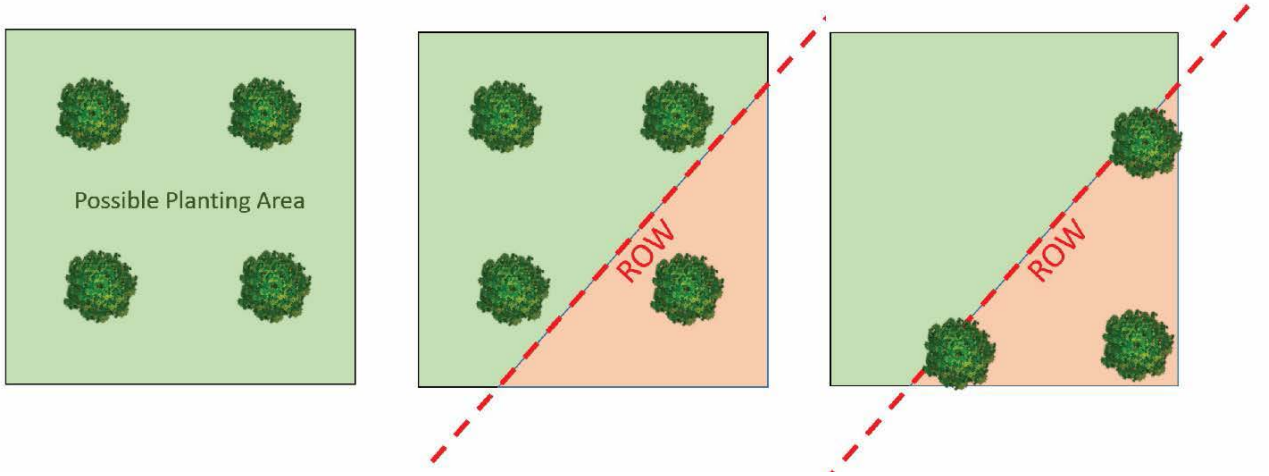
Following the identification of possible planting areas, further analysis was performed to estimate potential tree planting locations within the PPA. The *possible tree planting sites* dataset is a result of a high-level GIS analysis, serving as first-level screening of where there may be space for tree planting within the city. Additional on-the-ground field assessment is necessary to determine if these sites are suitable or appropriate for planting.

The information is intended to be used as a high-level, city-wide planning tool. A citywide screening of where there may be potential to plant trees is a useful first step in understanding not only where and how many trees might be planted, but also what benefits might be associated with planting in a given location.

These points were created by the Green Infrastructure Center (GIC) using the best available GIS data, not field surveys. The datasets included in the methodology are under constant revision, and may not be perfectly accurate or current. This analysis is not a suitability study and does not represent recommended tree planting sites. The locations identified may include areas where trees

could not be physically planted, and could also include areas that may not be suitable for planting. Further field investigation will be needed to determine if the points identified are suitable for planting and to identify the precise tree planting site.

If a metric doesn't have a discrete value, such as population density, it was given a value of 0 if it does not meet the metric, and 1 if it does. Metrics that include Proximity have distances included. For these metrics, a distance of -1 indicates the point falls outside the maximum range for that metric.



For planning and analysis purposes, a number of additional metrics were collected for each identified point. These were:

- Census Data (by block group)
  - Population Density (Persons/Acre)
  - Median Household Income
- Proximity (up to 100 meters) to Major Roads (including ADT numbers)
- Proximity (up to 10 meters) to Trails (Existing and Proposed)
- Proximity (up to 15 meters) to Bike Lanes (Existing and Proposed)
- Proximity (up to 200 meters) to Streams
- Nearby Forest Cores (100 Feet)
- Sub-Catchment Imperviousness Percentage
- Relative Temperature
- Type of Framework Street (50 Feet)
- Zoning
- Steep Slopes
- Floodplain
- Underneath Overhead Power Lines (Dominion Data)
- Entrance Corridor
- State-Owned Property
- City/County-Owned Property
- School Property
- UVA Property
- Walking Distance to Schools (1/4 Mile)

Given interest in potential planting opportunities in the right-of-way, a specific analysis was conducted. Right-of-way possible planting area points are calculated from their own analysis, not a selection from all potential tree planting locations. This is because the points were placed randomly to maximize the number of points. The random points did not take into account the right-of-way, leading to an under-estimation of points that could fit into the right-of-way. A second, identical calculation was done on just the PPA within the right-of-way so that the number of points were not under-represented. The points in the right-of- way should be considered as a separate analysis from the map book depicting "all" potential tree planting locations in the city.

This series of images above demonstrates the difference between the possible planting points generated specifically inside the right-of-way. The image at left shows where possible planting points would be located by ArcGIS to maximize the number of points in a given possible planting area (green square) with a specified minimum spacing between points. The middle image demonstrates what would happen assuming the portion of the PPA shown in orange was in the ROW. Under this scenario, only one point would be found to be in the ROW. The image at right shows what would happen if the same analysis is

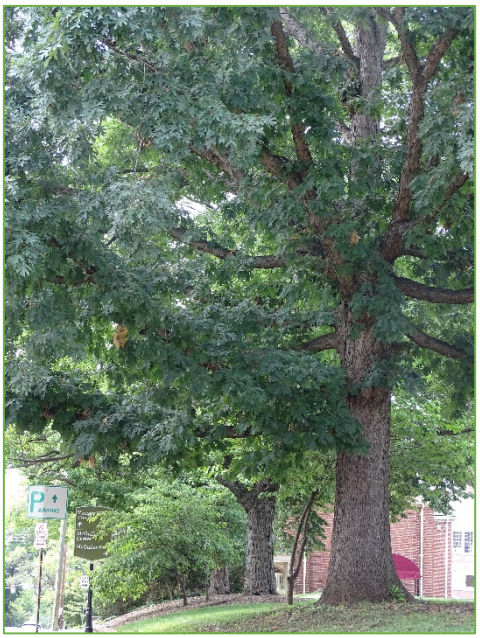
run only considering the ROW. Under this scenario, three points can be located in the ROW, using the same assumptions. Thus, if one is interested in only what can be done in the ROW, the ROW-specific analysis should be used, as it looks at how planting sites can be maximized in the ROW.

3.2 Example Weighting Schemes for Creating a Composite Score Using the Parcel Metrics

Another way to look at data for how to green the city is to consider benefits provided at the parcel scale. To account for multiple metrics simultaneously, the GIC created scoring scenarios using the parcel metrics. Doing so helps address the question, "If a green infrastructure asset (e.g. tree planting or rain garden) were to be located in a given parcel, would multiple benefits be achieved?" A composite score can be created by combining or adding several metrics together. The metrics chosen depend on the desired outcome of a green infrastructure project. Each metric should be normalized to a consistant scale before combining with others (e.g. convert each metric to a number between 0 and 1, or 1 to 9).

The three example scoring scenarios on the following page show how different metrics can be weighted to influence a composite score. The scenarios are loosely based around "environmental," "economic," and "public health" related benefits, with the understanding that many benefits are interrelated. The green 'plus' symbols indicate if a metric has been given relatively more weight when the metrics are combined (metrics with a single plus symbol are weighted higher than those without, and metrics with a double plus symbol are weighted higher than those with a single plus symbol).

The map of a portion of Charlottesville immediately below the charts shows an example of how weighting can influence the resulting composite score, with green parcels having a higher composite score (more benefits) and red parcels having lower composite scores (fewer benefits).



Environmental Weighting

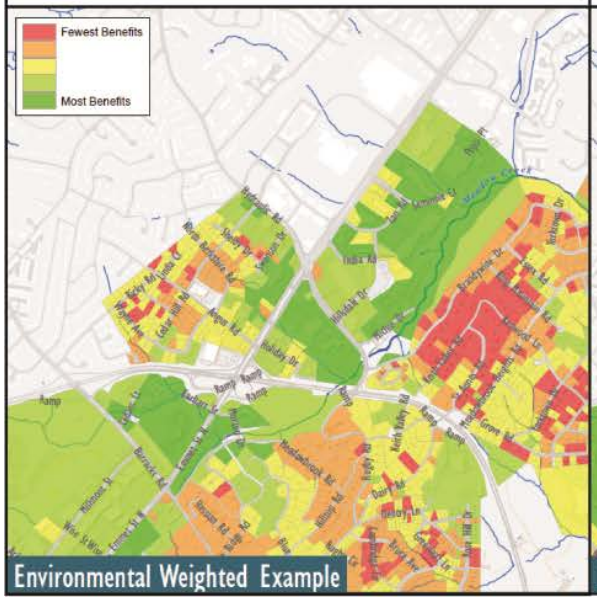
Benefit	Measurement Variable	Weight
Air Quality	Proximity to high-traffic roads	✚✚
Cooling (Heat Island)	Daytime Thermal Radiation	
Aesthetics/Beautification	Entrance Corridors	
Commercial Enhancement	Commercial Zones	
Water	Steep Slopes (>25%)	✚✚
	Impervious Surfaces (Non-Building)	✚
	Flood Prone Areas (Flood Zones)	✚✚
Population	Population Density	
Sociodemographic	Median Family Income	
Public Health/Walkable Neighborhoods	Current & Future Trails	
	5-minutes walk zones to schools	
	Current and Future Bike Lanes	

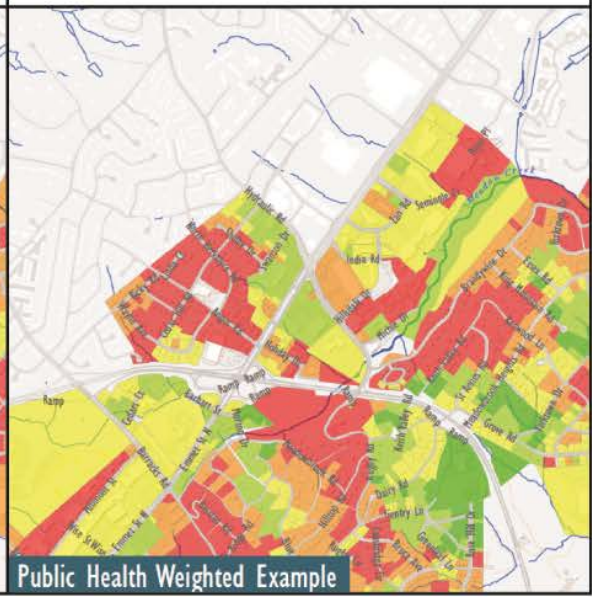
Economic Weighting

Benefit	Measurement Variable	Weight
Air Quality	Proximity to high-traffic roads	
Cooling (Heat Island)	Daytime Thermal Radiation	
Aesthetics/Beautification	Entrance Corridors	✚✚
Commercial Enhancement	Commercial Zones	✚✚
Water	Steep Slopes (>25%)	
	Impervious Surfaces (Non-Building)	✚
	Flood Prone Areas (Flood Zones)	✚
Population	Population Density	
Sociodemographic	Median Family Income	
Public Health/Walkable Neighborhoods	Current & Future Trails	
	5-minutes walk zones to schools	
	Current and Future Bike Lanes	

Public Health/Social Weighting

Benefit	Measurement Variable	Weight
Air Quality	Proximity to high-traffic roads	✚
Cooling (Heat Island)	Daytime Thermal Radiation	✚
Aesthetics/Beautification	Entrance Corridors	✚
Commercial Enhancement	Commercial Zones	
Water	Steep Slopes (>25%)	
	Impervious Surfaces (Non-Building)	
	Flood Prone Areas (Flood Zones)	
Population	Population Density	✚✚
Sociodemographic	Median Family Income	✚✚
Public Health/Walkable Neighborhoods	Current & Future Trails	✚✚
	5-minutes walk zones to schools	✚✚
	Current and Future Bike Lanes	✚✚



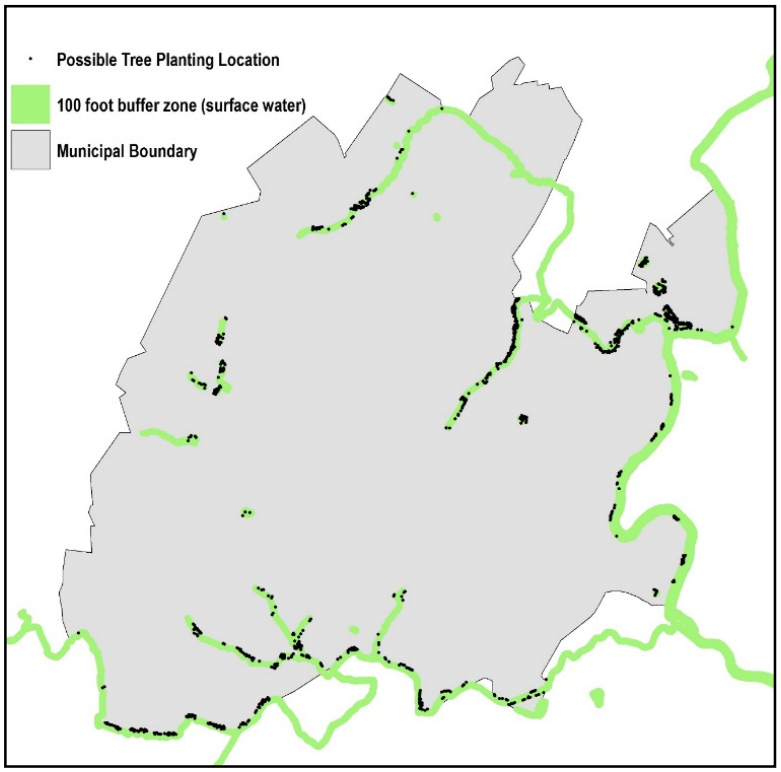


3.3 Examples of How the Possible Tree Planting Points Data Can Be Used

Finding Potential Opportunities for Restoring Stream Buffers

In 2005, Charlottesville adopted a Water Protection Ordinance that included 100-foot stream buffer protections for three city waterways, Moores Creek, Meadow Creek, and the Rivanna River. The possible tree planting points dataset can be used to explore opportunities to plant trees within 100 feet of surface waters, thereby improving the quality and functionality of vegetated stream buffers.

Approximately 862 points fall within 100 feet of surface waters. These are areas that may warrant further investigation to assess feasibility or see if trees have already been planted in these locations since 2014 (the date of the land cover information that the possible tree planting sites analysis is based upon). This subset of 862 points can be further refined to highlight more specific opportunities. For example, 353 points (41%) are located on City-owned property.

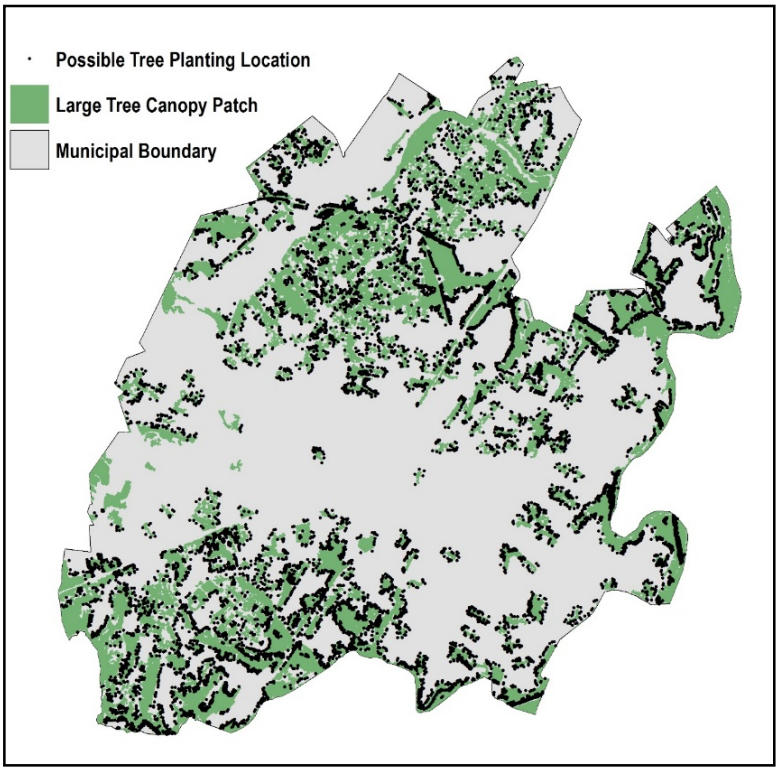


Map 14: Possible Planting Locations in Stream Buffers

Finding Potential Opportunities to Enhance Existing Large Patches of Tree Canopy

Large patches of tree canopy were mapped for the City as part of this project. These include areas equal to or greater than 1 acre of contiguous tree canopy and that are at least 10 meters wide. Large patches of tree canopy, and especially forest cover, can provide benefits that individual trees do not. Trees planted adjacent to these large patches can help enhance these benefits (as the patch effectively becomes larger).

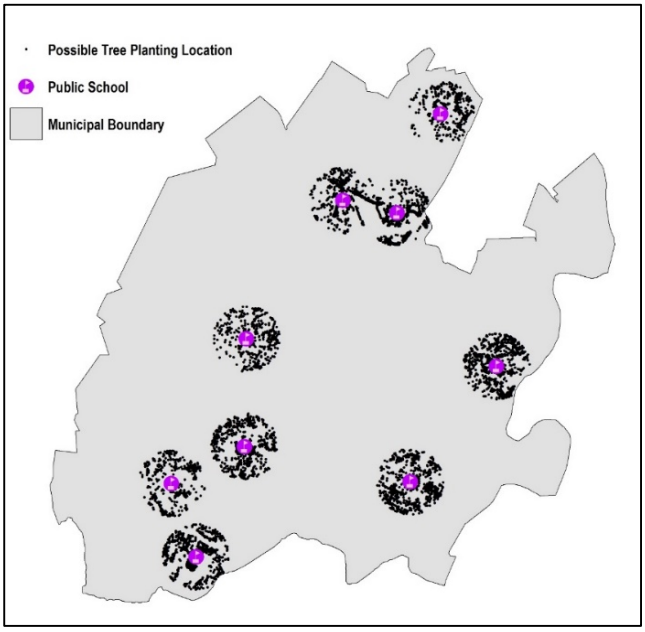
There are 270 patches of tree canopy that meet the criteria above, with a total combined area of 1,709 acres (this comprises 54 percent of the city's total tree canopy). There are 9,272 possible tree planting points that are within 100 feet of a large tree canopy patch.



Map 15: Possible Planting Areas Near Canopy Patches

Finding Potential Opportunities to Promote Safe Routes to Schools

Trees are one of many elements that can contribute to safe and walkable environments, and can help create safe routes for children to walk to school. The map below shows the possible tree planting locations within one quarter mile of public schools in Charlottesville.

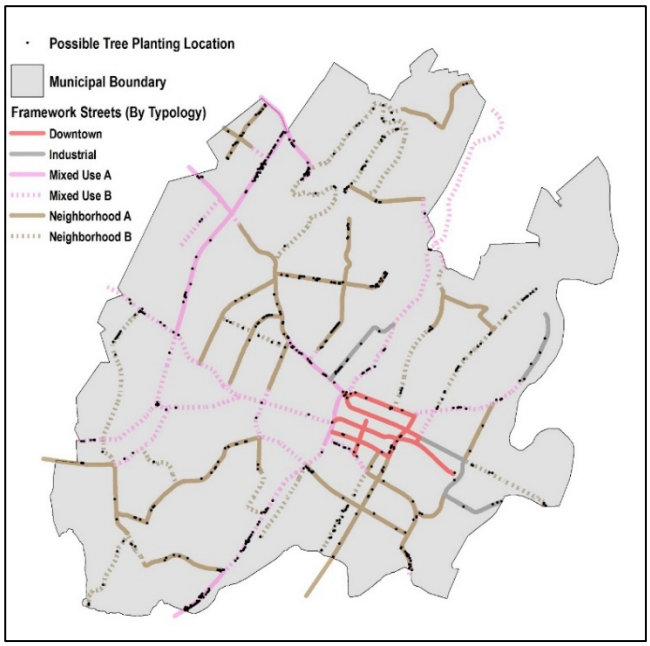


Map 16: Possible Planting Areas Near Schools

Schools	*# of Possible Planting Locations*
Buford	505
Burnley-Moran	590
Charlottesville HS	426
Clark	539
Greenbrier	333
Jackson-Via	519
Johnson	324
Venable	363
Walker	379

Finding Potential Tree Planting Locations Along Priority Streets

Map 17 shows 567 points that are in the City right-of-way and along a street identified as a "Framework Street" by the City's *Streets That Work Guidelines*. The Streets That Work Guidelines recommend that wherever possible, streets should include green and blue stormwater infrastructure to capture stormwater in the public right-of-way before it enters the City's stormwater system and to accommodate more street trees planted in ways that ensure longevity (adequate soil volume, right species, good maintenance).



Map 17: Possible Planting By Key Streets

Finding Potential Opportunities to Look at PPA on Streets in Low Tree Canopy Cover Areas

These results can be further refined to address the question, "Which streets are in areas with low tree canopy coverage?". Map 18 shows the subset of points that meet this criteria, and are also along street segments with less than 10 percent tree canopy coverage within 50 feet of the street centerline.

How to Access the PPA Analysis Results

In order to make the results of the PPA analysis as accessible as possible, a set of Map Books have been generated. Different people will want to see the information at different scales, depending on the questions that are being asked. The Map Books are available via the following website: www.charlottesville.gov/greeninfrastructure.

- Citywide Scale (with evenly established tile grid across the city)
- Possible Tree Planting Sites Analysis
- Possible Tree Planting Sites Analysis – ROW

Neighborhood Scale Map Books have been developed according to the following five metrics that provide insight into potential benefits of tree planting. Each metric is summarized in two forms, citywide and right-of-way specific, for a total of ten Map Books.

- **Potential Planting Locations-Density:** This analysis shows potential tree planting location density. These maps serve as a visualization, highlighting where many potential tree planting locations are clustered together. The shaded bands on the maps indicate how many potential planting points fall nearby any given location.
  One of the most obvious reasons for identifying such clusters of potential locations is from a maintenance efficiency standpoint. If 100 trees are planted in close proximity, the maintenance costs for these trees (especially the needs during the first several years after planting such as watering and pruning), is expected to be lower than if the 100 trees were planted in disparate locations throughout the city.

Map 18: Possible Planting in Streets With Low Canopy

Estimating Potential Benefits: Single Family Residential Tree Planting Scenario

Approximately 72% of the city's existing tree canopy is on privately owned land. Since most land in the city is privately owned, there are considerable opportunities to increase the city's tree canopy in these areas.

There are 7,135 parcels zoned R-1 or R1-S (approximating single-family residential land uses). According to this analysis, 4,037 of these parcels (57%) have room to plant at least one tree (many have more than one possible planting location). Let's assume half of these landowners (roughly 2,000) plant a single tree. Knowing the range of annual stormwater uptake can vary from 400 gallons/year for a small tree to 3,000 gallons/year for a large tree in an open space, we can make a conservative estimate of 1,000 gallons of stormwater absorbed per tree per year. We then arrive at a total for the city of approximately 2,000,000 gallons of stormwater runoff that could be absorbed every year once the trees reach the mid-point of their life cycle.

- **Median Household Income:** This map book shows the median household income, based on census block groups, at each potential tree planting location. These maps are intended to show the relationship between income and potential tree planting locations. The maps can ensure that the many benefits provided by trees can be enjoyed by residents across the spectrum of incomes in the city. Median household income is represented on the map using three categories, each category representing one third of the census block groups in the city. In other words, the block groups in the city were sorted from highest income to lowest income, and separated into three equally sized groups. For example, one third of the block groups in the city fall into the lowest income category (less than $48,800).

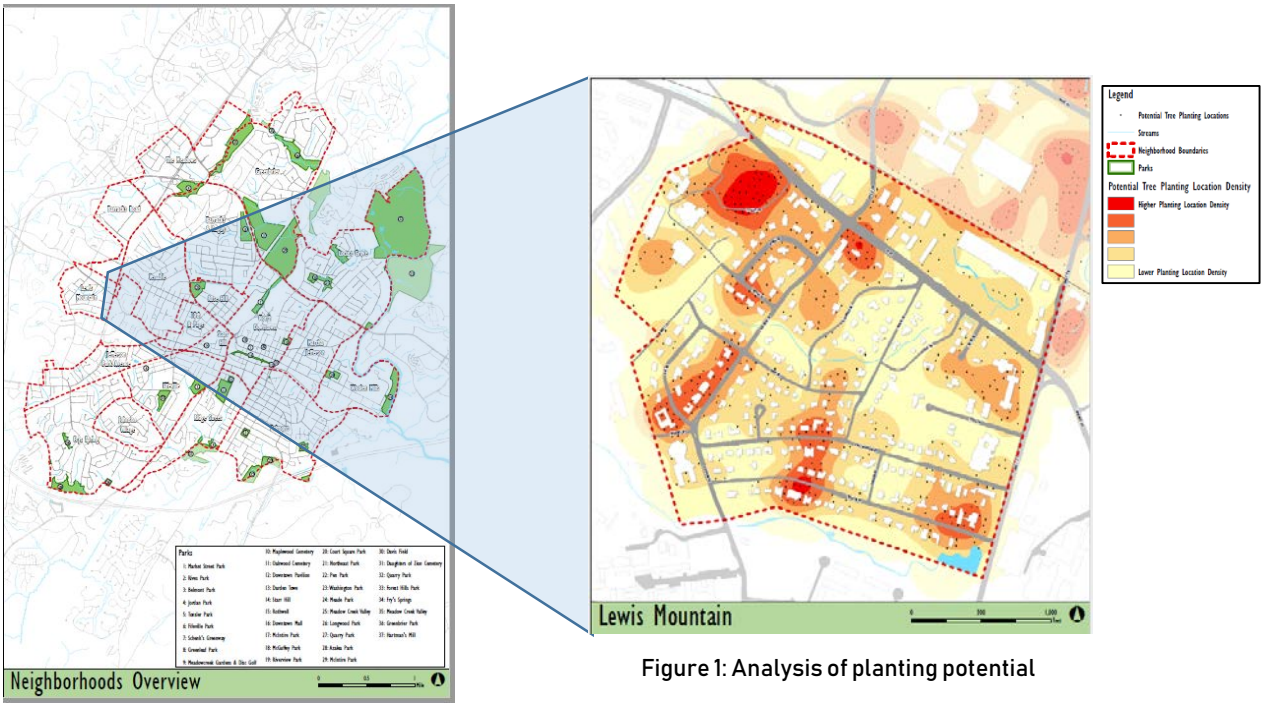


Figure 1: Analysis of planting potential

- **Population Density:** This analysis book shows the relative population density at each potential tree planting location. Trees planted in densely populated areas will provide more benefits to those in close proximity. Population density is represented on the map using three categories, each category representing one third of the census block groups in the city. In other words, the block groups in the city were sorted from highest population density to lowest population density, and separated into three equally sized groups. For example, one third of the block groups in the city fall into the lowest population density category.

- **Relative Temperature:** This analysis book shows the relative temperature at each potential tree planting location. Trees provide shade and mitigate the "urban heat island" effect. This map series shows where temperatures are highest and lowest at each potential tree planting location, which indicates where trees may provide maximum benefit for temperature regulation. Temperature data was obtained from LANDSAT Enhanced Thematic Mapper thermal radiation images during several summer months.

- **Sub catchment Imperviousness:** This analysis shows the impervious surface coverage of stormwater sub-catchments at each potential tree planting location. One of the major benefits provided by trees is reducing stormwater runoff. These maps show the potential planting locations in relation to imperviousness throughout the city. Impervious surfaces do not allow water to pass through, thereby creating runoff that must be managed by the City's stormwater infrastructure. Imperviousness is represented on the map using three categories,

each category representing one third of sub-catchments in the city. In other words, the sub-catchments in the city were sorted from highest imperviousness to lowest imperviousness (as a percentage of total sub-catchment area), and separated into three equally sized groups. For example, one third of the sub-catchments in the city fall into the least impervious category (less than 25 percent impervious).

In the grid analysis below, the city has been analyzed by a series of grid squares. These are yet another way to review the city to realize opportunities to plant trees or other vegetation. It can show where to focus efforts and where there are the greatest planting opportunities (indicated by small circles).

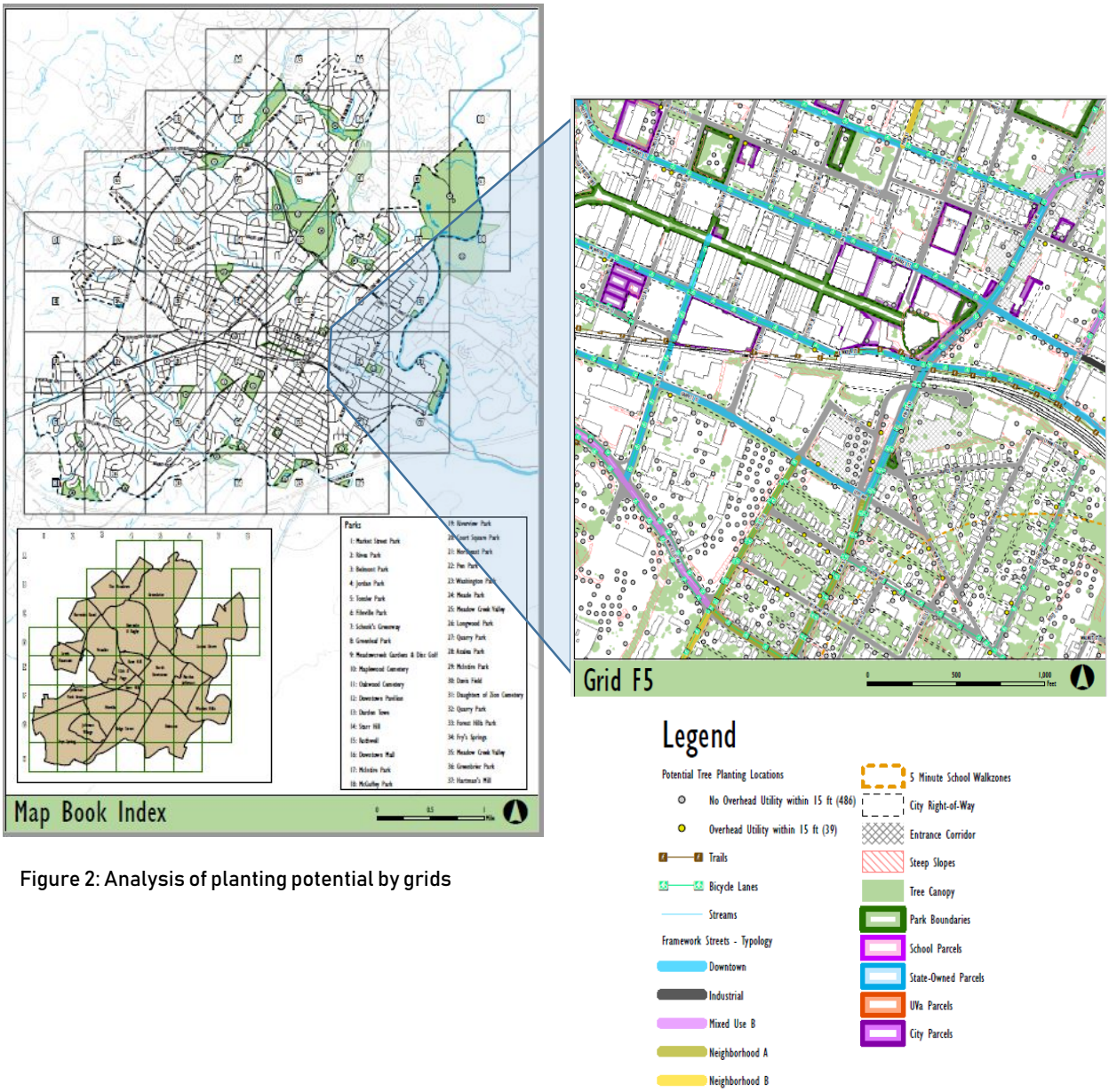


Figure 2: Analysis of planting potential by grids

3.4 How to Build On This Work

There are many ways to engage in greening the city. Retaining vegetation is key, as is restoring vegetation and infiltration where it has been lost. This will help infiltrate and clean stormwater runoff, clean the air, protect the Rivanna watershed, keep the city cooler, and create a livable city.

In places where the city lacks areas to plant with native vegetation, a hybrid approach can be taken that uses constructed green infrastructure. See *Resources* for sources mentioned throughout this document, including the Virginia Department of Forestry.

"What If…" Tree Planting Scenarios for Canopy Goals

It can often be a challenge to set strategic tree planting or canopy coverage goals without information to determine what goals may be realistic or feasible. The following chart is an example that shows various scenarios based on the Possible Planting Area in the Meadows neighborhood. The first column assumes that a certain amount of the possible planting area is to be covered by tree canopy, and the remaining columns estimate the implications of such a change.

Percent of PPA Covered	New Canopy (acres)	New Neighbor-hood TC %	Small Trees	Medium Trees	Large Trees	Total Trees
1%	2	28.49%	22	53	7	82
2%	4	28.97%	45	106	15	166
3%	5	29.45%	68	159	23	250
4%	7	29.93%	91	212	31	334
5%	9	30.41%	114	265	39	418
6%	11	30.88%	137	318	47	502
7%	13	31.36%	159	371	55	585
8%	14	31.84%	182	424	63	669
9%	16	32.32%	205	477	71	753
10%	18	32.80%	228	530	79	837
11%	20	33.28%	251	583	87	921
12%	21	33.76%	274	636	95	1,005
13%	23	34.23%	297	689	103	1,089
14%	25	34.71%	319	742	111	1,172
15%	27	35.19%	342	795	119	1,256
16%	29	35.67%	365	848	127	1,340
17%	30	36.15%	388	901	135	1,424
18%	32	36.63%	411	954	143	1,508
19%	34	37.11%	434	1,007	150	1,591
20%	36	37.58%	457	1,060	158	1,675
21%	38	38.06%	479	1,113	166	1,758
22%	39	38.54%	502	1,166	174	1,842
23%	41	39.02%	525	1,219	182	1,926
24%	43	39.50%	548	1,272	190	2,010

For example, covering 5 percent of the possible planting area equates to about 9 acres of new tree canopy. This would raise the neighborhood's total canopy to 30.41 percent. The remaining columns estimate how many individual trees it would take to create this amount of new tree canopy.

Example Planting Prioritization Based On Need and Possible Planting Area

There are numerous ways to make strategic decisions for increasing tree canopy in areas with the greatest need or that will provide the maximum value and most benefits. The Starr Hill neighborhood, for example, has the lowest overall tree canopy (14%), but has the least possible planting area compared to other neighborhoods, as a percent of the overall neighborhood area.

The Meadows neighborhood is an example of a neighborhood that has relatively low tree canopy coverage (28%), while also having a relatively high possible planting area, since 6.7% of the neighborhood meets the criteria of pervious PPA. Specifically, it has the 16th lowest tree canopy out of 19 neighborhoods, and the 7th highest possible planting area.

Figure 3 shows which parcels are in the highest 25th percentile for daytime thermal radiation (based on Landsat satellite reflectance) and imperviousness. In other words, this shows the parcels in the hottest and most impervious portions of the Meadows neighborhood.

Parcels that meet these selection criteria are shown in red hatching. Planting trees on these parcels would help alleviate the urban heat-island effect, while reducing the amount of stormwater runoff generated. The City of Charlottesville now has this data to use for planning and to educate the community about where and how to select the most strategic places to plant trees to meet City environmental and social goals.

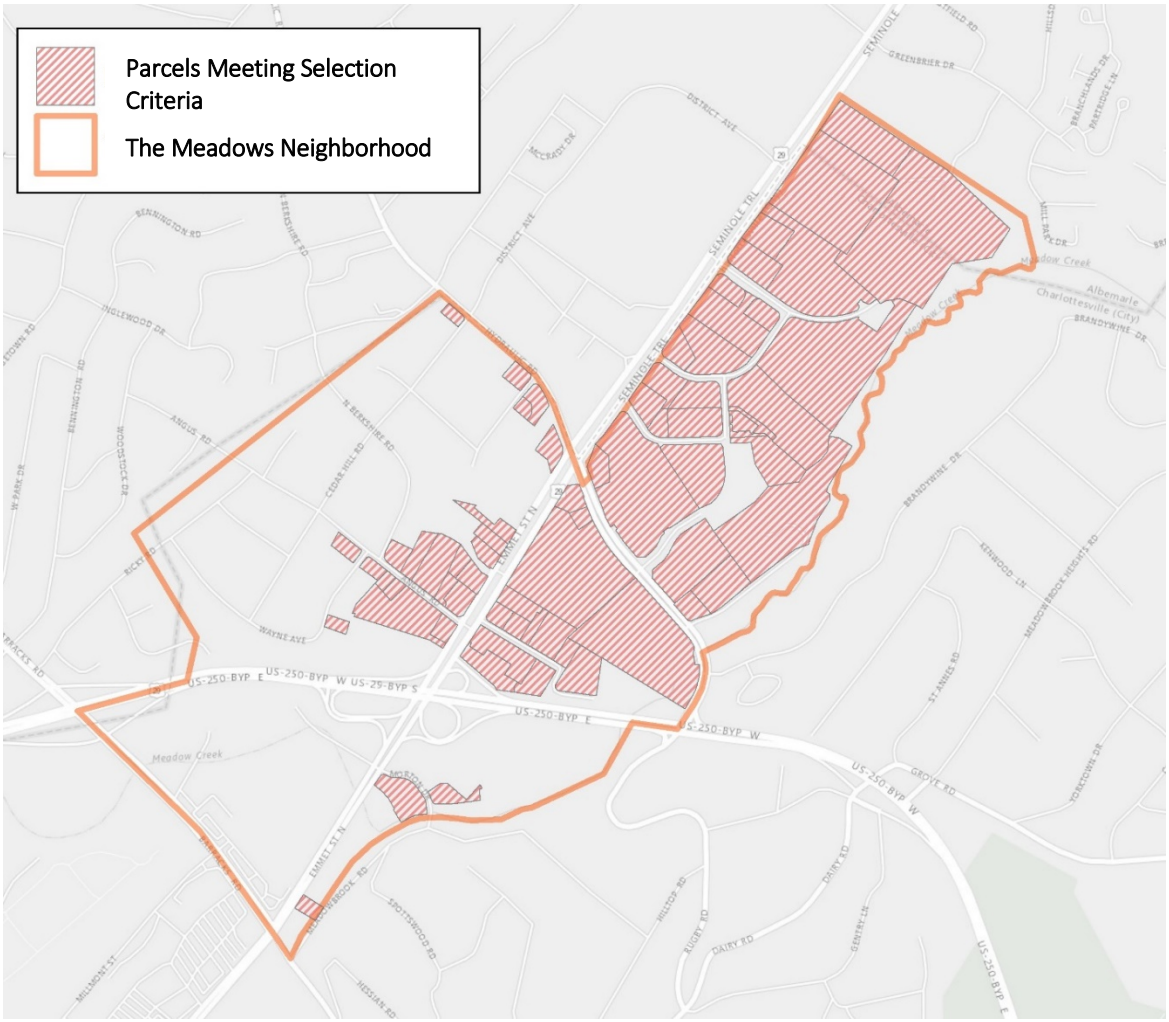


Figure 3: Parcels for which planting results in cooling

Scenarios such as these help address questions such as, "What is a realistic canopy goal for a specific area?" and "How many trees would have to be planted to achieve a certain canopy goal?".

At a minimum, the City could create a tracking system to determine annual tree loss in the city, as well as a new tree planting registry; it could create metrics for tracking shade along framework streets and trails and update the canopy map every five years, in order to compare losses and gains. It could also track the installation of constructed green infrastructure. As a result of all these efforts, over time, the City could become more permeable, less hot, more walkable, and more beautiful. All residents would be able to access nature and lead healthier lifestyles. And businesses should benefit significantly as well.

The City's draft *2018 Comprehensive Plan Update* moves the City in these directions. It includes the specific goal to: "Pursue a healthy ecosystem, including a robust urban forest that delivers valuable ecosystem services." It also sets objectives to use green infrastructure, improve stream buffers, establish stream-side conservation easements, implement the City's urban forest management plan, monitor and track changes in urban canopy, include trees in streetscape plans, use the PPA to guide

planting locations, conduct demonstration projects, and use regionally-adapted and drought tolerant plants.

City staff who use GIS have been trained in use of the data so that staff from Planning, Engineering, Housing, Public Works, Economic Development, Parks and Recreation, or the City Manager's Office can use the information for strategic decision making. The data and maps will help the City make better informed decisions for development, City projects and public-private sector partnerships to meet environmental, social, and economic goals.

Engaging the broader community in this work is key. This document is the City's GreenPrint 1.0, an initial step in an on-going process to establish a green infrastructure program. Additional resources have been put on the City's website to foster more engagement in its efforts to '*go green*.' As the City updates data and strategies, this work will continue. This document is only a guide; the real implementation is in using the data every day to make better decisions to meet the City's vision of a green, healthy, and connected city.

APPENDICES

Appendix A: Public Meeting Map Notes

City of Charlottesville PLACE Green Infrastructure Workshop | July 14, 2016

Neighborhood (Starr Hill and The Meadows) Station

- Code enforcement – overhang => too draconian
- Hillsdale – is it +/-
- Redevelopment impact?
- Code require? (Audit vs. Goal)
- Location – front vs backyard
    - Does code prioritize location?
- Street shade vs ecosystem value
- Plan for public works yard?
- High demand for parking – how to balance?
    - More pleasant/shade/walk to car
- Storm utility offset?
- Conflict: Urbanize vs greening
- Alley utilities?
- Is there new technology and implementation to support trees?
- Starr Hill Park as a vulnerable green space – potential parking as part of W. Main work
- 4th St. Public Works yard – opportunities for tree planting and pedestrian access?
- Railroad crossing above City Yard – pesticide use along slope
- ROW along 4th St side of Staples? Tree Planting Opportunities?
- Existing shopping centers for tree planting – parking lots
- How to require increased % of canopy in parking lots without code changes (Dillon rule state)
- Vegetated rooftops
- 250 Bypass – median and sides – Opportunities for tree planting – Rugby to Hydraulic good example of where it's good
- Block size in redevelopments
- More creek buffer (100')

- Storm utility – tree planting not a credit
- Homeowner mindset and tree maintenance
    - Education on value
- Remove some on-street for trees
- Storm fee on grass?
- Structured parking (Starr Hill)
- Connect commerce to McIntire
- Do we plant before we plant (holistic systems)?
- Short term planting vs Long term redevelopment
    - Don't punish
- Public Works Redevelopment
- Utilities in Alley
- Make McIntire Rd median/Blvd.

Framework Streets/*Smart Scale* Examples

- What about alleys with deep lots? Can we use alleys for green dot #1?
    - Incentivize acquiring them or planted utilities are 4-5' underground + trees only 18"
        - Not necessarily – hitting some utilities during repaving
        - Is there a way to know what utilities are older and closer to pavement? Informs small area plans/capital budget
- Fredericksburg has 5' utility requirement – where did 10' come from? Is it national standard?
- Build parallel networks into existing canopy – Emmet
- Emmet – very high canopy (nearby), but least walkable
- Adding streets in large blocks to provide opportunities for utilities – older streets become bike/walk/tree friendly #2
- Need to think in terms of phasing – blocks, alleys (public or private ownership
- Intersection deficits – need more blocks
- Incentivize private property – free trees, stormwater utility credits for trees, entitlement (dot #3)
    - Increase in land values
- Parking lots - increase curb cuts
- Design of parking lots is inefficient for planting
- Financial incentive to redesign parking lots
- Block perimeter max and limit curb cuts in zooming => inherently gives more opportunities for trees
- There is no "place" along intersections
    - Add green features
- Trees in median (dot #4)
- Not much can be done at 7th and Market – need to look at private
- Get tree benefits through other means – bioswales, green walls, green canopy/trellis structures (horizontal shade structures) – living vegetation and shade
- Green fences (where thick hedges don't fit)
- Incentivize private landowners – i.e. stormwater utility credit for owners that do more (need minor code change)
    - Accelerated tax credit to reimburse up-front costs of improvements
- If people walk and bike they become advocates for trees
    - Street is Meadow creek – if people walk along day-lighted stream they are direct users
- Trees are great, but there is value in quality urban place
- More creative about parking – think about materials/quality

- Opportunities to rethink urban infrastructure – might provide more trees
- Recommended street trees at Key Rec Center – is that a conflict?
- How to convince all new pipes to be in central location?
    - How can we collaborate more with utility?
- Why do utilities have to be so far apart?
    - Storm runs edge of curb – in center can be more expensive
- Public works should be in charge of trees (with a budget)
- W Main – 5' utility buffer = 3' underground space – will street trees be able to fit?
- What is driving force for 5' separation – Mainly trenching
- Ideally would like to walk away with low hanging fruit/high priority list for planting
- Tree Commission wants to use data to increase canopy – know where to plant where we can
- Consolidate above ground utilities
- Tree in private backyards

Strategic Investment Area Station

- Through redevelopment (known) some tree canopy is going to be lost (dot #1)
- ? Forested area by Mt Zion – is this correct?
- Replace/Plant trees (old ones falling down) (dot #3)
- Aging trees
- Want to see TC % go up
- Mixed use area vs residential area – difference strategies?
- Concern: Tree canopy requirements: how to ensure its met later (enforcement)
- Prioritize streets without canopy (street trees) at specific spacing, how many can we plant?
- Consider trees as utility/public infrastructure
- Consider how to incentivize planting or retention of trees on private property
    - (rebate, stormwater utility fee decrease, other)
- Tree Commission: 2020 by 2020 where do we start with the first cluster?
    - To share "priorities characteristics" for future analysis
- Which kinds of parcels lend themselves to easiest tree planting (Big? (Friendship Court), small residential?)
- Daylighting Pollocks Branch
- Green Walls
- Add connections/green space as part of planning
- Cemetery: lots of non-tree vegetation
- High Veg: Pollocks Branch
- Install pump station to bring Pollocks branch to surface
- Do stormwater volume mitigation projects upstream of SIA to manage
- Set the tone for redeveloping SIA
    - "Greening the SIA" with alleys
- Does diminishing block size (SIA) plan present opportunities? (both for utility placement and GI)
- Could "the Plaza" be permeable?
- Could there be collection/infiltration under hardscape?
- Do a hydraulic analysis of DTM/SIA
- TIF. could establish $ to use for green infrastructure (grey/green)
- Acquire alleys to relocate utilities so trees can go onto streets
- Existing green is by Pollocks Branch
    - Cemetery, much is lawn

    - Much is backyards and alleys (gives some funky 'open space')
- Already a walkable neighborhood
- Routes to parks, schools, DTM, Ix area should be shaded (cross check with trees streets analysis)
- Ix property: opportunity
- Source of influences (stormwater quality/quantity) is coming from outside SIA
- As relocating utilities in SIA, consider future elimination of GI (e.g. put them on one side or as close as allowed.)
- Parking policies and mobility policies will influence opportunities/barriers
- Families and children in SIA need inviting and comfortable places
- Take a closer look at tree age/condition in SIA for maintenance, replacement
- "Fund" to support private trees
    - How can this be established?
- Consider public benefit (GI) of SUP or PUD in SIA
- SIA GI map for reference
- Make data publically available ☺

Recurrent Themes

- Parking lot design
- Storm water utility fee credit
- Opportunities in alleys
- How to think about big picture urban design/redevelopment when considering planting trees. Phasing.
- Incentives for planting on private land

Appendix B: References Cited

Fazio, James R. "How trees can retain stormwater runoff." *Tree City USA Bulletin* 55 (2010): 1-8.

Tilt, Jenna H., T. M. Unfried, and B. Roca. "Using objective and subjective measures of neighborhood greenness and accessible destinations for understanding walking trips and BMI in Seattle, Washington." *American Journal of Health Promotion* 21, no. 4_suppl (2007): 371-379.

Roman, Lara A., J. J. Battles, and J.R. McBride. "The balance of planting and mortality in a street tree population." Urban Ecosystems 17, no. 2 (2014): 387.

Appendix C: Resources

Following are resources to support topics addressed in this GreenPrint.

City of Charlottesville Webpages

Green Infrastructure
www.charlottesville.gov/greeninfrastructure

Stormwater
www.charlottesville.gov/stormwater

Parks and Trails
https://www.charlottesville.gov/163/Parks-Trails

Streets That Work Design Guidelines
https://www.charlottesville.gov/DocumentCenter/View/482/2016-Streets-That-Work-Plan-PDF?bidId=

Urban Forest Management Program
www.charlottesville.gov/trees

Tree Resources

Charlottesville's Master Tree List
https://www.charlottesville.gov/DocumentCenter/View/898/Charlottesville-Master-Tree-List-PDF

Virginia's Urban Forest Council
http://www.treesvirginia.org

Pests: How to identify emerald ash borer
https://www.fs.usda.gov/naspf/publications/emerald-ash-borer-idenfication-guide-id-card

Native Plants

Piedmont Virginia Native Plant Database
www.albemarle.org/nativeplants/list.asp?ShowAll=ALL

Virginia Native Plant Society
www.vnps.org

Piedmont Master Gardeners
www.piedmontmastergardeners.org

Habitat Gardening for Wildlife

Habitat Gardening Guide
https://www.dgif.virginia.gov/wp-content/uploads/habitat-gardening.pdf

Virginia Department of Game and Inland Fisheries, Managing Land in the Piedmont
https://www.dgif.virginia.gov/wp-content/uploads/Managing_Land_Guide_2016_large.pdf

Habitats

Esri National Green Infrastructure Map
http://www.esri.com/about-esri/greeninfrastructure

Master Naturalists in Virginia
http://www.virginiamasternaturalist.org/home/giving-monarchs-a-boost-in-virginia

Monarch Butterfly Gardens
http://www.dcr.virginia.gov/natural-heritage/save-the-monarch

Monarch Waystation Program
https://www.monarchwatch.org/waystations/

Center for Urban Habitats
http://centerforurbanhabitats.com

Virginia Working Landscapes
http://www.vaworkinglandscapes.org

Water Resources

Rivanna River Basin Commission – Rivanna Snapshot
http://www.albemarle.org/upload/images/forms_center/departments/Community_Development/forms/Comp_Plan_Round_4/R452012RivannaWatershedSnapshot.pdf

Rivanna Conservation Alliance – become a volunteer and monitor water quality
https://www.rivannariver.org/monitoring-about/

Chicago Green Alley Handbook
https://www.cityofchicago.org/content/dam/city/depts/cdot/Green_Alley_Handbook_2010.pdf

National Association of City Transportation Officials: Urban Street Stormwater Guide
https://nacto.org/publication/urban-street-stormwater-guide/