URBAN TREE CANOPY

ASSESSMENT

WASHINGTON, D.C.,

JANUARY | 2022

PLANIT GEO™

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AN ASSESSMENT OF
URBAN TREE CANOPY

WASHINGTON, D.C.

> **Someone is sitting in the shade today because someone planted a tree a long time ago.**
> **-Warren Buffet**

PREPARED BY
PlanIT Geo, LLC, Arvada, Colorado

PREPARED FOR
City of Washington, D.C.

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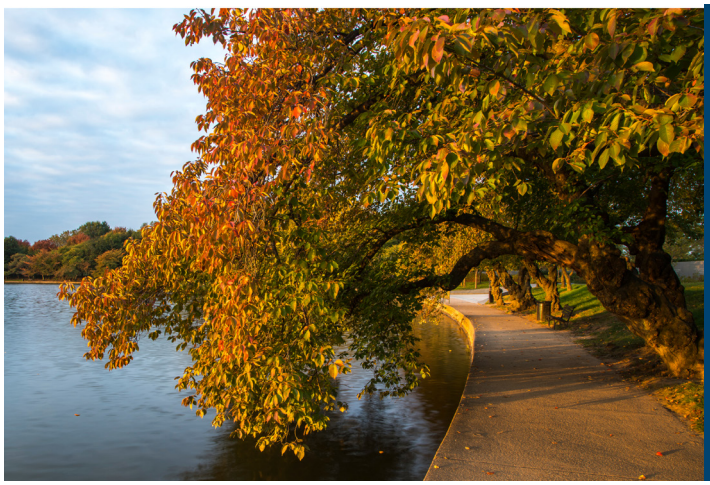


WASHINGTON, D.C. CONTAINS ENOUGH URBAN TREE CANOPY TO FILL ROCK CREEK PARK 8 TIMES

EXECUTIVE SUMMARY

PURPOSE OF THIS ANALYSIS

The City of Washington, D.C. (Figure 1) is approximately 68 square miles or 43,853 acres. Across the city, trees along streets, in parks, yards, and natural areas constitute a valuable urban and community forest. This resource is a critical element of the region's green infrastructure, contributing to environmental quality, public health, water supply, local economies, and aesthetics. The primary goal of this assessment was to provide an updated benchmark of the City's tree canopy and interpret the result across a range of geographic boundaries. Additionally, this assessment aims to continue monitoring efforts to maintain, expand, and ensure the equitable distribution of tree canopy.

URBAN TREE CANOPY IN WASHINGTON, D.C.

In 2020, Washington, D.C had 37% urban tree canopy (UTC) cover and 24% possible planting area (PPA), not including any surface water bodies within the district boundary. The City's total land cover including surface water bodies contained 33% tree canopy, 15% non-canopy vegetation; <1% soil/dry vegetation; 41% impervious surfaces, and 10% water. Urban tree canopy assessments routinely exclude surface water bodies when reporting tree canopy and plantable space percentages. In further dividing the City's urban tree canopy, 19% was overhanging impervious surfaces, and 81% of all canopy was overhanging pervious surfaces. This project is the continuation of tree canopy assessments beginning in 2006. Previous assessments provide a view into the changing nature of tree canopy, the impacts of development and management strategies. Washington D.C. gained 1% (425 acres) urban tree canopy since 2006, saw a neutral change since 2011, and lost 1% (565 acres) since 2015.

ASSESSMENT BOUNDARIES

This study assessed UTC and PPA at multiple geographic scales in order to provide actionable information to a diverse range of audiences. By identifying what resources and opportunities exist at these scales, the City can be more proactive in their approach to protect and expand their urban tree canopy. Land cover metrics were generated at the following geographies: the citywide boundary (1); right-of-way (4); wards (8); land use (11); advisory neighborhood commissions (40); single member districts (296); census block groups (571); census blocks (6,012); and common ownership lots (137,200).

RECOMMENDATIONS

The results of this analysis can be used to develop a continuing strategy to protect and expand the urban forest in Washington, D.C. The UTC and PPA metrics along with the Urban Forestry Program Review completed as part of this study, can be used as a guide to determine where the city has been successful in protecting and expanding its urban forest resource, while also targeting areas to concentrate future efforts based on needs, benefits, and available planting space. Washington, D.C. can use these results to ensure that their urban forest policies and management practices continue to prioritize its maintenance, health, and growth.

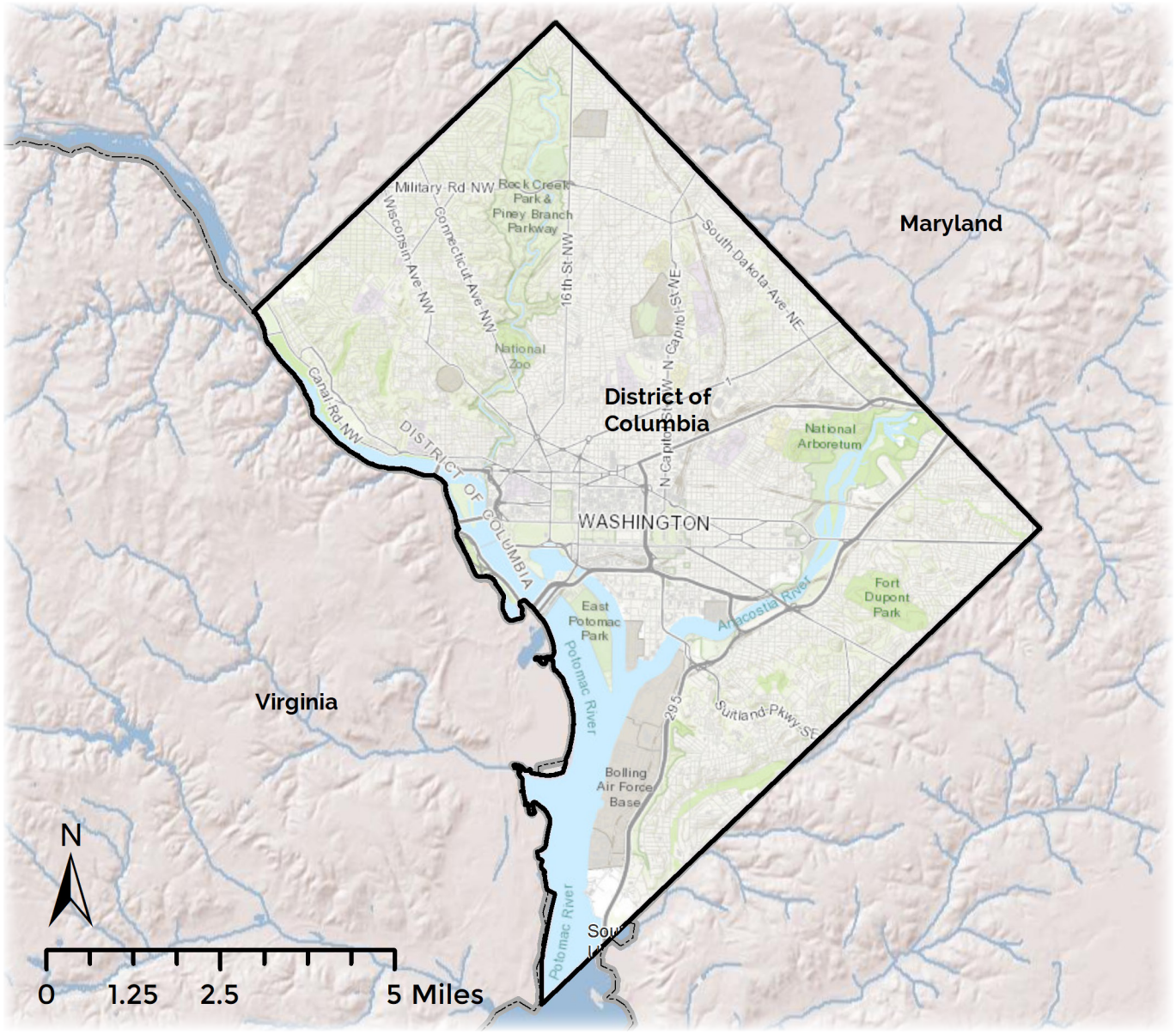


Figure 1. Washington, D.C. occupies approximately 68 square miles between Maryland and Virgina.

37%
URBAN TREE CANOPY

24%
POSSIBLE PLANTING AREA

41%
IMPERVIOUS SURFACE

Figure 2. Based on an analysis of 2020 high-resolution imagery and LiDAR, Washington, D.C. contains 37% tree canopy, 24% areas that could support canopy in the future, and 41% total impervious areas.

PROJECT METHODOLOGY

Land cover, urban tree canopy, and possible planting areas were mapped using the sources and methods described below. These data sets provide the foundation for the metrics reported at the selected geographic assessment scales.

DATA SOURCES

This assessment utilized high-resolution (1-meter) multispectral imagery from the Pleiades satellite constellation collected in June and November 2020 and LiDAR data from the District of Columbia collected in fall 2020 to derive the land cover data set. The satellite imagery was used to classify all types of land cover, whereas the LiDAR data was primarily used to determine vegetation height and distinguish tree canopy from other types of vegetation. Additional GIS layers provided by the District of Columbia were also incorporated into the analysis.

MAPPING LAND COVER

An initial land cover data set was to be created prior to mapping tree canopy. The land cover data set is the most fundamental component of an urban tree canopy assessment. An object-based image analysis (OBIA) software program called Feature Analyst was used to classify features through an iterative approach. In this process, objects' spectral signatures across four bands (blue, green, red, and near-infrared), textures, pattern relationships, and object height were considered. This remote sensing process used the Pleiades imagery and LiDAR to derive five initial land cover classes. These classes are shown in Figure 3 and described in the Glossary in the Appendix.

After manual classification improvement and quality control were performed on the remote sensing products, additional data layers from the city (such as buildings, roads, and other impervious surfaces) were utilized to capture finer feature detail and further categorize the land cover dataset.

Figure 3. Five (5) distinct land cover classes were identified in the 2020 tree canopy assessment: urban tree canopy, other non-canopy vegetation, bare soil and dry vegetation, impervious (paved) surfaces, and water.

IDENTIFYING POSSIBLE PLANTING AREAS AND UNSUITABLE AREAS FOR PLANTING

In addition to quantifying Washington, D.C.'s existing tree canopy cover, another metric of interest in this assessment was the area where tree canopy could be expanded. To assess this, all land area in Washington, D.C. that was not existing tree canopy coverage was classified as either possible planting area (PPA) or unsuitable for planting. Possible planting areas were derived from the Non-Canopy Vegetation class. Unsuitable areas, or areas where it was not feasible to plant trees due to biophysical or land use restraints (e.g. golf course playing areas, recreation fields, etc.), were manually delineated and overlaid with the existing land cover data set (Figure 4). The final results were reported as PPA Vegetation, PPA Impervious, Total PPA, Unsuitable Vegetation, Unsuitable Impervious, Unsuitable Soil, and Total Unsuitable.

Figure 4. Vegetated areas where it would be biophysically feasible for tree plantings but undesirable based on their current usage (left) were delineated in the data as "Unsuitable" (right). These areas included recreational sports fields, golf courses, and other open space.

DEFINING ASSESSMENT LEVELS

In order to best inform the D.C. Council and Washington, D.C.'s various stakeholders, urban tree canopy and other associated metrics were tabulated across a variety of geographic boundaries (Figure 5). These boundaries include the city boundary, right-of-way, wards, land use, advisory neighborhood commissions, single member districts, census block groups, census blocks, and common ownership lots.

- The Washington, D.C. citywide boundary is the one (1) main area of interest over which all metrics are summarized.
- The right-of-way (ROW) in D.C. was assessed. ROW refers to the areas that are publicly managed such as streets, sidewalks, and medians, and is helpful for quantifying canopy coverage of the City's street trees. Four (4) unique ROW feature types were assessed including parking, roadway, service road, and sidewalk.
- Tree canopy was assessed for the (8) election wards in the City. Wards provide an important and relevant summary scale to assess tree canopy as it relates to election districts and to inform the council members and citizens residing in them.
- Eleven (11) generalized land use classes provide detail on tree canopy within the current human uses of land.
- Tree canopy was assessed for the forty (40) advisory neighborhood commissions in Washington, D.C. to identify the amount of tree canopy as it relates to neighborhoods.
- Two hundred and ninety six (296) single member districts were assessed to determine how tree canopy is distributed within the smallest area of the City's electoral regions.
- Five hundred and seventy one (571) census block groups were assessed along with over six thousand (6,012) census blocks to provide information at a small geographic scale. Census block groups (CBGs) and census blocks are used by the U.S. Census Bureau to assure statistical consistency when tracking populations across the United States and can be valuable indicators of environmental justice as they are directly linked with demographic and socioeconomic data.
- The smallest unit of analysis was common ownership lots, of which there were over one hundred and thirty thousand (137,200) in total. This is helpful for assessing the canopy on an individual piece of property.

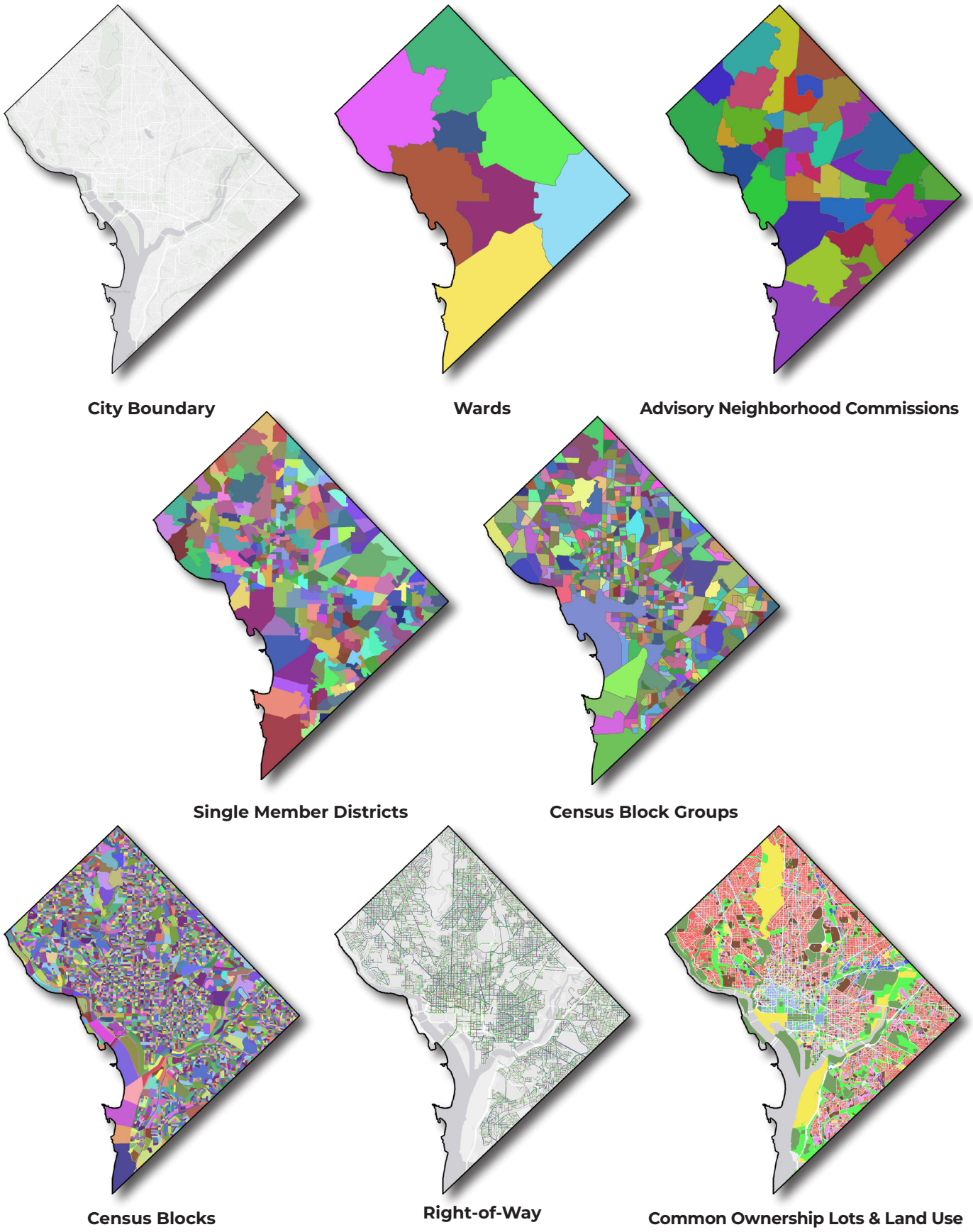


Figure 5. Eight (8) distinct geographic boundaries were explored in this analysis: the full city boundary, right-of-way, wards, land use, advisory neighborhood commissions, single member districts, U.S. census block groups, U.S. census blocks, and common ownership lots.

STATE OF THE CANOPY AND KEY FINDINGS

The results and key findings of this study, including the land cover map and canopy analysis results, are presented below. These results, or metrics, help inform a strategic approach to identifying existing canopy and future planting areas. Land cover percentages are based on the total area of interest while urban tree canopy, possible planting area, and unsuitable percentages are based on land area. Water bodies are excluded from land area because they are typically unsuitable for planting new trees without significant modification.

CITYWIDE LAND COVER

In 2020, tree canopy constituted 33% of Washington, D.C.'s land cover, non-canopy vegetation was 15%, soil/dry vegetation was <1%, impervious was 41%, and water was 10%. These generalized land cover results are presented below in Table 1. The impervious land cover class was then subdivided into more specific classifications. Approximately 14% of Washington, D.C. was buildings, 11% was roads, 4% was parking lots, 4% was sidewalks, and 8% was "other impervious". The detailed land cover results, including impervious classifications, are presented in Figure 6.

Table 1. Generalized land cover classification results.

Washington D.C.	City Boundary	Tree Canopy	Non-Canopy Vegetation	Impervious Surfaces	Soil & Dry Vegetation	Water
Acres	43,853	14,670	6,711	17,887	60	4,524
% of Total	100%	33%	15%	41%	<1%	10%

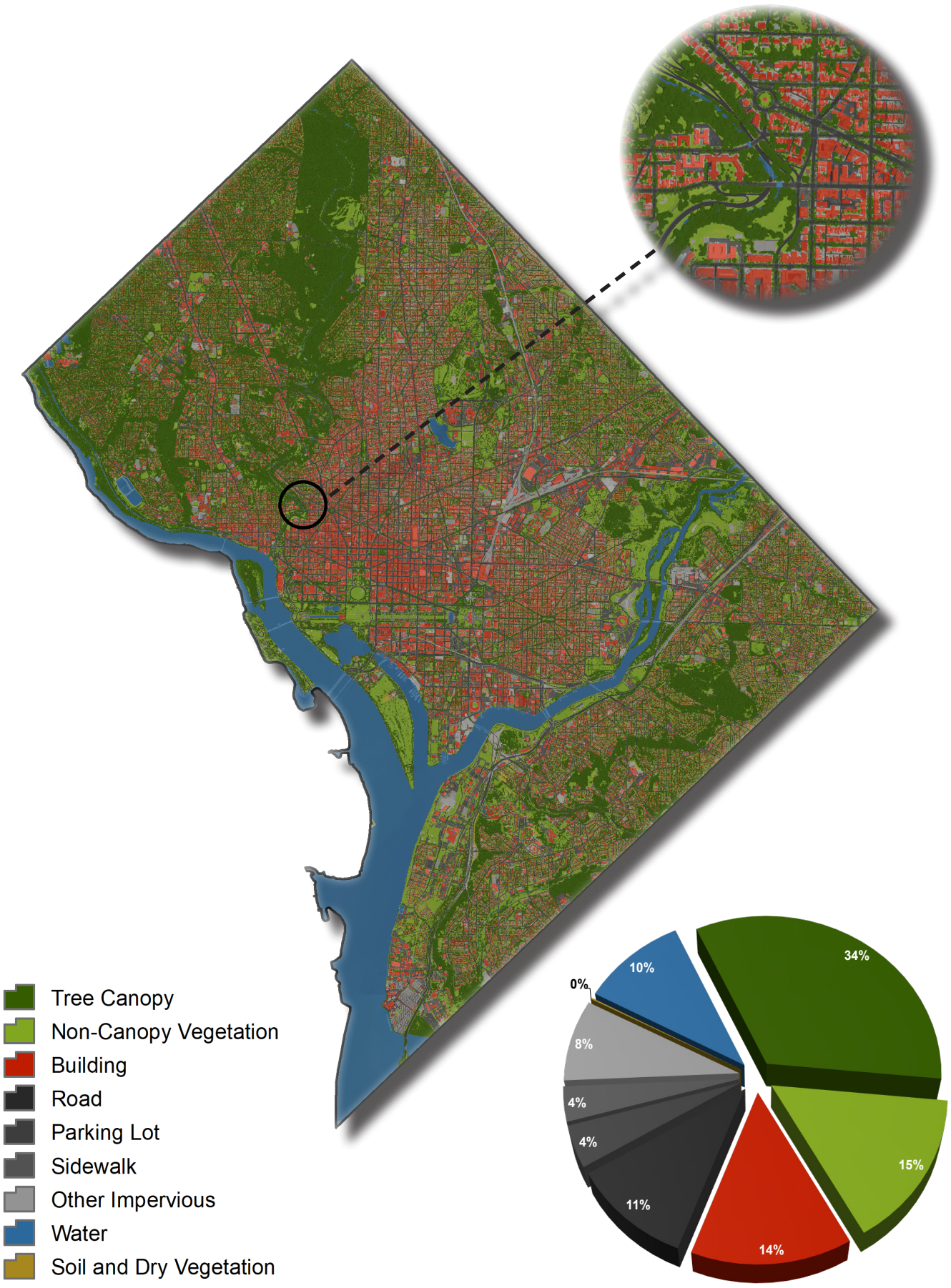


Figure 6. Land cover classes for Washington, D.C., based on 2020 Pleiades imagery and LiDAR.

CITYWIDE URBAN TREE CANOPY

This urban tree canopy assessment utilized the land cover map as a foundation to determine possible planting areas throughout the City. Additional layers and information regarding land considered unsuitable for planting were also incorporated into the analysis. Note that the results of this study, shown in Table 2, are based on land area, which excludes water bodies, as opposed to total area, which includes water bodies.

Results of this study indicate that within Washington, D.C., 14,670 acres are covered with urban tree canopy, making up 37% of the City's 39,329 land acres; 9,380 acres are covered with other vegetation or impervious surfaces such as parking lots where it would be possible to plant trees (PPA), making up 24% of the City; and the other 15,279 acres were considered unsuitable for tree planting, making up 39% of the City. The unsuitable areas include recreational sports fields, golf course playing areas, buildings, roads, and areas of bare soil and dry vegetation.

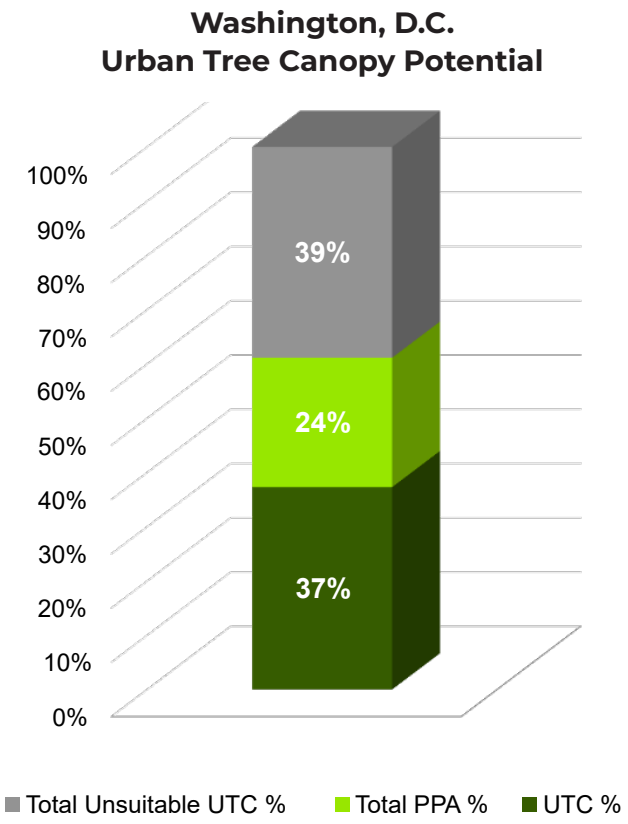
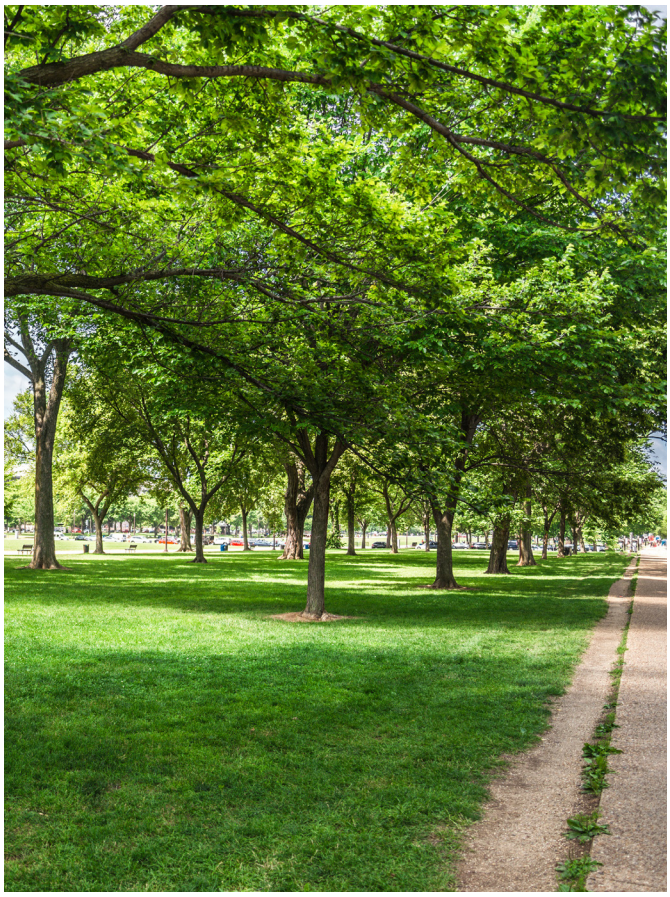


Figure 7. Urban tree canopy, possible planting area, and area unsuitable for UTC in the City of Washington, D.C.

Table 2. Urban tree canopy assessment results by acres and percent. (Percentages based on land acres.)

Washington D.C.	Acres	%
Total Area	43,853	100%
Land Area	39,329	90%
Urban Tree Canopy	14,670	37%
Possible Planting Area - Vegetation	6,024	15%
Possible Planting Area - Impervious	3,356	9%
Total Possible Planting Area	9,380	24%
Unsuitable Vegetation	667	2%
Unsuitable Impervious	14,555	37%
Unsuitable Soil	57	<1%
Total Unsuitable Area	15,279	39%



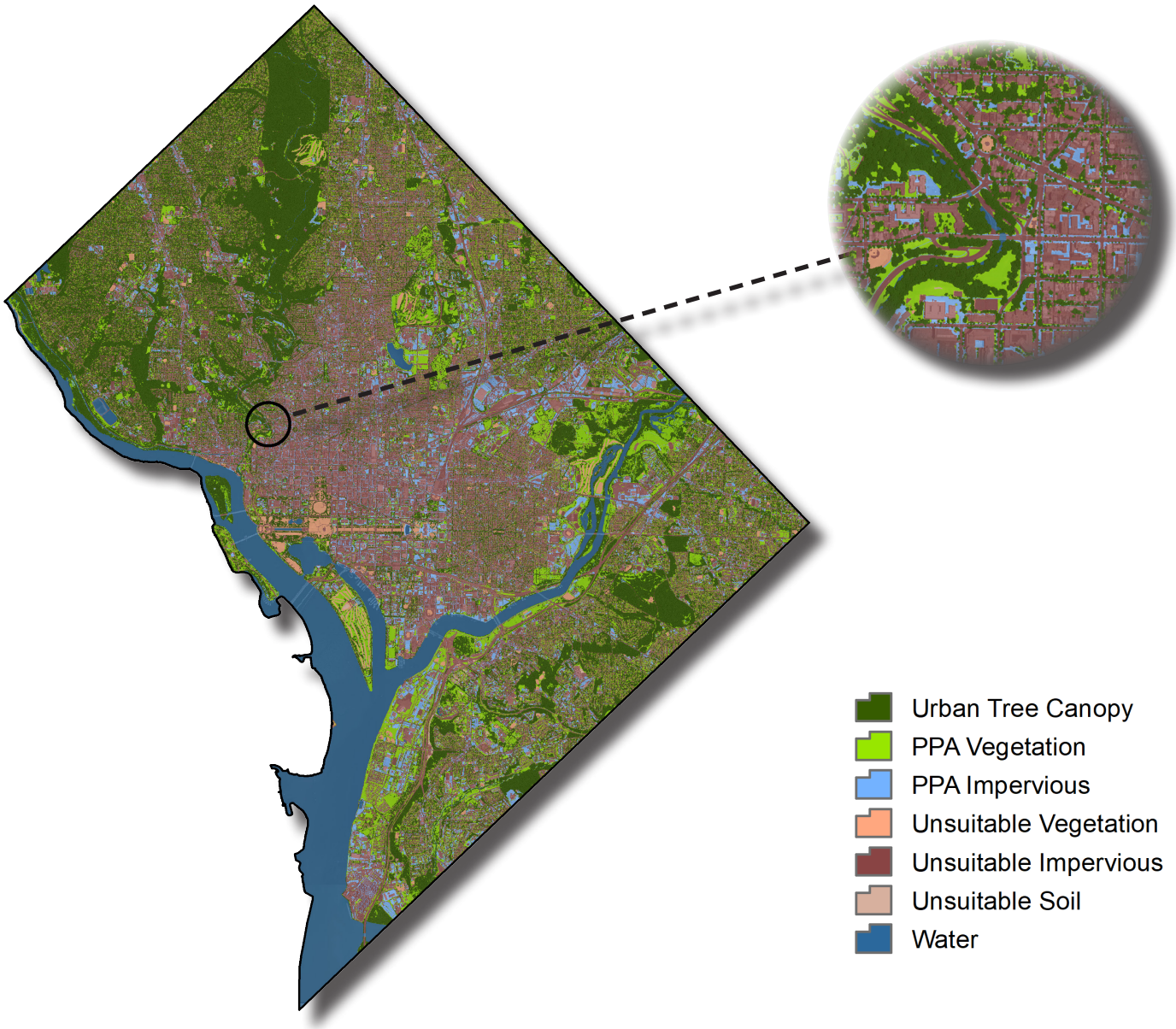


Figure 8. Urban tree canopy, possible planting area, and unsuitable areas for UTC in Washington, D.C.

The City's 14,670 acres of urban tree canopy were further divided into two subcategories based on whether their canopy had an impervious or pervious understory. Tree canopy overhanging an impervious surface can provide many benefits through ecosystem services such as localized cooling provided by shading of impervious surfaces and increased stormwater absorption.

Results indicated that a majority of Washington, D.C.'s UTC was overhanging pervious surfaces, as 81% of all tree canopy had a pervious understory.

Table 3. Detailed urban tree canopy classifications.

Washington D.C.	Acres	%
Overhanging Pervious Surfaces	11,812	81%
Overhanging Impervious Surfaces	2,858	19%

URBAN TREE CANOPY BY RIGHTS-OF-WAY

UTC and PPA were evaluated in the right-of-way (ROW) at the citywide level and for four different types of ROW. The total land area of ROW in D.C. is 8,960 acres. Results showed that the ROW contained 37% UTC, equal to the citywide average, and 17% PPA. 55% of the ROW is impervious surfaces. The greatest percentage of UTC by area was found in the sidewalk ROW type (47%) followed closely by parking (46%). The lowest UTC was found in service road (20%). Trees in the ROW help improve air quality, combat the urban heat island effect, and provide shade to high traffic and pedestrian areas. Since the ROW is primarily owned and managed by the District, possible planting areas located within them are good opportunities for increasing tree canopy cover.

Table 4. Urban tree canopy assessment results by rights-of-way. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the City's total UTC or PPA within each right-of-way type.

Rights-of-Way	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Parking	1,989	22%	908	46%	28%	691	35%	45%
Roadway	4,771	53%	1,330	28%	41%	123	3%	8%
Service Road	20	0%	4	20%	0%	4	19%	0%
Sidewalk	2,180	24%	1,033	47%	32%	724	33%	47%
All Rights-of-Way	**8,960**	**100%**	**3,275**	**37%**	**100%**	**1,542**	**17%**	**100%**

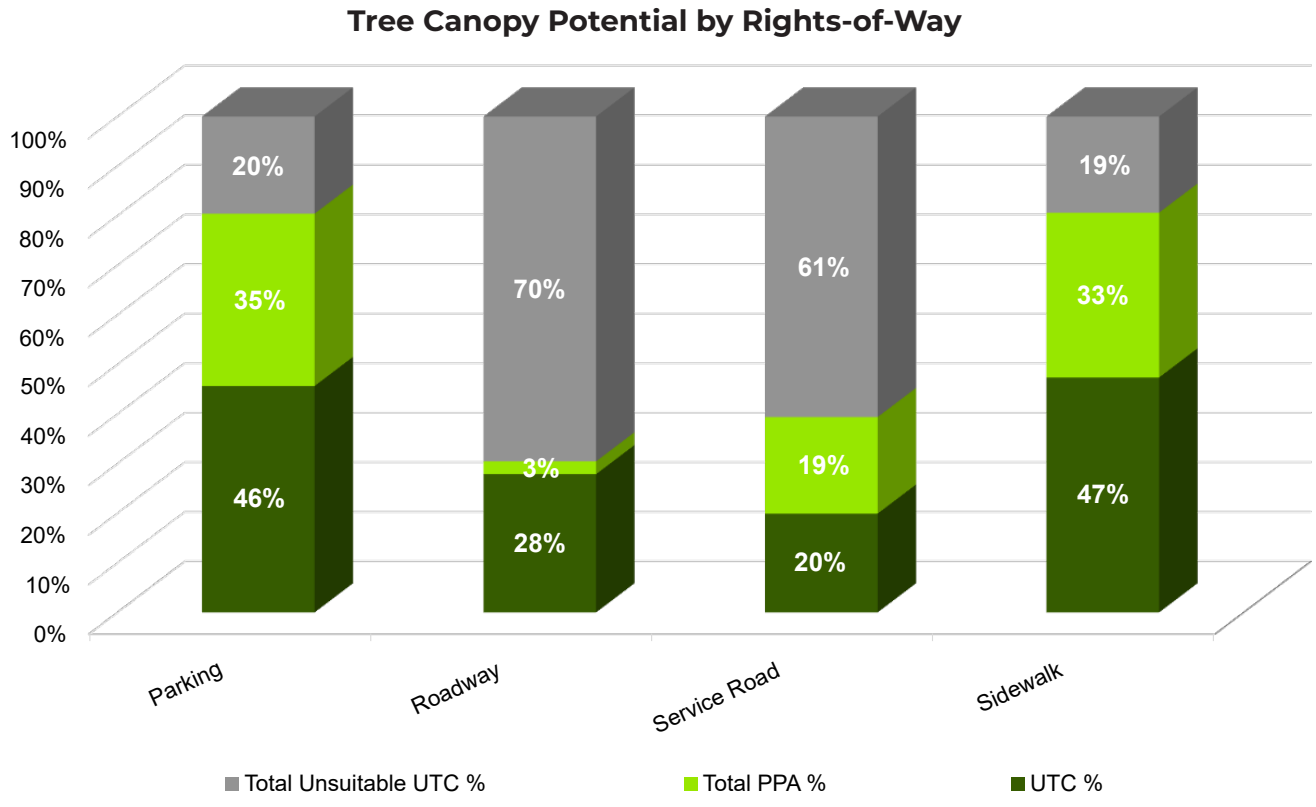


Figure 9. Urban tree canopy, possible planting area, and area unsuitable for UTC by right-of-way.

URBAN TREE CANOPY BY WARDS

The District's eight wards had varying levels of UTC and PPA. The ward with the lowest canopy cover was ward 6 (19%), and the ward with the highest canopy cover was ward 3 (59%). Ward 3 is the largest ward by land area and contains over one-quarter (27%) of the District's tree canopy. Wards 3 and 4 had 59% and 50% canopy, respectively, while the other five wards ranged from 19% to 38%. PPA also varied between wards but to a lesser degree. The lowest PPA was in ward 3 (16%), and the highest was in ward 8 (34%). Ward 5 contained 22% of all PPA within the District.

Table 5. Urban tree canopy assessment results by wards. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the City's total UTC or PPA within each ward.

Wards	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Ward 1	1,582	4%	386	24%	3%	284	18%	3%
Ward 2	4,087	10%	1,115	27%	8%	757	19%	8%
Ward 3	6,695	17%	3,952	59%	27%	1,073	16%	11%
Ward 4	5,749	15%	2,848	50%	19%	1,018	18%	11%
Ward 5	6,560	17%	1,929	29%	13%	2,034	31%	22%
Ward 6	3,664	9%	690	19%	5%	794	22%	8%
Ward 7	5,431	14%	2,091	38%	14%	1,535	28%	16%
Ward 8	5,559	14%	1,660	30%	11%	1,886	34%	20%
Totals	**39,328**	**100%**	**14,670**	**37%**	**100%**	**9,379**	**24%**	**100%**

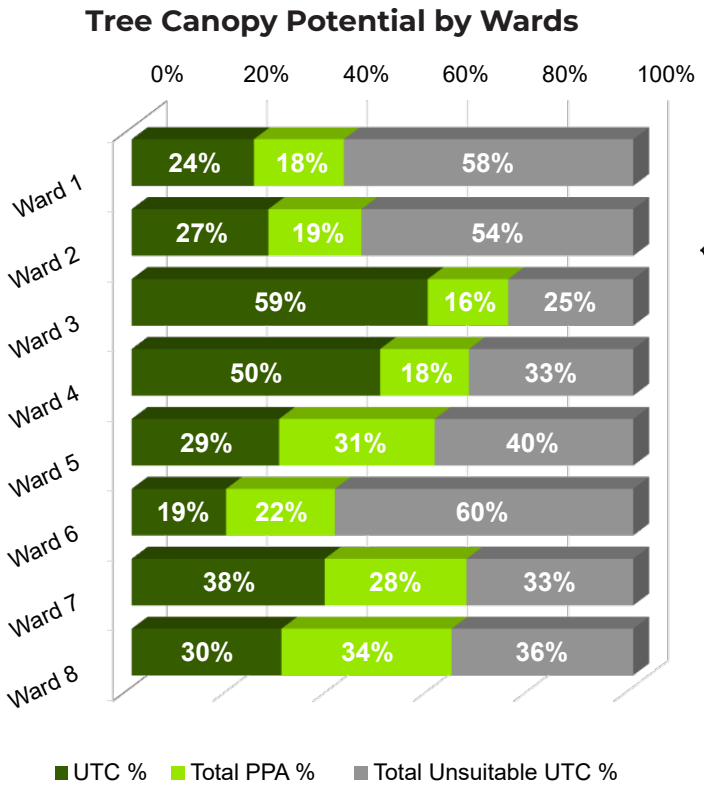


Figure 10. Urban tree canopy, possible planting area, and area unsuitable for UTC by wards.

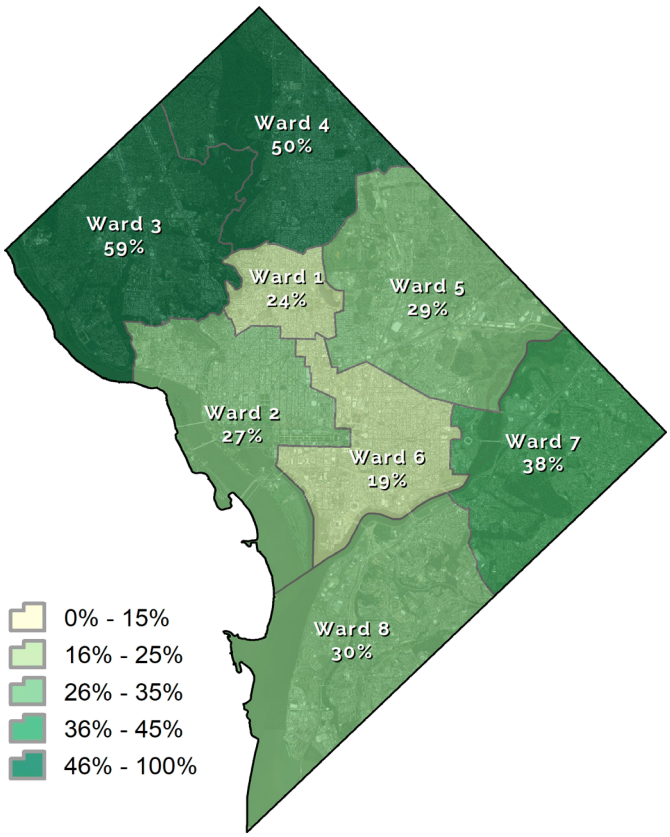


Figure 11. Urban tree canopy by wards.

URBAN TREE CANOPY BY LAND USE

UTC and PPA were assessed in 11 generalized land use categories within the District. UTC was not evenly distributed across land use categories. The land use with the lowest canopy cover was commercial (7%), and the land use with the highest canopy cover was vacant (51%).Low density residential composed 26% of all land area in D.C. and contained the largest portion of UTC in the District (27%). PPA also varied throughout the District's land use with the lowest PPA found in medium density residential (17%) and the highest in parking (66%). The greatest opportunity for future expansion was found in public and parks which contained 21% of all PPA in the District. Low density residential and vacant also contained large amounts of PPA with 19% and 18% of all PPA, respectively.

Table 6. Urban tree canopy assessment results by land use. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the City's total UTC or PPA within each land use.

Land Use	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Commercial	1,390	5%	102	7%	1%	323	23%	4%
High Density Residential	1,497	5%	306	20%	3%	507	34%	7%
Hotels and Dormitories	179	1%	35	19%	0%	46	26%	1%
Industrial	339	1%	38	11%	0%	109	32%	1%
Institutional	2,414	8%	548	23%	5%	807	33%	11%
Low Density Residential	7,678	26%	3,010	39%	27%	1,469	19%	19%
Medium Density Residential	1,031	4%	225	22%	2%	170	17%	2%
Not Specified	4,338	15%	2,093	48%	19%	986	23%	13%
Parking	318	1%	43	14%	0%	211	66%	3%
Public and Parks	4,746	16%	1,939	41%	18%	1,582	33%	21%
Vacant	5,237	18%	2,685	51%	24%	1,346	26%	18%
Totals	**29,168**	**100%**	**11,023**	**38%**	**100%**	**7,557**	**26%**	**100%**

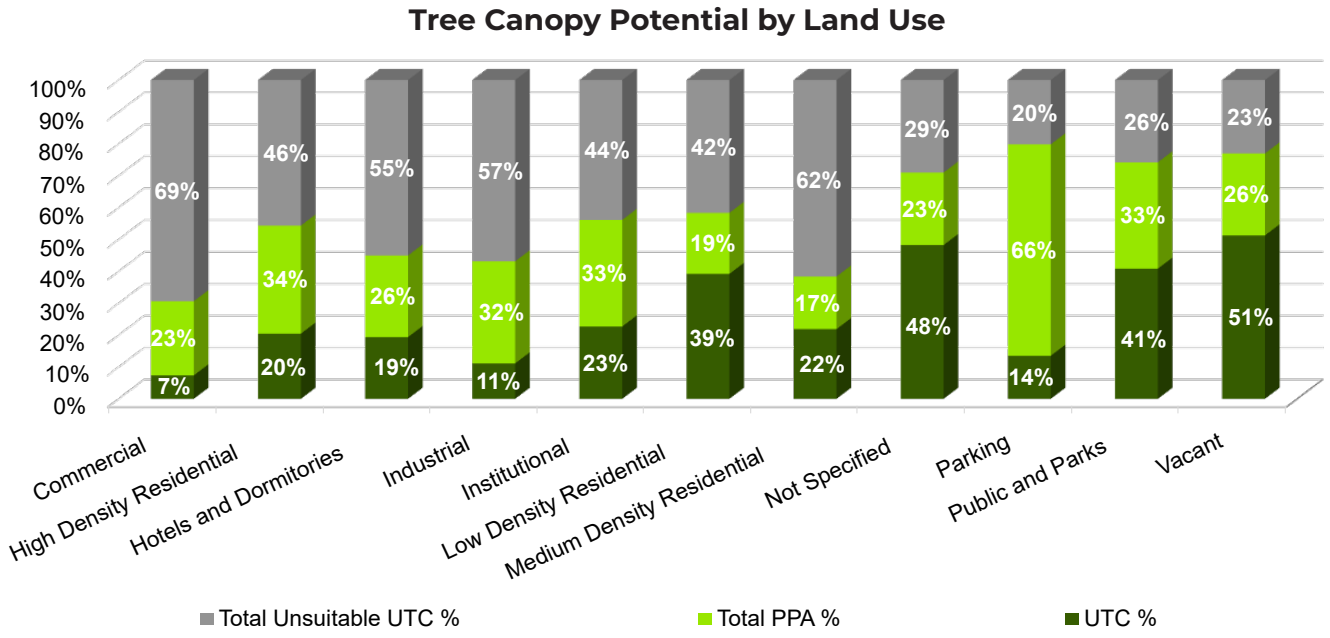


Figure 12. Urban tree canopy, possible planting area, and area unsuitable for UTC by land use.

URBAN TREE CANOPY BY ADVISORY NEIGHBORHOOD COMMISSIONS

Washington, D.C. includes 40 advisory neighborhood commissions (ANC). Results showed that ANC 2C had the least canopy coverage with 14% or 101 acres of UTC, and the most canopy coverage was found in ANC 3G with 70% or 1,198 acres of UTC.The largest portion of UTC was found in ANC 3D which contained 1,513 acres of tree canopy or 10% of all tree canopy in the District. The ANC with the least amount of PPA was ANC 1D which had 10% or 23 acres of PPA, and the most PPA was in ANC 8D with 38% or 693 acres of PPA. The greatest opportunity for future canopy expansion was found in ANC 5C which contained 790 acres of plantable space or 8% of all PPA in D.C.

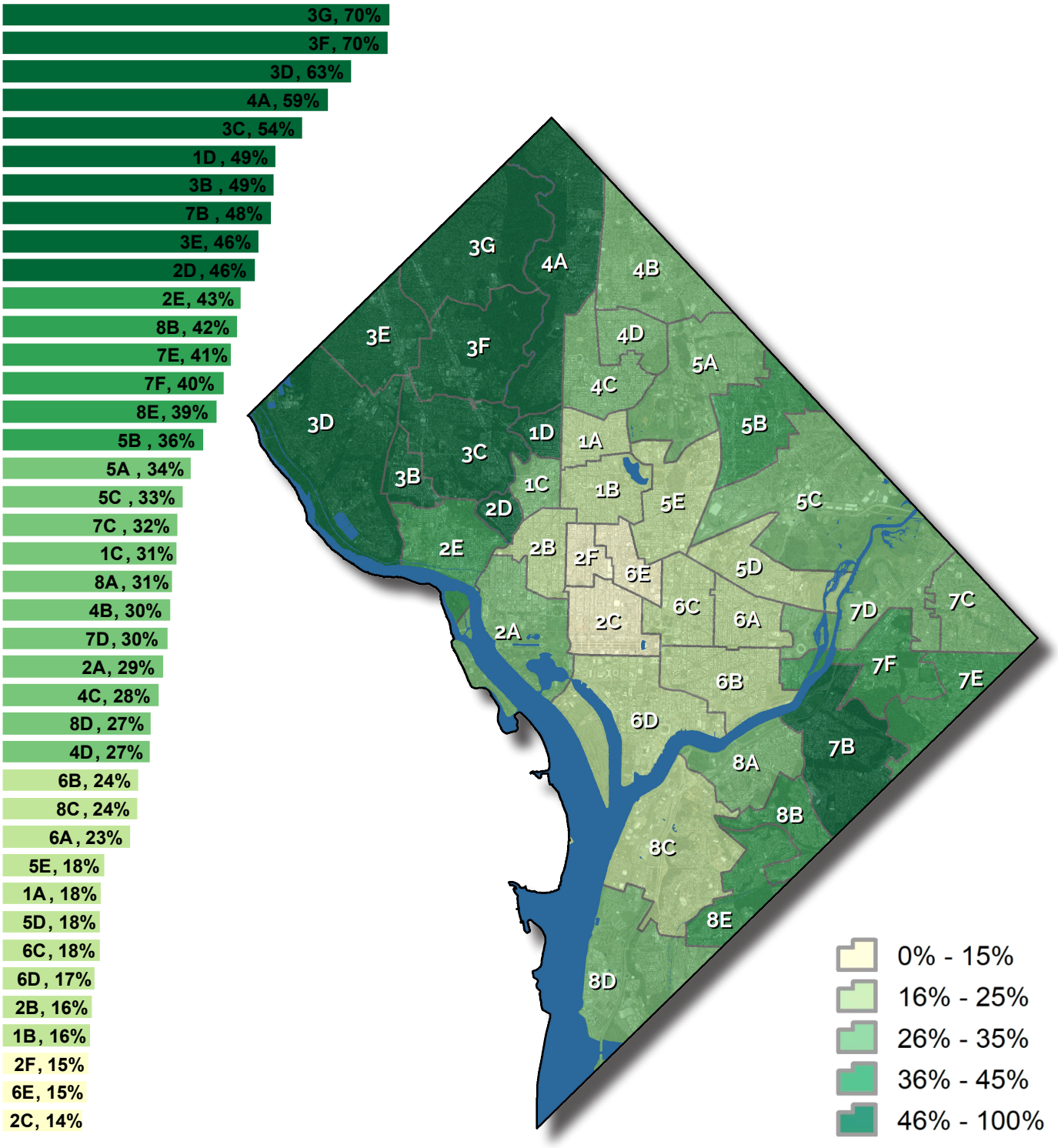


Figure 13. Urban tree canopy in Washington, D.C. by advisory neighborhood commissions.

URBAN TREE CANOPY BY SINGLE MEMBER DISTRICTS

UTC and PPA were assessed for single member districts in Washington, D.C. Results indicated that UTC in D.C. is not uniformly distributed throughout the City. Some of the City's 296 single member districts contained less than 10% canopy cover, while others contained over 70%. The average canopy cover for a single member district in D.C. was 31%. Over 25% of single member districts had UTC higher than the citywide average of 37%. PPA also varied greatly and ranged from 7% to 50%. For the complete results by single member district, refer to the UTC Results spreadsheet.

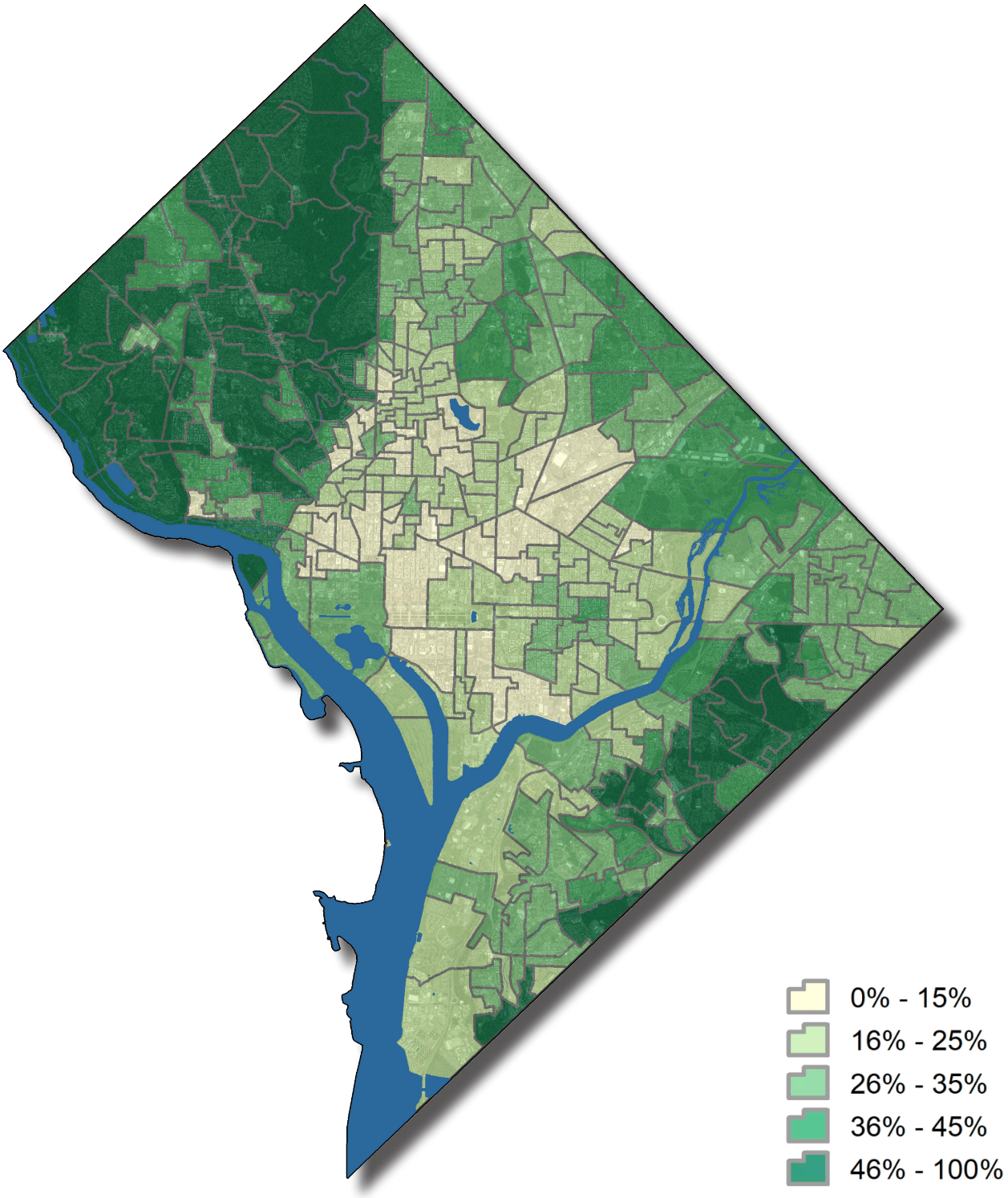


Figure 14. Urban tree canopy in Washington, D.C. by single member districts.

URBAN TREE CANOPY BY CENSUS BLOCK GROUPS

UTC and PPA were assessed at the census block group level. Block groups contain clusters of census blocks and block group boundaries do not cross state, county or census tract boundaries. This is the smallest geographic unit of measure at which the U.S. Census publishes sample data. This scale links to socio-demographic data making it a useful boundary for assessing the equitable distribution of tree canopy within a city. Results indicated that UTC is not uniformly distributed throughout the District. Some of the City's 571 census block groups contained less than 5% cover while others contained over 80%. PPA also varied greatly and ranged from 6 to 57%. For the complete results by census block group, refer to the UTC Results spreadsheet.

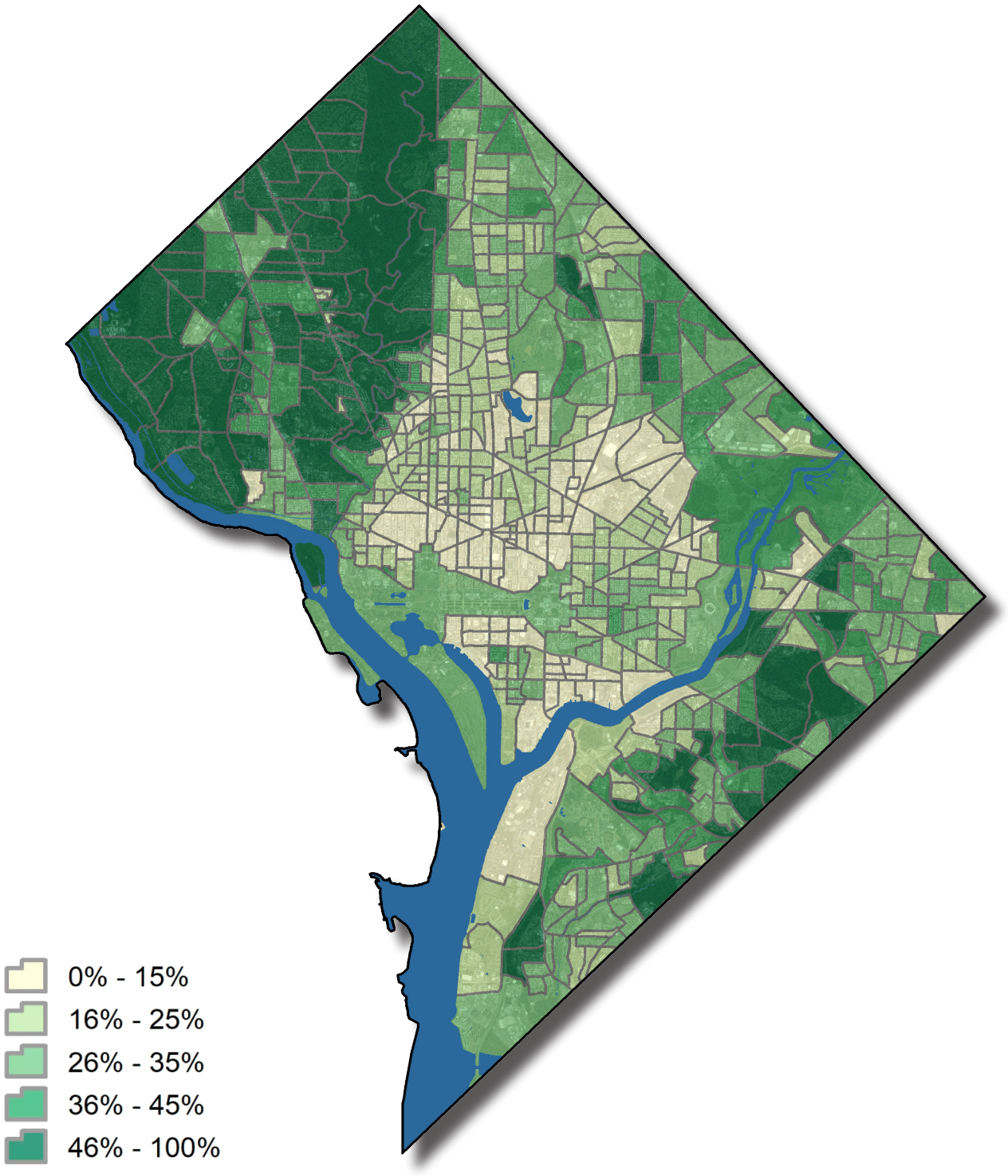


Figure 15. Urban tree canopy in Washington, D.C. by census block groups.

URBAN TREE CANOPY BY CENSUS BLOCKS

UTC and PPA were also assessed at the census block level. This is the smallest geographic unit of measure in which U.S. Census and ACS data are available. In urban areas, census blocks are generally small in size and bounded by streets. In suburban and rural areas, census blocks may be larger and bounded by visible features such as streets, streams, or railroad tracks or invisible features like property lines, school districts, or the county boundary. A collection of census blocks make up a census block group. Some of the City's 6,012 census blocks contained no UTC at all, while others contained nearly 100% tree canopy. PPA also varied greatly and ranged from 0 to over 80%. For the full UTC results by census block, refer to the census block shapefile and attribute table in the UTC Results geodata.

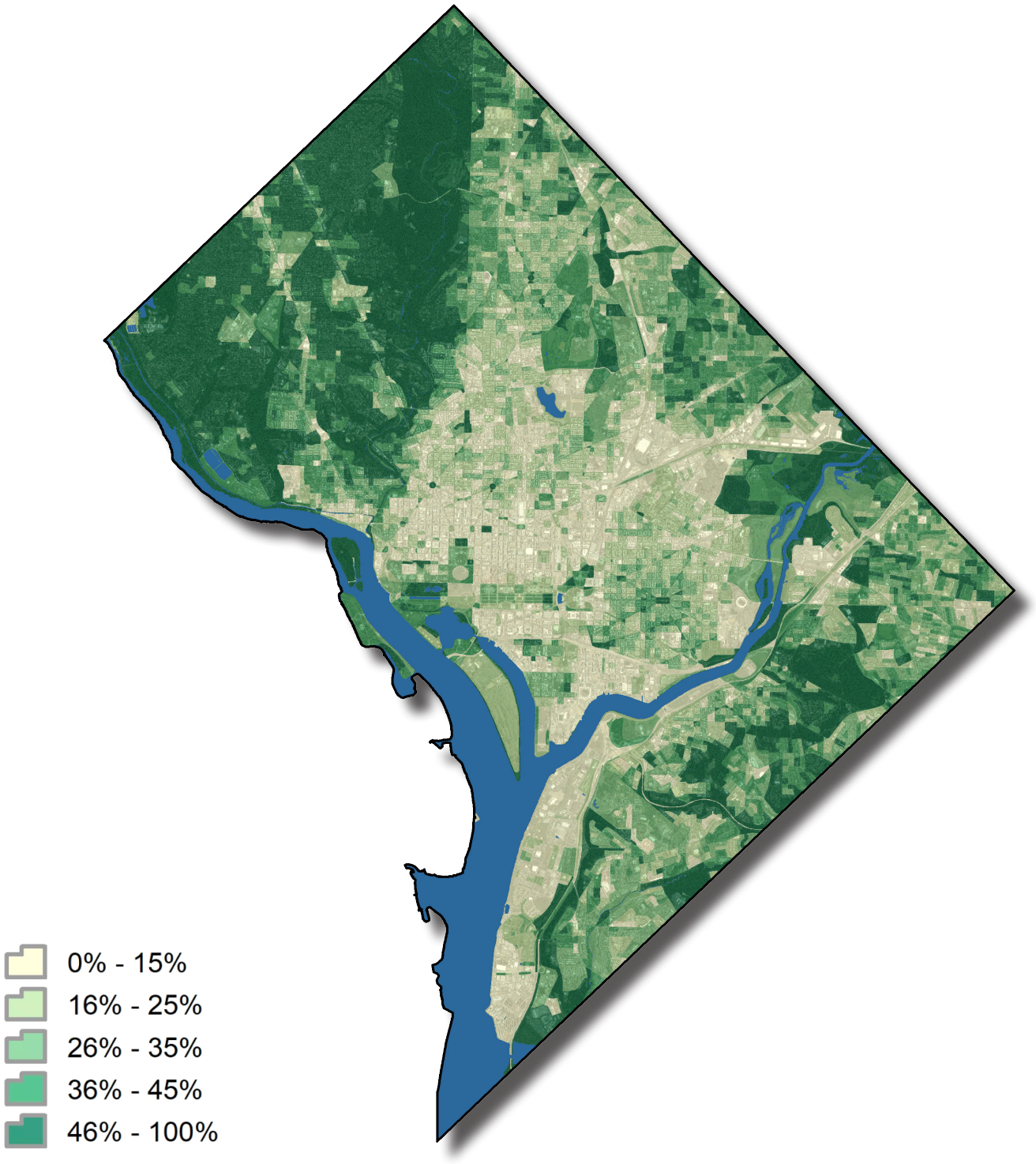


Figure 16. Urban tree canopy in Washington, D.C. by census blocks.

URBAN TREE CANOPY BY POPULATION

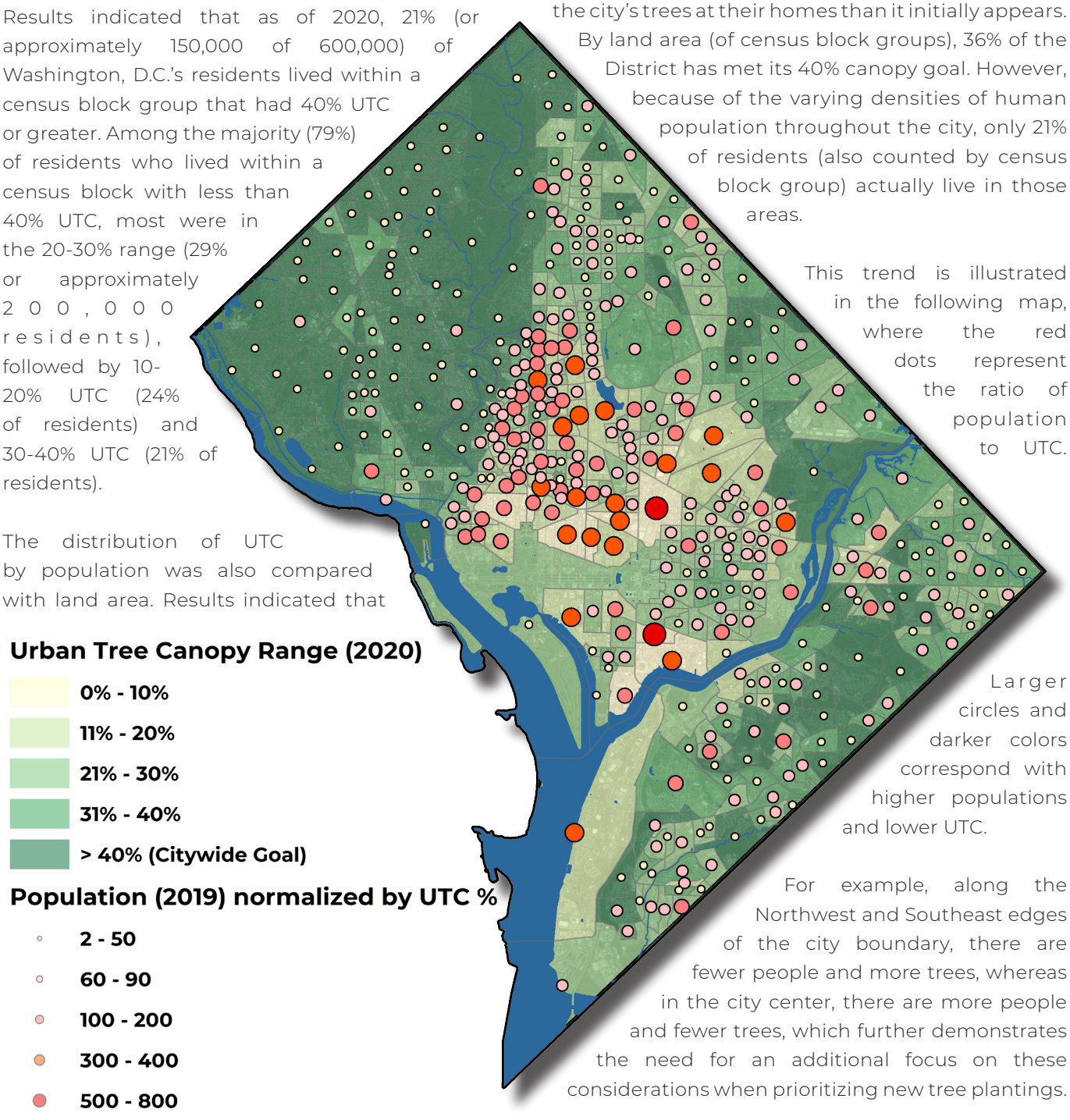
In addition to assessing UTC and PPA by acres and percent at the census block group level, this study also compared UTC with population per census block group in order to assess the distribution of residents living within various ranges of urban tree canopy and determine the proportion of the District's population who live somewhere that is meeting their canopy goal.

Results indicated that as of 2020, 21% (or approximately 150,000 of 600,000) of Washington, D.C.'s residents lived within a census block group that had 40% UTC or greater. Among the majority (79%) of residents who lived within a census block with less than 40% UTC, most were in the 20-30% range (29% or approximately 200,000 residents), followed by 10-20% UTC (24% of residents) and 30-40% UTC (21% of residents).

The distribution of UTC by population was also compared with land area. Results indicated that typically, the proportion of the District's residents that lived within less canopy covered census block groups was greater than the proportion of the District's land area containing the same UTC range; similarly, greater canopy covered census block groups comprised a greater proportion of land area but are home to fewer residents.

Ultimately, the analysis of UTC by population revealed that fewer residents may be receiving the benefits of the city's trees at their homes than it initially appears. By land area (of census block groups), 36% of the District has met its 40% canopy goal. However, because of the varying densities of human population throughout the city, only 21% of residents (also counted by census block group) actually live in those areas.

This trend is illustrated in the following map, where the red dots represent the ratio of population to UTC.



Larger circles and darker colors correspond with higher populations and lower UTC.

For example, along the Northwest and Southeast edges of the city boundary, there are fewer people and more trees, whereas in the city center, there are more people and fewer trees, which further demonstrates the need for an additional focus on these considerations when prioritizing new tree plantings.

Figure 17. Urban tree canopy in Washington, D.C. by population of census block groups.

Table 7. Population of Washington, D.C. residents living within urban tree canopy ranges of 10 percent.

Population by Urban Tree Canopy Ranges						
Urban Tree Canopy Range	**2010 Population**	**% within Range (2011 UTC)**	**2015 Population**	**% within Range (2015 UTC)**	**2019 Population**	**% within Range (2020 UTC)**
Less than 10%	20,978	3%	27,511	4%	29,984	**4%**
10-20%	154,876	26%	166,543	26%	163,058	**24%**
20-30%	158,413	26%	156,197	24%	203,713	**29%**
30-40%	136,008	23%	139,769	22%	148,268	**21%**
40-50%	57,324	10%	56,116	9%	56,648	**8%**
50-60%	45,032	7%	45,612	7%	40,256	**6%**
60-70%	20,453	3%	38,480	6%	38,767	**6%**
70% or greater	8,639	1%	17,256	3%	11,989	**2%**
Grand Total	**601,723**	**100%**	**647,484**	**100%**	**692,683**	**100%**

Table 8. Cumulative population of Washington, D.C. residents living within urban tree canopy ranges of 10 percent. (The proportions of residents meeting 30% and 40% targets are discussed in greater detail on the following pages.)

Cumulative Population by Urban Tree Canopy Ranges						
Urban Tree Canopy Range	**2010 Population**	**% within Range (2011 UTC)**	**2015 Population**	**% within Range (2015 UTC)**	**2019 Population**	**% within Range (2020 UTC)**
At least 10%	580,745	97%	619,973	96%	662,699	**96%**
At least 20%	425,869	71%	453,430	70%	499,641	**72%**
At least 30%	267,456	44%	297,233	46%	295,928	**43%**
At least 40%	131,448	22%	157,464	24%	147,660	**21%**
At least 50%	74,124	12%	101,348	16%	91,012	**13%**
At least 60%	29,092	5%	55,736	9%	50,756	**7%**
70% or greater	8,639	1%	21,842	3%	11,989	**2%**
Grand Total	**601,723**	**100%**	**4,586**	**100%**	**692,683**	**100%**

URBAN TREE CANOPY ACCESS

While evaluating UTC by population per census block group where people live is useful, it still does not capture a complete picture of residents' access to the District's urban forest resource since people do not necessarily remain at their homes at all times. Many commute to work or school, and the value of taking a stroll through the neighborhood has been increasingly recognized. For this reason, the number of people who live within "walking distance" (represented by 1,000 feet) of areas of high UTC were also assessed.

This analysis was modeled after a new recommendation for urban forest management called the "3-30-300 Rule," proposed by Professor Cecil Konijnendijk van den Bosch (Director of the Nature Based Solutions Institute and the Master of Urban Forestry Leadership Program at the University of British Columbia) in early 2021. The rule seeks to establish a unified standard that urban forest managers can strive for when designing sustainable urban forests that benefit residents equitably. While keeping in mind that the needs of various communities will be highly nuanced based on things like geographic location, climate, population, and level of urbanization, etc., three basic targets have been established: every resident should be able to see 3 trees of a decent size from their home; every neighborhood should have at least 30 percent tree canopy cover; and the nearest park or green space should be within 300 meters (rounded up and represented by 1,000 feet in this assessment).

Assessing what kind of trees can be viewed from every home's window would be a large endeavor outside the scope of this project, but the canopy cover and distance from green space targets were assessed. To tailor the results to the District's unique needs, analyses were performed for both the 3-30-300 rule's recommended canopy cover target (30%) as well as the District's own canopy goal (40%).

The "3-30-300 Rule" states that every resident should be able to see at least 3 mature trees from their home, live in a neighborhood with at least 30% canopy cover, and walk to a park or green space within 300 meters.

*Konijnendijk van den Bosch, Cecil. *Promoting health and wellbeing through urban forests - Introducing the 3-30-300 rule.* The University of British Columbia, Vancouver, 2021/02/22.

Visit https://iucnurbanalliance.org/promoting-health-and-wellbeing-through-urban-forests-introducing-the-3-30-300-rule/ for more information.

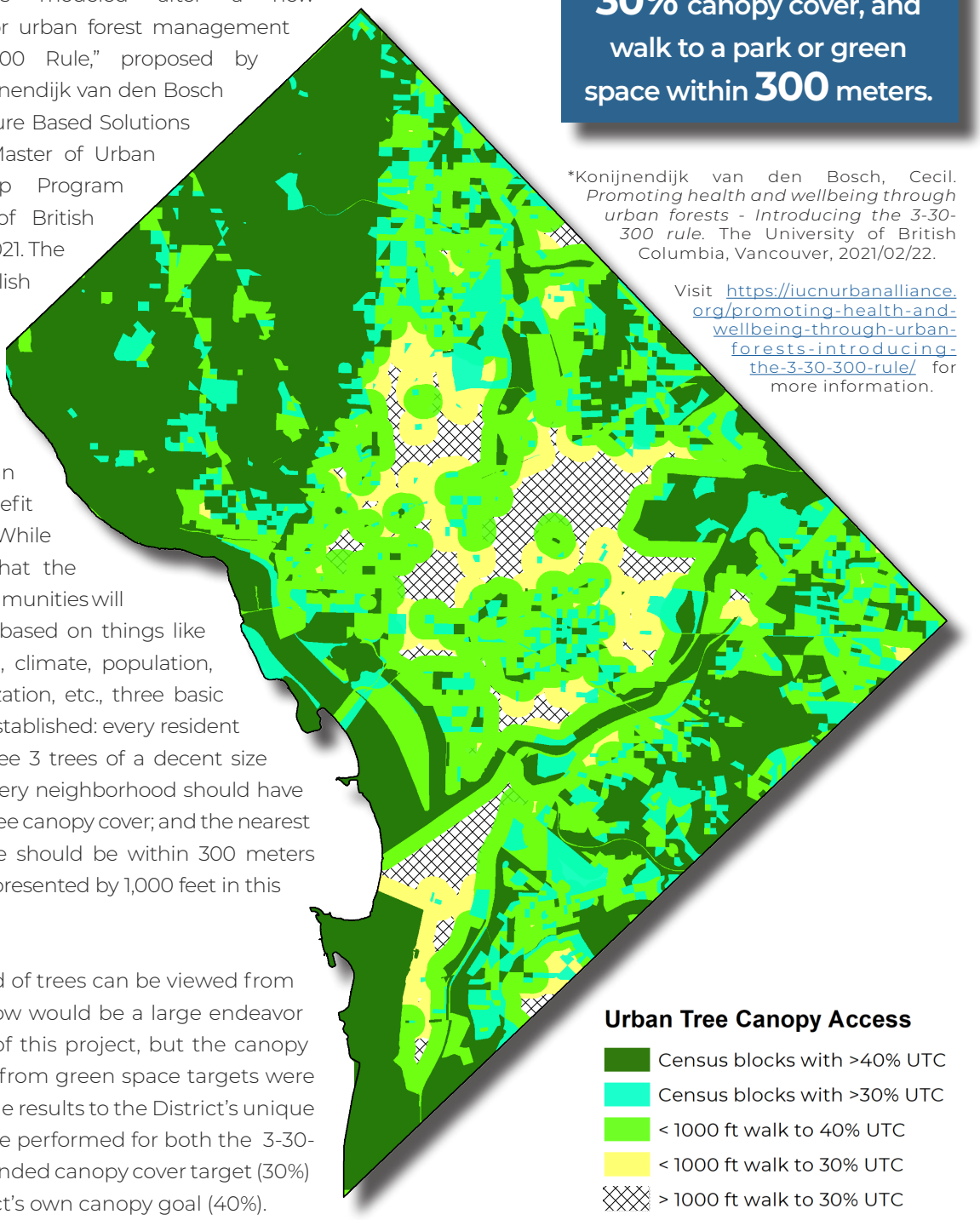


Figure 18. Areas in Washington, D.C. with access to areas of high (40%) or adequate (30%) urban tree canopy.

Results indicated that when the analysis of UTC by population was expanded from solely the canopy cover where residents *live* to the canopy cover *within 1,000 feet* of where they live, the amount of residents with access to the District's urban forest improved significantly. As described above, in 2020, 21% of Washington, D.C.'s residents lived in a census block group that had 40% UTC or greater, and 79% did not. With respect to the 3-30-300 rule's target, in 2020, 43% of residents lived in a census block group that had 30% UTC or greater, and 57% did not. On the contrary, this analysis revealed that 81% of all residents lived within 1,000 feet of a census block with at least 40% UTC – more than double the proportion of residents living in areas with 40% UTC, and effectively a reversal of the original result – and 93% lived within 1,000 feet of an area with 30% UTC.

The same process was repeated using previous UTC assessment data from 2011 and 2015 and determined that although the District's population has grown steadily over the last decade, the proportions of residents meeting these canopy targets have remained relatively constant (and in some cases even improved, e.g. residents living within 1,000 feet of areas of 40% UTC from 2011-2021). These results also align with the 2020 canopy change analysis results described in the following section, which often showed an increase in canopy from 2011-2015 followed by a decrease from 2015-2020. Overall, an application of the 3-30-300 rule to Washington, D.C.'s urban forest demonstrates that the District is making strides to ensure that all residents (93% so far) have convenient access to the city's trees and their many benefits, even if this is less apparent when assessing access only in terms of residents who live in areas meeting its own 40% canopy cover goal (currently 21%).

Figure 19. Population of residents meeting tree canopy access objectives.

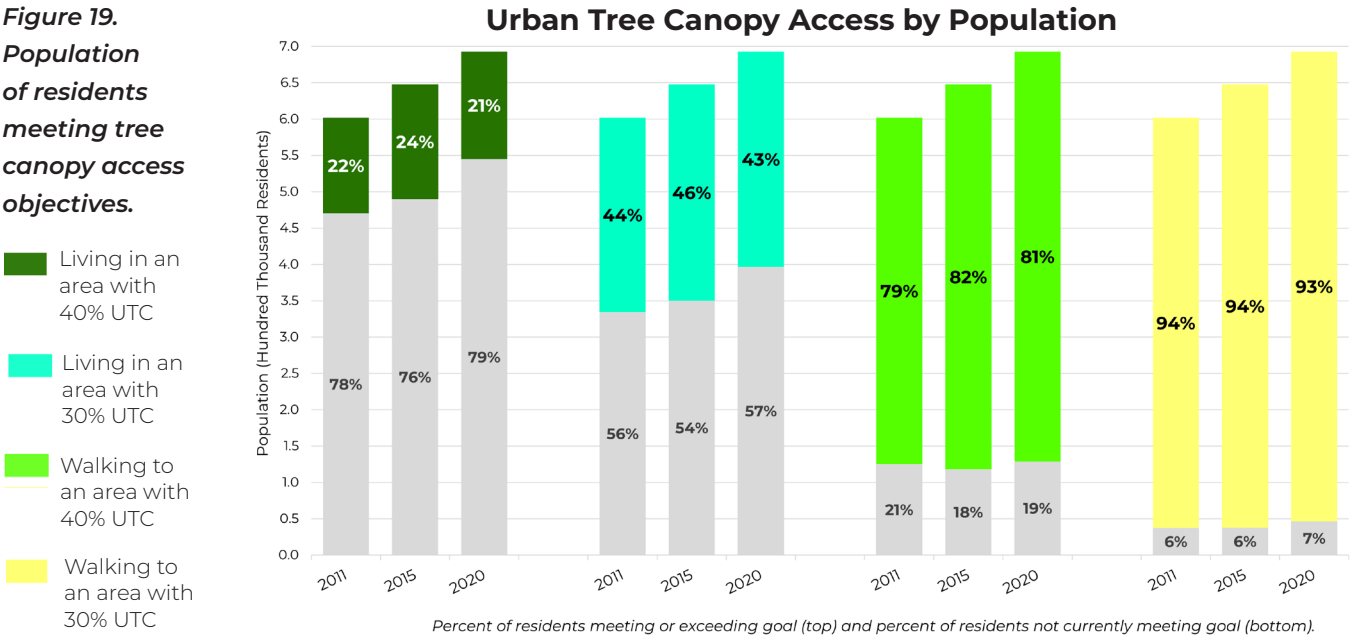


Table 9. Population of Washington, D.C. residents who either live in or can easily walk to an area with high UTC.

Population Meeting Urban Tree Canopy Access Objectives						
Urban Tree Canopy Access Objective	**2010 (2011 UTC)**		**2015 (2015 UTC)**		**2019 (2020 UTC)**	
	#	**%**	**#**	**%**	**#**	**%**
Live in a census block group with 40% UTC or greater	131,448	22%	157,464	24%	147,660	**21%**
Live in a census block group with less than 40% UTC	470,275	78%	490,020	76%	545,023	**79%**
Live in a census block group with 30% UTC or greater	267,456	44%	297,233	46%	295,928	**43%**
Live in a census block group with less than 30% UTC	334,267	56%	350,251	54%	396,755	**57%**
Live within 1,000 ft of a census block with 40% UTC	476,578	79%	529,340	82%	563,847	**81%**
Live farther than 1,000 ft from a census block with 40% UTC	125,146	21%	118,144	18%	128,835	**19%**
Live within 1,000 ft of a census block with 30% UTC	564,568	94%	609,711	94%	646,315	**93%**
Live farther than 1,000 ft from a census block with 30% UTC	37,155	6%	37,775	6%	46,368	**7%**
Grand Total	**601,723**	**100%**	**647,484**	**100%**	**692,683**	**100%**

URBAN TREE CANOPY CHANGE ANALYSIS

All results from this study were then compared with results from previous canopy assessments which were performed using imagery from 2015, 2011, and 2006. These assessments mapped tree canopy and other land cover types using nearly identical methods to those used for the 2020 data. 1-meter, high resolution NAIP aerial imagery was used for the 2015 and 2011 studies, and 2-foot, high resolution QuickBird satellite imagery was used in 2006. Changes between all time periods were assessed for each geographic scale used in this current assessment. Each assessment was compared to 2020 tree canopy to better understand how tree canopy has changed over time. For more details on how impervious surfaces and other land cover types have changed see page 25.

CITYWIDE URBAN TREE CANOPY CHANGE

In 2020, urban tree canopy coverage within the city limits of Washington, D.C. was 37.3% with 14,670 acres. In 2015, canopy coverage was 38.7% with 15,236 acres. A total of 565 acres of canopy were lost between 2020 and 2015 or a loss of over 1.4% citywide. In 2011, tree canopy coverage was nearly identical to 2020 with 14,601 acres or 37.1%. A total of 70 acres were gained between 2011 and 2020. In 2006, canopy coverage in D.C. was 36.2% with 14,246 acres. A total of 425 acres were gained between 2006 and 2020 or a change of 1.1% throughout the District.

While there were obvious and significant canopy losses due to urban development between 2015 and 2020, there was also evidence of an expansion of the urban forest through natural growth of existing street trees and plantings. The use of high resolution imagery in combination with LiDAR and human quality control was able to capture trees that otherwise would be obscured by buildings and left out of the classification. This both establishes a baseline against which canopy growth and loss can be accurately measured and allows the District to track progress towards its 40% canopy cover goal.

This study achieved 97% overall accuracy (see Appendix). With a 95% confidence interval, there was a 1.07% margin of error equating to 37.3% canopy cover +/- 1.07% or a range of 36.2% to 38.4%. Therefore, compared to 2015 coverage, there could have been a change ranging from -2.4% to -0.3% taking into account the 2020 margin of error. Compared to 2011 there could have been a change ranging from -0.9% to 1.2%, and for 2006 the change range is 0.01% to 2.1%.

Table 10. Urban tree canopy change for the City of Washington, D.C.

District Boundary	UTC 2006	UTC 2011	UTC 2015	UTC 2020	Change (2006-2020)	Change (2011-2020)	Change (2015-2020)
Percent	36%	37%	39%	37%	1%	0%	-1%
Acres	14,246	14,601	15,236	14,670	425	70	-565

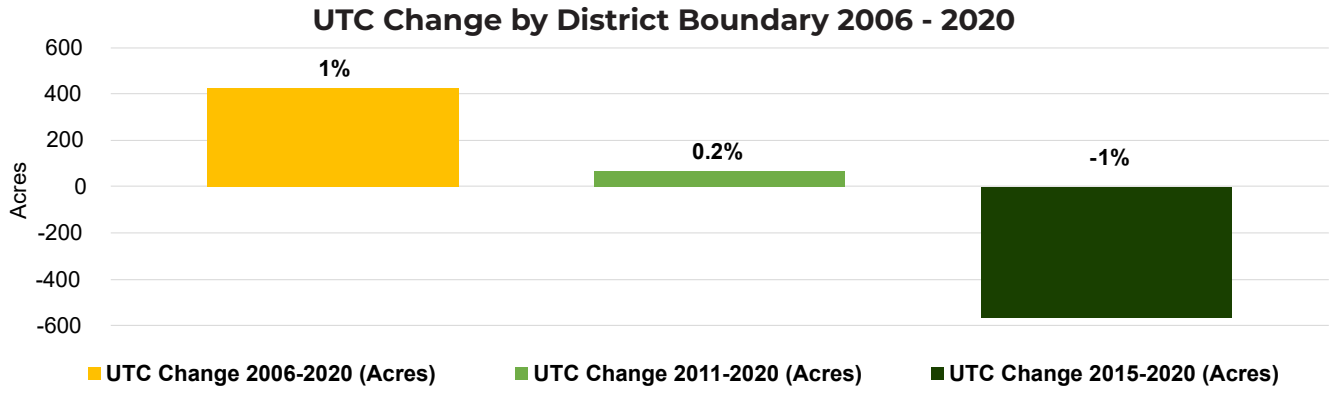


Figure 20. Urban tree canopy in Washington, D.C. boundary.

URBAN TREE CANOPY CHANGE BY WARDS

UTC change since 2006 was assessed within each of the District's eight wards. The changes ranged from -1% to 4% between 2006 and 2020 with five out of the eight wards experiencing a gain in that same time period. Ward 1 had the most consistent increase in UTC gaining 4% since 2006 and showed positive change in all three time periods. Ward 3 saw the largest canopy gain of all wards between 2011 and 2020 where UTC increased 6%. While there was a slight decline in UTC between 2015 and 2020, ward 3 did maintain its rank as the highest canopy covered ward. The largest canopy loss over the last five years occurred in ward 5 which lost 3% tree canopy. This caused it to also fall 1% below 2006 conditions. Similarly, canopy cover in wards 7 and 8 fell below 2006 cover with losses in the 15-year period of less than 1% and 1%, respectively.

Table 11. Urban tree canopy change by wards.

Wards	UTC 2006 (%)	UTC 2011 (%)	UTC 2015 (%)	UTC 2020 (%)	Change (%) 2006-2020	Change (%) 2011-2020	Change (%) 2015-2020
Ward 1	20%	22%	23%	24%	4%	3%	1%
Ward 2	24%	28%	28%	27%	3%	-0%	-1%
Ward 3	57%	53%	60%	59%	2%	6%	-1%
Ward 4	47%	50%	49%	50%	2%	-1%	0%
Ward 5	30%	31%	32%	29%	-1%	-1%	-3%
Ward 6	18%	21%	21%	19%	1%	-2%	-2%
Ward 7	39%	40%	41%	38%	-0%	-1%	-2%
Ward 8	30%	32%	32%	30%	-1%	-2%	-2%
Totals	**36%**	**37%**	**39%**	**37%**	**1%**	**0%**	**-1%**

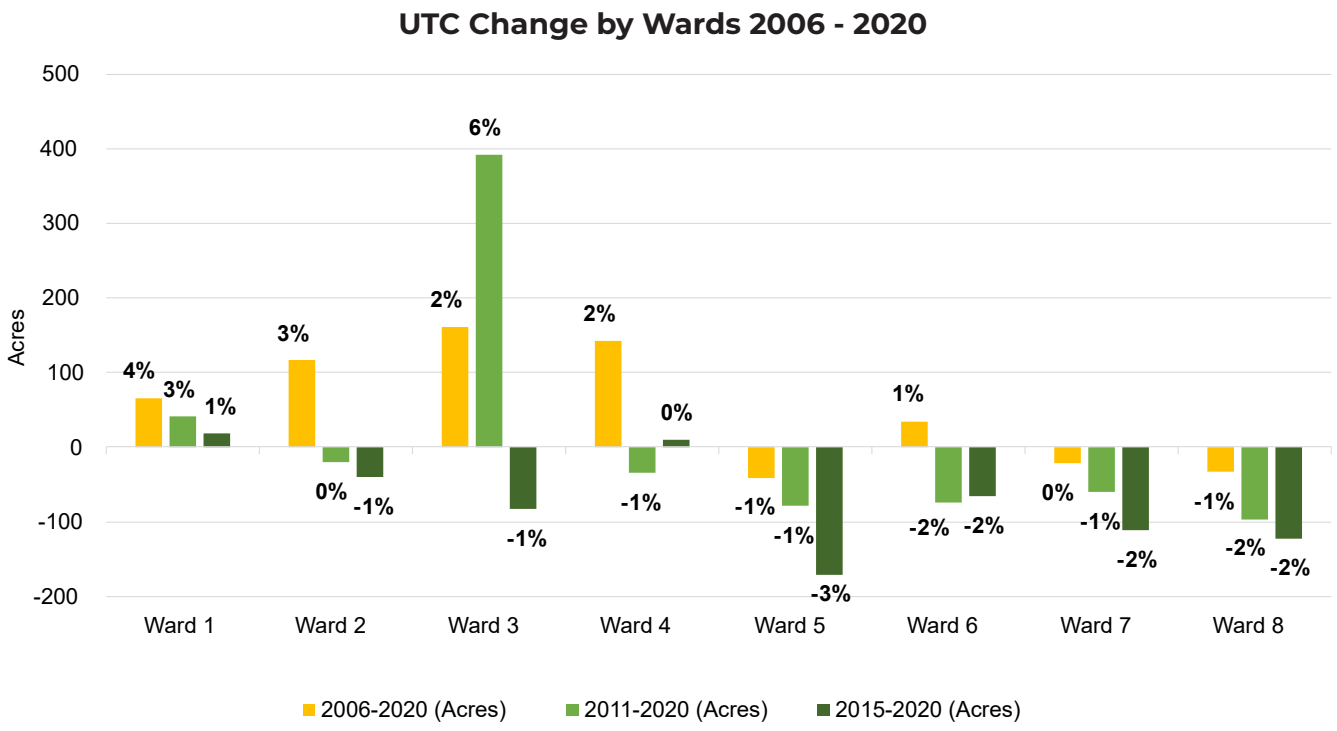


Figure 21. Urban tree canopy in Washington, D.C. by wards.

URBAN TREE CANOPY CHANGE BY LAND USE

Within the District's 12 types of land use, canopy change ranged from -2% to 3% between 2006 and 2020. Eight out of the 12 experienced a gain. Though a majority of land uses have seen gains in the last 15 years, In the last five years, all land use types lost canopy cover or experienced little to no measurable growth with the exception of right-of-way, which gained 1%. Institutional, low density residential, parking, and areas with no specified land use increased canopy by 2% between 2006 and 2020. Tree canopy in commercial land use areas decreased by 2% since 2006. Between 2015 and 2020, public and parks and vacant land uses both lost 3% canopy. Commercial land use experienced a similar decline of 3% between 2011 and 2020 with little significant change since 2015. Notably, the largest increases in UTC% between both all four assessment years was in the right-of-way, where UF has the greatest authority to plant and maintin trees.

Table 12. Urban tree canopy change by land use.

Land Use	Land Area Distribution	2006 UTC (%)	2011 UTC (%)	2015 UTC (%)	2020 UTC (%)	Change (%) 2006-2020	Change (%) 2011-2020	Change (%) 2015-2020
Rights-of-Way*	24%	34%	34%	36%	37%	3%	3%	1%
Medium Density Residential	20%	21%	24%	24%	22%	1%	-2%	-2%
Vacant	14%	52%	53%	54%	51%	-1%	-2%	-3%
Parks and Public Areas	12%	42%	41%	44%	41%	-1%	-1%	-3%
Not Specified	11%	46%	49%	49%	48%	2%	-1%	-1%
Low Density Residential	6%	38%	39%	41%	39%	2%	1%	-2%
Hotels and Dormitories	4%	18%	19%	20%	19%	1%	0%	-1%
Commercial	4%	9%	10%	7%	7%	-2%	-3%	0%
High Density Residential	3%	19%	21%	22%	20%	1%	-1%	-1%
Institutional	1%	21%	22%	23%	23%	2%	0%	-0%
Parking Lots*	1%	12%	13%	14%	14%	2%	1%	-0%
Industrial	0%	11%	11%	12%	11%	-0%	0%	-1%
Totals	**100%**	**37%**	**38%**	**40%**	**38%**	**1%**	**-1%**	**-2%**

*Note: the "Rights-of-Way" category in Table 12 above comes from a 2019 boundary that is subdivided into four categories, as shown on Page 10 in the Key Findings section and Page 30 in the Land Cover Change section. One of these is the "Parking right-of-way," which is a separate area from the "Parking Lots" land use listed above. The "Parking" right-of-way refers to "that area of public space devoted to open space, greenery, parks, or parking that lies between the property line, which may or may not coincide with the building restriction line, and the edge of the actual or planned sidewalk that is nearer to the property line, as the property line and sidewalk are shown on the records of the District. This area often includes spaces that appear to be front yards with private landscaping that create park-like settings on residential streets" (D.C. Public Realm Design Manual, March 2019).

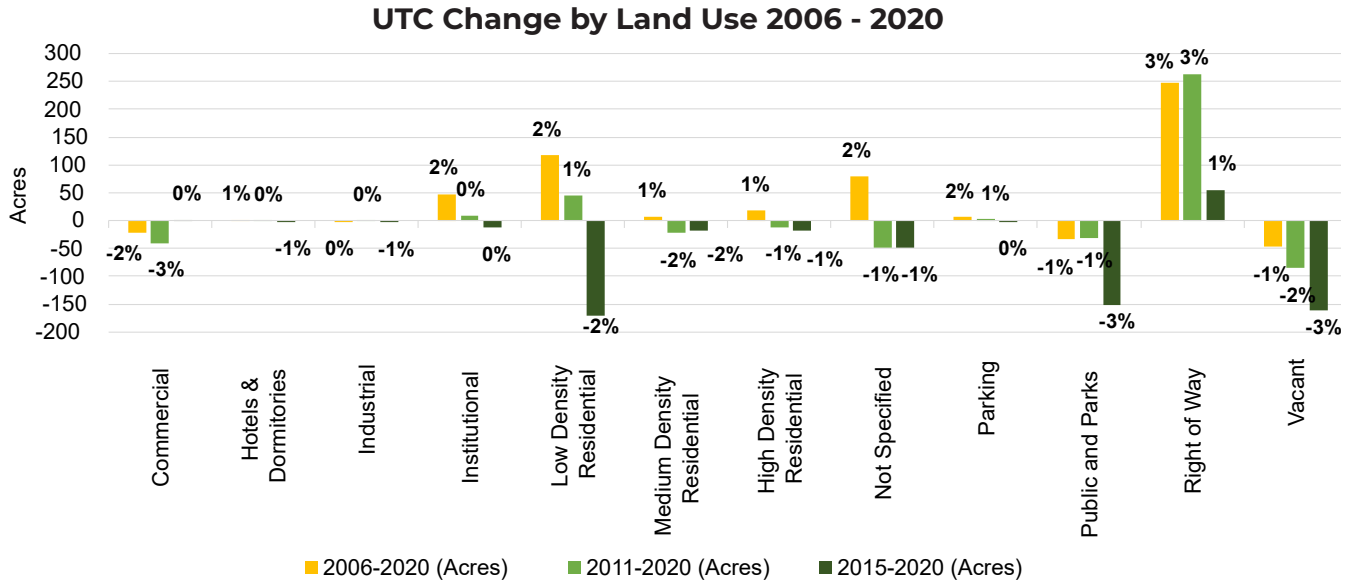


Figure 22. Urban tree canopy change in Washington, D.C. by land use.

URBAN TREE CANOPY CHANGE BY ADVISORY NEIGHBORHOOD COMMISSIONS

UTC change between 2006 and 2020 was assessed for advisory neighborhood commissions in Washington, D.C. The changes ranged from -4% to 6% between 2006 and 2020 with 31 out of 40 ANC's experiencing a gain in that same time period. Though a majority of ANC's have seen gains since 2006, only 10 out of 40 ANCs experienced a gain since 2015. ANC 1D had the largest gain (6%) since 2006 but had no change in canopy between 2015 and 2020. The two ANC's with the largest decrease in canopy cover since 2006 were 5C and 8A with 4% losses each.

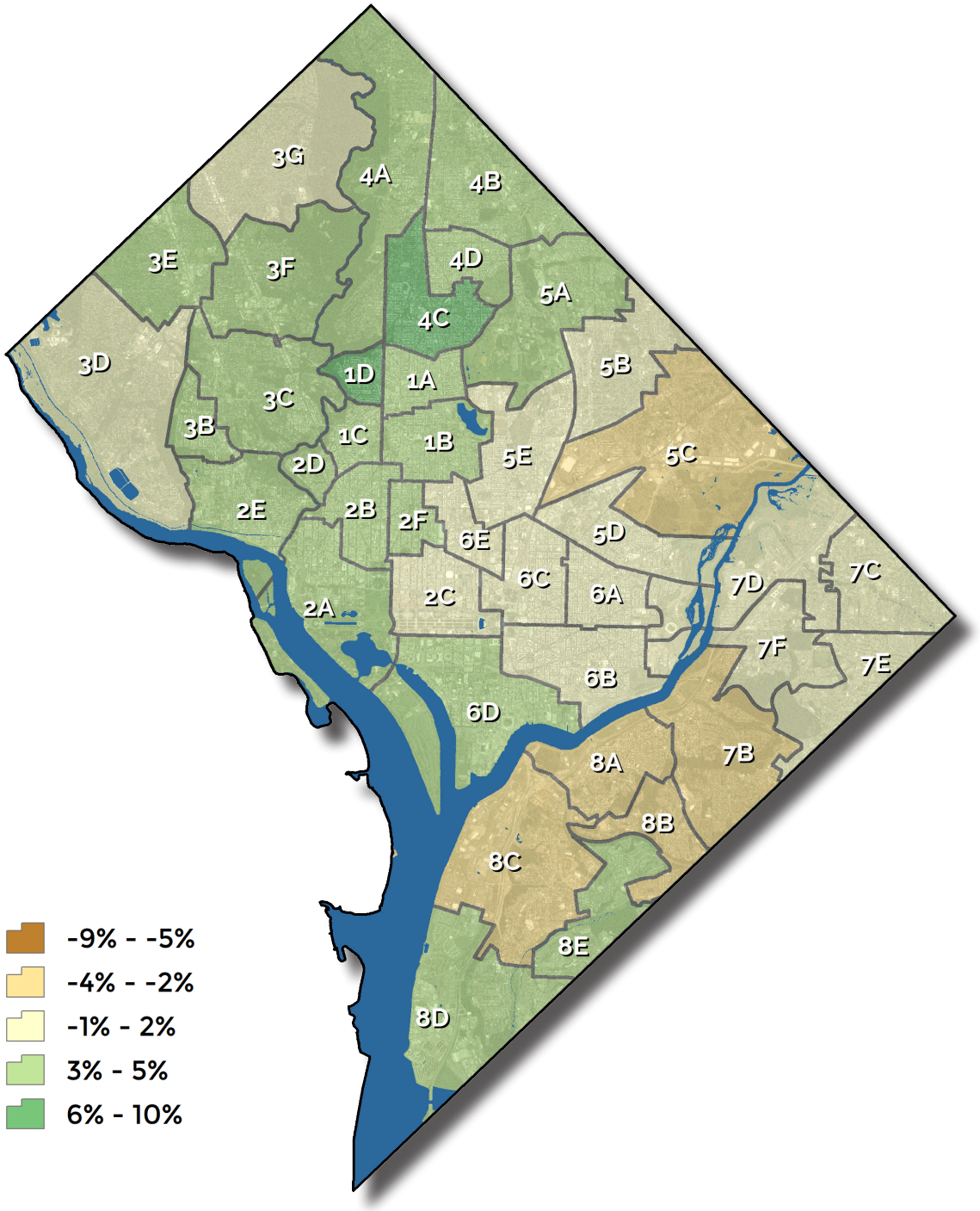


Figure 23. Urban tree canopy change from 2006-2020 in Washington, D.C. by advisory neighborhood commissions.

URBAN TREE CANOPY CHANGE BY CENSUS BLOCK GROUPS

UTC change between 2006 and 2020 was assessed for U.S. census block groups in Washington, D.C. Tree Canopy changes by block group ranged from -21% to +20% between 2006 and 2020. Over half (51%) of the 571 census block groups in the District gained more than 2% tree canopy since 2006. The portion of block groups that have gained more than 2% tree canopy has fallen in the two most recent time periods. Between 2011 and 2020, 31% of block groups had gains above 2%, and between 2015 and 2020 only 18% had gained more than 2% canopy. Though the number of block groups with a loss greater than 2% has increased in the two most recent time periods, the largest majority of block groups have seen only minor gains or losses. Between 2015 and 2020, 53% of block groups had tree canopy changes ranging from -2% to +2% compared to 34% when comparing tree canopy in 2006 to tree canopy in 2020.

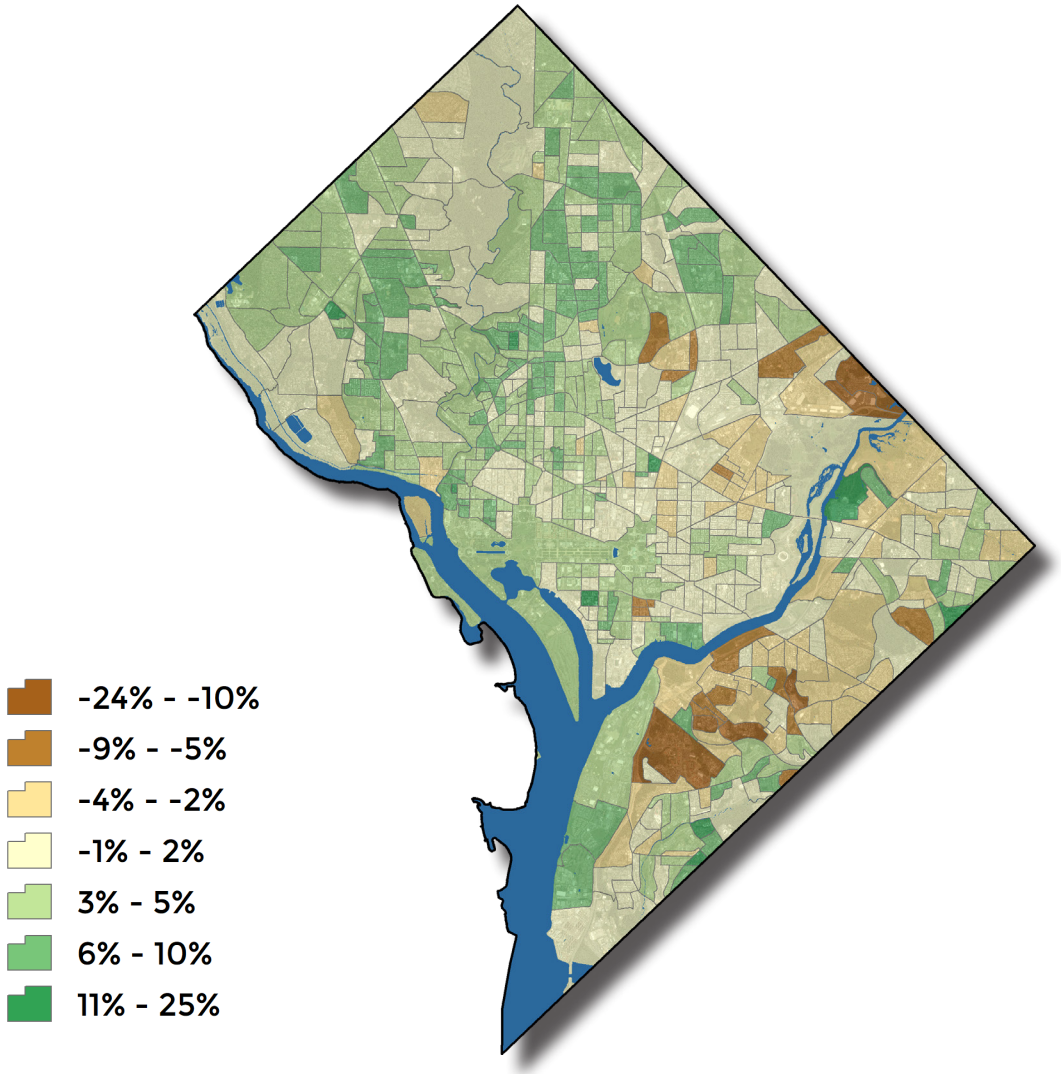


Figure 24. Urban tree canopy change in Washington, D.C. by census block groups.

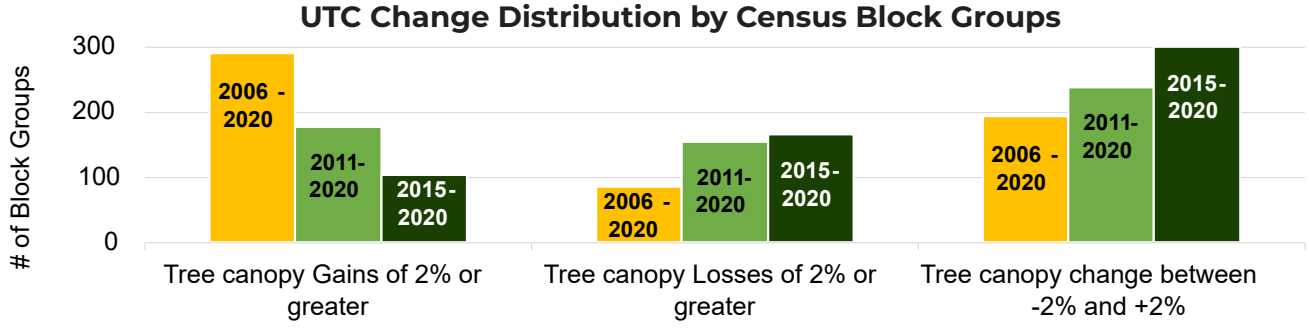


Figure 25. Distribution of tree canopy change amongst census block groups.

URBAN TREE CANOPY CHANGE BY CENSUS BLOCKS

Census blocks provided an even finer scale to assess canopy change. Tree Canopy changes by block ranged from -87% to +87% between 2006 and 2020. Nearly half (49%) of the 6,012 census blocks in the District gained more than 2% tree canopy since 2006. The portion of blocks that have gained more than 2% tree canopy has decreased in the two most recent time periods. Between 2011 and 2020, 38% of blocks had gains above 2% and, between 2015 and 2020, only 27% had gained more than 2% canopy. Though the number of blocks with a loss greater than 2% has increased in the two most recent time periods, the largest majority of blocks have seen only minor gains or losses. Between 2015 and 2020, 39% of block groups had tree canopy changes ranging from -2% to +2% compared to 26% when comparing tree canopy in 2006 to tree canopy in 2020.

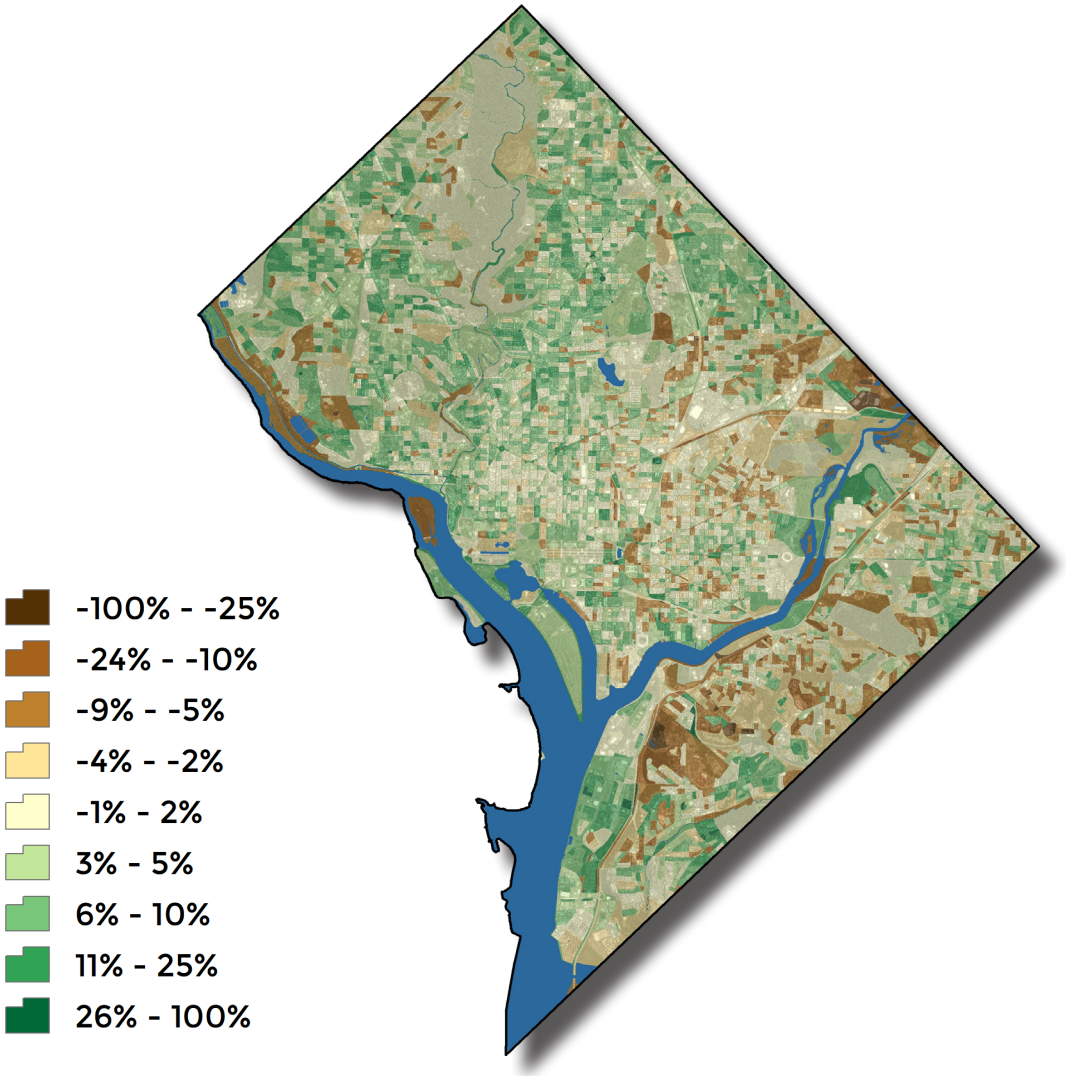


Figure 26. Urban tree canopy change in Washington, D.C. by census block groups.

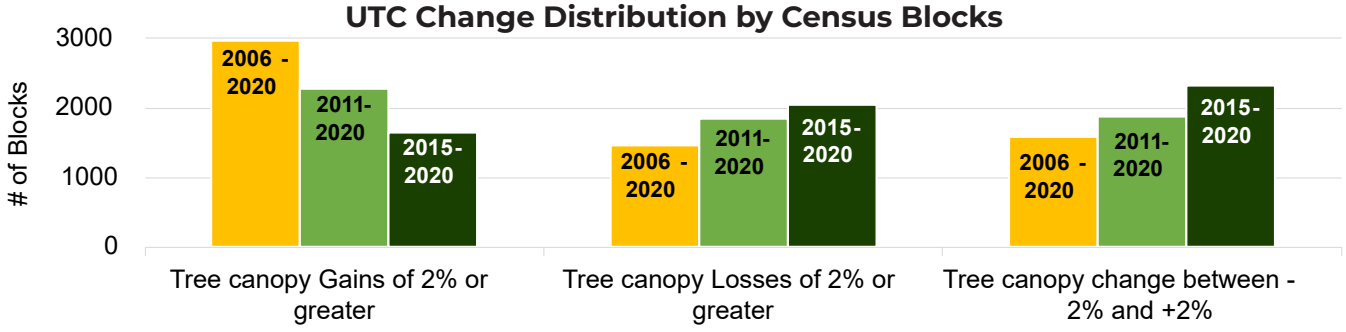


Figure 27. Distribution of tree canopy change amongst census blocks.

LAND COVER CHANGE ALLUVIAL DIAGRAMS

As previously described, a comparison of land cover data from two or more years can be used to identify areas where tree canopy has been gained, lost, or preserved within that time period. This information can then help to locate areas with the greatest need for new tree plantings which will be described in the Tree Planting Prioritization section. However, without performing any additional analyses on the complete (5-class) land cover data sets, the tree canopy change analysis does not include any insights on where changes in canopy are coming from., such as which other land cover classes had been successfully converted into urban tree canopy and which land cover types had taken the place of tree canopy that was lost. Therefore, in order to further assess the factors influencing changes in urban tree canopy, alluvial diagrams were created for each land use type, right-of-way type, and the full District boundary.

First, a set of random points was created within each boundary of interest. Using the same technical methods in the USFS' i-Tree Canopy tool, the number of points per boundary was calculated based on the amount that would be needed to achieve a standard error of 1.0% at the existing UTC% of that boundary. Next, land cover values from each assessment year were extracted to create a new data set where each unique point was assigned its value at each of the four years. This information was then summarized by calculating the total number of points that follow a given "alluvia," or flow -- i.e. a specific combination of transitions from one land cover type to another across the four years. The frequency of occurrence of each possible transition is represented in the diagram as the thickness of the flowing lines. For example, when citywide urban tree canopy increased between 2006-2011, the flow lines illustrate that the majority of this new tree canopy had previously been other vegetation and a small amount had been impervious. This process was then repeated for each land use and right-of-way type so that biophysical land cover changes could be assessed in comparison to anthropogenic uses of land.

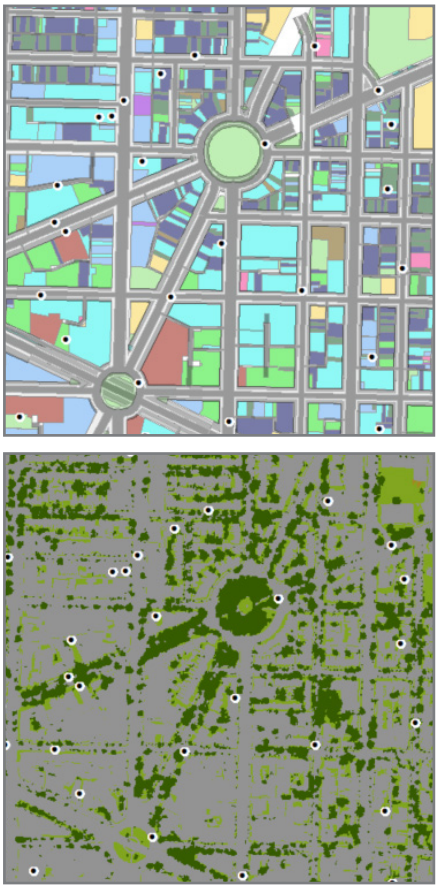


Figure 28. A set of random points was generated for each land use (top) and assigned land cover values at each year to evaluate specific changes.

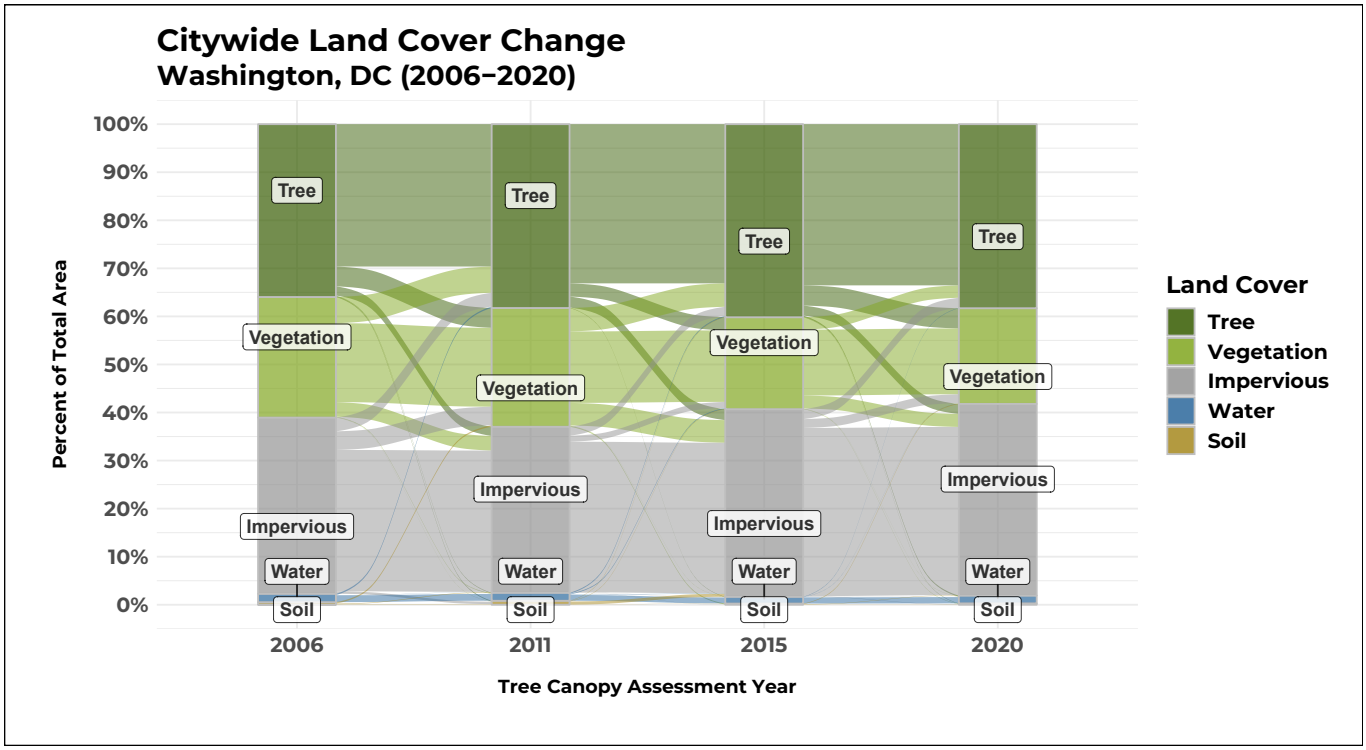


Figure 29. Land cover change throughout the full Washington, D.C. boundary (2006-2020).

LAND COVER CHANGE IN SELECTED LAND USES

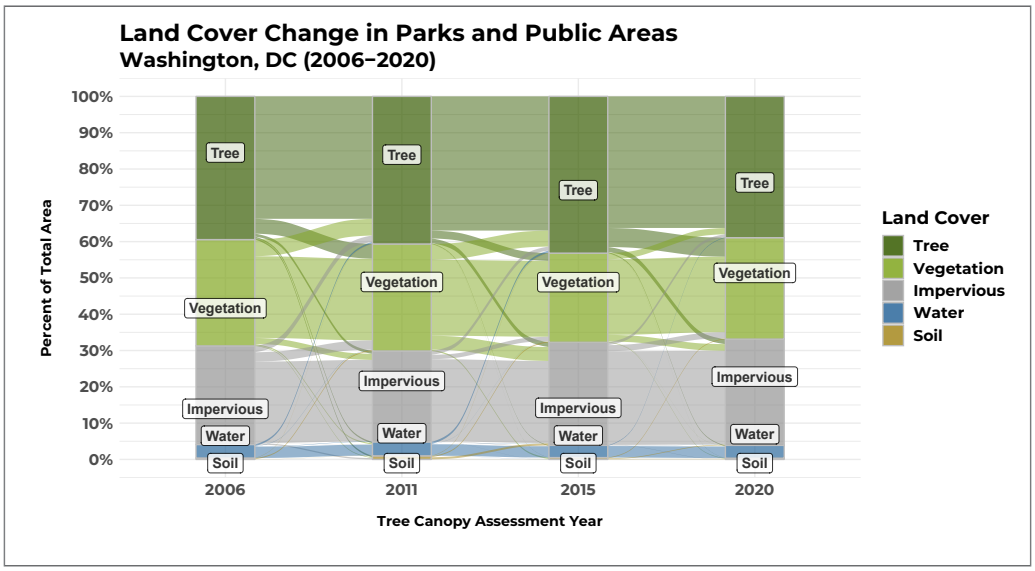


Figure 30.
Land cover change in parks and public areas, or those managed by UFD. Parks and public areas contained the most Total PPA of any land use by area: over 1,582 acres, of which 1,184 were PPA Vegetation and 399 were PPA Impervious.

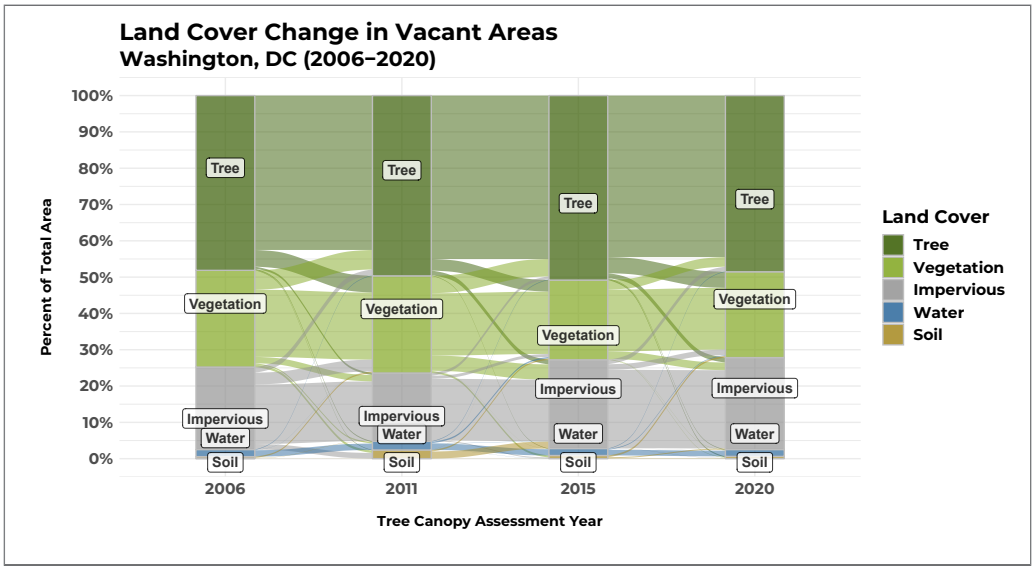


Figure 31.
Land cover change in vacant areas, the land use with the highest percentage of UTC (51%) and lowest percentage of total impervious areas (26%) with respect to its total area in 2020.

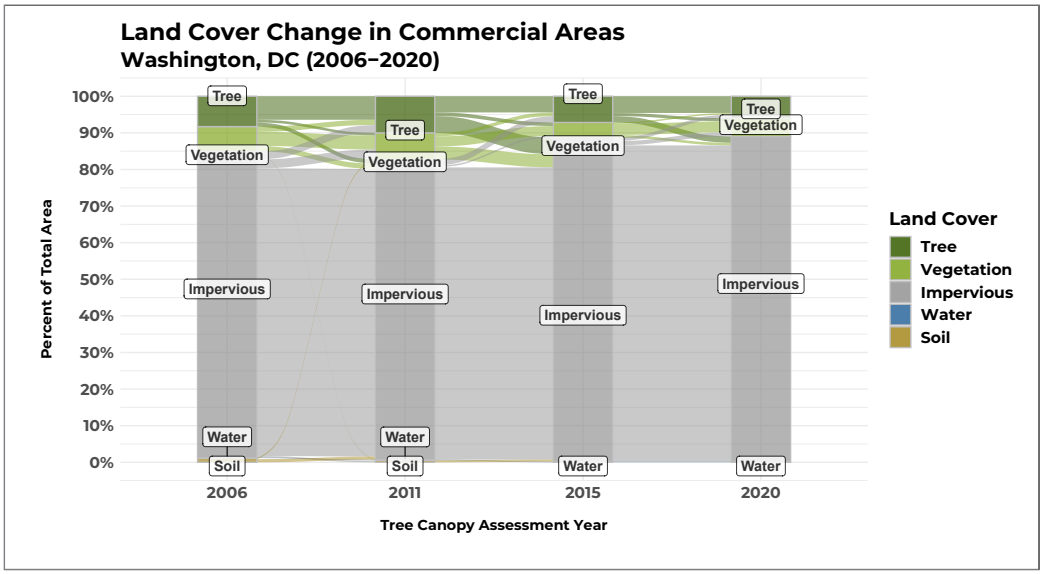


Figure 32.
Land cover change in commercial areas, the land use with the greatest UTC% loss from 2006-2020.

LAND COVER CHANGE IN RESIDENTIAL AREAS

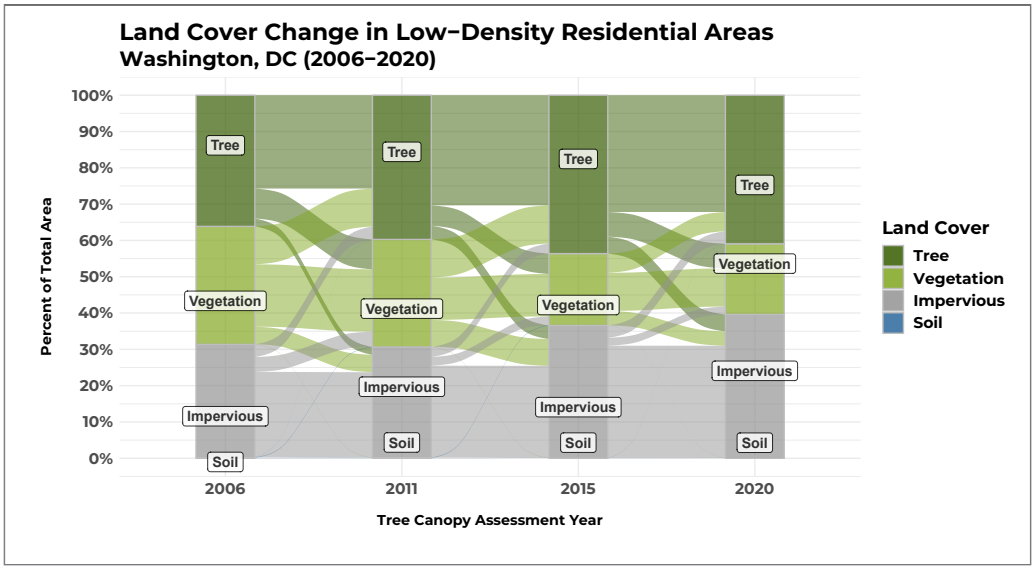


Figure 33.
Land cover change in low-density residential areas.

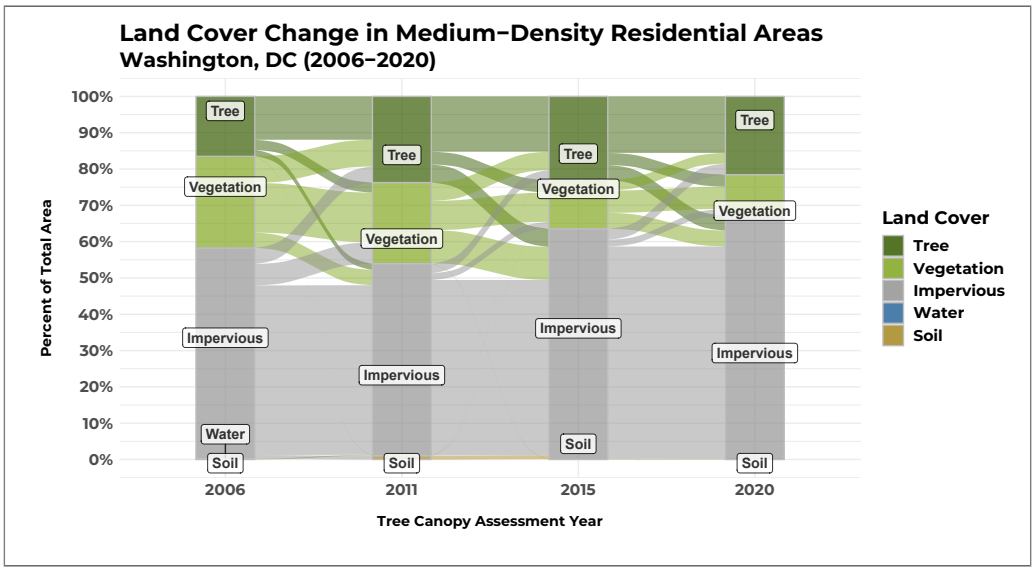


Figure 34.
Land cover change in medium-density residential areas.

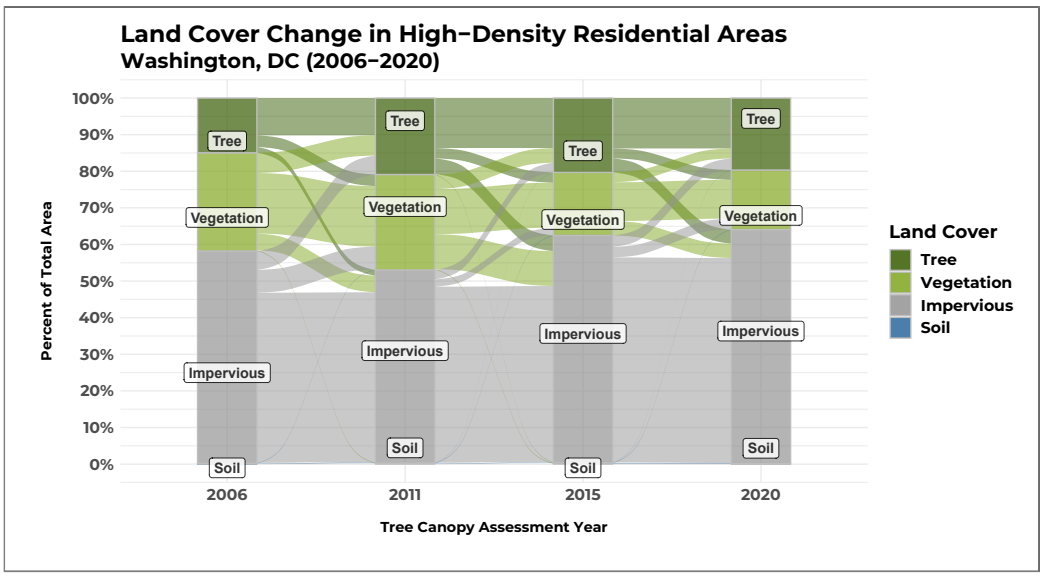


Figure 35.
Land cover change in high-density residential areas.

LAND COVER CHANGE IN RIGHTS-OF-WAY

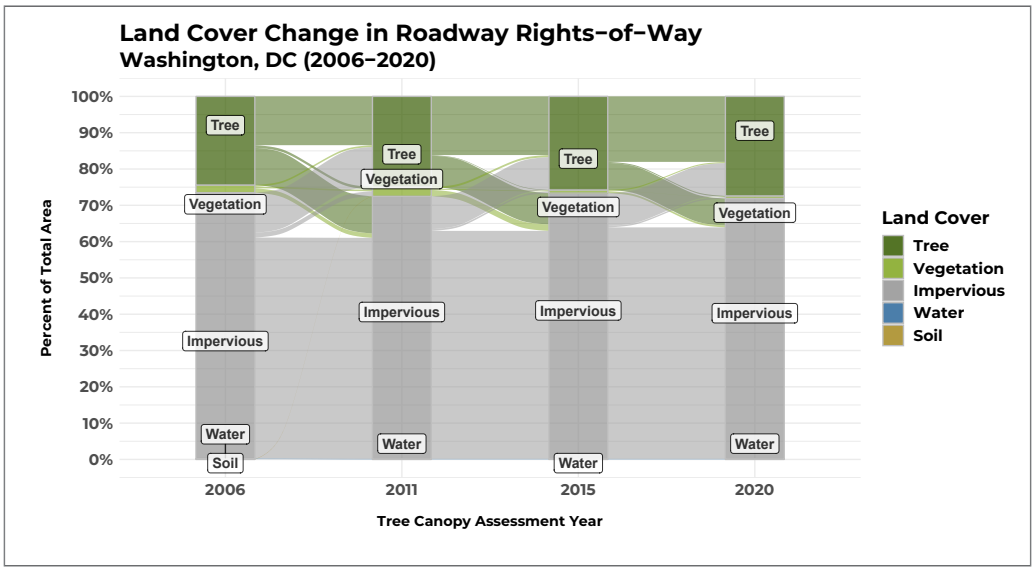


Figure 36.
Land cover change in roadway rights-of-way.

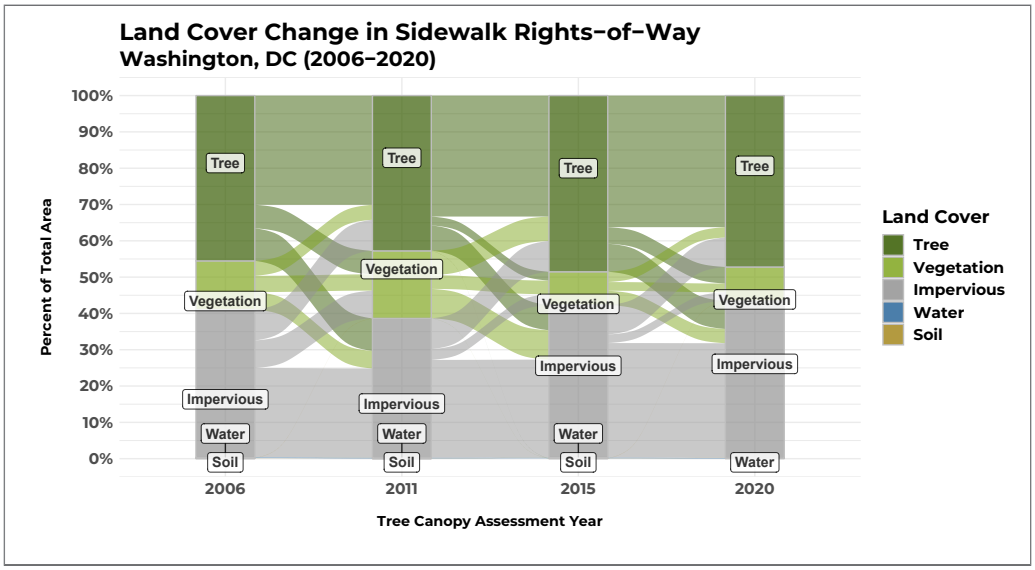


Figure 37.
Land cover change in sidewalk rights-of-way.

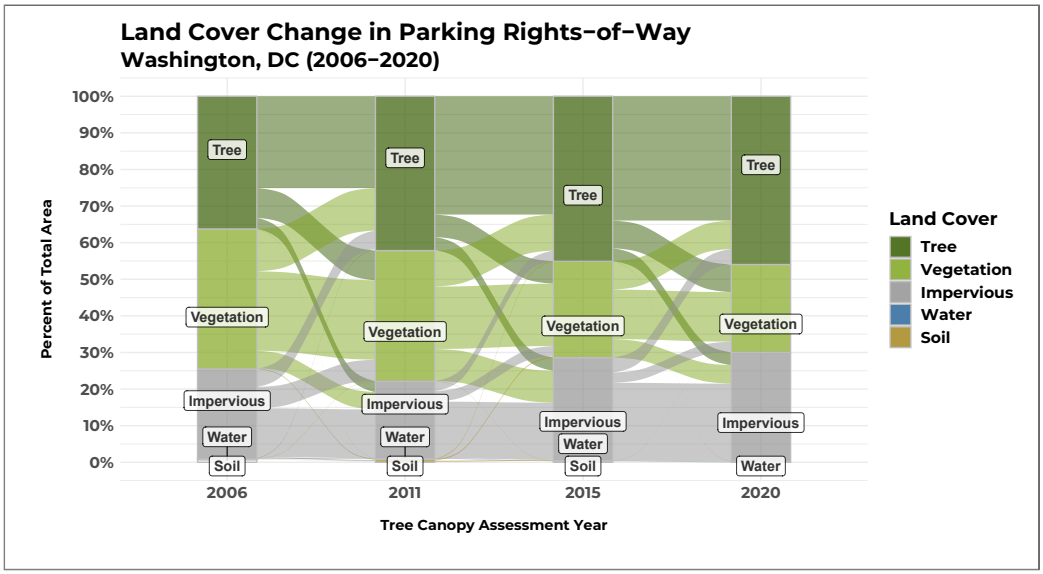


Figure 38.
Land cover change in parking rights-of-way.

URBAN FORESTRY PROGRAM REVIEW

PURPOSE

A critical component in the life cycle of any ongoing program's operational process is the need to continuously re-evaluate the intermediate results, identify which approaches are succeeding and which are not, and make adjustments as necessary. Conscious of this, the District has already performed several repeat urban tree canopy (UTC) assessments using comparable methods and source imagery to measure its progress in achieving its citywide canopy cover goal of 40% by 2032.

The current UTC results and UTC change results by various geographies, described in the previous report sections, can be used to determine where the District has succeeded in growing or maintaining its canopy over the study period, as well as where canopy has been lost, and thereby inform the prioritization of future tree plantings. However, these results alone do not offer any insights into the program management activities that the District has been performing internally which directly influence these urban forest changes. Therefore, an additional evaluation was performed to combine this information with the UTC results in order to assess how well the actions that the Urban Forestry Program has taken are aligned with and achieving its goals.

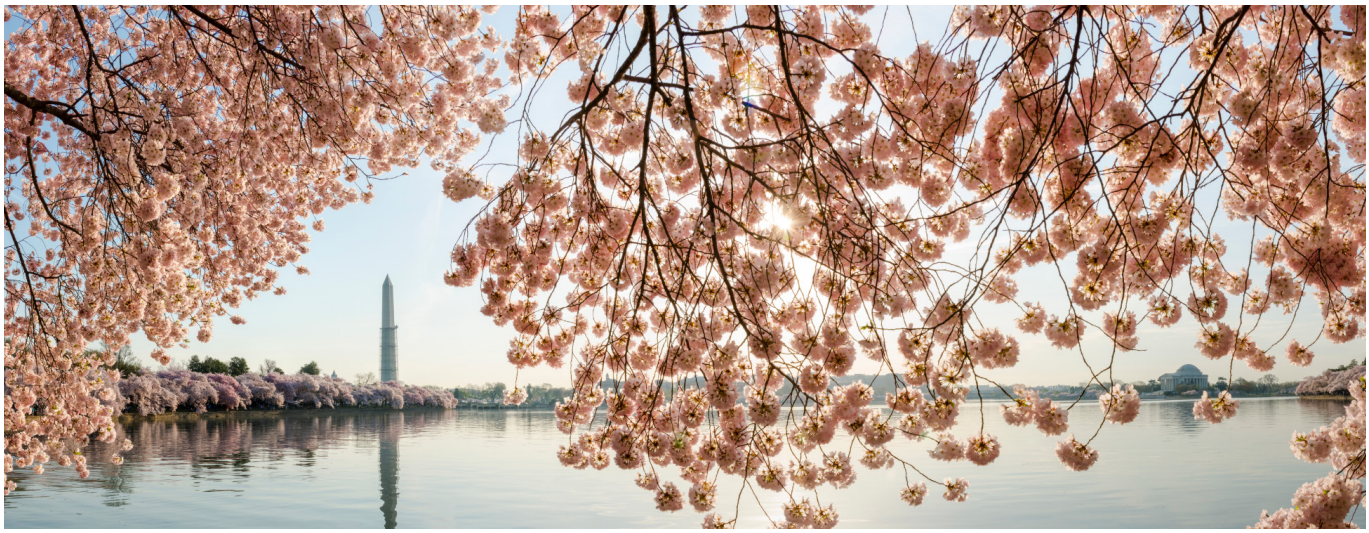
BACKGROUND

Since establishing this as a primary goal in 2011, the District has put great effort and resources into achieving 40% tree canopy coverage by 2032. In 2011, UF began utilizing money paid as mitigation for non-hazardous tree removal to augment the number of street trees planted. These expenditures, in conjunction with other funding sources such as MS4 Grants & Clean Water Revolving Fund, enabled the District to dramatically increase its stocking levels, or percentage of planting spaces that contain a live tree, across the city.

Previously, the locations for Tree Fund plantings were loosely aligned with regions where Tree Fund dollars were generated. Tree Fund collections have been central to the District's ability to more than double its tree plantings per season from 4,000 to 8,000. More recently, local funding and other grants have been deployed to the remainder of the city, resulting in a large increase in stocking levels citywide. At the end of the April 2015 planting season, UF had achieved 90% stocking levels in every ward of the city. By the end of the 2020-21 planting season, stocking levels exceeded 98% throughout the District. Now, with the completion of this 2020 urban tree canopy assessment, the updated UTC metrics can be compared with UF's recent tree management activities to evaluate the tangible impacts that these actions have had.

METHODOLOGY

To build on previous efforts and tell the story of the District's efforts in expanding canopy over time, an assessment of planting site stocking over time, the rate of conversion to street trees, and the impacts that these trees have made on the canopy cover goal was performed. Similarly, planting site data, tree plantings over time, UTC/PPA results, and other sources were employed to identify areas that failed to be converted into productive tree canopy. Incorporating data from previous studies, the analysis highlights the programs, initiatives, trends, opportunities, and ongoing challenges to achieving and sustaining the District's 40% canopy goal.



However, it is also important to note that UFD does not have complete authority over the District's tree population. While they are responsible for trees located along streets, in parks, and at public schools, any trees located on private or federal lands are managed by their respective owner. This detail, combined with the fact that the tree planting boxes maintained by UFD are already nearly 100% stocked, means that UFD cannot completely control the inputs, actions, and outputs affecting its urban forest, and therefore will never be able to achieve its 40% canopy goal without the help of other stakeholders such as nonprofits and private landowners. Keeping that in mind, this approach was designed to assess the variables that UFD *can* control and determine how well their actions are aligning with the needs of the urban forest. The following outcomes-based program logic model illustrates the datasets that were assessed as a part of the program evaluation. These measurable inputs, actions, outputs, and outcomes can be used to help the District understand patterns of failure and success to develop a plan for the next decade in the face of urban migration and development to ensure that, with the help of other relevant parties in conjunction with their own management actions, the canopy goal is met.

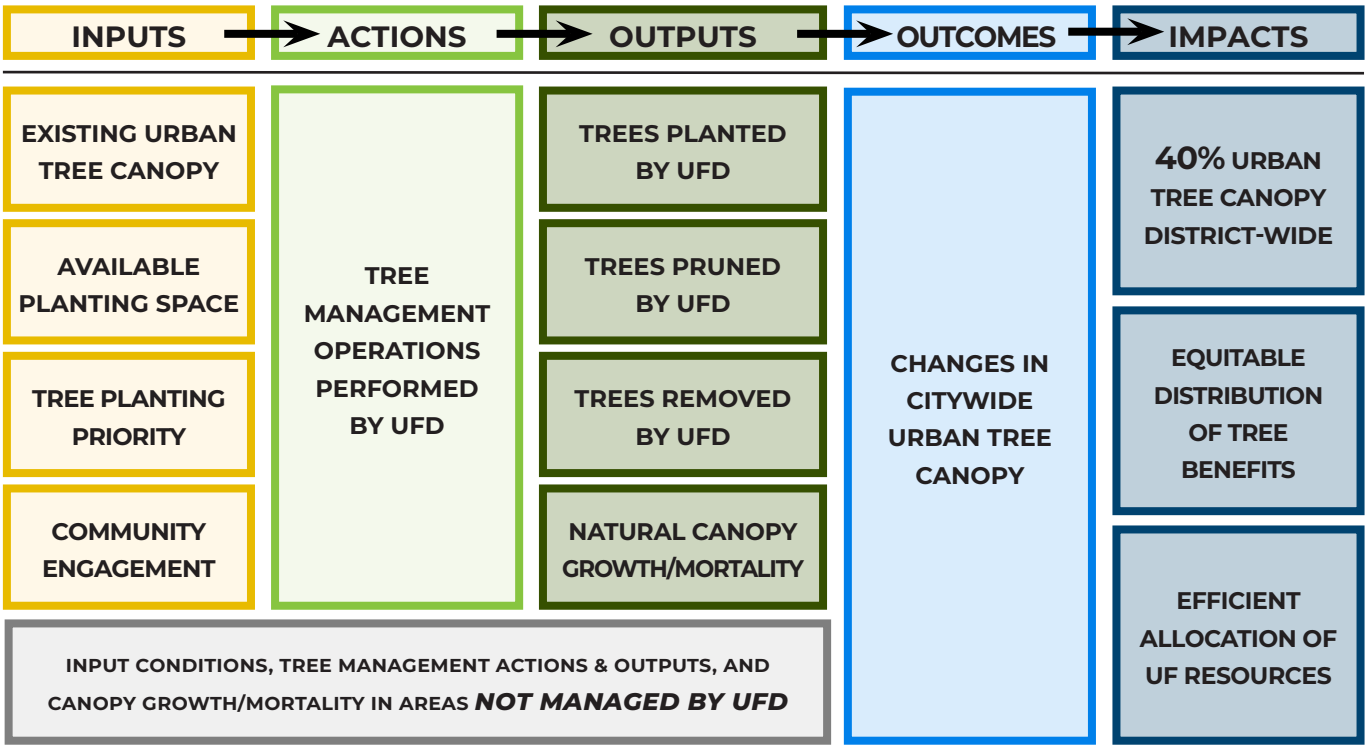


Figure 39. Logic model containing the datasets analyzed and general approach used in the UF Program Review.

The purpose of creating a program logic model to assess the UF's operations was to determine the most relevant inputs and logical approach needed to derive an empirical answer to an open-ended question: how well are the District's urban forest managment actions aligning with its goals? A logic model outlines the overarching goals of the program, the intermediate steps that may be taken to reach those goals, and the datasets that can be analyzed to assess the program's successes and challenges in meeting the goals.

As the model above illustrates (from left to right), the "**inputs**" of the UF's program operations represent the urban forest's quantifiable baseline conditions, the "**actions**" refer to the specific activities that UF can do to influence those conditions, the "**outputs**" are the immediate measurable results of those actions, and the "**outcomes**" and "**impacts**" represent the short- and long-term goals of the program, respectively. (Again, since the District is only able to manage trees within its jurisdiction, there will inherently be some inputs, actions, and outputs that it cannot control for, shown in gray in the graphic above.)

To complete the assessment, simple correlations were performed to compare the program's inputs, outputs, and outcomes to test how closely the District's management activities are meeting the urban forest's needs, as well as identify the areas most in need of intervention from other parties. All analyses were performed for the full District boundary and each of the District's eight wards. After the quantitative analyses were completed, the results were incorporated into the Vibrant Cities Lab's Urban Forest Assessment tool which is used to quantify how well a municipality is doing, relative to other communities, industry standards, and its own urban forestry program's goals. A synthesis on the management objectives and broad recommendations based on these results is provided in the Recommendations and Conclusions section.

RESULTS

As of this most recent urban tree canopy assessment, the District's existing canopy cover was approximately 37%. Although this amount has fluctuated over the past decades, as described in detail in the previous section, it is still less than the citywide canopy goal of 40% that the District established in 2011. Currently, there is a gap of 3% between the District's existing and target canopy cover percentages. Since 2011, the District has planted over 74,000 new trees, received a total of 126,861 tree-related service requests from residents through the Cityworks portal, and completed a total of 285,379 tree-related work orders. In spite of these management actions, citywide canopy has only grown by approximately 70 acres, equating to a nearly 0% change across all areas that UFD does and does not manage. Currently, there are a total of 175,890 UF-managed tree boxes that contain a tree compared to only 3,404 that are open. This equates to a 98% "stocking rate," or percent of tree boxes that are "stocked" with a live tree, and only 2% available for new trees to be planted within District-managed land, which further demonstrates the importance of working together with other landowners to achieve the citywide canopy goal.

INPUTS

Trees in Good Condition

Citywide, 83% of all trees in the public inventory are in "Good" or "Excellent" condition. Within the eight wards, this number varies from 85% in Wards 1 and 4 to 77% in Ward 6.

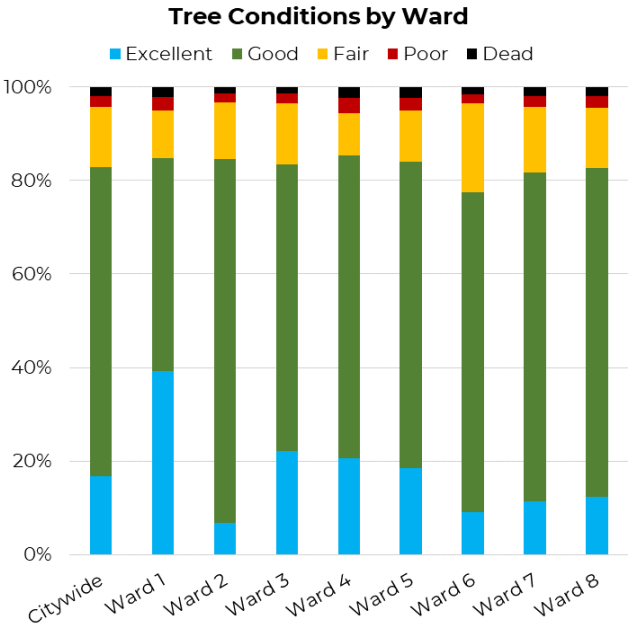
Species Composition

Washington, D.C. has a species richness of 205, meaning there are 205 unique species of trees in their inventory. However, within all individual wards, there are fewer. Ward 1 has the lowest species richness (154 species) whereas Ward 4 has the highest (191 species).

Simpson's Diversity Index for species diversity, which measures not only the number of unique species in a population, but their relative distribution as well, was also calculated for each ward and within the full city boundary. These scores range from 0 to 1, with 1 being the most diverse. The District-wide score was 0.98, and individual ward scores were slightly lower ranging from 0.971 (Ward 3) to 0.977 (Ward 6).

Trees Managed by UF

Although they are responsible for 93% of trees incuded in District's public tree inventory, UF shares tree management responsibilities with six other organizations. The greatest proportion of UFD-managed trees is found in Wards 4 and 5 (95% and 96%, respectively) which is promising since those two wards also have some of the lowest existing UTC with 29% in Ward 4 and 19% in Ward 5. Conversely, Ward 7 contains the smallest proportion of trees managed by UF (89%).



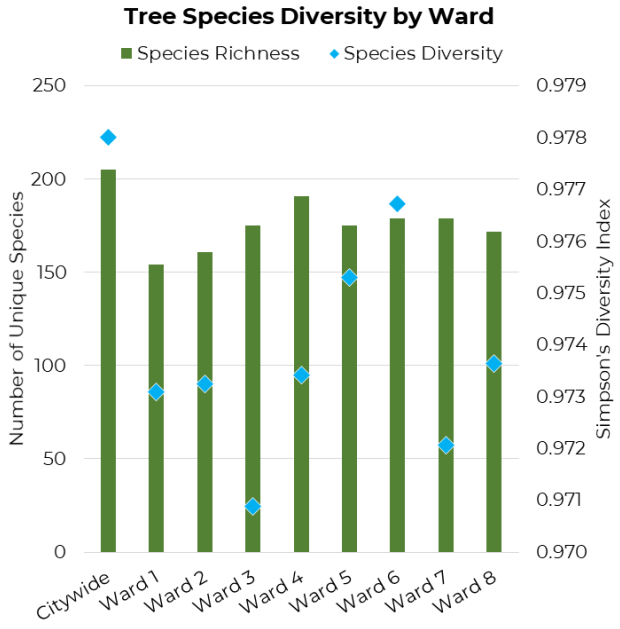


Figure 40. (Top right) Tree health conditions by ward.

Figure 41. (Bottom right) Tree species diversity by ward.

Trees in Smallest Size Class

It is recommended that the greatest proportion of a city's urban tree population be in the smallest size class at any given time ensuring there is always enough of a new population of smaller trees growing to eventually replace larger, mature trees that might be lost due to factors like mortality or development and lead to large losses in canopy. With 50% of trees in this size class citywide, the District is already exceeding this goal, and this demonstrates UF's commitment to significantly increase the amount of new tree plantings annually since 2011.

When subdivided by wards, Ward 3 has the least amount of trees in the smallest size class (37%), however, with an existing UTC of 59%, it is less in need of new trees than some other wards. Wards 8 and 5 had the highest amount of trees in the smallest size class with 61 and 60%, respectively. Although it already has nearly 50% of its trees in the smallest size class as well, Ward 6 had the lowest UTC (19%) of any ward in 2020, making it an especially good target for additional future tree plantings (which appear to have been successful so far based on this ward's tree size/age distribution).

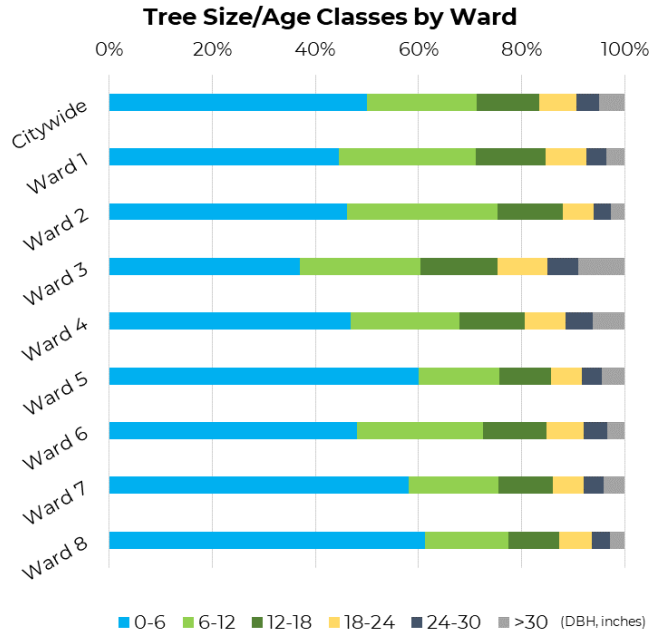


Figure 42. Tree age structure by ward.

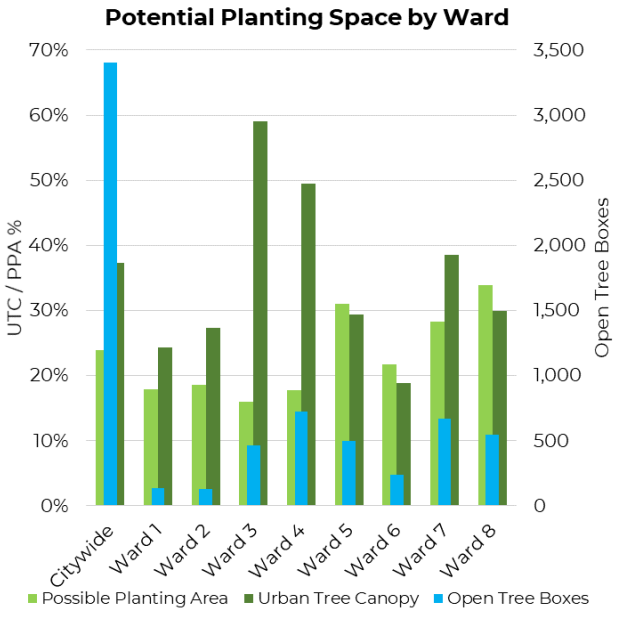


Figure 43. Potential planting spaces by ward.

Existing Canopy

The District's citywide canopy cover of 37% is only 3% short of its 40% canopy goal, but canopy cover within subsets of the city, such as wards, varies dramatically. Only two wards are currently exceeding the citywide canopy cover goal with 59% in Ward 3 and 50% in Ward 4. Ward 6 had the lowest existing UTC-- 19%, or less than half the citywide goal-- but the remaining wards fall within the 20-40% canopy range. Based on these starting points (as well as the implicit changes in canopy since 2010 and 2015), we would expect to see fewer plantings in higher-canopied wards and more plantings in lower-canopied wards.

Available Planting Space

In addition to a location's relative need for new trees based on its existing urban forest characteristics and urban tree canopy, another important consideration when developing a planting strategy is the available planting space that exists.

Citywide, 24% of all land area is classified as plantable space. However, this figure represents all areas of non-canopy vegetation and some impervious areas. For UF's purposes, stocking rates (or the percent of occupied vs. vacant tree boxes) are of greater importance, especially considering the citywide stocking rate of 98%. Several wards (1, 2, and 6) have a 99% stocking rate, and two of those (1 and 2) have only ~130 available planting boxes. This indicates that wards with both a low existing UTC and high stocking rate, such as Wards 1 and 6, will need the most strategic management actions to incentivize tree plantings by other organizations on their private property in order to maximize the available planting space, increase the canopy in these areas, and achieve the District's 40% citywide canopy goal.

Planting Priority

Priority rankings for future tree planting locations based on the potential for several environmental benefits (such as stormwater and air quality) were calculated as a part of the 2020 tree canopy assessment and an "Overall Priority" composite score was calculated for each ward. Wards 3 and 4 had the lowest environmental priority scores, whereas Wards 5 and 7 had the highest. These scores are of interest because they are based on separate inputs from publicly available sources, compared to the rest of the assessment variables which came from the tree canopy assessment, UF inventory, or Census.

Community Input

Although not guaranteed to translate into a work order, service requests are the method for the general public to request help with their trees (including new plantings, prunings, inspections, and removals). Out of a total of ~127,000 service requests submitted from 2011-2021, requests-per-ward ranged from 7,000 in Ward 8 to more than 25,000 in Ward 4, perhaps indicating that there is a difference in the level of community engagement and interest in trees across the District.

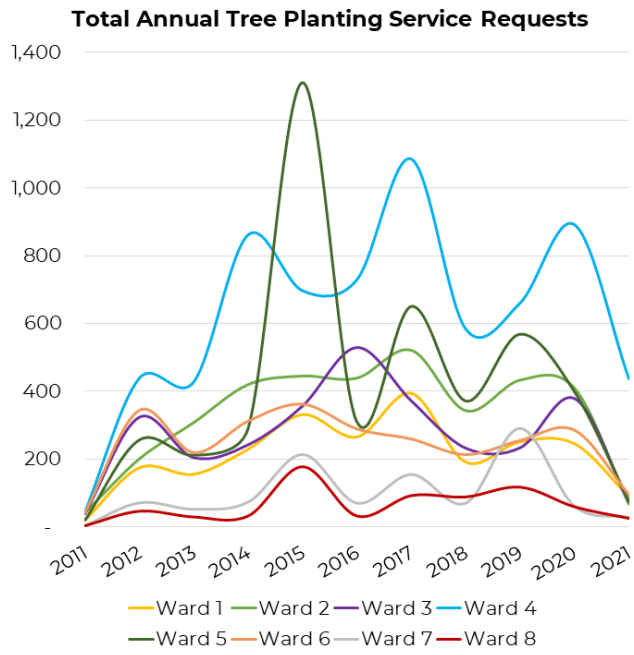


Figure 44. Tree planting requests by ward.

Sociodemographic factors

In addition to the "input" variables such as tree canopy and plantable space that represent the urban forestry program's starting point in this assessment, a variety of sociodemographic factors were also assessed. While these are not variables that UF has the direct ability to impact, they are useful as a tool to assess how well the variables that UF does have the ability to change, such as tree plantings, are being equitably distributed throughout the city.

The following data from the US Census were analyzed:

- Population density
- Median household income
- Per-capita income
- Unemployment
- Vulnerable population
- Underserved population
- (All) Minority populations
- White population
- Black population
- Native population
- Asian population
- Hawaii Native population
- Hispanic population
- Other race population
- Two or more races population
- Male population
- Female population

CityWorks Database

The following charts contain the cumulative total service requests from residents and city staff work orders from 2011-2021, aggregated by category (e.g. the "pruning" category includes elm and elm sanitation pruning).

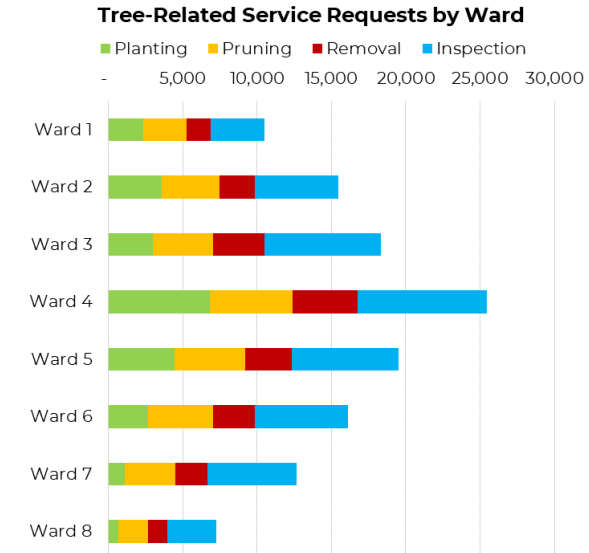


Figure 45. Aggregated service requests by ward.

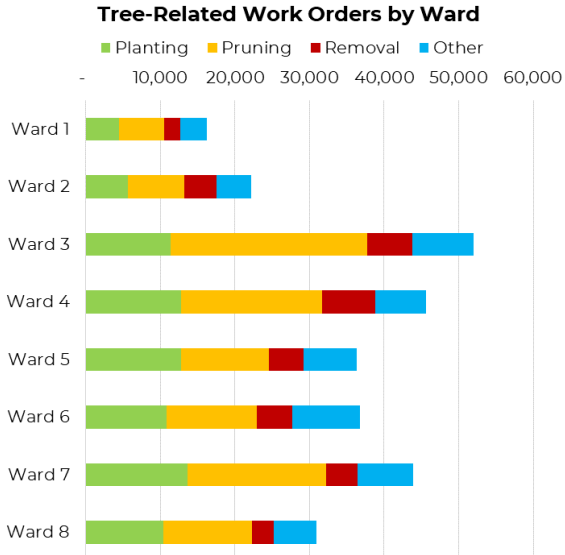


Figure 46. Aggregated work orders by ward.

OUTPUTS

Management Activities (Source: CityWorks database)

The outputs of the UF program's efforts can be most directly represented by the District's work order dataset which contains information about the management activities that were performed on all public trees such as plantings, prunings, removals, and any other tree-related work. From 2011-2021, over 285,000 tree-related work orders were performed within the District's eight wards. Again, the distribution of these management activities varied greatly throughout the wards. In Ward 1, just 16,000 work orders were performed, compared with Wards 3, 4, and 7, which all had upwards of 40-50,000 work orders in the same time period. In all cases, the majority of work orders were for pruning.

New Trees in Inventory (Source: UFD inventory)

Another metric that captures the UF program's outputs is the number of new trees added to their inventory dataset. From 2011-2021, nearly 74,000 new trees were planted across the District. The Ward with the greatest number of new trees added was Ward 7 (13,500 trees). Wards 3, 4, and 5 each had over 10,000 new trees added as well. Conversely, Wards 1 and 2 had the fewest number of new trees added (approximately 3,900 and 4,500 trees, respectively). These results reflect the District's decision to focus their resources on locations where opportunities and needs are greatest (e.g. where open planting spaces exist in greatest quantity, such as Wards 4, 7, and 8), while still planting in areas with higher levels of density but fewer open spaces (such as Wards 1 and 2).

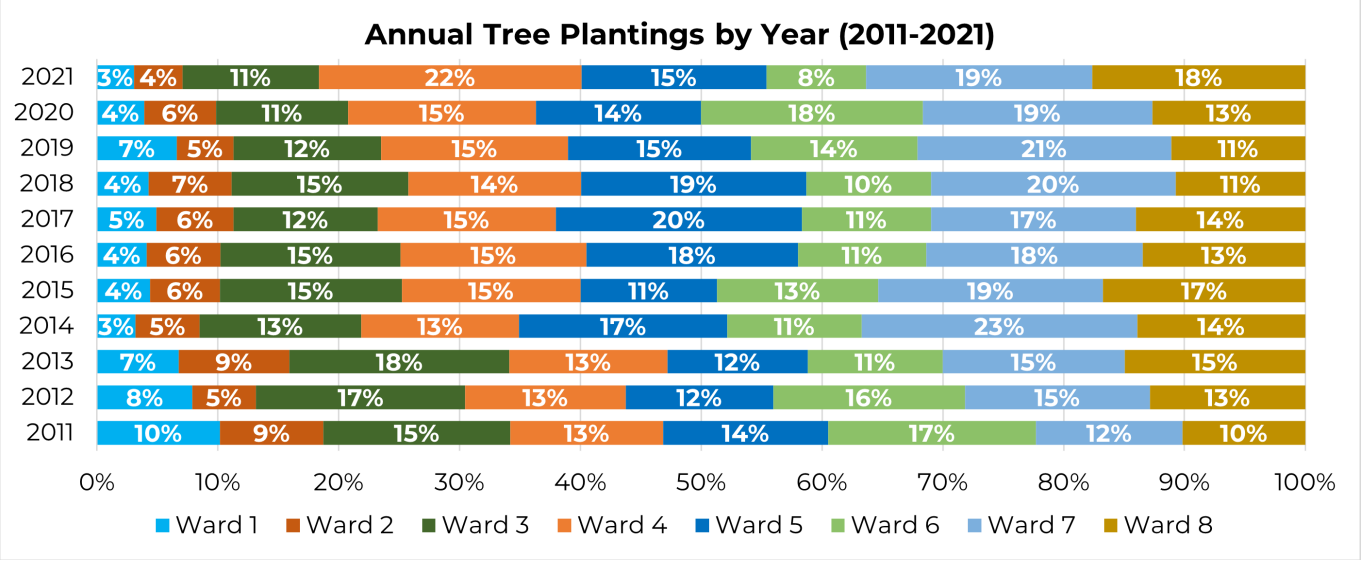


Figure 47. Proportion of new trees added annually to UFD's inventory since 2011 by year and Ward.

OUTCOMES

Urban Tree Canopy Change

The ultimate goal of UF's program based on these "inputs" and "outputs" is to increase canopy across the city. This "outcome" can be measured by the longer-term changes in urban tree canopy which result from the District's management actions ("outputs") that were informed by the existing urban forest characteristics, canopy cover, and available planting space ("inputs"), with the caveat that the UF program is only able to fully control these inputs and outputs on the land that it has authority over. As such, in spite of considerable increases in both the number of public trees and ROW canopy cover in all wards (outputs), District-wide canopy neither increased nor decreased over the 10-year period from 2011-2021 in which the city had implemented its 40% canopy goal and major planting initiatives (outcome). During that time, four wards (5, 6, 7 and 8) experienced canopy losses ranging from 1-2% (or 1-10% relative to their own previous amount of canopy), and another two wards (2 and 4) had little to no change. Almost all of the increases in canopy that were captured in the 2011-2020 tree canopy change assessments took place in Ward 1, which had a 3% (12% relative) increase, and Ward 3, which already had the highest UTC prior to this planting initiative in 2011 (53%), had a 6% (11% relative) increase and still contains the highest UTC after it in 2021 (59%). Above all, these results point to the need for strategic partnerships to target tree plantings in areas that have available planting space, such as private property, in order to help the District continue to expand its urban canopy when the planting boxes that it has authority to plant trees in are essentially at their capacity.

VIBRANT CITIES LAB URBAN FOREST ASSESSMENT

Once the analysis of the UF's program inputs, outputs, and outcomes was complete, those results, as well as other relevant canopy, inventory, and operational capacity data, were incorporated into the Community Assessment and Goal Setting Tool. This tool, created by the Vibrant Cities Lab, is designed to be used by municipal forestry programs to assess how their community measures up against many common industry standards and best practices.

Similar to an audit (such as the USFS Urban Forest Sustainability and Management Audit), the Goal-Setting Tool evaluates various elements of the urban forestry program and urban forest itself and assigns two scores: a current ranking as well as a target goal. By comparing the differences, or "gaps," between current and target conditions, the District defines another metric that can be used to describe which parts of the UF's program model are succeeding at meeting their goals and which elements still require more attention.

Note: each question in the Goal-Setting Tool is answered with a ranked choice and accompanying numerical score of "Low" (-1), "Fair" (1), "Good" (2), or "Optimal" (4). For the purpose of this assessment, it was assumed that the District's goal would be "Optimal" (4) in all categories.

Overall, the District scored 81 points out of a possible 111 points for the target, which yields a gap of 30 points. This score indicates that the District is currently achieving approximately 72% of its program goals according to industry standards and best practices within the Goal-Setting Tool..

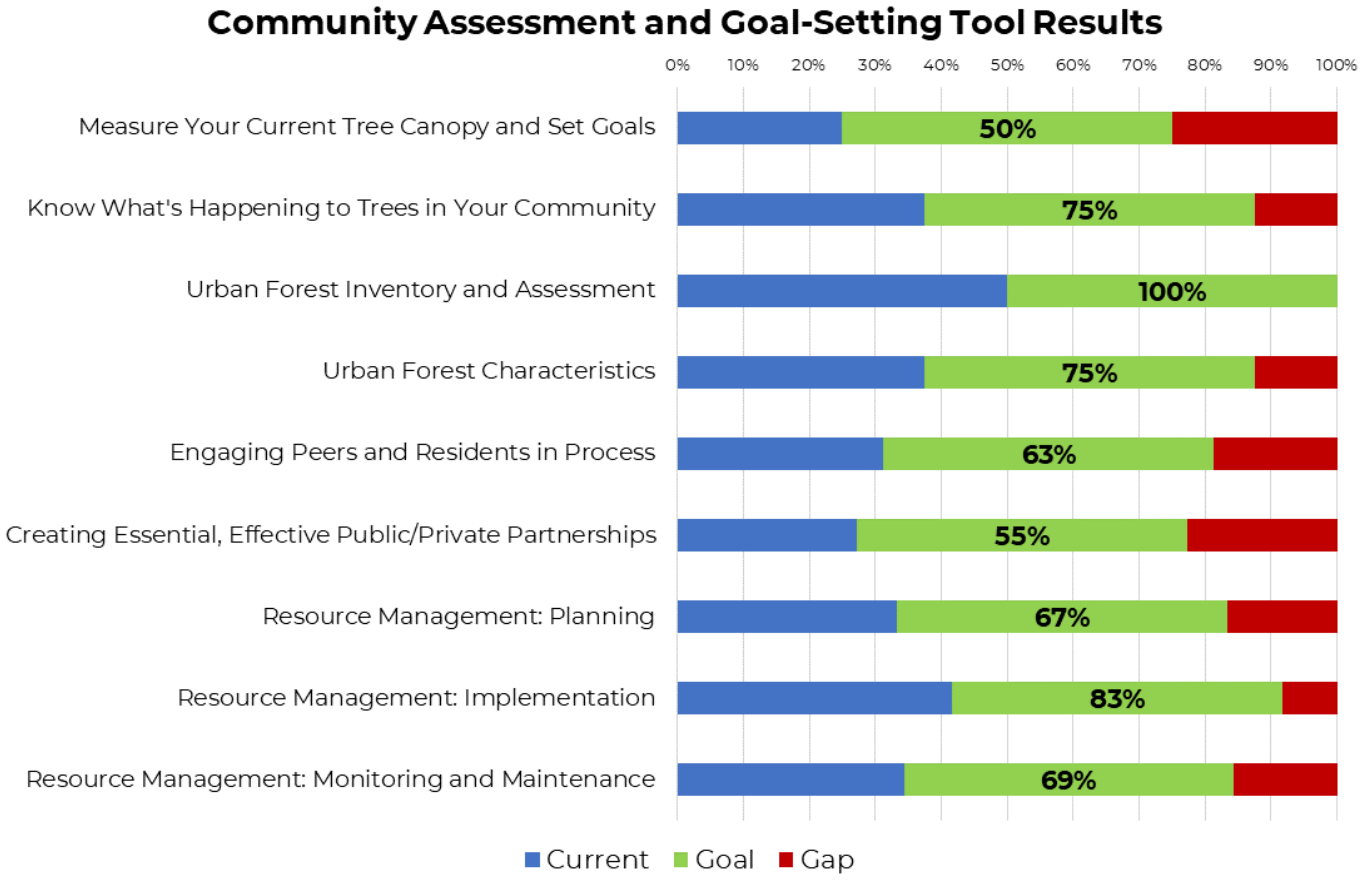


Figure 48. Results of the Vibrant Cities Lab Urban Forest Community Assessment and Goal-Setting Tool.

Measure Your Current Tree Canopy and Set Goals **2/4**

The objective of this theme is to assess how well a city is meeting its desired level of tree cover, which may be based on the city's goals or plantable space, within the citywide boundary and each individual neighborhood or land use. Currently, the District contains 37% tree canopy, which falls within >75%-100% of its desired canopy. However, at the neighborhood level, 65% or 26 of 40 neighborhood commissions have not yet achieved 40% canopy cover, which is why the District was ranked "good" (2 points) instead of its goal, "optimal" (4 points).

Know What's Happening to Trees in Your Community **9/12**

Building upon the previous theme, this category rates the city's level of understanding about all publicly-owned trees, trees in publicly-owned natural areas, and trees on private property. The District is already meeting the "optimal" criteria for publicly-owned trees due to its comprehensive inventory and for its natural areas as a result of the Sustainable DC 2.0 plan (4 points each). However, although they are included in the aerial canopy assessments and in a separate, estimated inventory dataset based on feature extraction of the aerial imagery, the District's bottom-up tree inventory does not currently include trees on private property which earned a rating of "fair" (1 point).

Urban Forest Inventory and Assessment **8/8**

In addition to assessing tree canopy at a high level, it is also important to assess it from the ground up with a field inventory. This theme evaluates the city's tree inventory and geospatial tree canopy assessment based on the data they contain, methods used to obtain it, and incorporation into management activities, and in both cases, the District is already meeting the maximum "optimal" criteria (4 points each). The District is excelling in this category thanks to its "systematic comprehensive inventory system of the entire urban forest – with information tailored to users and supported by mapping in municipality-wide GIS system [that] provides for change analysis" and "complete, detailed, and spatially explicit, high-resolution Urban Tree Canopy (UTC) assessment based on enhanced data (such as LiDAR) – accompanied by comprehensive set of goals by land use and other parameters [that is] all utilized effectively to drive urban forest and green infrastructure policy and practice municipality-wide and at neighborhood or smaller management level."

Table 13. Citywide program review results.

District-Wide	
Urban Forest Characteristics	
Trees in Good Condition	83%
Species Richness	205
Simpson's Diversity Index	0.98
Trees in Smallest Size Class	50%
Trees Managed by UF	93%
Tree Box Status	
Planted Tree Boxes	175,890
Open Tree Boxes	3,404
Stocking Rate	98%
Urban Tree Canopy	
UTC %	37%
UTC Deficit %	-3%
PPA %	24%
2011-2020 Tree Management Activities	
Service Requests	126,861
Work Orders	285,379
Trees Planted 2011-2020	73,987
2011-2020 Raw Change %	0.2%
2011-2020 Relative Change %	0.5%

Urban Forest Characteristics 6/8

This theme looks deeper into the characteristics of the city's urban forest in terms of its species composition and use of native vegetation. The value of a given species can be represented by calculating its RPI (relative performance index), which refers to the ratio of trees in "good" condition or better compared to all trees (within a given species or total). The District received an "optimal" (4 point) score for species diversity since all of the six most common species in the inventory -- red maples, willow oaks, pin oaks, red oaks, American elms, and Japanese zelkovas -- have an RPI greater than the citywide average of .83. In terms of its use of native biodiversity in its landscape, the District received a rating of "good" (2 points) since the use of native species is encouraged while invasive species are discouraged, but not yet to the "maximum extent possible."

Table 14. Relative perfomance index of the 6 most common species.

Top 6 Species	# of Trees in Good Condition	Total # of Trees	% of Trees in Good Condition	Relative Performance Index
Red maple	9,133	12,449	73%	0.89
Willow oak	8,526	10,079	85%	1.02
Pin oak	6,384	8,658	74%	0.89
Red oak	4,157	5,771	72%	0.87
American elm	4,072	5,715	71%	0.86
Japanese zelkova	4,717	5,423	87%	1.05
All other species	114,183	134,333	85%	1.03
Grand Total	**151,172**	**182,428**	**83%**	--

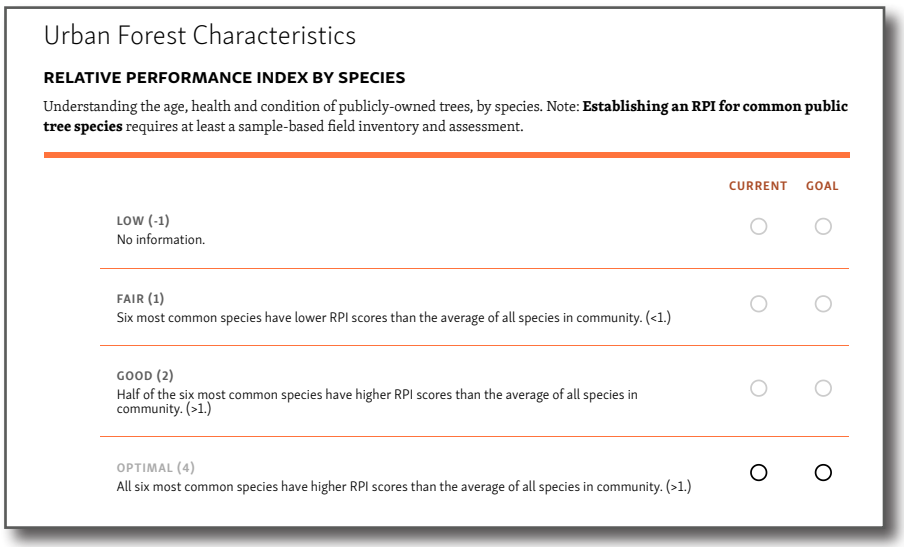


Figure 49. A question from the Community Assessment and Goal-Setting Tool.

Engaging Peers and Residents in Process 10/16

This theme evaluates a city's effectiveness at aligning its own municipal departments, engaging its residents in planning processes, ensuring an equitable distribution of tree benefits throughout the city, and advocating for trees as a vital community resource. The District is already performing at an "optimal" alignment capacity (4 points) since all municipal policies and projects are implemented by formal, interdepartmental teams as outlined in the overall Government and DDOT-specific organizational charts. As for resident engagement, environmental equity, and the perceived value of trees, the District is operating at a "good" but not yet "optimal" standard (2 points each). Although there are neighborhood groups engaged in urban forestry activities but they are not centrally coordinated by the city or its urban forestry nonprofit Casey Trees. Furthermore, future planning and planting efforts are focused on low-canopy/high-need areas (thanks to the District's commitment to frequently reassessing its urban canopy and practicing adaptive management), but there is less resident involvement in these areas. Lastly, although trees are generally viewed as valuable to the community, there remains room for improvement in communicating their value as a vital form of infrastructure to the general public.

Creating Essential, Effective Public/Private Partnerships **7/11**

This theme focuses on creating a cohesive system between the city, its private landowners, its utilities, and other green industry partners. Currently, all utilities are employing best management practices (and, in fact, the UF is uniquely equipped to communicate with other District utilities as it falls under the DDOT) and performing at an "optimum" (4 points) level. The District has established a range of public/private partnerships that are incentivize tree plantings by private landowners, with a coordinated focus on neighborhoods where higher levels of engagement are required, but private landowners are not yet engaged in tree management and planning to the maximum extent possible ("good," 2 points), and while the many segments of the District's green industry are functioning and "collaborative," they are not yet "extensive" ("good," 2 points) in terms of shared standards and credentialing.

Resource Management:

Planning **8/12**

The Planning section of the Resource Management theme specifically addresses a city's urban forest management plan (UFMP). With the Metro Washington Council of Governments (MWCOG), the District is already performing at the "optimal" level of cooperative planning. The District's urban forest management plan, which is currently being completed by their nonprofit partner Casey Trees, is rated as "better" (between "good" and "optimal," 3 points) since it is comprehensive for public trees/planting spaces but does not cover private land. Since the District's UFMP is still in development, it has not yet been widely incorporated into other city planning efforts, but once completed, the goal is to involve all agencies who work with urban forestry in its implementation ("fair," 1 point).

Implementation **22/24**

The Implementation section of the Resource Management theme pertains to the degree to which the city's UFMP, as described above, is successfully being implemented in the real world. Though the UFMP is still in development, the District's current urban forestry program capacity is "good" in that there are likely enough staff to achieve the goals of the UFMP, although not all program goals-- such as the 40% citywide canopy goal-- have been met at this point (2 points). Fortunately, the District has been able to secure long-term funding to implement its urban forestry activities (as evidenced by the many assessments and initiatives described in this analysis) and is utilizing the "optimal" approach to manage its planting sites and assess site suitability, promote the health and establishment of newly-planted trees, enhance the ecological integrity of natural areas while allowing for appropriate public use, and address the treatment/permitting of trees on private land (4 points in each of 4 categories).

Monitoring and Maintenance **11/16**

The Monitoring and Maintenance section of the Resource Management theme looks to the future, considering the ways that the city's urban forest and UFMP implementation will be reevaluated (with corresponding actions updated accordingly) over time. The District's existing tree protection policies practices are considered "better" (3 points) since they "conform to and reference ANSI Standards for arboricultural practices (A300), safety (Z133), and nursery stock (Z60.1), as well as applicable ISA BMPs," but cannot always be consistently applied with consequences great enough to deter violations. Tree monitoring and urban wood utilization practices are both currently rated as "good" (2 points each) since they are functionally operating at a high standard but have the potential for improvement. Risk management practices are "optimal" since TRAQ-certified contractors are utilized on District projects (4 points).

TREE PLANTING PRIORITIZATION

Urban tree canopy provides a multitude of direct and indirect benefits. To provide the most complete understanding of where those benefits are lacking, tree planting priorities were identified based on environmental, socio-demographic, and public health data sets. Data sources include land cover data created by this assessment, Centers for Disease Control and Prevention (CDC) PLACES health data, Washington DC Department of Energy and Environment (DOEE) Heat Exposure Sensitivity Index (HESI), and the American Community Survey.

Tree planting prioritization ranking is needs-based and designed to rank each ward, neighborhood commission, and block group based on each area's need for a particular benefit that trees can provide. Rankings are sorted from high to low and were calculated for each individual criteria as well as overall to show where multiple needs overlap. Viewing combined ranks show where tree canopy benefits can have the greatest impact by addressing multiple needs.

PRIORITIZATION CRITERIA DESCRIPTIONS

Twelve individual criteria related to three themes were identified and analyzed. These themes included environmental, socio-demographic, and public health.

ENVIRONMENTAL

- **Property ownership:** Possible planting area on District-owned, operated, or managed public and public/private land. Values equal the percentage of plantable space within public land within each geographic area.
- **Stormwater Runoff Mitigation:** This indicator represents the available planting area on or adjacent to impervious surfaces and surface water bodies to indicate areas where new trees can intercept rainfall and absorb runoff.
- **Energy Conservation:** This indicator identifies residentially-zoned areas with less than the district average tree cover and higher than average total possible planting area. Planting trees near residences can decrease seasonal cooling and heating costs.
- **Urban Heat Island:** The average temperature value within each feature. Evening temperature values from a 2018 Portland State University study were used. Temperature values were also used in the DOEE Heat Exposure Index.
- **Wildlife Habitat Connectivity:** This indicator identifies available planting areas within 100' of large canopy tracts (equal to or greater than 5 acres).

SOCIO-DEMOGRAPHIC

- **Population Below Poverty:** This indicator shows the percentage of residents living below the poverty level according to American Community Survey 2014-2019 5-year estimates.
- **Homeownership:** This indicator shows the percentage of residents who own the home they live in according to American Community Survey 2014-2019 5-year estimates. Combined prioritization ranking considers rates where home ownership rates are high to be high priority.

PUBLIC HEALTH

- **Asthma:** This indicator shows the CDC model-based estimate for crude prevalence of current asthma among adults aged >=18 years in 2017 at the census tract scale.
- **Heart Disease:** This indicator shows the CDC model-based estimate for crude prevalence of coronary heart disease among adults aged >=18 years in 2017 at the census tract scale.
- **Obesity:** This indicator shows the CDC model-based estimate for crude prevalence of obesity among adults aged >=18 years in 2017 at the census tract scale.
- **Health Insurance:** This indicator shows the CDC model-based estimate for crude prevalence of current lack of health insurance among adults aged 18-64 years in 2017 at the census tract scale.
- **Mental Health:** This indicator uses CDC data to show the crude prevalence of mental health that is reported as "not good" for 14 days or more among adults.

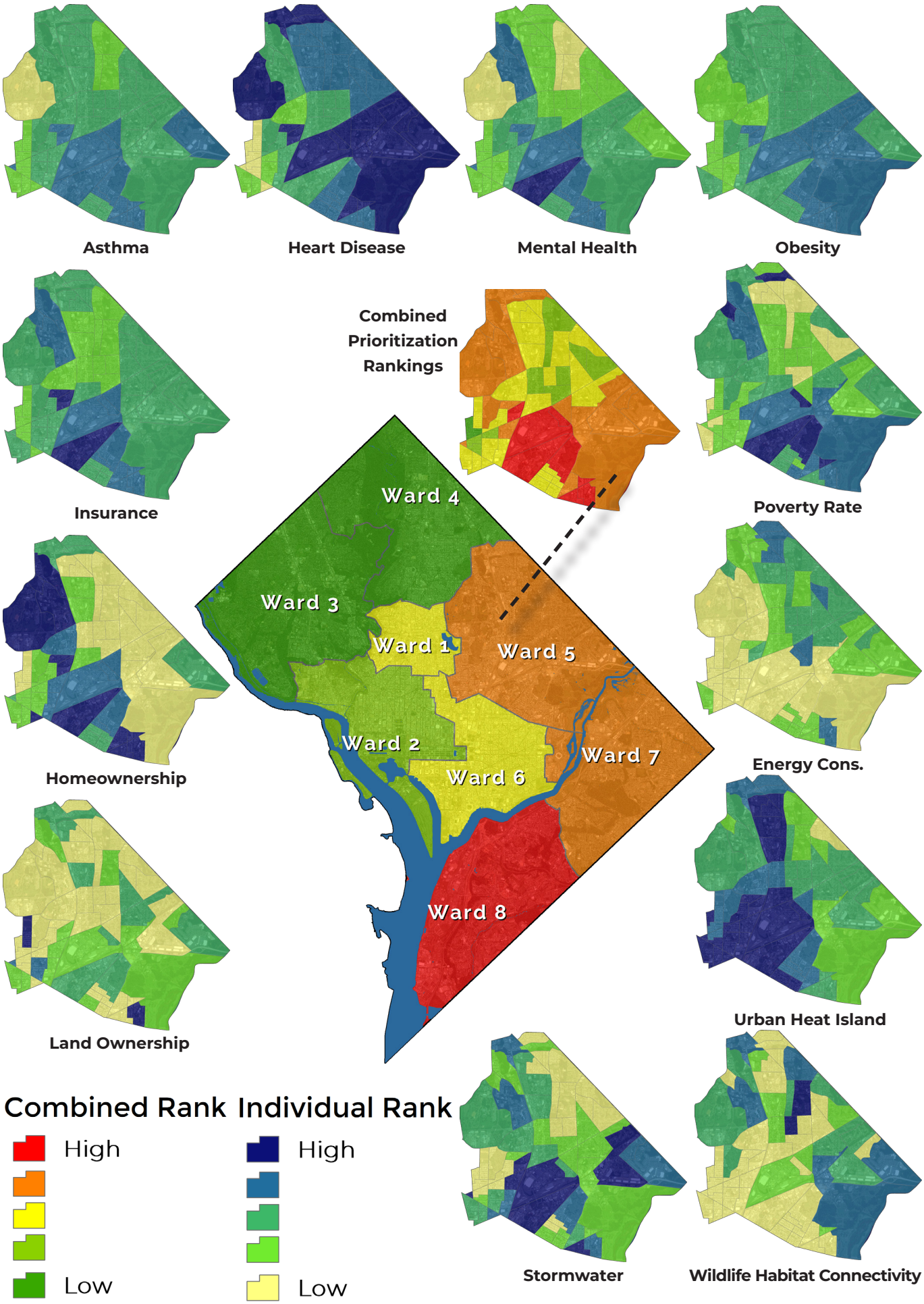
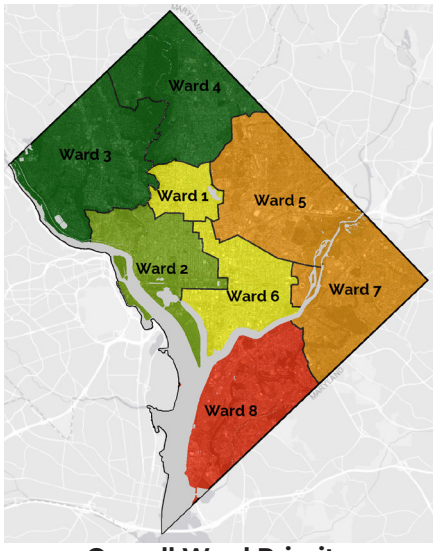
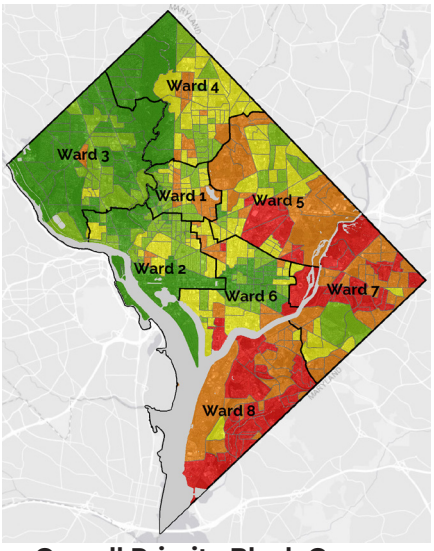


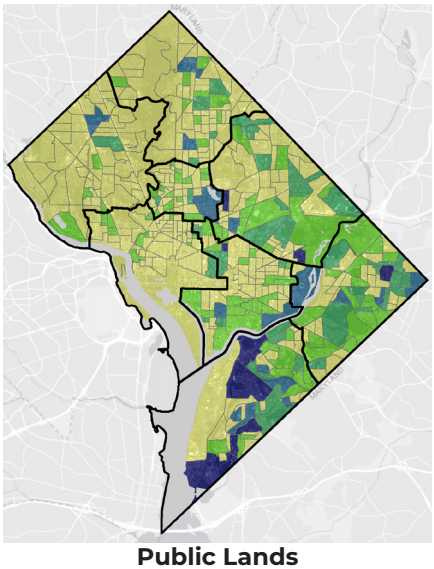
Figure 50. Combined planting prioritization by wards (center) and individual rankings by census block groups in Ward 5.

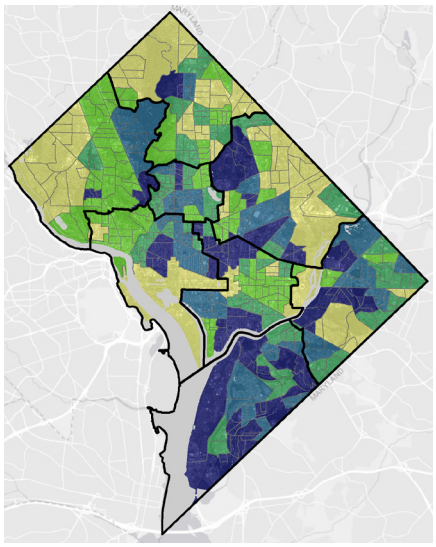


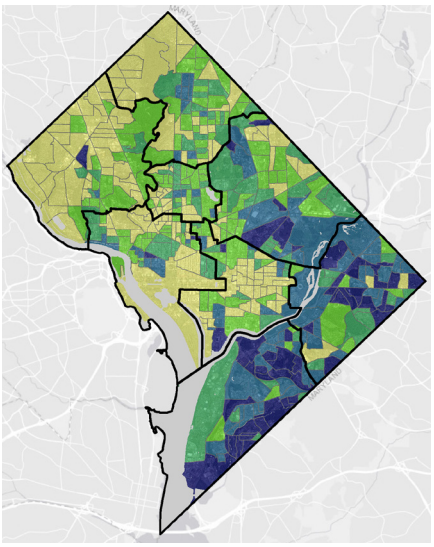
Overall Ward Priority

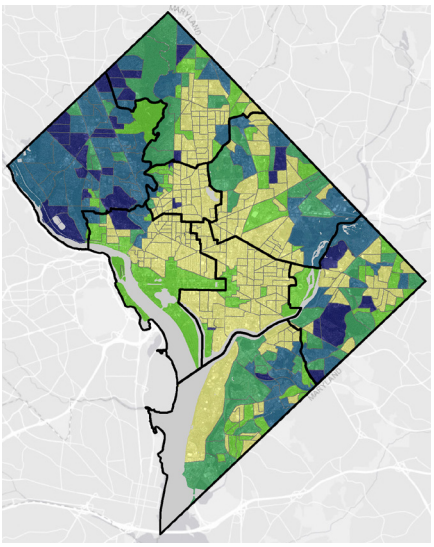


Overall Priority Block Groups


Public Lands


Homeownership


Population Below Poverty


Wildlife Connectivity

Individual Rank

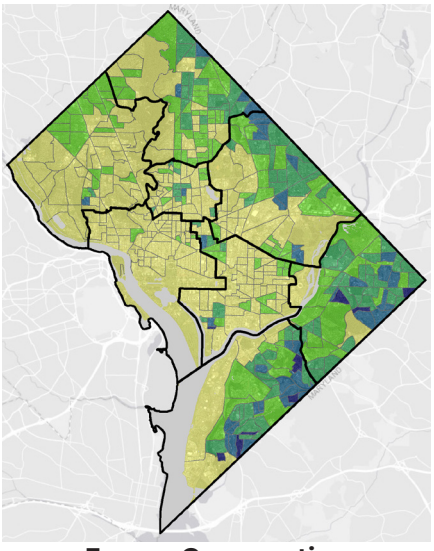
High

Low

Combined Rank

High

Low


Energy Conservation

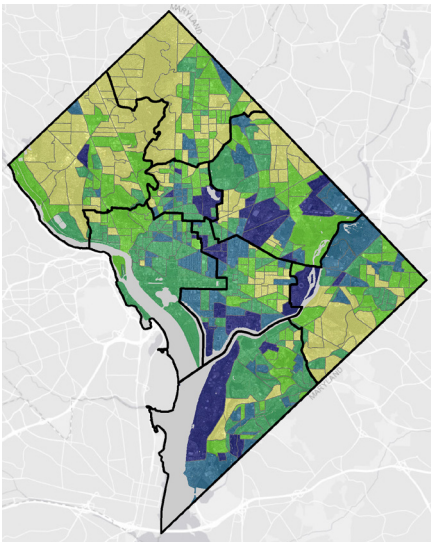

Stormwater

Figure 51. Combined planting prioritization by wards (top left) and census block groups (center top). individual rankings by census block groups for individual environmental criteria and demographics.

HESI Compared to Tree Planting Since 2016

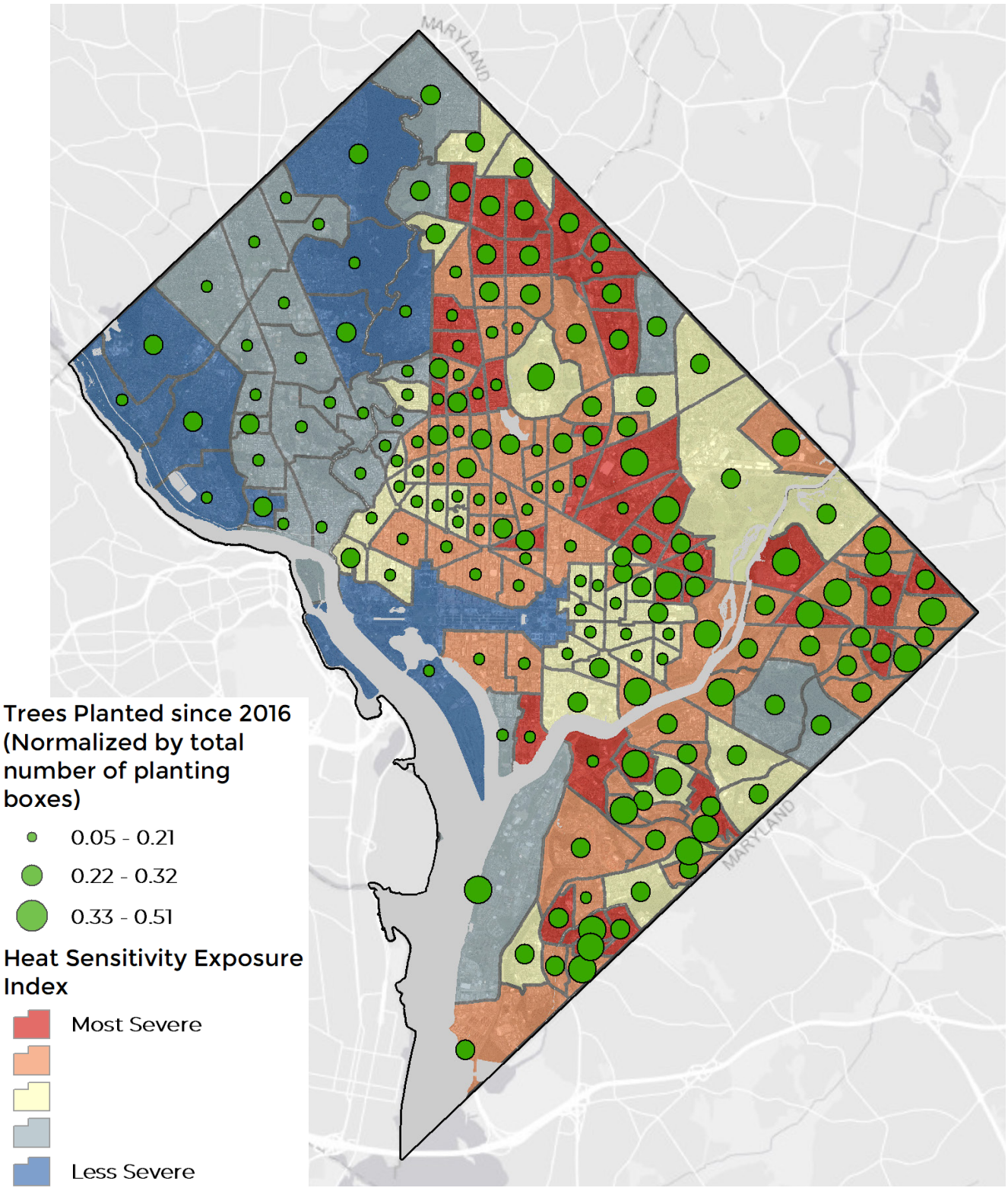


Figure 52. This map shows the heat sensitivity exposure index compared with the normalized number of trees planted in each census tract since 2016. Overlaying these data shows how planting efforts are responding to heat exposure and sensitivity.

CONCLUSIONS AND RECOMMENDATIONS

Washington, D.C. has demonstrated that it values its natural resources and wants to maintain a healthy and sustainable urban environment. Recurring assessments of the City's tree canopy represent important steps in ensuring the long-term health of its urban forest. Increasing canopy cover and reaching the District's goal of 40% tree canopy coverage can be achieved with proper planning, investment, and care of existing trees. The District should continue to monitor the health of the urban forest and implement the following recommendations to ensure the urban forest is considered during future planning and development to sustain and enhance the benefits that trees provide to the community.

UTILIZE THE CANOPY ASSESSMENT AND PROGRAM REVIEW TO ALIGN THE URBAN FORESTRY DIVISION'S SHORT-TERM MANAGEMENT ACTIVITIES WITH THE DISTRICT'S LONG-TERM CANOPY GOALS

1. Leverage the results of this canopy assessment and program review to promote the urban forest

To preserve, protect, and maintain Washington, D.C.'s tree canopy, the District should continue to have a tree canopy assessment performed on a regular interval. As Washington, D.C. changes, they will be able to use these data to ensure that their urban forest policies and management practices prioritize its maintenance, health, and growth. The urban forest provides Washington, D.C. with a wealth of environmental, social, and even economic benefits which relate back to greater community interest in district-wide initiatives and priorities. These results can be used to identify where existing tree canopy cover should be preserved, where there are opportunities to expand the District's canopy cover, and which areas would receive the greatest benefits from the investment of valuable time and resources into the urban forest.

The results of this assessment should be used to encourage investment in urban forest monitoring, maintenance, and management; to prepare supportive information for local budget requests/grant applications; and to develop targeted presentations for District leaders, planners, engineers, resource managers, and the public on the functional benefits of trees in addressing environmental issues. The land cover and planting prioritization data should be disseminated to diverse partners for urban forestry and other applications while the data are current and most useful for decision-making and implementation planning. The information from this study can help establish canopy cover goals for the short- and long-term.

Additionally, the District can use the Program Review as a guide to utilize or establish an Urban Forestry Work Group and develop strategies that will close gaps identified in the Community Assessment and Goal Setting Tool. The table on the following page provides a summary of gaps identified in the program review and suggested or recommended strategies to consider as part of the District's Urban Forest Management Plan (in development).

2. Use planting prioritization and UTC/PPA data to prioritize future plantings

The City of Washington, D.C. and its various stakeholders can utilize the results of the UTC, PPA, and priority planting analysis to identify the best locations and areas in most need in which to focus future tree planting and canopy expansion efforts. Results indicate that urban tree canopy coverage in the District is not evenly distributed. Trees can play a large role in improving public health by improving air quality, reducing temperature, and reducing stress. The District should continue to use the planting prioritization rankings to identify planting opportunities in underserved or impoverished communities as well as areas with higher rates of asthma, cardiovascular disease, poor mental health, and lack of health insurance.

Table 15. Summary of suggested strategies to address gaps idenfitied in the Vibrant Cities Lab Assessment.

Suggested Strategies for the Urban Forestry Division
Measure Your Current Tree Canopy and Set Goals
26 of 40 neighborhood commissions have not achieved 40% canopy cover.
Continue to prioritize tree plantings and preservation using the guidance provided in the Program Review.
Know What's Happening to Trees in Your Community
Tree inventory data does not include trees on private property, but an accurate, actionable estimated inventory of private trees derived from LiDAR data does exist.
Create a public-facing mapping interface for residents to map the trees planted on their private property, utilize crowd-sourcing to map existing trees, capture data from tree nurseries relating to the types of trees purchased, strengthen community partnerships, and map the location of trees planted as part of free tree giveaway programs.
Urban Forest Inventory and Assessment
The program is currently meeting the goal.
Continue to assess canopy cover change and planting opportunities. Maintain an up-to-date inventory of public trees (and estimated inventory of private trees where applicable).
Urban Forest Characteristics
There is a need to reduce invasive species currently in the landscape and encourage the use of more native tree species.
Maintain, update, and share the tree species list recommended for planting with departments, partners, nurseries, developers, contractors (landscape and tree care), and residents. Support community groups involved in invasive removals, habitat restoration, tree plantings, and other environmental services through information sharing and workshops as feasible. Continue to monitor the inventory to maintain tree species frequency below the recommended thresholds to sustain diversity and resiliency.
Engaging Peers and Residents in Process
More resident involvement in projects and planning is needed.
Conduct biannual public surveys to raise awareness about the programs, gather viewpoints and perceptions, and inform changes to programs or services. Continue to share information on the website, social media, and other platforms regarding the benefits of trees, proper tree care, tree preservation, ordinances, tree species selection, and pest/disease monitoring. Utilize community partners for localized messaging to reach a diverse population. Establish clear and consistent messaging tailored to various audiences (e.g., age or ethnicity) guided by a community outreach strategy that is shared among departments and partners.
Creating Essential, Effective Public/Private Partnerships
Improved outreach, partnership, and education to private land owners is encouraged.
With partner support, provide resources, workshops, and training for private landowners relating to tree care, planting, policies/ordinances, tree benefits, pest and diseases, and other topics relevant to the audience and location. Biannual surveys as recommended above may gather information relating to urban forest management planning, resource and information needs, and tree planting interest. It is recommended the District establish or revamp tree maintenance manuals detailing industry standards and best practices along with the District's tree-related policies and ordinances.
Resource Management – Planning
The District's Urban Forest Management Plan, in partnership with nonprofit partner Casey Trees, is currently underway but not completed.
Review and refine the suggested strategies provided in this section to integrate into the Urban Forest Management Plan as applicable.
Resource Management – Implementation
Implementation of program services to achieve goals is not currently guided by an Urban Forest Management Plan that is supported by the District, partners, and the community.
Align the Urban Forest Management Plan vision, goals, and actions with strategies provided in this section to guide implementation for long-lasting success.
Resource Management – Monitoring and Maintenance
An Urban Forest Management Plan that provides guidance for monitoring the urban forest and associated programs or strategies is not currently available.
Guided by the Urban Forest Management Plan, conduct annual program reviews using the Vibrant Cities Lab's Community Assessment and Goal-Setting Tool or similar auditing tool to effectively evaluate progress, identify new gaps or challenges, and leverage strengths and opportunities. Specific to tree monitoring and maintenance, continue to inventory the public tree population and maintain the database to prioritize pruning and removals. Grow an urban forest that is healthy and resilient to the effects of climate change and pests/diseases. Continue to adhere to industry standards and best practices for tree maintenance, removal, planting, and preservation and recommend similar adherence by other departments, partners, private landowners, developers, and contractors.

REPORT APPENDIX

ACCURACY ASSESSMENT

Classification accuracy serves two main purposes. Firstly, 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 Table A1 contain 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 2020. 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 THESE STEPS:

1. One thousand (1000) sample points, or approximately 20 points per square mile area in Washington, D.C. (68 sq. miles), were randomly distributed across the study area and assigned a random numeric value.
2. Each sample point was then referenced using the Pleiades satellite aerial photo and assigned one of five generalized land cover classes ("Ref_ID") mentioned above by a technician.
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, no points were dropped.
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 cover.[1]
5. 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 D.C.'s landscape. The error matrix shown in Table A1 represent the intersection of reference pixels manually identified by a human observer (columns) and classification category of pixels in the classified image (rows). The blue boxes along the diagonals of the matrix represent agreement between the two-pixel maps. Off-diagonal values represent the number of 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 (317 + 138 + 414 + 1 + 99 = 969 / 100 = 96.9%), and the matrix can be used to calculate per class accuracy percentage's. For example, 324 points were manually identified in the reference map as Tree Canopy, and 317 of those pixels were classified as Tree Canopy in the 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: (324/317 = .98), meaning that we can expect that ~98% of all 2020 tree canopy in the Washington, D.C. study area was classified as Tree Canopy in the 2020 classification map.

Conversely, the "User's Accuracy" is calculated by dividing the total number of agreement pixels by the total number of classified pixels in the row category. For example, 317 classification pixels intersecting reference pixels were classified as Tree Canopy, but 8 pixels were identified as Vegetation and 10 were identified as impervious in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (317/335 = 0.95), meaning that ~95% 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 D.C. in 2020. The largest sources of classification confusion exist between tree canopy and vegetation.

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.

Table A1. | Error matrix for land cover classifications in Washington, D.C. (2020).

Classification Data	Reference Data: Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	317	8	10	0	0	335
Vegetation	5	138	5	0	0	148
Impervious	2	1	414	0	0	417
Soil / Dry Veg.	0	0	0	1	0	1
Water	0	0	0	0	99	99
Total	324	147	429	1	99	1,000

Overall Accuracy = 97%

Producer's Accuracy	
Tree Canopy	98%
Veg./ Open Space	94%
Impervious	97%
Bare Ground / Soil	100%
Water	100%

User's Accuracy	
Tree Canopy	95%
Veg./ Open Space	93%
Impervious	99%
Bare Ground / Soil	100%
Water	100%

ACCURACY ASSESSMENT RESULTS

Interpretation of the sample error matrix offers some important insights when evaluating D.C.'s urban tree canopy coverage and how well aligned the derived land cover data are with interpretations by the human eye. The high accuracy of the 2020 data indicates that regardless of how and when it was achieved, the District's current tree canopy can be safely assumed to match the figures stated in this report (approximately 37%).

GLOSSARY/KEY TERMS

Land Acres: Total land area, in acres, of the assessment boundary (excludes water).

Non-Canopy Vegetation: Areas of grass and open space where tree canopy does not exist.

Possible Planting Area - Vegetation: Areas of grass and open space where tree canopy does not exist, and it is biophysically possible to plant trees.

Possible Planting Area - Total: The combination of PPA Vegetation area and PPA Impervious area. In this project no impervious areas were identifies as plantable.

Soil/Dry Vegetation: Areas of bare soil and/or dried, dead vegetation.

Total Acres: Total area, in acres, of the assessment boundary (includes water).

Unsuitable Impervious: Areas of impervious surfaces that are not suitable for tree planting. These include buildings and roads and all other types of impervious surfaces.

Unsuitable Planting Area: Areas where it is not feasible to plant trees. Airports, ball fields, golf courses, etc. were manually defined as unsuitable planting areas.

Unsuitable Soil: Areas of soil/dry vegetation considered unsuitable for tree planting. Irrigation and other modifiers may be required to keep a tree alive in these areas.

Unsuitable Vegetation: Areas of non-canopy vegetation that are not suitable for tree planting due to their land use.

Urban Tree Canopy (UTC): The "layer of leaves, branches and stems that cover the ground" (Raciti et al., 2006) when viewed from above; the metric used to quantify the extent, function, and value of the urban forest. Tree canopy was generally taller than 10-15 feet tall.

Water: Areas of open, surface water not including swimming pools.

LAND COVER CHANGE ANALYSIS RESULTS BY ADDITIONAL LAND USES

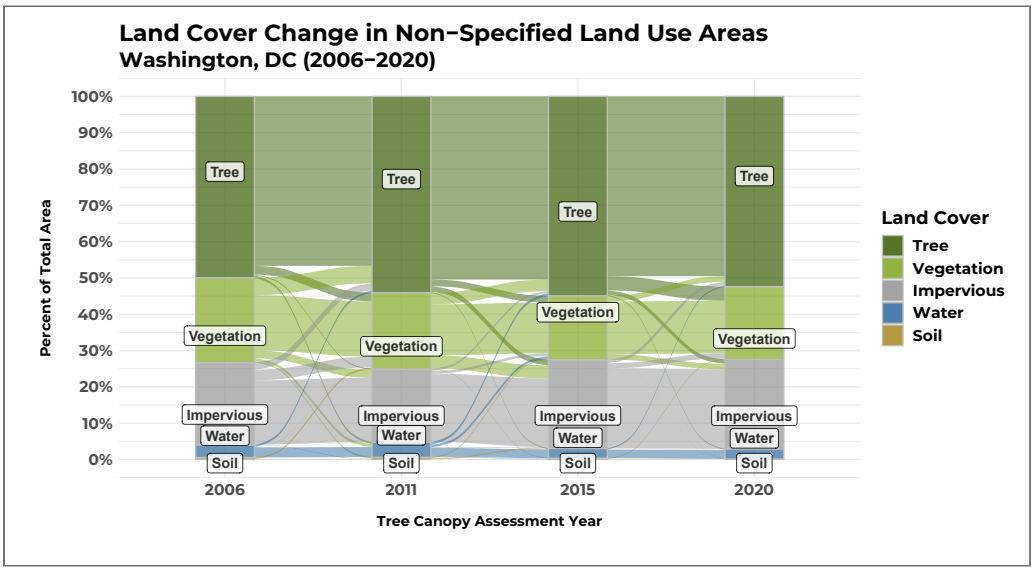


Figure 53.
Land cover change in unspecified areas.

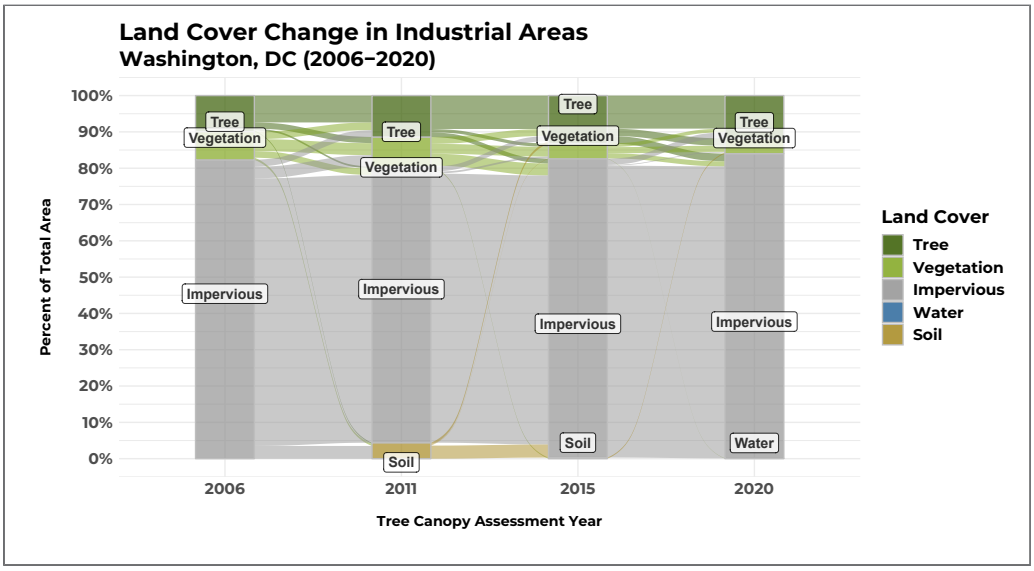


Figure 54.
Land cover change in industrial areas.

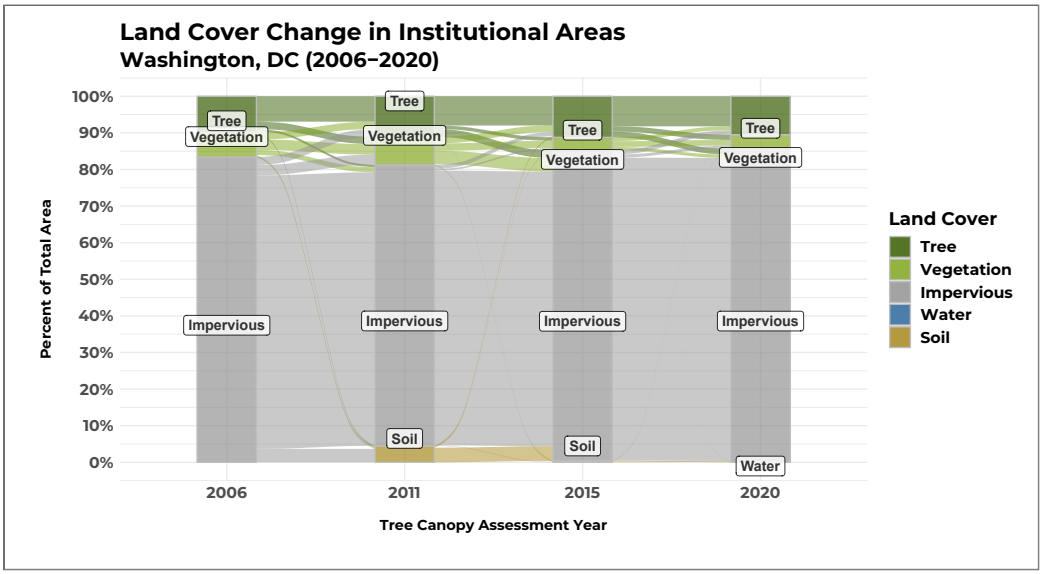


Figure 55.
Land cover change in institutional areas.

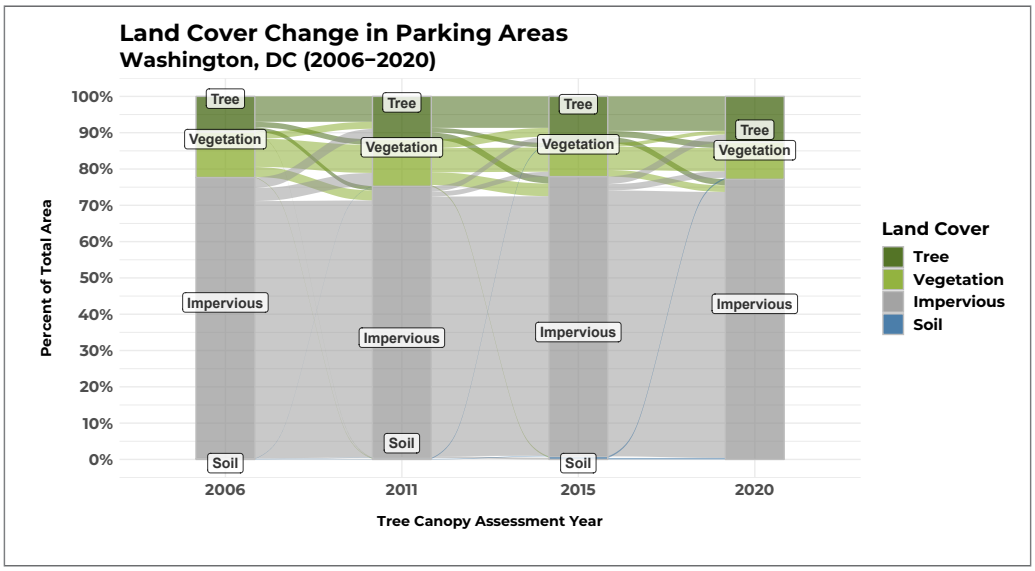


Figure 56.
Land cover change in parking land use areas.

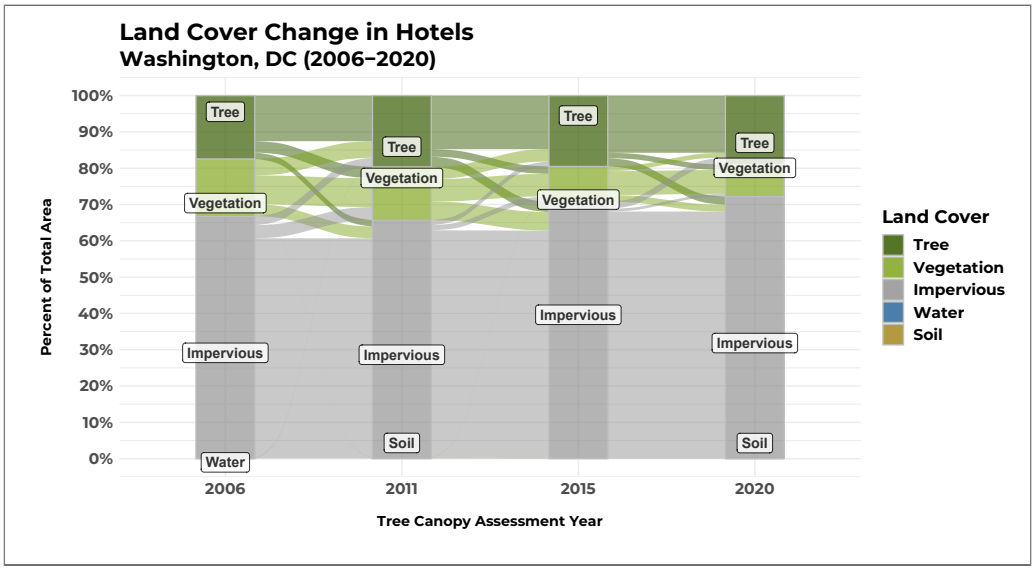


Figure 57.
Land cover change in hotel land use areas.

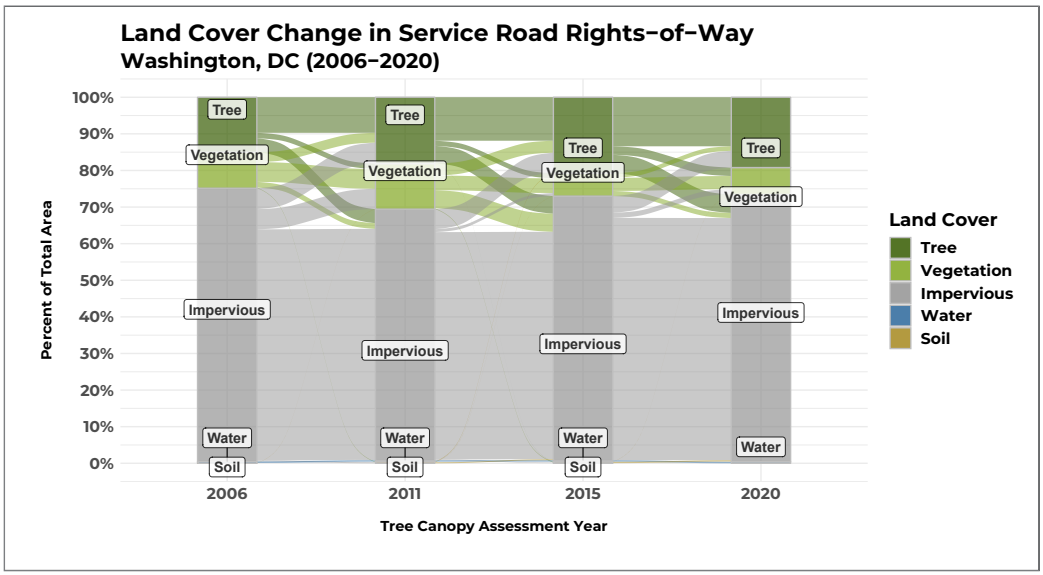


Figure 58.
Land cover change in service road rights-of-way.

DETAILED PROGRAM REVIEW RESULTS BY WARD

The following tables summarize the full results of the data analyses performed during the UF program review by ward.

Ward 1	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	85%
Species Richness	154
Species Diversity Index (Simpson's)	0.97
Trees in Smallest Size Class	45%
Trees Managed by UF	94%
Tree Box Status	
Planted Tree Boxes	10,444
Open Tree Boxes	133
Stocking Rate	99%
Urban Tree Canopy	
UTC %	24%
UTC Deficit %	-16%
PPA %	18%
2011-2020 Tree Management Activities	
Service Requests	10,491
Work Orders	16,247
Trees Planted 2011-2020	3,870
2011-2020 Raw Change %	2.6%
2011-2020 Relative Change %	11.8%

Ward 2	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	84%
Species Richness	161
Species Diversity Index (Simpson's)	0.97
Trees in Smallest Size Class	46%
Trees Managed by UF	91%
Tree Box Status	
Planted Tree Boxes	16,076
Open Tree Boxes	131
Stocking Rate	99%
Urban Tree Canopy	
UTC %	27%
UTC Deficit %	-13%
PPA %	19%
2011-2020 Tree Management Activities	
Service Requests	15,485
Work Orders	22,180
Trees Planted 2011-2020	4,524
2011-2020 Raw Change %	-0.5%
2011-2020 Relative Change %	-1.8%

Ward 3	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	83%
Species Richness	175
Species Diversity Index (Simpson's)	0.97
Trees in Smallest Size Class	37%
Trees Managed by UF	92%
Tree Box Status	
Planted Tree Boxes	28,976
Open Tree Boxes	464
Stocking Rate	98%
Urban Tree Canopy	
UTC %	59%
UTC Deficit %	19%
PPA %	16%
2011-2020 Tree Management Activities	
Service Requests	18,347
Work Orders	52,016
Trees Planted 2011-2020	10,238
2011-2020 Raw Change %	5.9%
2011-2020 Relative Change %	11.0%

Ward 4	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	85%
Species Richness	191
Species Diversity Index (Simpson's)	0.97
Trees in Smallest Size Class	47%
Trees Managed by UF	95%
Tree Box Status	
Planted Tree Boxes	28,162
Open Tree Boxes	721
Stocking Rate	98%
Urban Tree Canopy	
UTC %	50%
UTC Deficit %	10%
PPA %	18%
2011-2020 Tree Management Activities	
Service Requests	25,461
Work Orders	45,577
Trees Planted 2011-2020	10,949
2011-2020 Raw Change %	-0.6%
2011-2020 Relative Change %	-1.2%

Ward 5	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	84%
Species Richness	175
Species Diversity Index (Simpson's)	0.98
Trees in Smallest Size Class	60%
Trees Managed by UF	96%
Tree Box Status	
Planted Tree Boxes	24,494
Open Tree Boxes	498
Stocking Rate	98%
Urban Tree Canopy	
UTC %	29%
UTC Deficit %	-11%
PPA %	31%
2011-2020 Tree Management Activities	
Service Requests	19,547
Work Orders	36,279
Trees Planted 2011-2020	11,488
2011-2020 Raw Change %	-1.2%
2011-2020 Relative Change %	-3.9%

Ward 6	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	77%
Species Richness	179
Species Diversity Index (Simpson's)	0.98
Trees in Smallest Size Class	48%
Trees Managed by UF	93%
Tree Box Status	
Planted Tree Boxes	23,992
Open Tree Boxes	238
Stocking Rate	99%
Urban Tree Canopy	
UTC %	19%
UTC Deficit %	-21%
PPA %	22%
2011-2020 Tree Management Activities	
Service Requests	16,134
Work Orders	36,733
Trees Planted 2011-2020	9,524
2011-2020 Raw Change %	-2.0%
2011-2020 Relative Change %	-9.7%

Ward 7	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	82%
Species Richness	179
Species Diversity Index (Simpson's)	0.97
Trees in Smallest Size Class	58%
Trees Managed by UF	89%
Tree Box Status	
Planted Tree Boxes	25,908
Open Tree Boxes	669
Stocking Rate	97%
Urban Tree Canopy	
UTC %	38%
UTC Deficit %	-2%
PPA %	28%
2011-2020 Tree Management Activities	
Service Requests	12,692
Work Orders	43,922
Trees Planted 2011-2020	13,520
2011-2020 Raw Change %	-1.1%
2011-2020 Relative Change %	-2.8%

Ward 8	
Urban Forest Characteristics	
Trees in "Good" or "Excellent" Condition	83%
Species Richness	172
Species Diversity Index (Simpson's)	0.97
Trees in Smallest Size Class	61%
Trees Managed by UF	91%
Tree Box Status	
Planted Tree Boxes	17,510
Open Tree Boxes	545
Stocking Rate	97%
Urban Tree Canopy	
UTC %	30%
UTC Deficit %	-10%
PPA %	34%
2011-2020 Tree Management Activities	
Service Requests	7,249
Work Orders	30,952
Trees Planted 2011-2020	9,716
2011-2020 Raw Change %	-1.7%
2011-2020 Relative Change %	-5.5%

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URBAN TREE CANOPY

ASSESSMENT

WASHINGTON, D.C.

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