

Urban Tree Canopy Assessment for the City of Charlottesville, VA



Prepared By
Plan-It Geo, LLC, Arvada, Colorado



Prepared For
City of Charlottesville, Virginia

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PUBLISHING>**

An Assessment of Urban Tree Canopy and Canopy Change in the City of Charlottesville, Virginia December 2015

Prepared By

Plan-It Geo, LLC, Arvada, Colorado



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CONTENTS

- EXECUTIVE SUMMARY 3**
- PROJECT FUNDAMENTALS & METHODOLOGY 4**
 - MAPPING LAND COVER 5
 - IDENTIFYING POSSIBLE PLANTING AREAS 5
 - DEFINING ASSESSMENT LEVELS 6
 - ESTIMATING CHANGE IN CANOPY OVER TIME 7
 - ECOSYSTEM SERVICES 8
- ASSESSMENT RESULTS & KEY FINDINGS 9**
 - CITYWIDE LAND COVER AND URBAN TREE CANOPY 9
 - PLANNING NEIGHBORHOODS 10
 - RIGHT-OF-WAY 10
 - RIGHT-OF-WAY BY PLANNING NEIGHBORHOOD 11
 - PARCELS 11
 - PROPERTY OWNERSHIP TYPE 11
 - CANOPY CHANGE OVER TIME 12
 - ECOSYSTEM SERVICES 14
 - IDENTIFYING LOCATIONS FOR NEW PLANTINGS 16
- APPENDIX 17**
 - ACCURACY ASSESSMENT 17
 - COMPREHENSIVE ASSESSMENT AREA RESULTS 19
 - I-TREE HYDRO INPUT PARAMETERS 25
 - CANOPY COMPARISONS 26

FIGURES & TABLES

FIGURES

Figure 1: Five Primary Land Cover Classes generated from Aerial Imagery-based Analysis.....5

Figure 2: Areas Unsuitable for Planting6

Figure 3: Examples of Target Geographies, including Parcels, Rights-of-Way, and Planning Neighborhoods7

Figure 4: Ecosystem Services Provided by Trees8

Figure 5: Detailed Land Cover Classifications and Distribution9

Figure 6: Urban Tree Canopy Assessment Results by Planning Neighborhood10

Figure 7: Percent Urban Tree Canopy in Right-of-Way* by Planning Neighborhood11

Figure 8: Examples of Canopy Loss from Development (2005-2014)13

Figure 9: Examples of Canopy Loss from Sewer Replacement and Stream Restoration (2005-2014)13

Figure 10: Urban Tree Canopy Comparisons14

Figure 11: Priority Planting Parcels16

Figure 12: Charlottesville, VA Land Cover Error Matrix18

Figure 13: Urban Tree Canopy Assessment Results by Planning Neighborhood (Current)20

Figure 14: Urban Tree Canopy Assessment Results in Rights-of-Way by Planning Neighborhood23

Figure 15: Urban Tree Canopy Assessment Results by Parcel24

TABLES

Table 1: Generalized Land Cover Classifications9

Table 2: Urban Tree Canopy Assessment Results for Citywide Right-of-Way, excluding Alleys and Railroad ROW11

Table 3: Urban Tree Canopy Results by Property Type12

Table 4: Urban Tree Canopy Results (2005 - 2014) Using the Point Sampling Technique.....12

Table 5: Urban Tree Canopy Results (2009 - 2014) Using Land Cover Maps Derived Using Remote Sensing Technology 12

Table 6: Citywide Annual Urban Forest Ecosystem Services14

Table 7: Urban Tree Canopy Assessment Results by Planning Neighborhood (Current)19

Table 8: Urban Tree Canopy Assessment Results by Planning Neighborhood (2009 - 2014).....21

Table 9: Urban Tree Canopy Assessment Results in Rights-of-Way by Planning Neighborhood22

Table 10: Urban Tree Canopy Comparisons26

EXECUTIVE SUMMARY

Tree canopy is a critical component of a city’s green infrastructure and contributes to environmental quality, public health, water resource management, local economies, and the beautification of often harsh, paved landscapes. This urban tree canopy assessment provides a top-down view of Charlottesville’s entire urban tree canopy, including both public and private lands, from a quantitative perspective. The data are analyzed not only citywide, but at a variety of geographic scales to inform various stakeholders, such as city officials, city staff, and residents alike as to how much tree canopy exists where. By identifying what resources and opportunities exist, the City can be more proactive in its approach to expanding and promoting the urban tree canopy, reducing canopy loss, and setting and attaining future canopy goals.

Urban Tree Canopy in Charlottesville

The results of this study showed that 3,152 acres of the 7,006 acres of Charlottesville is covered by urban tree canopy (UTC), or 45% of the City. These trees provide a multitude of economic, environmental, and social benefits, conservatively valued at just under \$1 million annually.



Assessment Boundaries

This study assessed Urban Tree Canopy (UTC) and Possible Planting Areas (PPA) at multiple geographic levels in order to provide actionable information to multiple audiences. Metrics were generated at the following scales: The City of Charlottesville citywide boundary, Planning Neighborhoods, parcels, property ownership type (public vs. private lands), Rights-of-Way (ROW), and ROW by Planning Neighborhood. Additional detailed analysis of ROW by type has also been completed, allowing for the exclusion of alleys and railroads from the ROW.

Within the City of Charlottesville, the Barracks/Rugby Planning Neighborhood boasts the greatest relative amount of UTC at 65% (324 acres), while Starr Hill contains the least with only 14% UTC (9 acres). Woolen Mills has the highest percentage of Vegetated Possible Planting Area (PPA-Veg) with 27% (74 acres), while Locust Grove contains the most absolute area with 160 acres of PPA-Veg (22%).

Within the 1,097 acres of total ROW, there are 296 acres of UTC, comprising 27% of the ROW area and 9.4% of the City’s total UTC. After additional analysis was completed to remove alleys and railroads from the ROW, results showed that there are 95 acres identified as PPA-Veg, or 10% of the non-alley, non-railroad ROW.



Private property accounts for the majority of the City’s UTC with 72% of all of Charlottesville’s UTC falling on private land. City-owned property and Right-of-Way account for 21% of the City’s total UTC, with the remaining UTC is found on the University of Virginia campus, school properties, and the Charlottesville Redevelopment & Housing Authority (CRHA). City-owned parcels and privately owned parcels each contain approximately 50% UTC, however, private land contains the most opportunity for new plantings with over 800 acres of PPA-Veg identified. Meanwhile, combined City-owned parcels and non-alley, non-railroad Right-of-Way contain only 275 acres of PPA-Veg.

Canopy Loss

Natural and anthropogenic pressures threaten Charlottesville’s trees and the benefits they provide. Factors such as development pressures and invasive pests can take a toll on the urban forest. This study evaluated change over time using two different methodologies over two different time periods, both of which revealed a decline in urban tree canopy across the City of Charlottesville. Canopy trends were evaluated in approximately 5 year intervals since 2005. Details about the methodologies can be found on page 7.

Planting Opportunities

Despite the decline in urban tree canopy, there is much opportunity for planting trees and incorporating new canopy into the City. 1,243 acres of vegetated possible planting area (PPA-Veg) remains, or 18% of the entire land area. This excludes areas identified as unsuitable for planting, such as sports fields, baseball diamonds, and golf course fairways. Other areas excluded from the total planting area (i.e. vegetation and impervious area) include buildings and roads. Priority planting maps have also been developed as part of this project and identify parcels and Planning Neighborhoods where there is less than average UTC and greater than average vegetated PPA.

1,243
**Acres of Vegetated
Possible Planting
Area***

**Subject to various feasibility studies*

Methodology

Using a top-down approach, and 2014 high-resolution imagery, land cover was mapped using an automated classification process resulting in five initial land cover classes which were then refined with other layers (e.g. building footprints, parking lots, and roads). The automated classification was then reviewed and edited with particular focus on urban tree canopy, plantable space, and impervious surface area. Finally, an accuracy assessment was conducted to produce a standard error matrix.

The accuracy assessment was conducted using *Error Matrix Interpretation*. In this process, land cover is manually interpreted than compared with the automated classification. Approximately 1,000 randomly generated points were assessed then the overall accuracy was computed by dividing the total number of correct pixels by the total number of pixels reported in the matrix. This results in an overall accuracy of 94% for the assessment.

(More details can be found in the Appendix on page 17)



PROJECT FUNDAMENTALS & METHODOLOGY

This section describes Plan-It Geo’s approach to Charlottesville’s urban tree canopy assessment, from the foundational land cover dataset to the target geographies for which the urban tree canopy and possible planting areas were assessed.

Mapping Land Cover

The most fundamental component of this urban tree canopy assessment is the creation of an initial land cover data set. Using a top-down approach, and 2014 high-resolution (1-meter) aerial imagery from the USDA’s National Agricultural Imagery Program (NAIP) and ESRI’s Image Classification Toolset, land cover was mapped from spectral signatures across the imagery’s four bands (blue, green, red, and near-infrared). The automated classification process resulted in five initial land cover classes as shown in Figure 1. Supplementary impervious data provided by the City of Charlottesville was layered in to improve accuracy, including building footprints, roads, driveways, and parking lots. GIS technicians then reviewed and edited the automated classification with particular focus on urban tree canopy, plantable space, and impervious surface area. Finally, an accuracy assessment was conducted to produce a standard error matrix (see Appendix, pages 17-18).

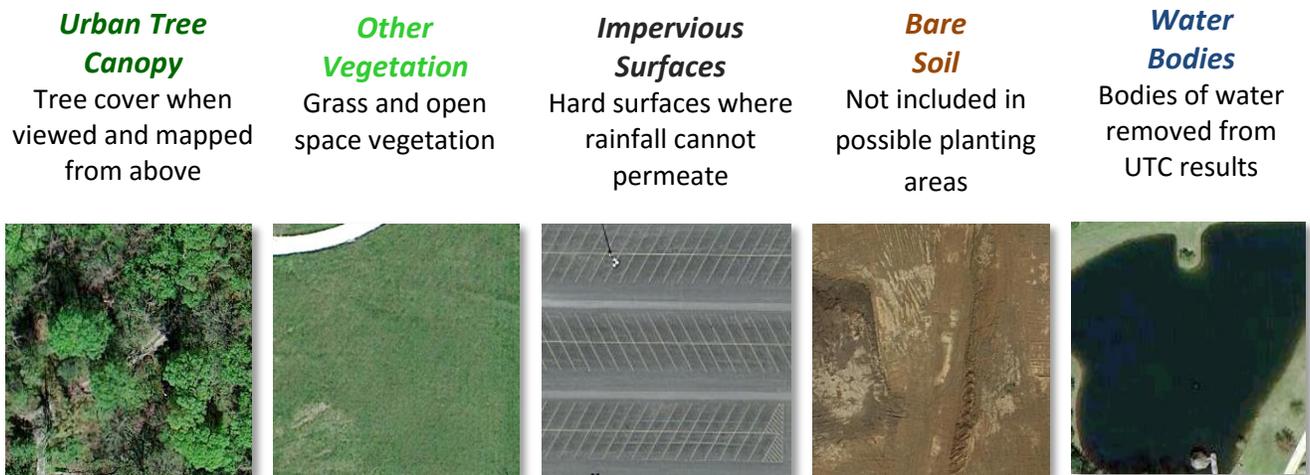


Figure 1: Five Primary Land Cover Classes generated from Aerial Imagery-based Analysis

Identifying Possible Planting Areas

Once the land cover mapping results were finalized, and the existing Urban Tree Canopy (UTC) was established, Possible Planting Areas (PPA) were derived from the Other Vegetation and Impervious land cover classes. Areas in Charlottesville where it is not feasible to plant trees, such as sports fields and golf courses fairways, were incorporated into the map as unsuitable planting areas. These areas cover both the baseball and softball fields provided by the City of Charlottesville GIS, as well as additional areas manually mapped by Plan-It Geo GIS staff. An example is shown in Figure 2.

Impervious areas were also broken down into detailed classes in order to differentiate between impervious surfaces that offer planting opportunity and those that do not. Buildings, roads, and driveways are considered unsuitable for planting, while other impervious areas, such as sidewalks and parking lots, are considered feasible. While it is, obviously, not realistic to assume these entire areas can be replaced with trees, there may be potential to develop urban canopy within these areas, contributing to the mitigation of stormwater runoff and the urban heat island effect, both of which result from extensive and concentrated impervious surfaces. Not every area that is possible planting area is preferable. In some cases, management of the land as open space for unprogrammed recreational uses or other activities may preclude the ability to plant in all PPA areas.

The resulting possible planting areas were identified as **vegetated** PPA or **impervious** PPA, with an aggregated value for **total** PPA. It should be noted that cemeteries were not mapped as unsuitable for this assessment. Thus, areas such as Oakwood, Maplewood, and Riverview Cemeteries may not be practical for planting, but are reflected in the PPA values reported.



-  Baseball/Softball Fields
(Provided by Charlottesville)
-  Additional Unsuitable Areas
(Digitized by Plan-It Geo)

Figure 2: Areas Unsuitable for Planting

Defining Assessment Levels

In order to better inform various stakeholders, such as city officials, city staff, and citizens alike, urban tree canopy and associated information was calculated for a variety of geographic boundaries. These areas included the City of Charlottesville citywide boundary, Planning Neighborhoods, parcels, Rights-of-Way, and Rights-of-Way by Planning Neighborhood. The citywide land cover dataset served as the input for analysis at these finer assessment levels, and a series of values were summarized for each. Outputs include total area (in acres or feet) and relative values (as percentages) for tree canopy, possible planting areas (vegetation, impervious, and total), as well as unsuitable areas. Assessment levels include the following geographic boundaries:

- City of Charlottesville **citywide boundary** is the one (1) main area of interest for which all urban tree canopy metrics were summarized.
- **Planning Neighborhoods** include twenty one (21) areas for which the UTC results were summarized. This reflects the 19 Planning Neighborhoods of Charlottesville, plus two remaining areas within the University of Virginia campus (UVA). While the UVA areas are not within the purview of the City to implement change, they were included since they are within the City limit.
- **Parcels** are the smallest geographic boundaries that were summarized for this urban tree canopy assessment. These data include more than 13,500 property records.
- **Property Ownership Type** summarizes parcels by ownership type, including schools, city-owned parcels, University of Virginia (UVA) campus property, Charlottesville Redevelopment & Housing Authority (CRHA), and privately owned lands. This allows for the distinction between public and private property, in addition to Right-of-Way.

- Citywide **Right-of-Way (ROW)** reports the UTC results within ROW for the entire city, identified as any area not covered by parcels, or the inverse of the parcel area. It should be noted that not all space identified by this study as ROW is city-owned. Some of the area is private alleys and others may be VDOT or railroad company controlled, which may limit potential planting area. Thus, these data also identify ROW that are alleys or railroads.
- **Right-of-Way by Planning Neighborhoods** further dissects the ROW areas by each of the twenty one Planning Neighborhoods so the City can get a better idea of where to focus efforts within the publicly owned land across these different boundaries.



Figure 3: Examples of Target Geographies, including Parcels, Rights-of-Way, and Planning Neighborhoods

Estimating Change in Canopy over Time

As part of this project, urban tree canopy (UTC) was compared over two different time periods, using two different methodologies. First, urban tree canopy change from 2005 to 2014 was estimated using a point-based sampling technique. This involved the use of 1,000 randomly distributed sample points to identify the presence or absence of canopy in 2005 (using Google Earth) and in 2014 (using the aerial imagery from this assessment). To estimate canopy for 2005, sample points were imported into Google Earth (as a KMZ file) and 2005 historical aerial imagery was used to determine the presence or absence of tree canopy. Any offset or shifts in the historical imagery in the Google Earth application were visually accounted for so that the same geographic location was being evaluated in both 2005 and in 2014. Percent UTC cover was derived based on the total canopy points, compared to non-canopy points, and change was assessed by the difference in canopy percentages. This technique yielded a 1.6% standard error (SE) in the UTC estimates for both 2005 and 2014.

For the second comparison, results from a 2009 urban tree canopy assessment conducted for the City of Charlottesville were compared to results of this study. These tree canopy values were each calculated from land cover maps derived using remote sensing technology. As part of this study, an accuracy assessment was run against the 2009 urban tree canopy data using the same random points that were utilized to assess the accuracy for the new 2014 urban tree canopy data. These accuracy assessments revealed only 77.7% accuracy for the 2009 data, compared to 94.3% accuracy for this current canopy study. Thus, it should be noted that comparing the 2009 data against the present data may not effectively represent change over time.

Ecosystem Services

Urban forests provide significant value to the City of Charlottesville. Benefits of trees are referred to as “ecosystem services” and describe the ways that urban forests impact our lives and the environment. Trees can be valued in terms of public health, energy demand, and public infrastructure savings, which helps justify the many reasons to promote, establish, manage, and maintain a robust, “working” urban forest. Quantifying these benefits helps to demonstrate the value of urban forests beyond their aesthetic appeal.

To estimate the ecosystem services provided by Charlottesville’s trees, the **i-Tree** software suite, developed by the USDA Forest Service, was used (<http://www.itreetools.org/>). These tools are used by foresters, communities, and consultants throughout the world to quantify ecosystem services. Within this software suite, the **i-Tree Canopy** component estimates tree cover and tree benefits for a given area with a random sampling process that enables classification of ground cover types. This tool was utilized to estimate the carbon storage, annual carbon sequestration, and annual air pollution removal provided by the urban forest in Charlottesville. To estimate stormwater mitigation within Charlottesville, the **i-Tree Hydro** tool was used to model the effect that land cover has on runoff within a defined area. Both watershed and non-watershed areas can be modelled making it a great option for municipalities whose boundaries do not align with watershed boundaries. More information about i-Tree Hydro can be found in the Appendix of this report (page 25).

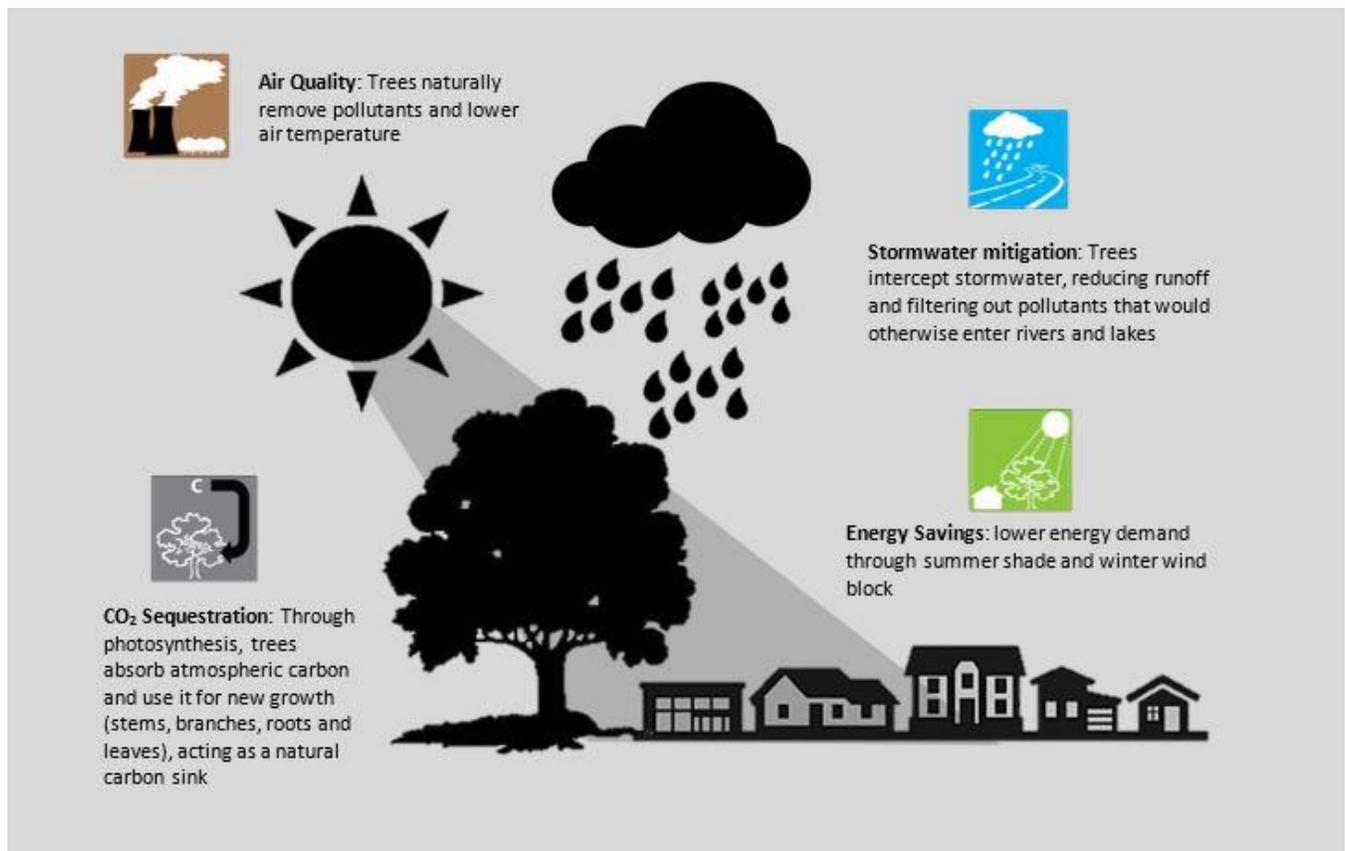


Figure 4: Ecosystem Services Provided by Trees

ASSESSMENT RESULTS & KEY FINDINGS

This section presents the key findings of this study, including the land cover base map as well as the canopy analysis results, or metrics, across the various geographic assessment boundaries. These results help to inform a strategic approach to identifying future planting areas. Complete assessment results for target geographies and additional maps can be found in the Appendix.

Citywide Land Cover and Urban Tree Canopy

The results of this study showed that 3,152 acres of the 7,006 acres of Charlottesville is covered by urban tree canopy (UTC), or 45% of the City. The remaining area is comprised of 19% grass and open space, 35% impervious, and 1% either water or bare soil and dry vegetation. The 35% of impervious area was further categorized into more detailed classes, including buildings (9%), roads (8%), parking lots (7%), driveways (2%), and other impervious (8%). The UTC results for the assessment boundaries in the following sections are subsequently based on total land area (6,976 acres) and exclude water.

Table 1: Generalized Land Cover Classifications

Total Acres	Tree Canopy (acres)	Tree Canopy %	Grass / Open Space (acres)	Grass / Open Space %	Impervious (acres)	Impervious %	Water (acres)	Water %	Soil / Dry Vegetation (acres)	Soil / Dry Vegetation %
7,006	3,152	45%	1,361	19%	2,429	35%	30	0.4%	34	0.5%

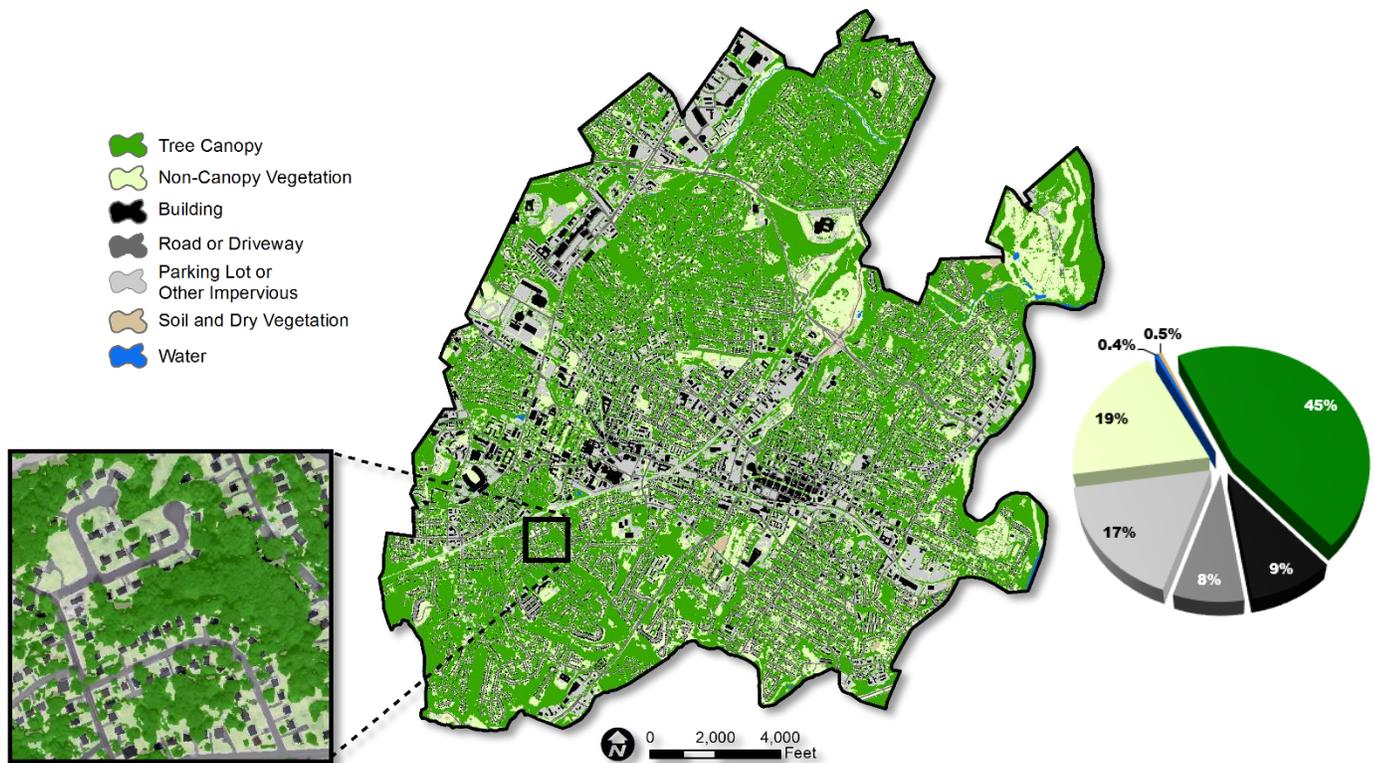


Figure 5: Detailed Land Cover Classifications and Distribution

Planning Neighborhoods

Urban Tree Canopy (UTC) and Possible Planting Areas (vegetation, impervious, and total) were analyzed for 21 Planning Neighborhoods. This reflects the 19 Planning Neighborhoods of Charlottesville, plus two remaining areas within the University of Virginia campus (UVA). While the UVA areas are not within the purview of the City to implement change, they were included since they are within the City limit and identified as UVA1 and UVA 2 to be consistent with the 2009 urban canopy assessment. Within the City of Charlottesville, the Barracks/Rugby Planning Neighborhood boasts the greatest relative amount of UTC at 65% (324 acres), while Starr Hill contains the least with only 14% UTC (9 acres). Woolen Mills has the highest percentage of Vegetated Possible Planting Areas (PPA-Veg) with 27% (74 acres), while Starr Hill contains the lowest with only 7% (4 acres). In terms of absolute area, Locust Grove contains the most acres of PPA-Veg with 160 acres, followed by Greenbrier with 150 acres, and Belmont with 123 acres.

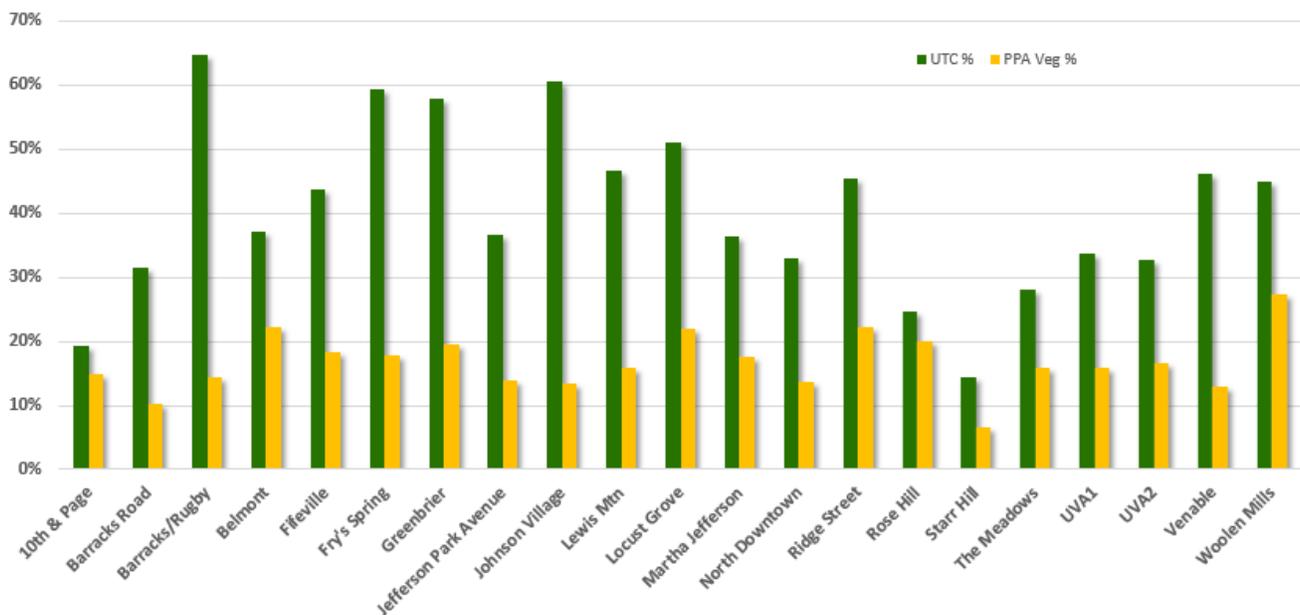


Figure 6: Urban Tree Canopy Assessment Results by Planning Neighborhood

Right-of-Way

Urban Tree Canopy (UTC) and Possible Planting Areas (vegetation, impervious, and total) metrics have been evaluated for citywide Right-of-Way (ROW). Within the 1,097 acres of total ROW, there are 296 acres of UTC, comprising 27% of the ROW area and 9.4% of the City's total UTC. For the purposes of this study, ROW was identified as any area not covered by parcels, or the inverse of the parcel area. Because not all of this space is city-owned and managed, additional analysis was completed to remove alleys and railroads from the areas identified for possible planting. Results for the remaining ROW area show that there are 95 vegetated acres identified for possible planting (PPA-Veg), or 10% of the ROW. While this possible planting area excludes road surfaces, it may still contain overhead and underground utilities such as water, sewer, stormwater, gas, electric, and communication lines. Thus, this value may still misrepresent the actual planting opportunity, and additional site-specific information is needed to determine ROW canopy potential.

Table 2: Urban Tree Canopy Assessment Results for Citywide Right-of-Way, excluding Alleys and Railroad ROW

Citywide Land Area (acres)	ROW* Land Area (acres)	UTC (acres)	UTC %	PPA Veg (acres)	PPA Veg %	PPA Impervious (acres)	PPA Impervious %	Total Possible Planting (acres)	Total Possible Planting %
6,976	982	247	25%	95	10%	108	11%	203	21%

*NOTE: ROW land area excludes alleys and railroad ROW

Right-of-Way by Planning Neighborhood

Urban Tree Canopy (UTC) and Possible Planting Areas (vegetation, impervious, and total) metrics by Right-of-Way have also been broken down by Planning Neighborhood. While these metrics have been generated for each of the three ROW types (alleys, railroads, and remaining), this section highlights only those ROW areas that do not include alleys and railroads. Barracks/Rugby Planning Neighborhood contains the most tree canopy in the ROW, both in terms of percentage (43%) and in terms of acreage (34 acres). Neighborhoods with the lowest amounts of tree canopy in the ROW include 10th & Page and Starr Hill, with 9% (2 acres) and 13% (1 acre), respectively. Belmont, Greenbrier, and The Meadows offer the most vegetated possible planting area (PPA-Veg) within the ROW, all at 13%, and totaling 37 acres, collectively. Again, it should be noted that these ROW areas may still contain various utilities that may limit planting, and additional information is still needed to determine ROW canopy potential.

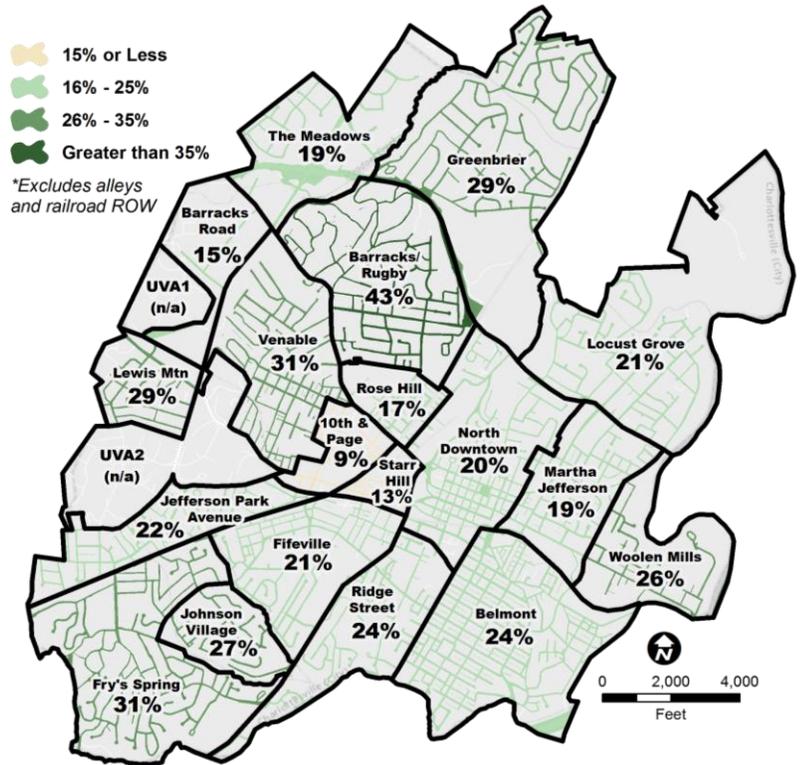


Figure 7: Percent Urban Tree Canopy in Right-of-Way* by Planning Neighborhood

Parcels

The smallest geometries analyzed for this study came from the parcel layer. Urban Tree Canopy (UTC) and Possible Planting Areas (vegetation, impervious, and total) metrics have been generated for each of the 13,580 parcel records. These results have been provided in GIS data format, as well as in an Excel spreadsheet. Maps displaying the distribution of UTC, PPA-Vegetation, PPA-Impervious, and PPA-Total can be found in the Appendix of this document (page 24).

Property Ownership Type

Urban Tree Canopy (UTC) and Possible Planting Areas (vegetation, impervious, and total) metrics have been processed for groupings of parcels that identify property ownership type. These summaries include schools, city-owned parcels, University of Virginia (UVA) campus property, Charlottesville Redevelopment & Housing

Authority (CRHA), and privately owned lands, allowing for the distinction between public and private property, in addition to Right-of-Way. Private property accounts for the majority of the City’s UTC with 72% of all of Charlottesville’s UTC falling on private land. This is derived by comparing the 2,282 acres of urban tree canopy on private land against the 3,152 acres of total UTC within the City of Charlottesville. City-owned property (367 acres of UTC) and ROW (296 acres of UTC) account for a combined total of 663 acres of UTC, or 21% of the City’s total UTC. Both City-owned parcels and privately owned parcels contain approximately 50% relative UTC, however, private land contains the most opportunity for new plantings with over 800 acres of PPA-Veg identified, compared to only 180 acres identified on City-owned parcels. Adding the 95 acres of PPA-Veg from the non-alley, non-railroad ROW brings the total PPA-Veg on City-owned property to 275 acres, which is still a fraction of the PPA-Veg identified on private land.

Table 3: Urban Tree Canopy Results by Property Type

Property Type	Total Land Acres	UTC Acres	UTC %	% of Citywide UTC	PPA Veg Acres	PPA Veg %	PPA IA Acres	PPA IA %	PPA Total Acres	PPA Total %	Un-suitable UTC (acres)	Un-suitable UTC %
City Property	700	367	52%	12%	180	26%	45	6%	225	32%	21	3%
CRHA	33	13	39%	0.4%	8	24%	8	23%	16	47%	5	14%
Schools	144	52	36%	2%	28	20%	28	20%	57	39%	15	10%
UVA	418	138	33%	4%	69	16%	89	21%	158	38%	99	24%
Private	4,576	2,282	50%	72%	839	18%	728	16%	1,567	34%	681	15%
Overall	5,871	2,851	49%	90.5%	1,124	19%	899	15%	2,023	34%	820	14%

Canopy Change over Time

As part of this assessment, change in urban tree canopy was estimated from 2005 to 2014, as well as from 2009 to 2014. The 2005 imagery was chosen because of the availability and quality (i.e. less shadow and cloud cover) and to give an estimate of canopy change over about a ten-year timespan. When also considering the 2009 data, it gives an estimate of canopy change in approximately five-year increments. These two analyses used different techniques that are described in detail in the methodology section of this report (page 7). Using the point sampling technique to estimate canopy in 2005 and 2014, a 6.2% decline in urban tree canopy was identified. Using the urban tree canopy assessment results calculated from the land cover maps derived using remote sensing technologies in 2009 and in 2014, a 1.4% loss of canopy was identified. Comprehensive assessment results for Planning Neighborhoods from 2009 to 2014 can be found in the Appendix section of this report (page 21).

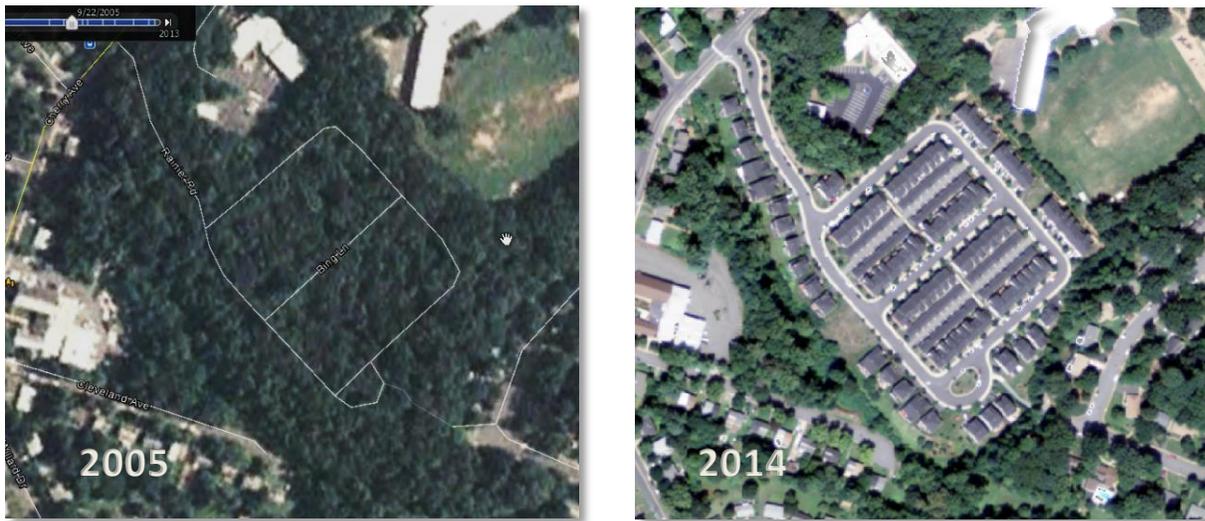
Table 4: Urban Tree Canopy Results (2005 - 2014) Using the Point Sampling Technique

2005 UTC % (Point Sampling Technique)	2014 UTC % (Point Sampling Technique)	UTC Change (2005 - 2014)
50.2	44.0	- 6.2%

Table 5: Urban Tree Canopy Results (2009 - 2014) Using Land Cover Maps Derived Using Remote Sensing Technology

2009 UTC % (Land Cover Map)	2014 UTC % (Land Cover Map)	UTC Change (2009 - 2014)
46.6	45.2	- 1.4%

The trend shows that given private development and large municipal projects, the rate of tree loss is declining over time. Since many of these projects include major follow-up replanting and development sites are required to meet future canopy cover thresholds, we may find over time that we are, in fact, maintaining a healthy overall canopy even as some areas see loss and/or gains. Losses reported in this assessment may be due to factors such as the development of formerly forested lands (Figure 8) and the Meadow Creek Restoration and Meadow Creek Sanitary Sewer Interceptor Replacement Projects (Figure 9). As part of these projects, many invasive ailanthus and other species were removed, in addition to trees that were falling into the creek. Since then, most have been replaced with native and riparian system appropriate species, and replanting efforts have been made to the maximum extent practical to replace canopy lost. The new trees aren't large enough to pick up through remote sensing at this time but in follow up assessments these trees will have a big impact on canopy.



*Figure 8: Examples of Canopy Loss from Development (2005-2014)
Sources: Google Earth for 2005; NAIP for 2014*



*Figure 9: Examples of Canopy Loss from Sewer Replacement and Stream Restoration (2005-2014)
Sources: Google Earth for 2005; NAIP for 2014*

Despite the decline in tree canopy over time, as calculated using this methodology, Charlottesville still boasts an average 45% urban forest canopy cover, greater than many cities of a similar size and region. This value doesn't take into account information about reforestation efforts, forest health, or invasive species, however, so continued management and studies are necessary for the promotion and development of a healthy and sustainable urban forest. Figure 10 shows the percentage of Urban Tree Canopy for comparable cities. Additional information can be found on page 26.

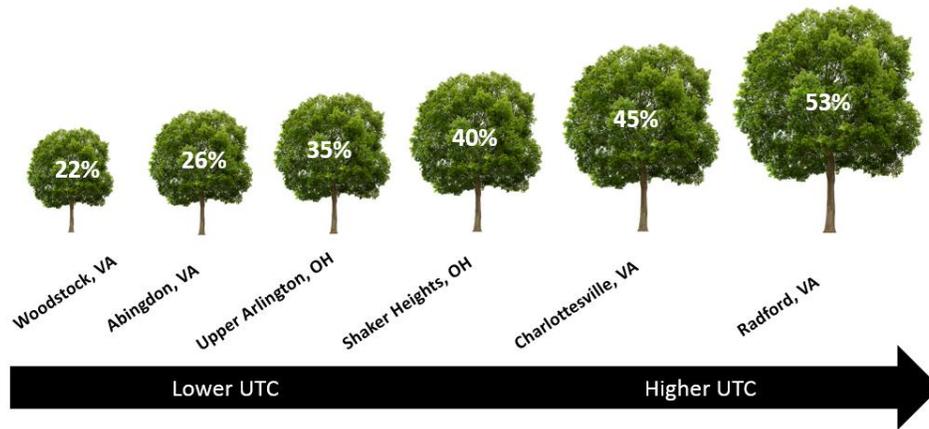


Figure 10: Urban Tree Canopy Comparisons

Ecosystem Services

Tree Canopy Ecological Benefits

Tree canopy and urban forests provide many benefits and ecosystem services that can be associated to economic costs or savings. While trees provide a multitude of benefits that cannot be valued, such as wildlife habitat, mental and physical well-being, noise abatement, and energy savings from summer cooling and winter wind block, estimates here are drawn from those which have an associated monetary value. Of these quantifiable ecosystem services, it is estimated that trees in Charlottesville provide close to \$990,071 annually in savings to the community from air pollution removal and carbon sequestration services alone. In addition, the total CO₂ storage over the lifetime of the tree canopy is approximately \$7.7 million, with almost 800 million pounds of carbon being stored. These numbers represent a savings at the overall society level, not necessarily dollar savings to the locality. The values were derived using the United States Department of Agriculture (USDA) i-Tree Canopy software tools (<http://www.itreetools.org/>), as described in the methodology section of this report. For more information on what these values mean, visit <http://www.treearch.fs.fed.us/pubs/28759>

Table 6: Citywide Annual Urban Forest Ecosystem Services

Pollutant	Pollutant Amount (lbs)	Value (\$)
Carbon Monoxide	3,360	\$2,240
NO ₂	15,778	\$4,116
O ₃	143,144	\$133,405
PM ₁₀	30,977	\$97,088
PM _{2.5}	5,850	\$213,824
SO ₂	5,736	\$287
CO ₂ Sequestration	30,190,551	\$548,109
Total	30,395,396	\$990,071

The urban tree canopy also helps mitigate stormwater by intercepting and absorbing rainwater and through evapotranspiration. To estimate the values associated with stormwater mitigation within Charlottesville, the i-Tree Hydro component of the i-Tree software suite was utilized. With localized weather data, land cover composition determined by Plan-It Geo, and one of i-Tree Hydro's Topographic Index files (detailed below), the current canopy was predicted to mitigate roughly 765 million gallons of runoff annually, the equivalent of 1,159 Olympic-sized swimming pools per year.

It is important to know that i-Tree Hydro comes with its own limitations. Some of the largest ones that had to be taken into account for this project are as follows:

1. Data availability. Without extensive research and data formatting, the most recent data available for this model dated back to the entire year of 2012.
2. Hydrologic processes do not follow municipal boundaries. Hydro gives the option to model watershed and non-watershed areas. In the case of Charlottesville, a non-watershed area was used in order to include the whole city area. The resulting model uses something called a topographic index, which is a type of elevation model used for municipal boundaries rather than natural ones.
3. The model breaks up estimated flow into impervious and pervious runoff. In the case of this study, impervious flow was treated as the stormwater runoff that would need to be mitigated by stormwater systems and pipe networks. This method has been confirmed as valid with various members of the i-Tree support staff.

Due to these limitations and various others, the runoff volumes estimated in the model should be taken as a rough approximation, not as exact calculations. The order-of-magnitude values serve to highlight the importance of healthy tree canopy within the city.

Identifying Locations for New Plantings

Using the results of this study, areas to target for new plantings can be identified. Figure 11 highlights all parcels where the percent of Urban Tree Canopy (UTC) is less than the citywide average of 45%, the percent of Possible Planting Area Vegetation (PPA-Veg) is greater than citywide average of 18%, and the parcel area is at least 10,000 square feet. These parcels include public and private property and would need further assessment to determine if they are preferred and desired. For example, the large parcels in the southwest portion of the study area are UVA property and not part of the city’s management. Also golf fairways would not be considered. Identifying properties with low UTC and high PPA offers a starting point, although any planting efforts will require deeper analysis of on the ground and underground conditions. Areas identified as unsuitable for planting are also called out in the map.

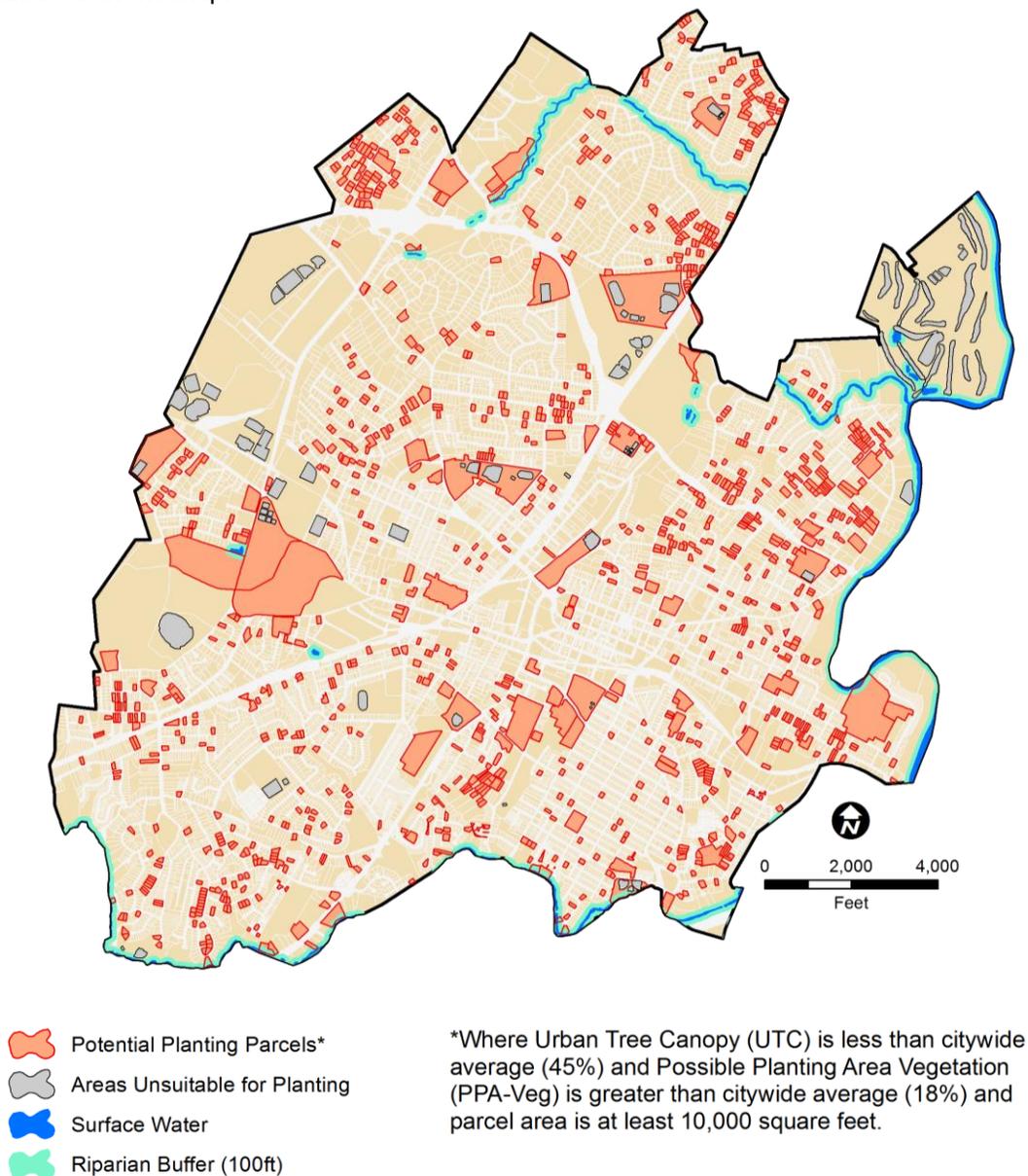


Figure 11: Priority Planting Parcels

APPENDIX

Accuracy Assessment

Classification accuracy serves two main purposes: First, accuracy assessments provide information to technicians producing the classification about where processes need to be improved and where they are effective. Secondly, measures of accuracy provide information about how to use the classification and how well land cover classes are expected to estimate actual land cover on the ground. Even with high resolution imagery, very small differences in classification methodology and image quality can have a large impact on overall map area estimations. The classification accuracy error matrix illustrated in Figure 12 contains confidence intervals that report the high and low values that could be expected for any comparison between the classification data and what actual, on the ground land cover was in 2014. This accuracy assessment was completed using high resolution aerial imagery, with computer and manual verification. No field verification was completed.

The internal accuracy assessment was completed in five (5) steps

1. Approximately one thousand (1,000) sample points were randomly distributed across the study area and assigned a random numeric value.
2. Each sample point was then referenced using the NAIP imagery and assigned one of the five land cover classes (“Ref_ID”) mentioned above.
3. In the event that the reference value could not be discerned from the imagery, the point was dropped from the accuracy analysis. In this case, only one point was dropped bringing the sample point count to nine hundred ninety nine (999) points.
4. An automated script was then used to assign values from the classification raster to each point (“Eval_ID”). The classification supervisor provides unbiased feedback to quality control technicians regarding the types of corrections required. Misclassified points (where reference ID does not equal evaluation ID) and corresponding land cover are inspected for necessary corrections to the land cover¹.

Accuracy is re-evaluated (repeat steps 3 & 4) until an acceptable classification accuracy is achieved.

Sample Error Matrix Interpretation

Statistical relationships between the reference pixels (representing the true conditions on the ground) and the intersecting classified pixels are used to understand how closely the entire classified map represents the Charlottesville, VA landscape. The error matrix shown in Figure 12 represents the intersection of reference pixels manually identified by a human observer (columns) and classification category of pixels in the classified image (rows). The gray boxes along the diagonals of the matrix represent agreement between the two pixel maps. Off-diagonal values represent the number pixels manually referenced to the column class that were classified as another category in the classification image. Overall accuracy is computed by dividing the total number of correct pixels by the total number of pixels reported in the matrix ($416 + 156 + 352 + 6 + 5 = 935 / 999 = 94\%$), and the matrix can be used to calculate per class accuracy percent's. For example, 416 points were manually identified in the reference map as Tree Canopy, and 441 of those pixels were classified as Tree Canopy in the

¹ Note that by correcting locations associated with accuracy points, bias is introduced to the error matrix results. This means that matrix results based on a new set of randomly collected accuracy points may result in significantly different accuracy values.

classification map. This relationship is called the “Producer’s Accuracy” and is calculated by dividing the agreement pixel total (diagonal) by the reference pixel total (column total). Therefore, the Producer’s Accuracy for Tree Canopy is calculated as: $(416/441 = .94)$, meaning that we can expect that ~94% of all tree canopy in the Charlottesville, VA study area were classified as Tree Canopy in the classification map.

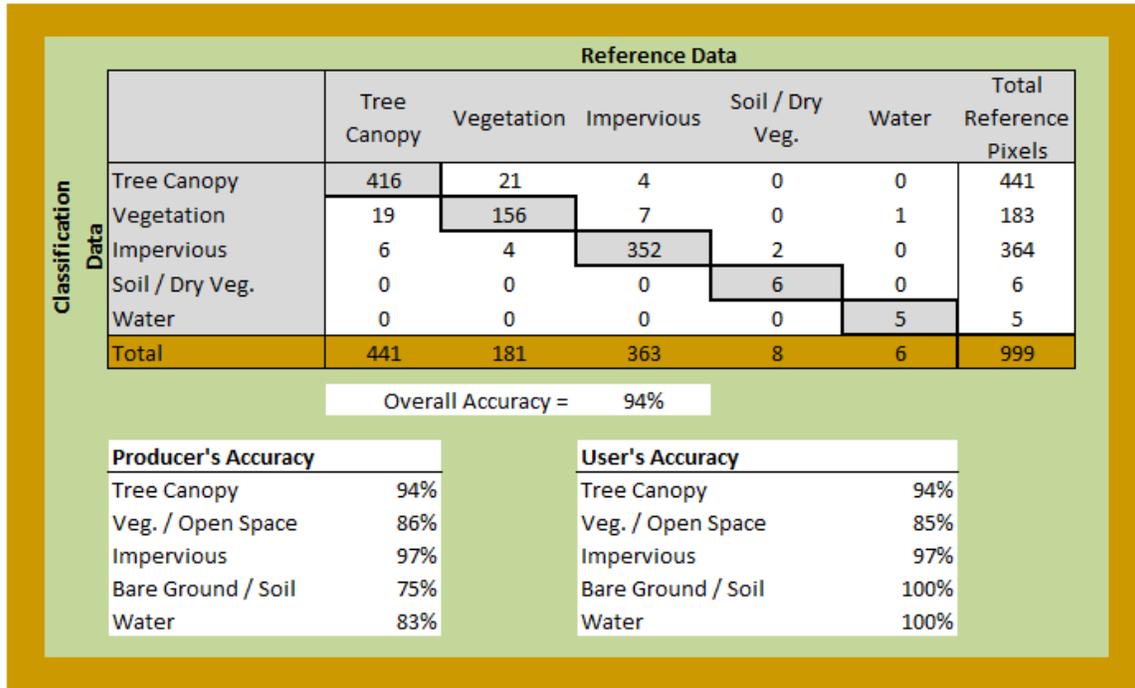


Figure 12: Charlottesville, VA Land Cover Error Matrix

Conversely, the “User’s Accuracy” is calculated by dividing the number agreement pixel total by the total number of classified pixels in the row category. For example, 416 classification pixels intersecting reference pixels were classified as Tree Canopy, but 21 pixels were identified as Vegetation and 4 pixels were identified as Impervious in the reference map. Therefore, the User’s Accuracy for Tree Canopy is calculated as: $(416/441 = 0.94)$, meaning that ~94% of the pixels classified as Tree Canopy in the classification were actual tree canopy. It is important to recognize the Producer’s and User’s accuracy percent values are based on a sample of the true ground cover, represented by the reference pixels at each sample point. Interpretation of the sample error matrix results indicates this land cover, and more importantly, tree canopy, were accurately mapped in Charlottesville, VA. The largest source of classification confusion exists between tree canopy and vegetation.

Comprehensive Assessment Area Results

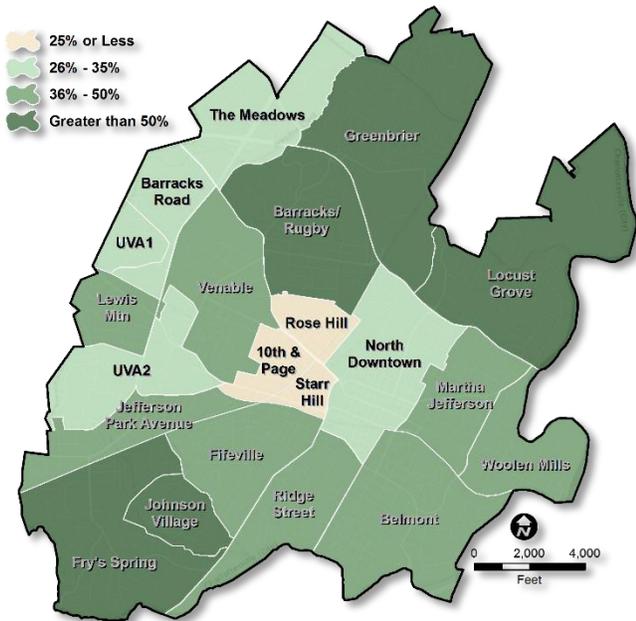
This Urban Tree Canopy (UTC) Assessment of Charlottesville, VA was conducted by Plan-It Geo, LLC for the City of Charlottesville. The assessment examined existing urban tree canopy (UTC) and Possible Planting Areas for vegetation (PPA-Veg), Impervious (PPA-IA), and total Possible Planting Area (PPA-Total), as well as areas unsuitable for planting across several geographic boundaries. This section provides results for each target geography, as well as maps showing the distribution of the results for UTC and PPA.

This table summarizes the UTC metrics by Planning Neighborhood in Charlottesville, VA in Acres and %.

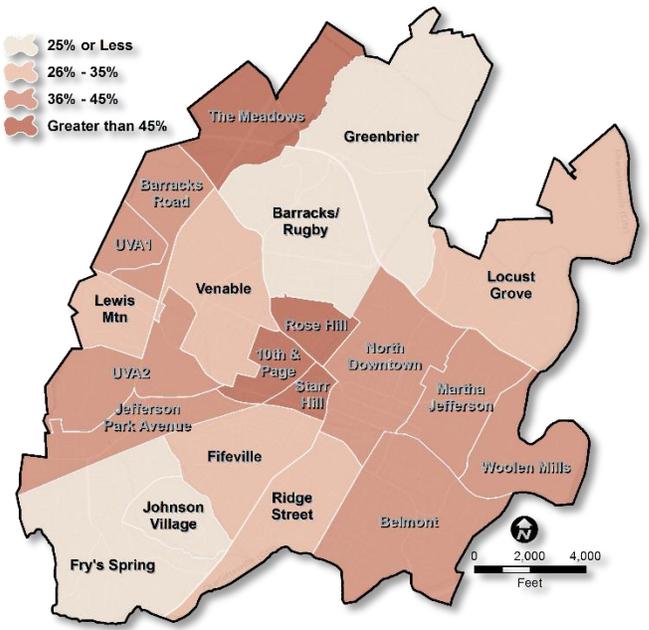
Table 7: Urban Tree Canopy Assessment Results by Planning Neighborhood (Current)

Planning NBHD	Total Land Acres	UTC Acres	UTC %	% of Total UTC	PPA Veg Acres	PPA Veg %	PPA IA Acres	PPA IA %	PPA Total Acres	PPA Total %	Un-suitable UTC (acres)	Un-suitable UTC %
10th & Page	111	21	19%	1%	17	15%	36	32%	52	47%	37	34%
Barracks Road	195	62	32%	2%	20	10%	54	28%	75	38%	59	30%
Barracks/Rugby	500	324	65%	10%	72	14%	29	6%	101	20%	75	15%
Belmont	553	206	37%	7%	123	22%	85	15%	208	38%	139	25%
Fifeville	329	144	44%	5%	60	18%	53	16%	113	34%	72	22%
Fry's Spring	592	352	59%	11%	105	18%	39	7%	144	24%	96	16%
Greenbrier	771	448	58%	14%	150	19%	36	5%	186	24%	138	18%
Jefferson Park Avenue	244	89	37%	3%	34	14%	56	23%	90	37%	64	26%
Johnson Village	160	97	61%	3%	21	13%	11	7%	33	20%	30	19%
Lewis Mtn	156	73	47%	2%	25	16%	22	14%	47	30%	36	23%
Locust Grove	725	371	51%	12%	160	22%	54	7%	214	30%	140	19%
Martha Jefferson	267	97	36%	3%	47	18%	53	20%	100	38%	70	26%
North Downtown	429	142	33%	5%	58	14%	103	24%	161	38%	126	29%
Ridge Street	311	142	46%	4%	70	22%	37	12%	107	34%	63	20%
Rose Hill	108	26	25%	1%	22	20%	27	25%	49	45%	33	30%
Starr Hill	60	9	14%	0.3%	4	7%	31	51%	35	58%	17	28%
The Meadows	374	105	28%	3%	60	16%	125	33%	184	49%	85	23%
UVA1	94	32	34%	1%	15	16%	19	21%	34	36%	28	30%
UVA2	327	107	33%	3%	54	17%	70	22%	125	38%	95	29%
Venable	398	184	46%	6%	52	13%	68	17%	120	30%	95	24%
Woolen Mills	272	122	45%	4%	74	27%	40	15%	114	42%	35	13%
Overall	6,976	3,152	45%	100%	1,243	18%	1,049	15%	2,292	33%	1,532	22%

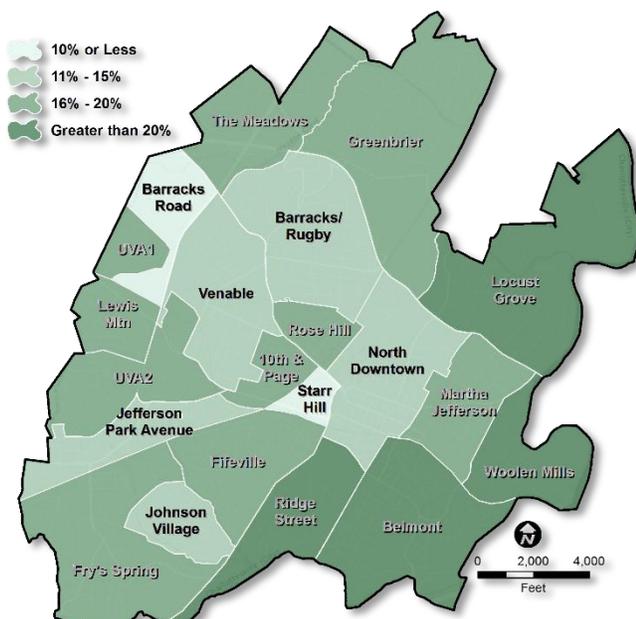
**Percent Urban Tree Canopy
by Planning Neighborhood**



**Percent Possible Planting Areas (Total)
by Planning Neighborhood**



**Possible Planting Areas (Vegetation)
by Planning Neighborhood**



**Possible Planting Areas (Impervious)
by Planning Neighborhood**

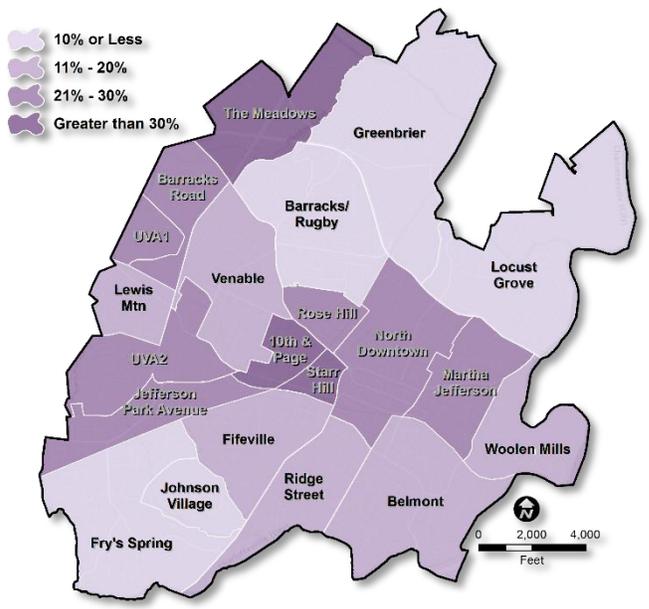


Figure 13: Urban Tree Canopy Assessment Results by Planning Neighborhood (Current)

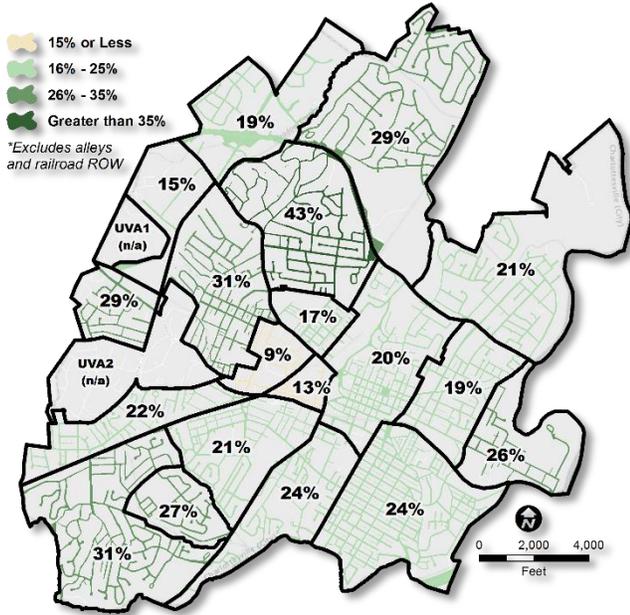
Table 8: Urban Tree Canopy Assessment Results by Planning Neighborhood (2009 - 2014)

Planning NBHD	2009 UTC %	2014 UTC %	2009 PPA Veg %	2014 PPA Veg %	2009 PPA IA %	2014 PPA IA %	2009 PPA Total %	2014 PPA Total %
10th & Page	22%	19%	21%	15%	25%	32%	46%	47%
Barracks Road	32%	32%	18%	10%	32%	28%	49%	38%
Barracks/Rugby	70%	65%	15%	14%	5%	6%	20%	20%
Belmont	32%	37%	32%	22%	12%	15%	44%	38%
Fifeville	45%	44%	24%	18%	12%	16%	36%	34%
Fry's Spring	63%	59%	19%	18%	5%	7%	24%	24%
Greenbrier	60%	58%	24%	19%	5%	5%	29%	24%
Jefferson Park Avenue	37%	37%	19%	14%	18%	23%	37%	37%
Johnson Village	63%	61%	19%	13%	8%	7%	27%	20%
Lewis Mtn	50%	47%	20%	16%	13%	14%	33%	30%
Locust Grove	50%	51%	33%	22%	8%	7%	41%	30%
Martha Jefferson	37%	36%	26%	18%	13%	20%	39%	38%
North Downtown	36%	33%	20%	14%	16%	24%	36%	38%
Ridge Street	49%	46%	27%	22%	9%	12%	36%	34%
Rose Hill	30%	25%	29%	20%	15%	25%	44%	45%
Starr Hill	15%	14%	13%	7%	40%	51%	53%	58%
The Meadows	34%	28%	15%	16%	28%	33%	43%	49%
UVA1	35%	34%	28%	16%	25%	21%	53%	36%
UVA2	34%	33%	21%	17%	22%	22%	44%	38%
Venable	51%	46%	16%	13%	15%	17%	31%	30%
Woolen Mills	38%	45%	38%	27%	12%	15%	51%	42%
Overall	47%	45%	23%	18%	13%	15%	36%	33%

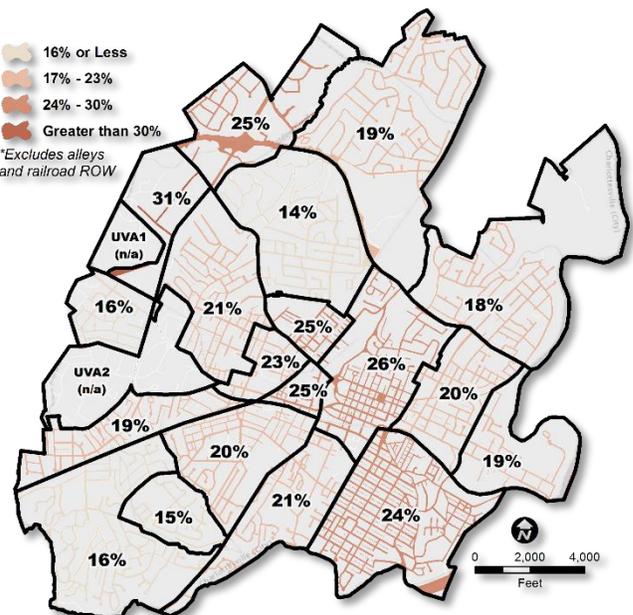
Table 9: Urban Tree Canopy Assessment Results in Rights-of-Way by Planning Neighborhood

Planning NBHD	Total ROW Land Acres	UTC Acres	UTC %	PPA Veg Acres	PPA Veg %	PPA IA Acres	PPA IA %	PPA Total Acres	PPA Total %	Un-suitable UTC (acres)	Un-suitable UTC %
10th & Page	19	2	9%	1	6%	3	17%	4	23%	13	68%
Barracks Road	20	3	15%	2	12%	4	19%	6	31%	10	53%
Barracks/Rugby	77	34	43%	7	9%	3	4%	11	14%	33	43%
Belmont	123	30	24%	16	13%	13	11%	29	24%	64	52%
Fifeville	51	11	21%	4	8%	7	13%	10	20%	30	58%
Fry's Spring	81	25	31%	7	8%	6	8%	13	16%	43	53%
Greenbrier	94	27	29%	13	13%	6	6%	18	19%	48	51%
Jefferson Park Avenue	40	9	22%	3	7%	5	12%	8	19%	23	58%
Johnson Village	22	6	27%	1	7%	2	9%	3	15%	13	57%
Lewis Mountain	21	6	29%	1	6%	2	10%	3	16%	11	55%
Locust Grove	63	13	21%	6	9%	6	9%	11	18%	38	61%
Martha Jefferson	50	10	19%	5	9%	6	11%	10	20%	30	61%
North Downtown	83	16	20%	6	7%	16	19%	21	26%	45	55%
Ridge Street	52	12	24%	5	10%	6	11%	11	21%	29	55%
Rose Hill	23	4	17%	2	8%	4	17%	6	25%	13	58%
Starr Hill	10	1	13%	0	3%	2	22%	3	25%	6	61%
The Meadows	65	13	19%	9	13%	7	11%	16	25%	36	56%
Venable	62	19	31%	6	9%	8	12%	13	21%	30	48%
Woolen Mills	24	6	26%	2	9%	2	10%	5	19%	13	56%
Overall	979	246	25%	95	10%	108	11%	202	21%	531	54%

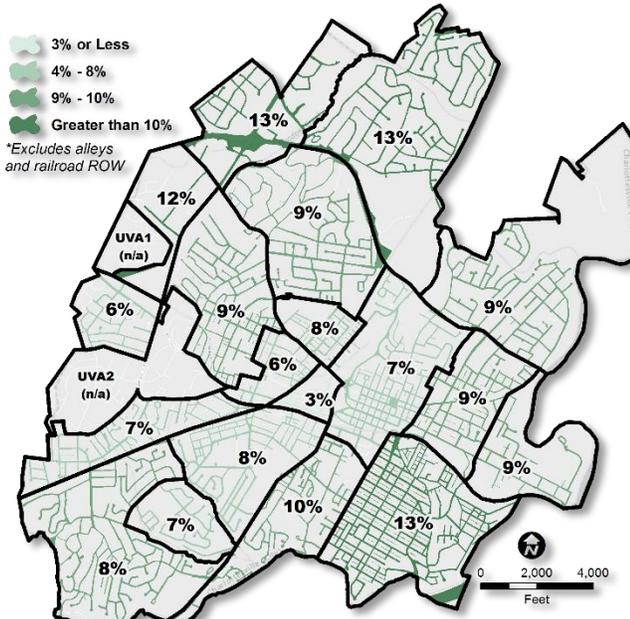
**Percent Urban Tree Canopy
in Rights-of-Way* by Planning Neighborhood**



**Percent Possible Planting Areas (Total)
in Rights-of-Way* by Planning Neighborhood**



**Possible Planting Areas (Vegetation)
in Rights-of-Way* by Planning Neighborhood**



**Possible Planting Areas (Impervious)
in Rights-of-Way* by Planning Neighborhood**

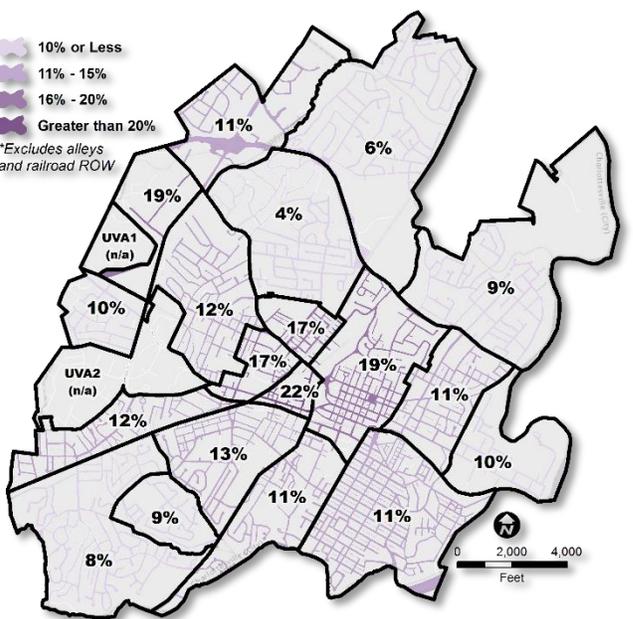
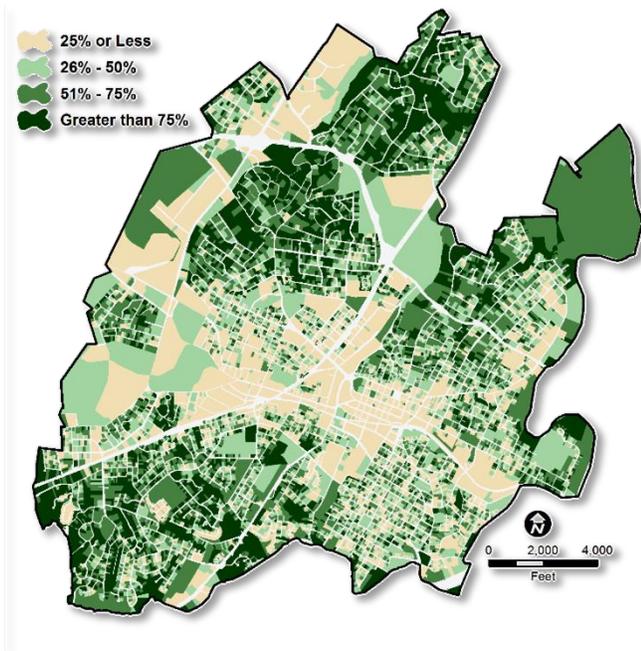
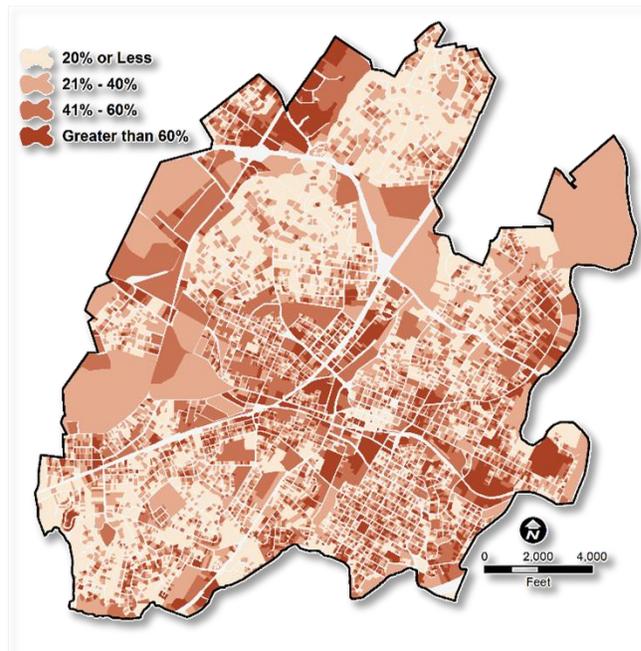


Figure 14: Urban Tree Canopy Assessment Results in Rights-of-Way by Planning Neighborhood

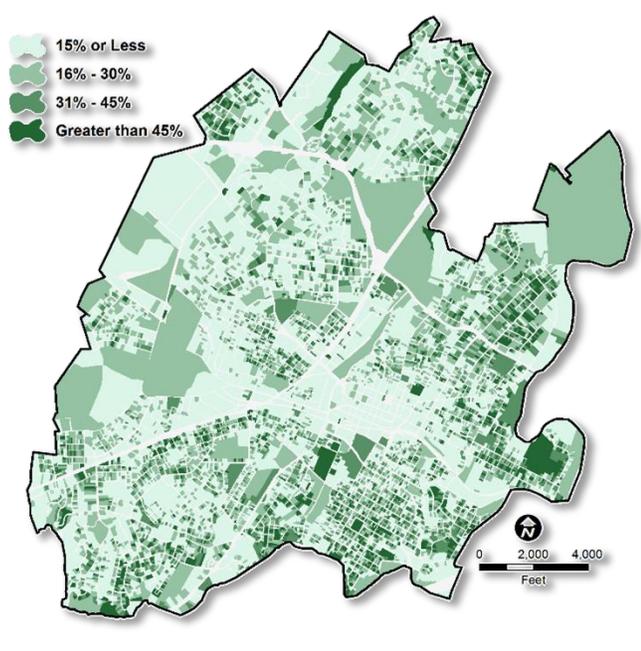
**Percent Urban Tree Canopy
by Parcel**



**Percent Possible Planting Areas (Total)
by Parcel**



**Possible Planting Areas (Vegetation)
by Parcel**



**Possible Planting Areas (Impervious)
by Parcel**

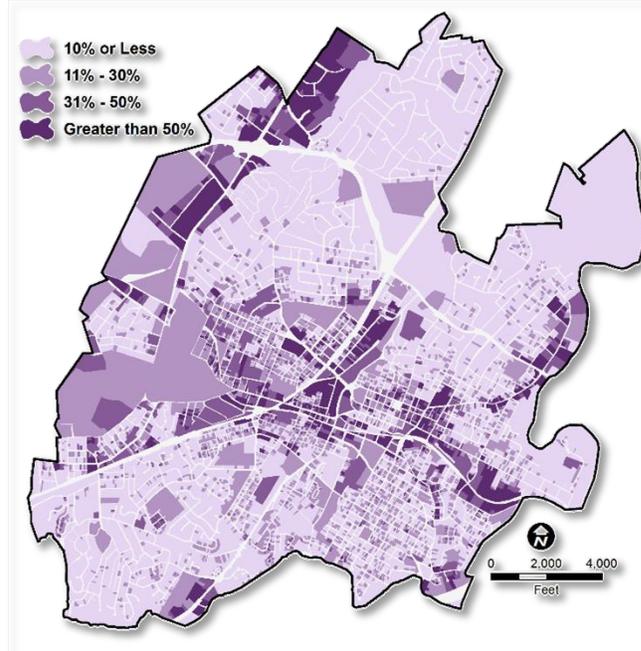


Figure 15: Urban Tree Canopy Assessment Results by Parcel

i-Tree Hydro Input Parameters

The USDA's i-Tree website states that:

“Hydro is a stand-alone application designed to simulate the effects of changes in tree and impervious cover characteristics within a defined watershed on stream flow and water quality. It was designed specifically to handle urban vegetation effects so urban natural resource managers and urban planners can quantify the impacts of changes in tree and impervious cover on local hydrology to aid in management and planning decisions.” (www.itreetools.org)

To estimate the amount of stormwater runoff mitigated by canopy cover in Charlottesville, a broad i-Tree Hydro analysis was completed on November 4th of 2015. The entire study area was included using the Topographic Index Method. Topographic indices (TI's) are a derivative of elevation models that are readily available as inputs for the United States in Hydro (for more information on TI's, visit <http://www.itreetools.org/hydro/>). Land cover values determined by Plan-It Geo's land cover classification study were used as the base case land cover scenario in Hydro. No alternate cover scenario was assessed.

Localized weather data for the analysis was obtained from the following weather station:

Station: CHARLOTTESVILLE ALB 724016-93736 (north of the city)

Period of Record: 01-01-2012 0:00 to 12-30-2012 23:00

For this study, impervious runoff was reported based on the input data. This assumes that only impervious flow reaches channel networks, piping systems, and treatment facilities. Generalized models across non-hydrologic boundaries (i.e. municipal/political boundaries) are inherently difficult to model. For example, the natural flow of water doesn't follow municipal boundaries. Given this example and other limitations, i-Tree Hydro outputs should be used primarily as qualitative estimates of runoff, not an exact calculation. All other parameters in the model were kept as default values.

Canopy Comparisons

In order to have a better understanding of where Charlottesville stands in terms of Urban Tree Canopy, Table 10 lists other cities of similar size and geographical location.

Table 10: Urban Tree Canopy Comparisons

City	Area (Square miles)	UTC (%)	Source
Woodstock, VA	3.8	22	Virginia Dept. of Forestry*
Abingdon, VA	8	26	Virginia Dept. of Forestry*
Upper Arlington, OH	9.9	35	Plan-It Geo
Shaker Heights, OH	6.3	40	Unknown
Charlottesville, VA	10.4	45	Plan-It Geo
Radford, VA	10.1	53	Virginia Dept. of Forestry*

*These analyses were performed by the Virginia Department of Forestry and the Virginia Geospatial Extension Program (VGEP) at Virginia Tech’s Department of Forest Resources and Environmental Conservation in consultation with the Center for Environmental Applications and Remote Sensing (CEARS) and the Spatial Analysis Laboratory (SAL) of the University of Vermont.