

URBAN TREE CANOPY ASSESSMENT

KIRKLAND,
WASHINGTON
OCTOBER | 2018





AN ASSESSMENT OF
URBAN TREE CANOPY

KIRKLAND, WASHINGTON



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



-Warren Buffet

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4,361
ACRES OF TREE CANOPY

EXECUTIVE **SUMMARY**

PURPOSE OF THIS ANALYSIS

The City of Kirkland is located within King County, Washington, in the Seattle metropolitan area (Figure 1). It is approximately 18.2 square miles or 11,671 acres, of which 11,394 are land 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 is to provide an updated baseline and benchmark of the City's tree canopy and interpret the results across a range of geographic boundaries. Canopy change since 2010 is also assessed to determine the extent and location of growth or decline in Kirkland's urban forest to better inform future management actions.

URBAN TREE CANOPY IN KIRKLAND

Results of this study indicate that in 2017, the city of Kirkland contains 37 percent urban tree canopy (or 4,361 of the city's 11,671 total acres); 20 percent non-canopy vegetation (2,392 acres); 2 percent soil/dry vegetation (244 acres); 38 percent impervious surfaces (4,398 acres); and 2 percent water (277 acres). In further subdividing the impervious areas, 12 percent (1,421 acres) of Kirkland's total area are buildings, 8 percent (973 acres) are roads, 5 percent (585 acres) are parking lots, 3 percent (326 acres) are driveways, 1 percent (159 acres) are sidewalks, and 8

percent (933 acres) are "other impervious" areas such as trails, medians, etc.

Existing urban tree canopy covers 38 percent of Kirkland's land area (4,361 of the city's 11,394 land acres). Of the city's 62 percent of land area not presently occupied by tree canopy, 30 percent (3,421 acres) are suitable for future tree plantings, and 32 percent (3,612 acres) are unsuitable due to its current land use or other restraint. In further dividing the city's urban tree canopy, 12 percent are overhanging impervious surfaces. A change analysis shows that the city's canopy has decreased by approximately 2 percent, down from 41 percent when it was last assessed based on 2010 imagery.

ASSESSMENT BOUNDARIES

This study assesses urban tree canopy (UTC), possible planting areas (PPA), and change 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. Metrics are available at the following geographic boundaries: the citywide boundary; the citywide boundary prior to annexation of the Finn Hill, North Juanita, and Kingsgate neighborhoods; HUC-12 watersheds (2); King County comprehensive plan land



Figure 1. | Kirkland occupies approximately 18.2 square miles in King County, Washington.

use classes (10); neighborhoods (14); drainage basins (15); U.S. census block groups (80); the Holmes Point overlay (1); rights-of-way (1); a buffer around the City’s critical area buffers (1); park and open space classes (4); and shoreline jurisdiction areas (48). Canopy change since 2010 was also assessed for all geographic boundaries. Additionally, the city’s urban tree canopy is delineated as overhanging impervious surfaces or not.

RECOMMENDATIONS

The results of this analysis can be used to develop a

continued strategy to protect and expand Kirkland’s urban forest. The UTC, PPA, and change metrics should be used as a guide to determine where the city has succeeded in protecting and expanding its urban forest resource, while also targeting the best areas to concentrate future efforts based on needs, benefits, and available planting space. Existing tree canopy in single-family residential areas and rights-of-way have decreased in the last seven years. Increased tree planting activities are recommended in these areas to expand Kirkland’s urban forest.

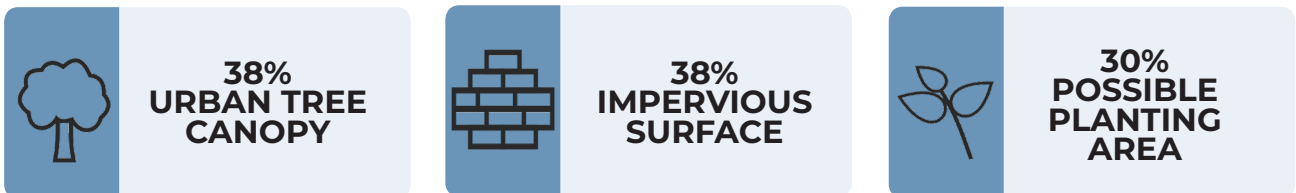


Figure 2. | Based on an analysis of 2017 high-resolution imagery, Kirkland contains 38% tree canopy, 30% areas that could support canopy in the future, and 38% total impervious areas.

PROJECT METHODOLOGY

This section describes the methods through which land cover, urban tree canopy, and possible planting areas were mapped. These datasets provide the foundation for the metrics reported at the selected target geographies, as well as the change in canopy over time.

DATA SOURCES

This assessment utilized 2017 high-resolution (1-meter) multispectral imagery from the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP) and 2016 LiDAR data from King County, Washington to derive the land cover data set. The NAIP imagery is used to classify all types of land cover, whereas the LiDAR is most useful for distinguishing tree canopy from other types of vegetation. Additional GIS layers provided by the City of Kirkland were also incorporated into the analysis, such as the impervious surfaces layers (buildings, roads, parking lots, etc.) and the 2010 urban tree canopy data which provided the basis of the change analysis.

MAPPING LAND COVER

An initial land cover dataset was to be created prior to mapping tree canopy and assessing change. 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 NAIP imagery and LiDAR to derive five initial land cover classes. These classes are shown in Figure 3. 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. Using those impervious surface data provided by the city (buildings, roads, parking lots, etc.), the amount of urban tree canopy overhanging impervious surfaces was also quantified to assist with hydrologic modeling.



Figure 3. | Five (5) distinct land cover classes were identified in the 2017 tree canopy assessment: urban tree canopy, 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 Kirkland'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 Kirkland 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 and impervious classes that could be modified or have trees planted adjacent to them (e.g. parking lots, driveways, and sidewalks) to provide aesthetic value as well as localized shading and cooling. Unsuitable areas, or areas where it was not feasible to plant trees due to biophysical or land use restraints (e.g. airport runways, 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 (vegetation and impervious), Unsuitable Vegetation, Unsuitable Impervious, Unsuitable Soil, and Total Unsuitable.

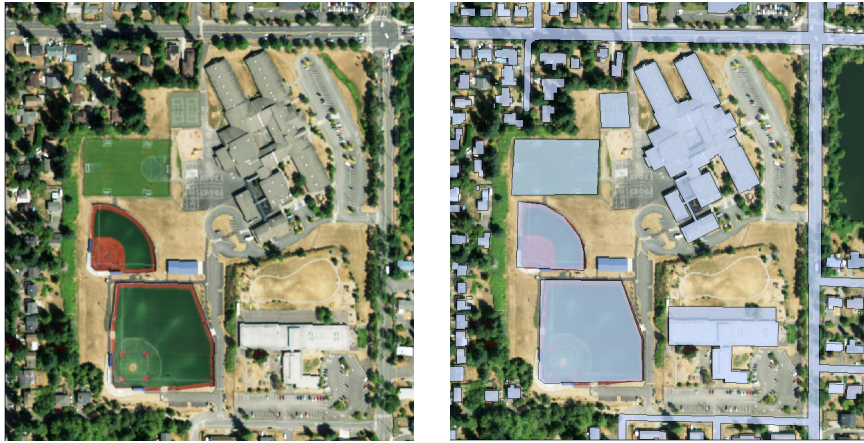


Figure 4. | Vegetated areas where it would be biophysically feasible for tree plantings but undesirable based on their current usage (left) were delineated in the data as “Unsuitable” (right). These areas included recreational sports fields and other open space.

DEFINING ASSESSMENT LEVELS

In order to best inform the City Council and all of Kirkland’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; the pre-annexation city boundary; HUC-12 watersheds; King County comprehensive plan land use classes; neighborhoods; drainage basins; U.S. census block groups; the Holmes Point overlay; rights-of-way; critical area buffers; parks and open spaces; and shoreline jurisdiction areas.

- The City of Kirkland’s citywide boundary is the one (1) main area of interest over which all metrics are summarized.
- Metrics were also calculated for the City of Kirkland’s area prior to its annexation of the Finn Hill, North Juanita, and Kingsgate neighborhoods (approximately 4,601 acres), which became effective in 2011.
- Two (2) HUC-12 watersheds were assessed to interpret differences in urban tree canopy across a naturally occurring geographic boundary.
- Ten (10) King County comprehensive plan land use classes were analyzed to assess differences in tree canopy across different human uses of land.
- Fourteen (14) neighborhoods were assessed to quantify tree canopy at an easily-conceptualized scale for local residents.
- Fifteen (15) drainage basins make up the city of Kirkland. Since trees play an important role in regulating stormwater runoff and preventing flooding, the basins were analyzed to explore differences in tree canopy across the City’s drainage areas.
- Eighty (80) census block groups were assessed. Census block groups (CBGs) 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.
- Metrics were assessed for Kirkland’s heavily-wooded, coastal region of Holmes Point.
- Right-of-way (ROW) was also assessed. ROW refers to the areas that are publicly maintained, such as streets, sidewalks, and medians, and is helpful for quantifying the city’s street trees.
- Trees also provide many environmental benefits such as preventing erosion, offering a habitat for wildlife species, and improving air and water quality. For this reason, a 100’ buffer was applied to all of the City’s critical areas and urban tree canopy was assessed within this area.
- Four (4) different classes of parks and open spaces were assessed to determine how tree canopy is distributed in the city’s green spaces.
- Forty-eight (48) shoreline jurisdiction areas were assessed to determine how tree canopy is distributed in the City’s coastal regions.

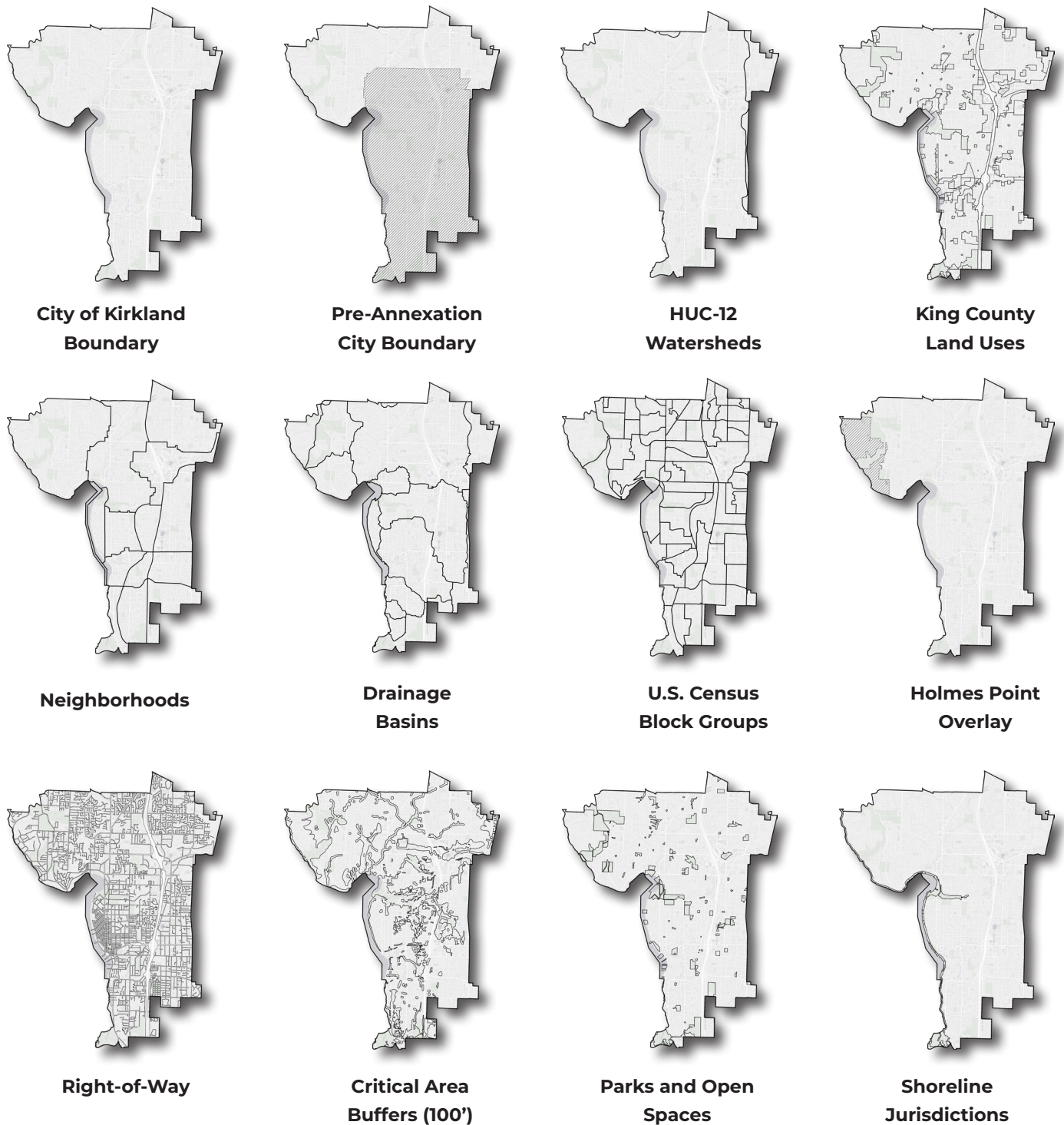


Figure 5. | Twelve (12) distinct geographic boundaries were explored in this analysis: the full city boundary, the pre-annexation city boundary, watersheds, land use classes, neighborhoods, drainage basins, U.S. Census block groups, the Holmes Point overlay, right-of-way, critical area buffers, parks and open spaces, and shoreline jurisdictions.

STATE OF THE CANOPY AND KEY FINDINGS



This section presents the key findings of this study including the land cover base map, canopy analysis, and change analysis results which were analyzed across various geographic assessment boundaries. These results, or metrics, help inform a strategic approach to identifying existing canopy to preserve 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 2017, tree canopy constituted 37 percent of Kirkland’s land cover; non-canopy vegetation was 20 percent; soil/dry vegetation was 2 percent; impervious was 38 percent; and water was 2 percent. These generalized land cover results are presented below in Table 1.

The impervious land cover class was then subdivided into more specific classifications. Approximately 12 percent was buildings, 8 percent was roads, 5 percent was parking lots, 1 percent was sidewalks, 3 percent was driveways, and 8 percent was “other impervious” (all other paved surfaces not included in the previous classes). Parking lots and sidewalks may offer opportunities for new tree plantings and additional canopy cover, but the data for these opportunistic impervious land classifications would require further analyses to determine their planting suitability. The detailed land cover results, including impervious classifications, are presented in Figure 6.

Table 1. | Generalized land cover classification results.

City Boundary	Total Area	Tree Canopy	Non-Canopy Vegetation	Impervious Surfaces	Soil & Dry Vegetation	Water
Acres	11,671	4,361	2,392	4,398	244	277
% of Total	100%	37%	20%	38%	2%	2%

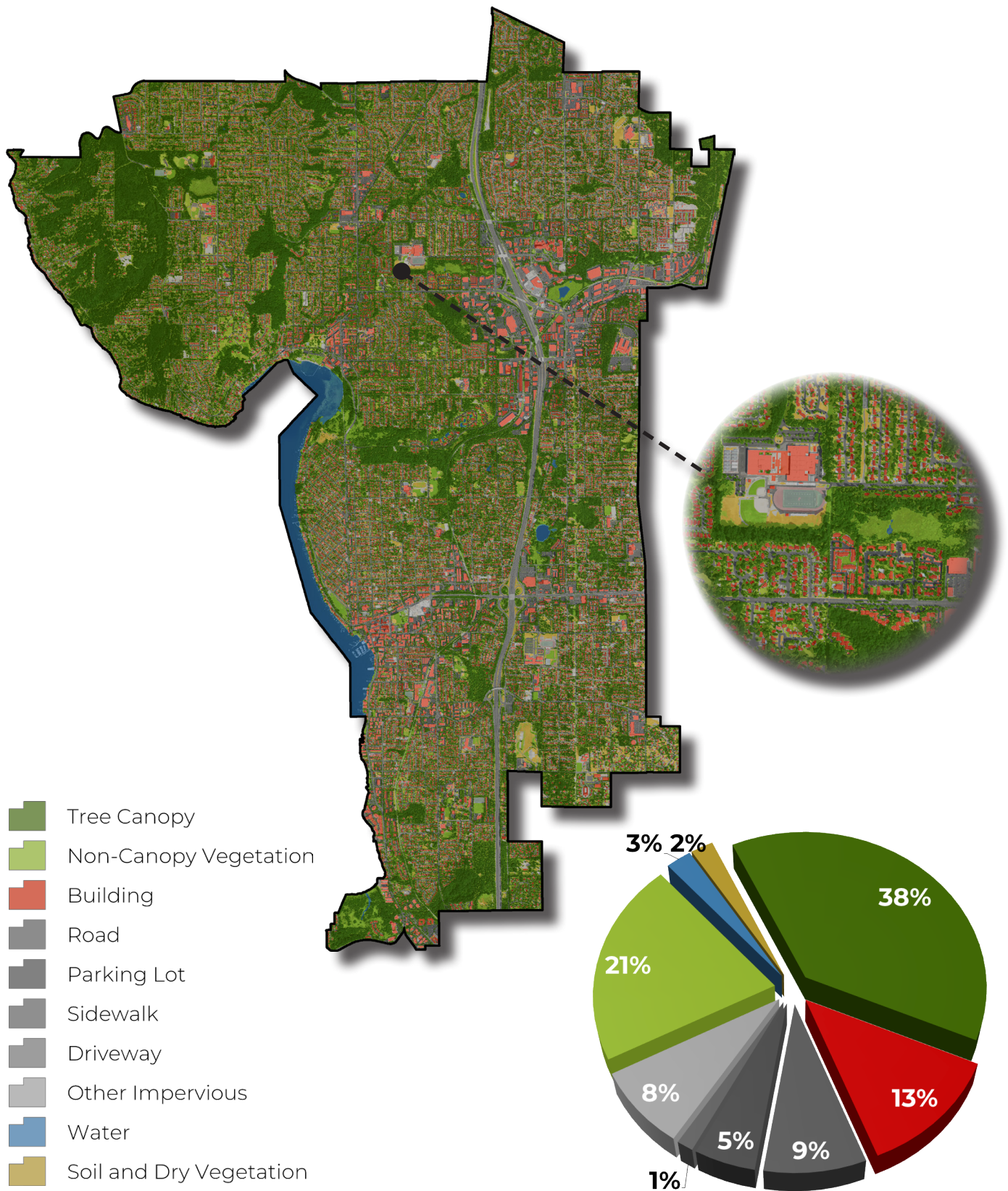


Figure 6. | Detailed land cover classes for Kirkland, Washington based on 2017 NAIP imagery and 2016 PSLC LiDAR data. (Percentages based on land acres.)

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 are based on land area as opposed to total area (note the difference between Total Acres and Land Acres in Table 2).

Results of this study indicate that within the City of Kirkland, 4,631 acres are covered with urban tree canopy, making up 38 percent of the city's 11,394 land acres; 3,421 acres are covered with other vegetation or impervious surfaces (parking lots, driveways, and sidewalks) where it would be possible to plant trees (PPA), making up 30 percent of the city; and the other 3,612 acres were considered unsuitable for tree planting, making up 32 percent of the city. The unsuitable areas include recreational sports fields, buildings, roads, other impervious surfaces, and areas of bare soil and dry vegetation. Bare soil and dry vegetation are considered unsuitable as these areas would require modification through irrigation or other methods to support healthy trees.

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

City of Kirkland	Acres	%
Total Area	11,671	100%
Land Area	11,394	98%
Urban Tree Canopy	4,361	38%
Possible Planting Area - Vegetation	2,351	21%
Possible Planting Area - Impervious	1,070	9%
Total Possible Planting Area	3,421	30%
Unsuitable Vegetation	40	<1%
Unsuitable Impervious	3,330	29%
Unsuitable Soil	242	2%
Total Unsuitable Areas	3,612	32%

Urban Tree Canopy and Possible Planting Area in the City of Kirkland

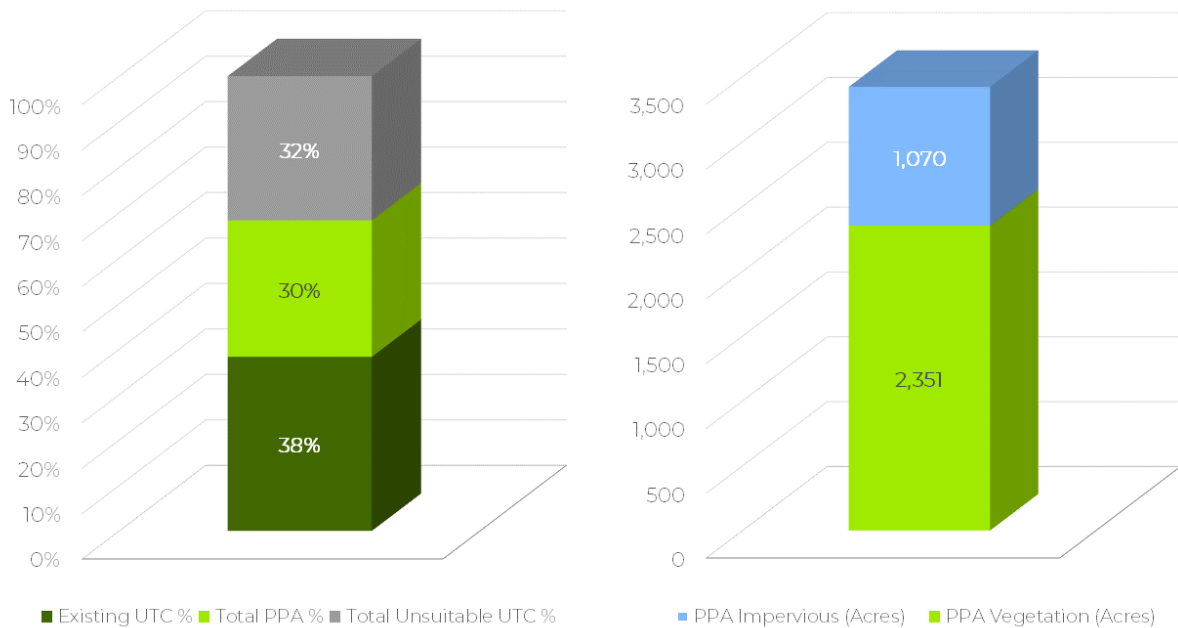


Figure 7. | Urban tree canopy, potential planting area, and area unsuitable for UTC by percentage (left) and types of possible planting area by acreage (right) in the City of Kirkland.

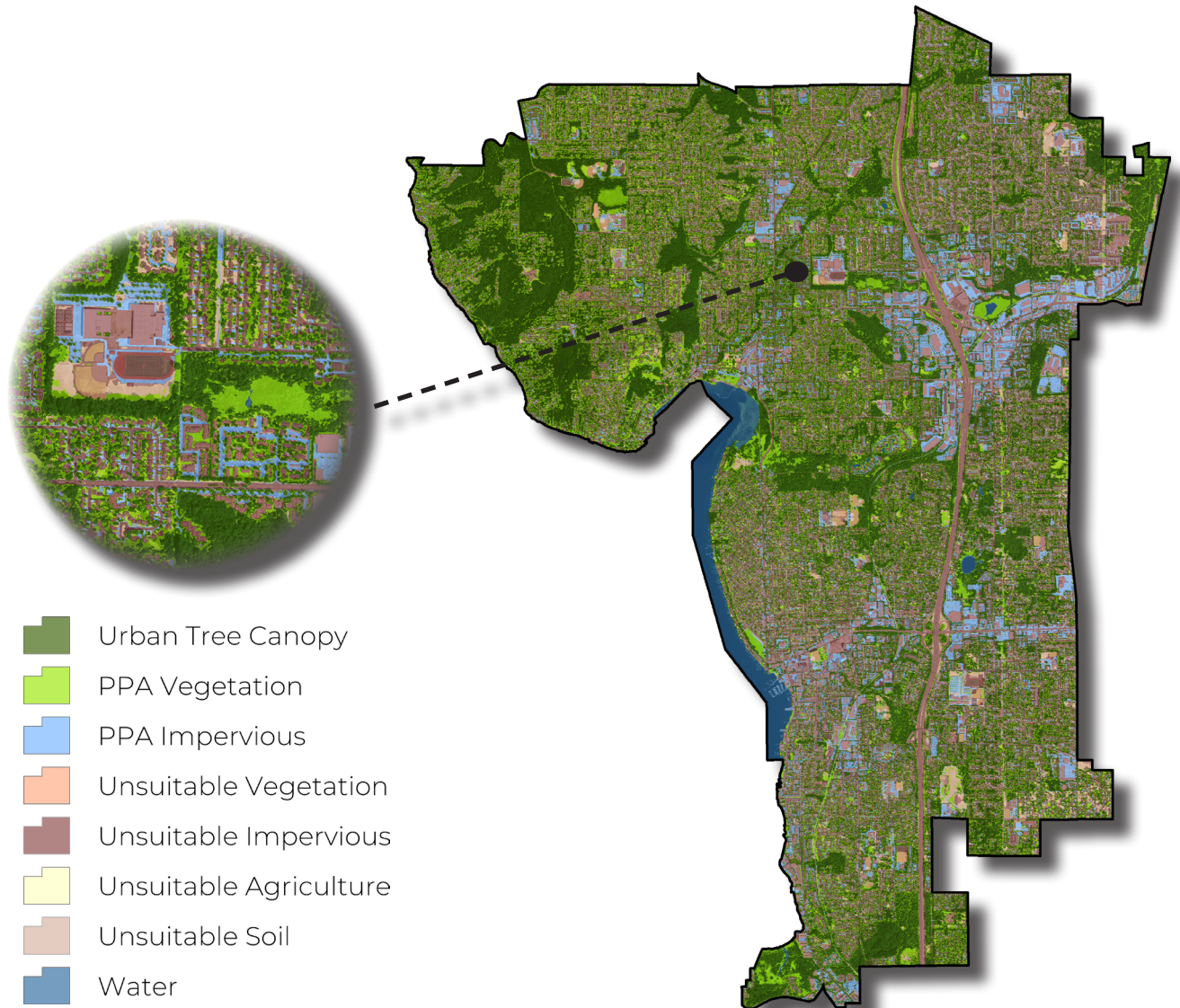


Figure 8. | Urban tree canopy, possible planting area, and area unsuitable for UTC in the city of Kirkland.

The city’s 4,631 acres of urban tree canopy were further divided into subcategories based on whether the trees’ canopy had an impervious understory 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 in Kirkland, 540 acres or 12 percent of urban tree canopy had an impervious understory.

Table 3. | Urban tree canopy classification for the City of Kirkland by acres and percent.

City of Kirkland	Acres	%
Tree Canopy with Pervious Understory	3,821	88%
Tree Canopy with Impervious Understory	540	12%

URBAN TREE CANOPY BY PRE-ANNEXATION CITY BOUNDARY

Prior to its annexation of three additional neighborhoods in 2011 (Finn Hill, North Juanita, and Kingsgate), the City of Kirkland was composed of approximately 11 square miles or 7,071 acres, of which 6,802 (96 percent) were land acres. In 2017, this pre-annexation boundary contained 35 percent UTC (2,371 acres), 30 percent total PPA (2,040 acres), and 35 percent total unsuitable acres (2,391 acres). The annexation of these three neighborhoods had a large impact on the total amount of tree canopy within the current city boundary: over 50% of all canopy is found in these neighborhoods.

Table 4. | Urban tree canopy assessment results by pre-annexation boundary. 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 the boundary (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Pre-Annexation Boundary	6,802	60%	2,371	35%	54%	2,040	30%	60%

Urban Tree Canopy Compared to Total Area and Land Area, Post- and Pre-Annexation

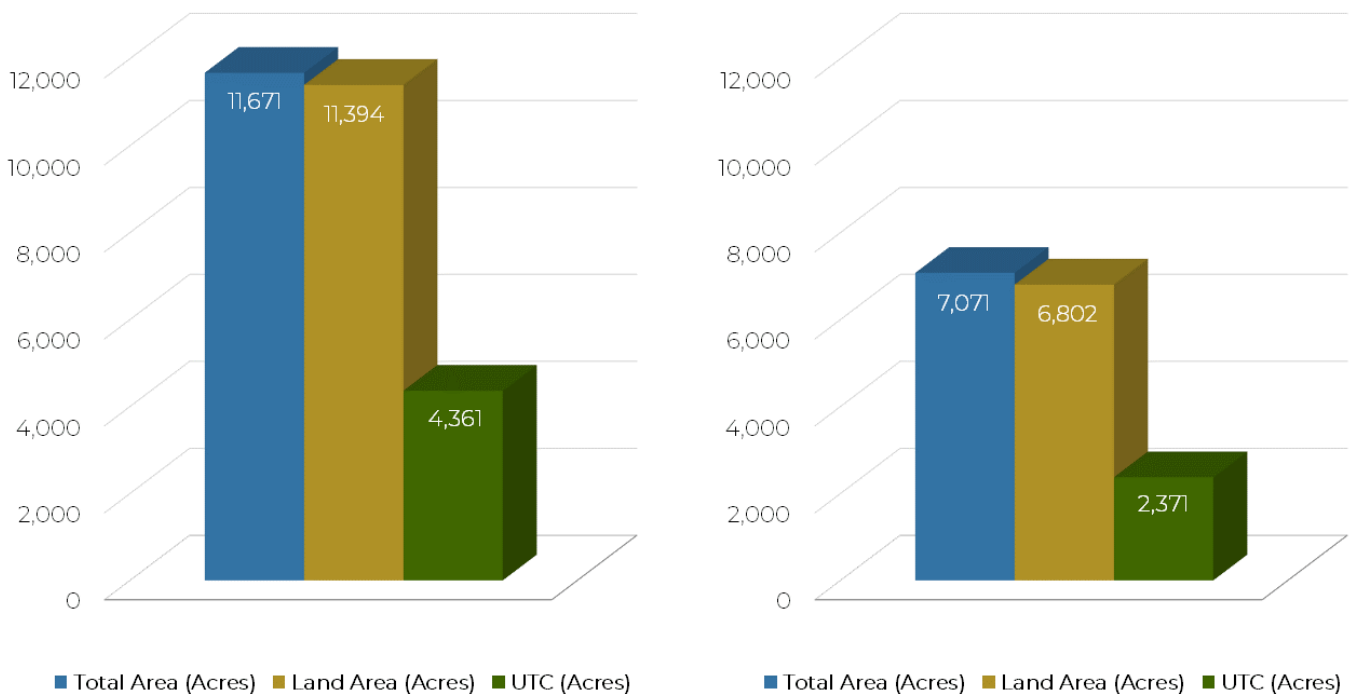


Figure 9. | Urban tree canopy, land acres, and total acres in the City of Kirkland's current boundary (left) and pre-annexation boundary (right).

URBAN TREE CANOPY BY WATERSHEDS

UTC and PPA were assessed for the two HUC-12 watersheds that intersect the City of Kirkland. The Lake Washington-Sammamish River watershed occupies the vast majority of the City’s area (94 percent), while the Bear Creek-Sammamish River watershed intersects a small portion of its northern and eastern edges. The larger of the two watersheds closely reflected the citywide metrics with 38 percent UTC and 30 percent total PPA, while the smaller watershed had slightly less of each with 36 percent UTC and 27 percent total PPA. However, the smaller watershed contained a higher percentage of PPA-Impervious than its counterpart with 12 percent compared to 9 percent.

Table 5. | Urban tree canopy assessment results by HUC-12 watershed. 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 watershed (dist.).

Watersheds	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Bear Creek-Sammamish River	699	6%	252	36%	6%	189	27%	6%
Lake Washington-Sammamish River	10,695	94%	4,108	38%	94%	3,232	30%	94%
Totals	11,394	100%	4,361	38%	100%	3,421	30%	100%

URBAN TREE CANOPY BY LAND USES

UTC and PPA were assessed for the ten different land uses found within the King County comprehensive plan land use data layer. UTC ranged from 17 percent in General Commercial areas to 70 percent in Park/Golf Course/Trail/Open Space areas, with the majority of other land uses having between 25-35 percent UTC. Although General Commercial areas had the lowest existing UTC, they contained the greatest percentages of all types of plantable space with 41 percent total PPA, 41 percent PPA-Vegetation, and 35 percent PPA-Impervious. Single-family residential areas contributed the most to the City’s total UTC and PPA, with 37 percent UTC making up 69 percent of the City’s total canopy and 30 percent total PPA making up 72 percent of the City’s total plantable space.

Urban Tree Canopy and Possible Planting Area by Land Use

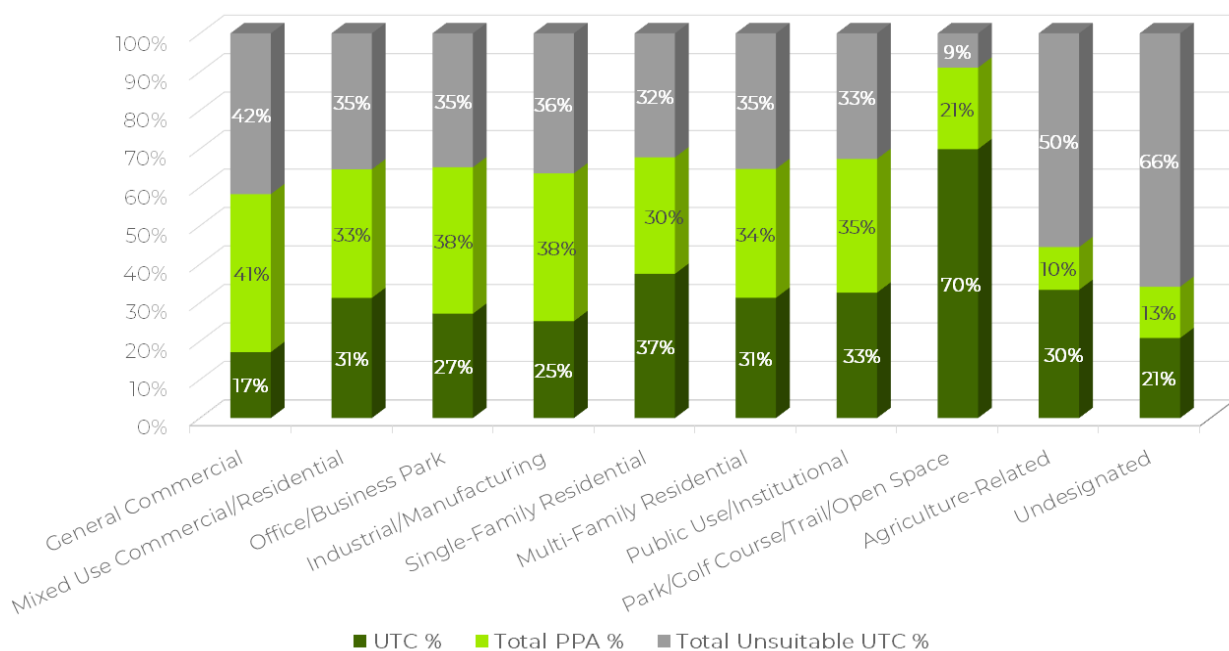


Figure 10. | Urban tree canopy, potential planting area, and area unsuitable for UTC by county land uses.

Table 6. | Urban tree canopy assessment results by King County 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 (dist.).

Land Use	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
General Commercial	602	5%	103	17%	2%	247	41%	7%
Industrial/Manufacturing	285	2%	72	25%	2%	109	38%	3%
Mixed Use Commercial/Residential	226	2%	71	31%	2%	76	33%	2%
Multi-Family Residential	414	4%	129	31%	3%	139	34%	4%
Office/Business Park	178	2%	48	27%	1%	68	38%	2%
Park/Golf Course/Trail/Open Space	1,132	10%	791	70%	18%	240	21%	7%
Public Use/Institutional	154	1%	50	33%	1%	53	35%	2%
Single-Family Residential	8,081	71%	3,029	37%	69%	2,446	30%	72%
Undesignated	323	3%	67	21%	2%	43	13%	1%
Totals	11,394	100%	4,360	38%	100%	3,421	30%	100%

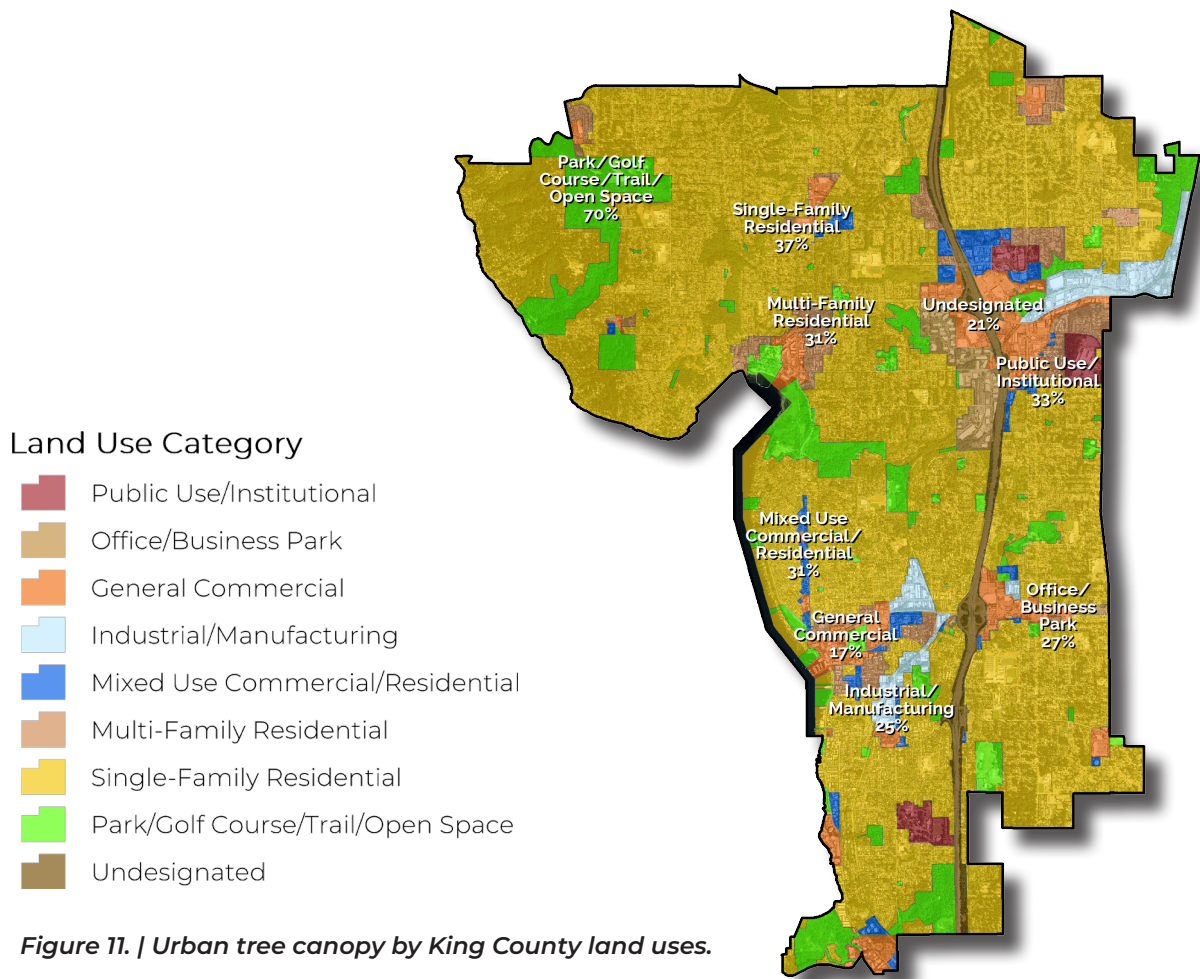


Figure 11. | Urban tree canopy by King County land uses.

URBAN TREE CANOPY BY NEIGHBORHOODS

UTC and PPA were assessed for Kirkland's 14 neighborhoods. The neighborhoods with the least existing UTC included Moss Bay with 22 percent, South Rose Hill with 27 percent, and Totem Lake with 29 percent. All other neighborhoods had a canopy cover of 30 percent or greater, and Highlands and Finn Hill contained the greatest percentage of UTC with 40 and 50 percent, respectively. Finn Hill, which was one of the three neighborhoods annexed by the City in 2011, also contained the greatest proportion of the City's total UTC, comprising 30 percent of all canopy in Kirkland. In terms of plantable space, the Highlands neighborhood offered the least PPA (25 percent) while Totem Lake offered the greatest (36 percent), indicating that PPA within Kirkland's neighborhoods tends to be inversely related to their existing UTC.

Table 7. | Urban tree canopy assessment results by neighborhood. 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 neighborhood (dist.).

Neighborhood	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Bridle Trails	610	5%	213	35%	5%	182	30%	5%
Central Houghton	610	5%	233	38%	5%	172	28%	5%
Everest	220	2%	81	37%	2%	60	27%	2%
Finn Hill	2,609	23%	1,313	50%	30%	802	31%	23%
Highlands	363	3%	147	40%	3%	92	25%	3%
Juanita	1,865	16%	712	38%	16%	609	33%	18%
Kingsgate	1,279	11%	438	34%	10%	340	27%	10%
Lakeview	363	3%	142	39%	3%	115	32%	3%
Market	291	3%	96	33%	2%	89	31%	3%
Moss Bay	314	3%	70	22%	2%	89	28%	3%
Norkirk	511	4%	162	32%	4%	139	27%	4%
North Rose Hill	978	9%	361	37%	8%	276	28%	8%
South Rose Hill	508	4%	139	27%	3%	144	28%	4%
Totem Lake	874	8%	254	29%	6%	310	36%	9%
Totals	11,394	100%	4,360	38%	100%	3,421	30%	100%

Urban Tree Canopy and Possible Planting Area by Neighborhoods

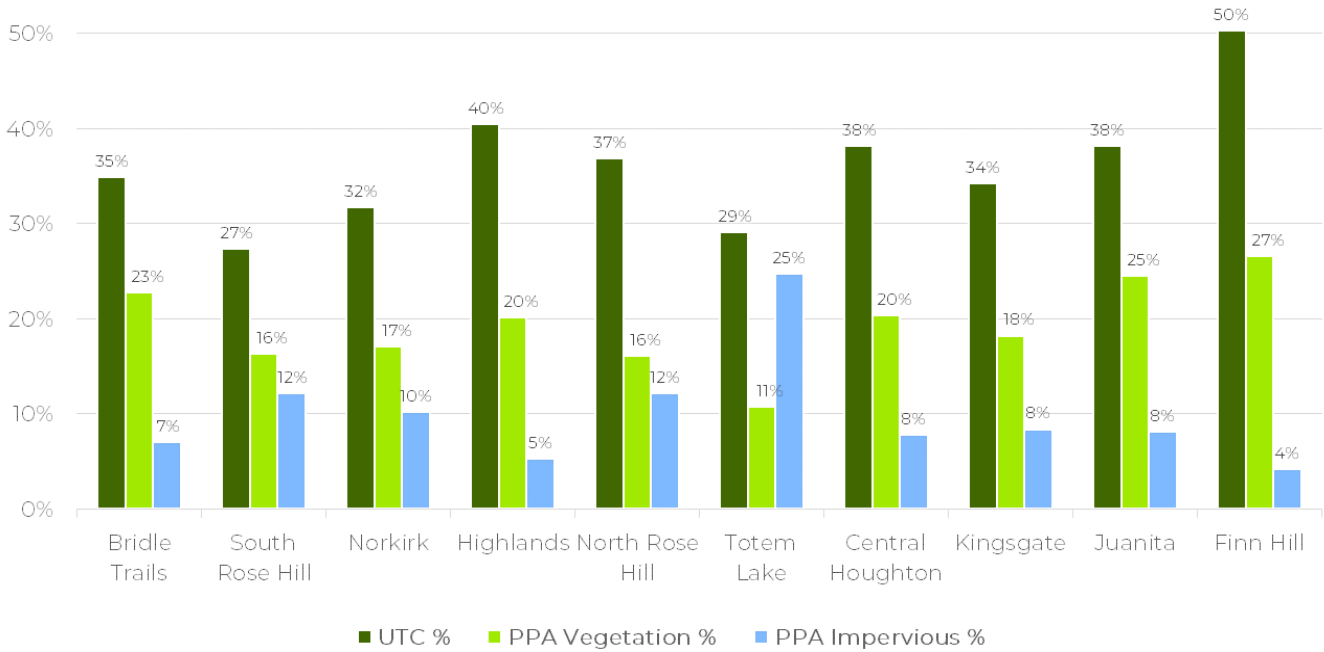


Figure 12. | Urban tree canopy and potential planting area in Kirkland neighborhoods.

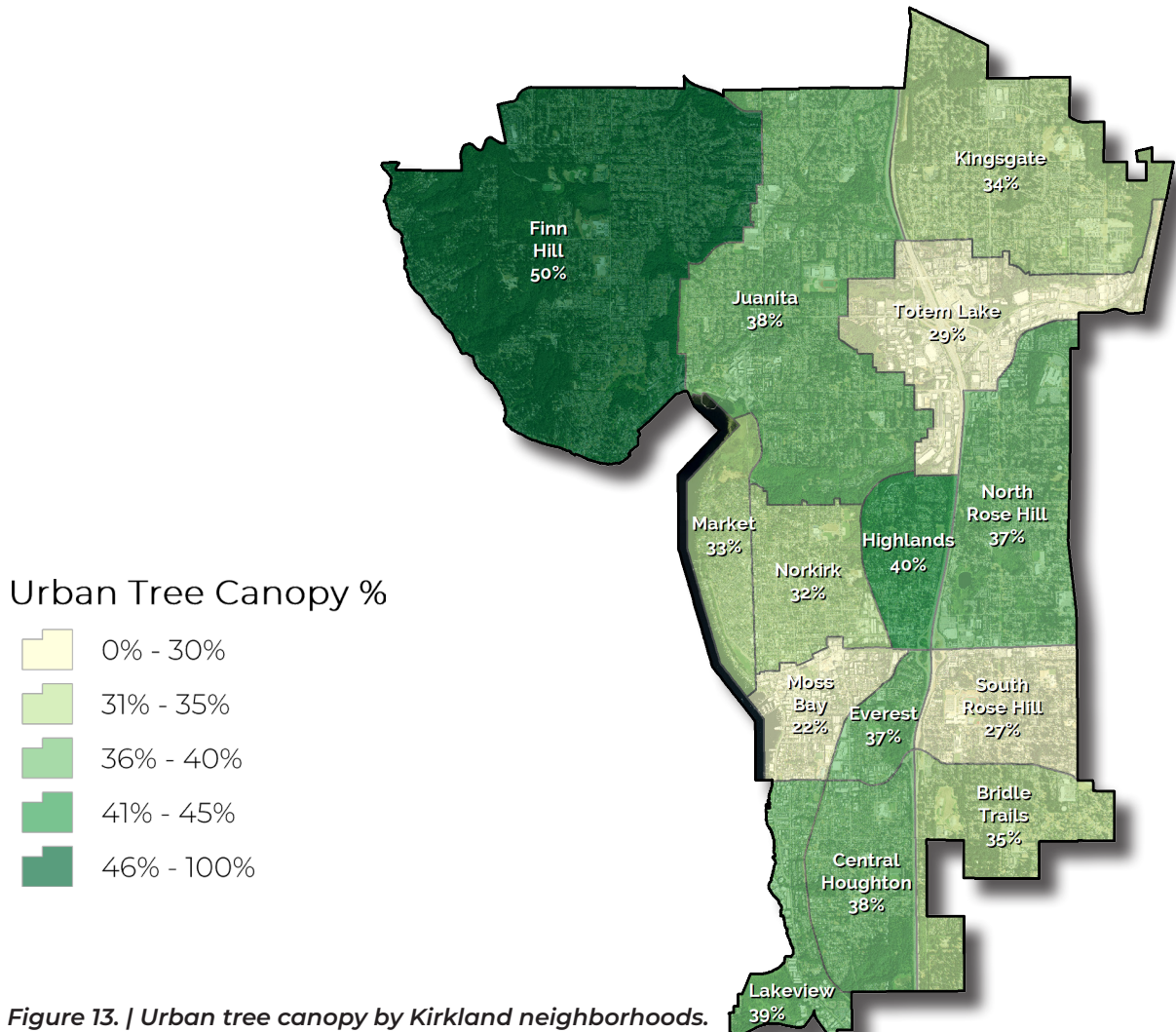


Figure 13. | Urban tree canopy by Kirkland neighborhoods.

URBAN TREE CANOPY BY DRAINAGE BASINS

Because trees play an important role in stormwater management, UTC and PPA were assessed for the 15 local drainage basins found within Kirkland. Houghton Slope A and To Redmond had the lowest percentages of existing UTC with 26 and 28 percent, while Yarrow Creek, Denny Creek, and Holmes Point had the greatest with 50, 53, and 60 percent respectively. PPA was varied less and ranged from 26 percent in Kingsgate Slope to 36 percent in South Juanita Slope. The largest drainage basin, Juanita Creek, contributed the most to the City's totals with 32 percent UTC contributing 29 percent of the City's total canopy and 32 percent total PPA contributing 35 percent of the City's total PPA.

Table 8. | Urban tree canopy assessment results by drainage basins. 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 basin (dist.).

Drainage Basin	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Carillon Creek	106	1%	36	34%	1%	35	33%	1%
Champagne Creek	621	5%	281	45%	6%	218	35%	6%
Denny Creek	803	7%	429	53%	10%	231	29%	7%
Forbes Creek	1,824	16%	715	39%	16%	515	28%	15%
Holmes Point	457	4%	276	60%	6%	130	28%	4%
Houghton Slope A	376	3%	99	26%	2%	117	31%	3%
Houghton Slope B	134	1%	44	33%	1%	45	33%	1%
Juanita Creek	3,615	32%	1,279	35%	29%	1,153	32%	34%
Kingsgate Slope	562	5%	212	38%	5%	145	26%	4%
Kirkland Slope	210	2%	66	31%	2%	62	30%	2%
Lower Sammamish River Valley	24	0%	10	43%	0%	8	33%	0%
Moss Bay	1,486	13%	444	30%	10%	405	27%	12%
South Juanita Slope	287	3%	94	33%	2%	105	36%	3%
To Redmond	303	3%	84	28%	2%	92	31%	3%
Yarrow Creek	577	5%	287	50%	7%	158	27%	5%
Totals	11,385	100%	4,356	38%	100%	3,419	30%	100%

URBAN TREE CANOPY BY CENSUS BLOCK GROUPS

UTC and PPA were assessed for the 80 U.S. census block groups (CBG) found within Kirkland. CBGs are delineated by the U.S. Census Bureau and tied to all population and demographic census data. This makes them helpful for assessing environmental equity. 6 percent of CBGs had less than 20 percent UTC; 28 percent had 20-30 percent UTC; 40 percent had 30-40 percent UTC; and the other 26 percent had 40 percent of greater. For the complete results by CBG, refer to the UTC Results spreadsheet.

Urban Tree Canopy and Possible Planting Area by Census Block Groups

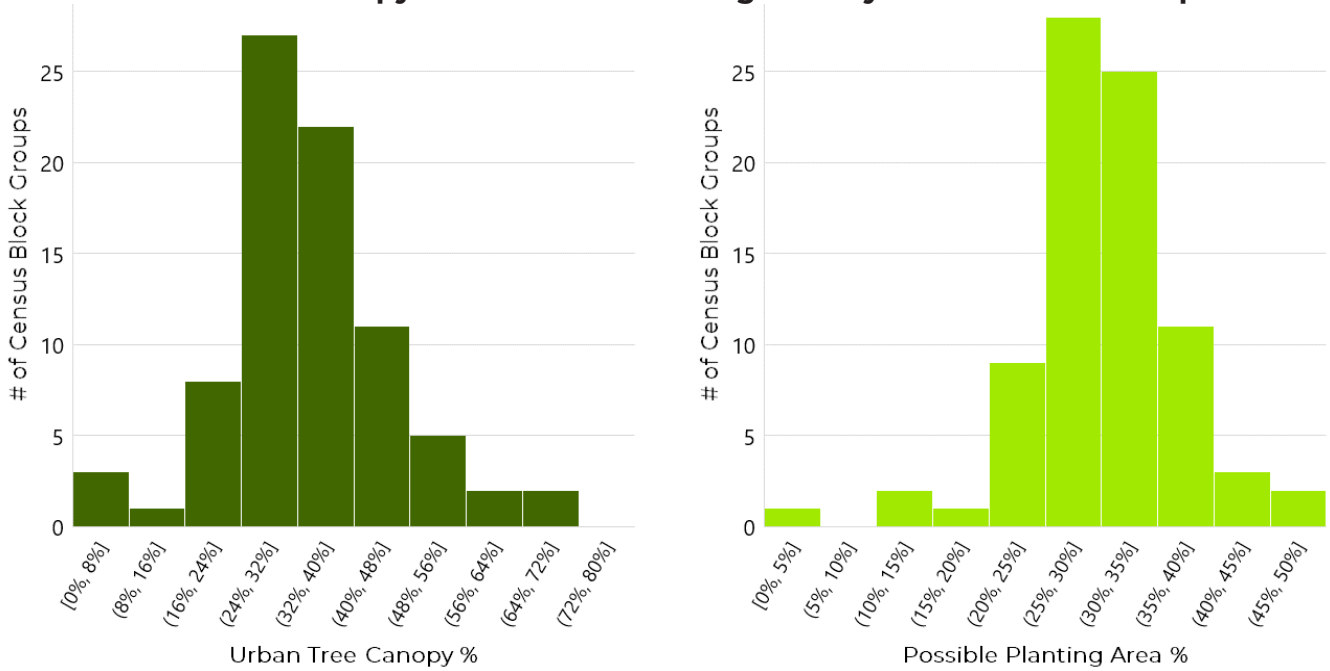


Figure 14. | Number of census block groups within urban tree canopy (left) and possible planting area (right) ranges.

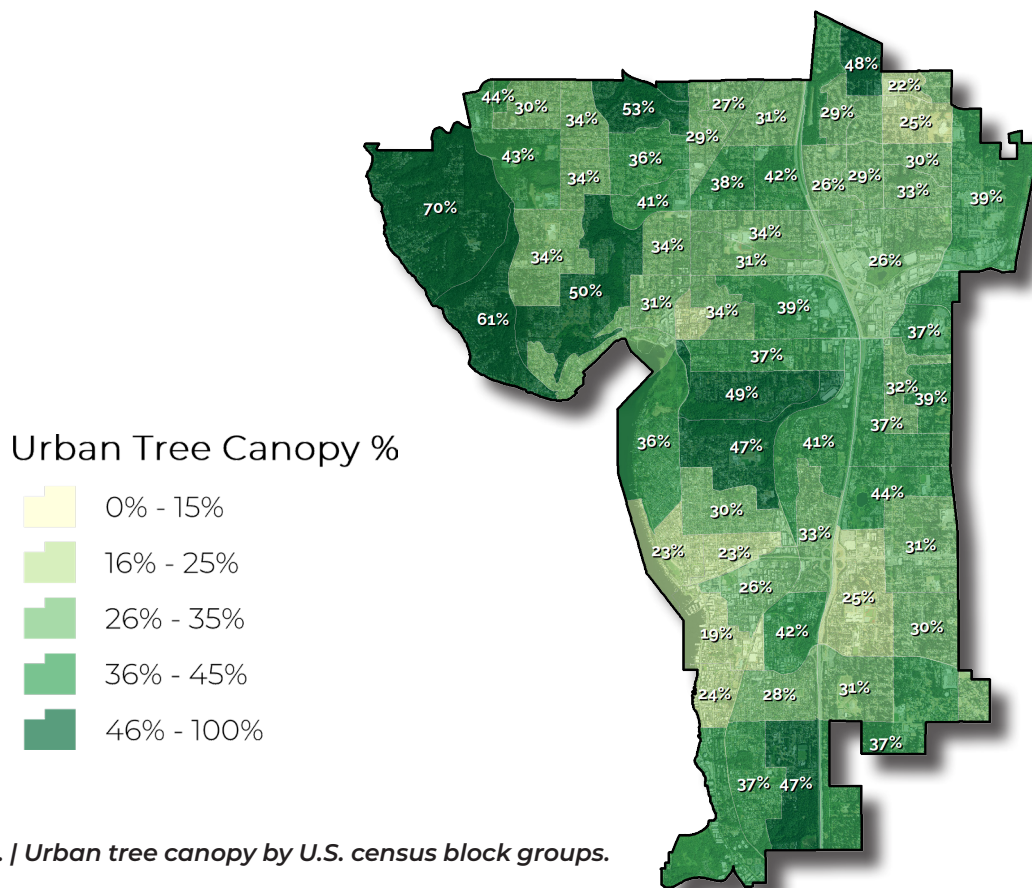


Figure 15. | Urban tree canopy by U.S. census block groups.

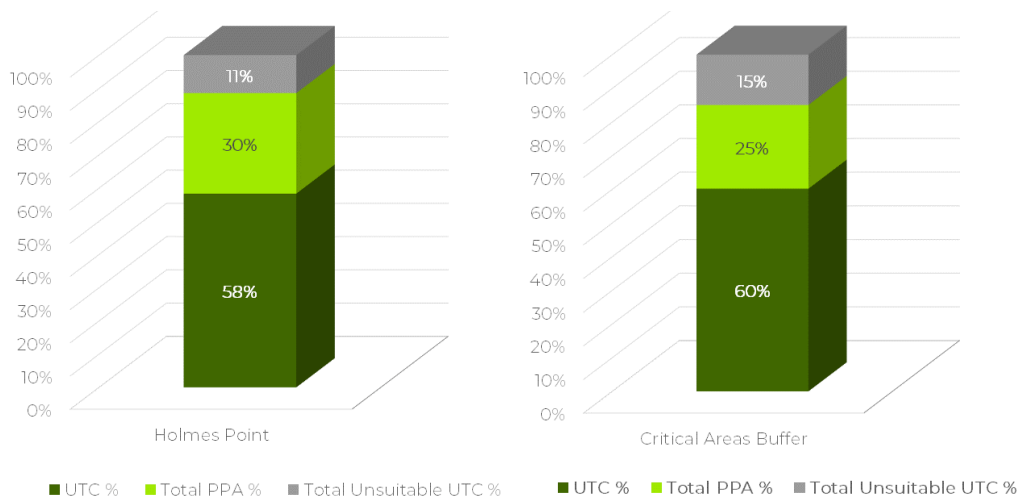
URBAN TREE CANOPY BY HOLMES POINT OVERLAY

UTC and PPA were assessed within the Holmes Point Overlay boundary. Historically, this area is one of the City’s most densely forested areas. In 2017, this region contained over 58 percent UTC, 30 percent total PPA (of which 28 percent was PPA-Vegetation and only 2 percent was PPA-Impervious), and 11 percent total unsuitable areas. With 380 acres of canopy, the Holmes Point Overlay contains 9 percent of Kirkland’s tree canopy, despite comprising only 6 percent of its land area.

Table 9. | Urban tree canopy in Kirkland’s Holmes Point region. 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 the overlay (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Holmes Point Overlay	651	6%	380	58%	9%	197	30%	6%

Urban Tree Canopy Potential by Holmes Point Overlay and Citywide Critical Area Buffers



Figures 16 and 17. | Urban tree canopy, possible planting area, and unsuitable areas for UTC in Kirkland’s Holmes Point Overlay (left) and citywide 100’ critical area buffers (right).

URBAN TREE CANOPY BY CRITICAL AREA BUFFERS

Trees in critical and sensitive environmental areas are also a valuable part of Kirkland’s urban forest resource. A buffer of 100 feet was applied to Kirkland’s streams, lakes, wetlands, and landslide areas and UTC and PPA metrics were assessed within this area. Results indicated that Kirkland’s critical area buffers contained 60 percent existing UTC, 25 percent total PPA (predominantly vegetation), and 15 percent total unsuitable areas. With 2,872 land acres and 1,729 acres of canopy, this region contains 40 percent of Kirkland’s citywide canopy while occupying just 25 percent of its land area.

Table 10. | Urban tree canopy in Kirkland’s critical area buffers. 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 the buffer (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Critical Area Buffers (100')	2,873	25%	1,729	60%	40%	715	25%	21%

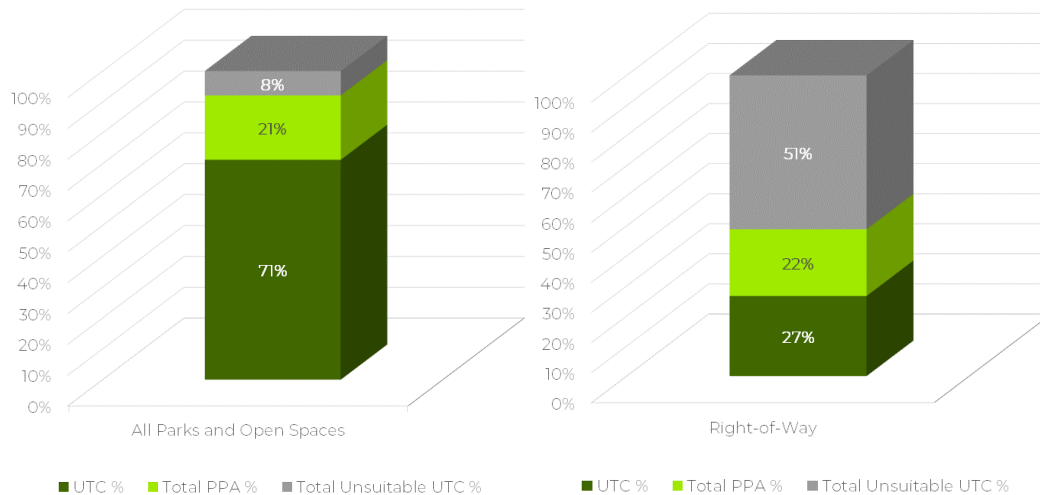
URBAN TREE CANOPY BY PARKS AND OPEN SPACES

UTC and PPA were assessed within Kirkland’s various classes of parks and open spaces: general parks (consisting of parks, swimming pool facilities, and cemeteries), open spaces, and all parks. UTC was 85 percent in open spaces, 70 percent in general parks, and 71 percent overall. General parks contained the majority of total UTC within this assessment scale with 70 percent canopy cover contributing 91 percent of the total canopy. PPA ranged from 13 percent in open spaces to 22 percent in general parks, which also contributed the most to the citywide total with 21 contributing 95 percent of all plantable space in these areas.

Table 11. | Urban tree canopy in Kirkland’s parks and open spaces. 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 the area (dist.).

Parks and Open Spaces	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
General Parks	943	93%	661	70%	91%	203	22%	95%
Open Spaces	75	7%	63	85%	9%	10	13%	5%
Totals	1,017	100%	725	71%	100%	213	21%	100%

UTC, PPA, and Impervious Areas in Kirkland’s Parks/Open Spaces and Right-of-Way



Figures 18 and 19. | Urban tree canopy, possible planting area, and impervious areas in Kirkland’s Parks and Open Spaces (left) and right-of-way (right).

URBAN TREE CANOPY BY RIGHT-OF-WAY

UTC and PPA were assessed for Kirkland’s right-of-way or publicly-maintained sidewalk and street areas. Trees in the ROW are especially valuable components of a city’s urban forest in terms of air pollution control, shading, and even social benefits. Within these areas, UTC was 27 percent, PPA-Vegetation was 14 percent, PPA-Impervious was 8 percent, and unsuitable areas were 50 percent. UTC and total PPA (22 percent) were lower in the ROW than the citywide average, but much of this area consists of sidewalks or roads where it would be impossible to plant trees.

Table 12. | Urban tree canopy in Kirkland’s right-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 the ROW (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Right-of-Way	2,166	19%	576	27%	13%	481	22%	14%

URBAN TREE CANOPY BY SHORELINE JURISDICTIONS

UTC and PPA were assessed within Kirkland's shoreline jurisdictions. The results were aggregated for reporting. Shoreline jurisdictions in Kirkland had 46% canopy cover or 4% of all canopy citywide. These areas also contained 116 acres of possible planting area (35%) with a majority of that on vegetated surfaces.

Table 13. | Shoreline jurisdiction urban tree canopy assessment results by acres and percent. 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 Kirkland's shoreline jurisdictions (dist.).

City of Kirkland	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
Shoreline Jurisdictions	332	3%	153	46%	4%	116	35%	3%

UTC, PPA, and Impervious Areas by Shoreline Jurisdictions

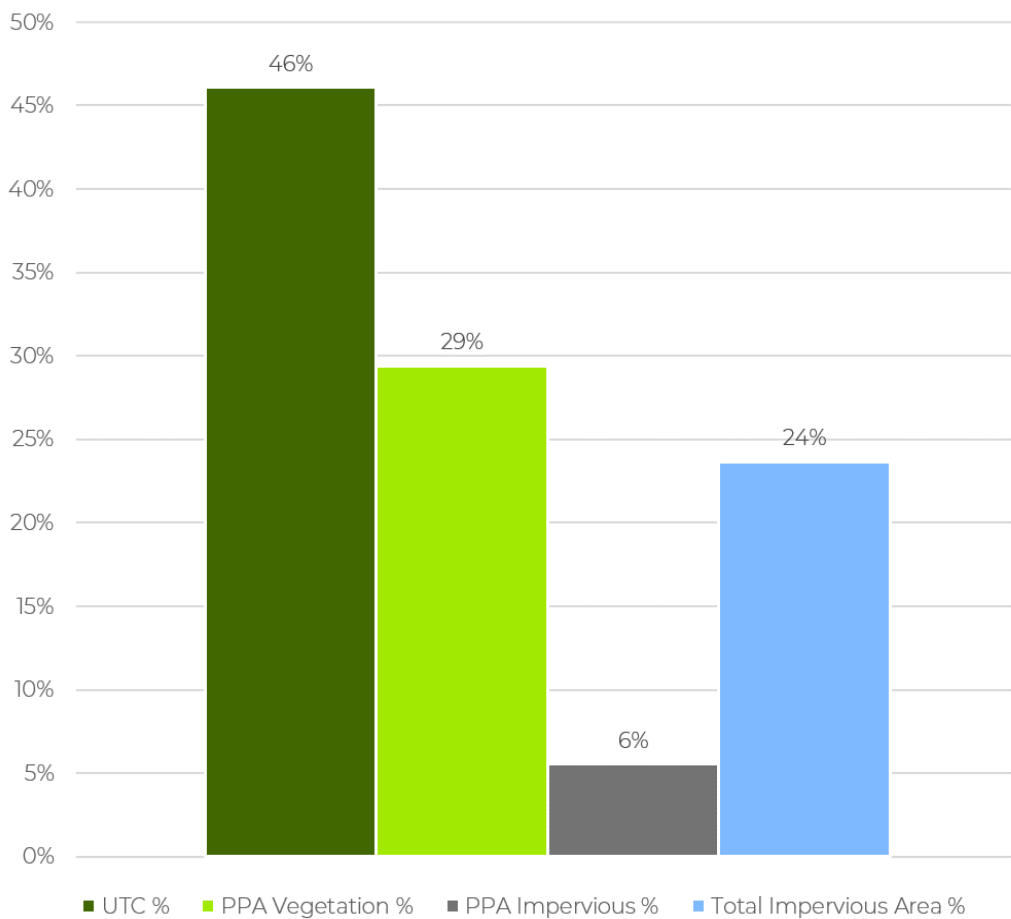


Figure 20. | Urban tree canopy, possible planting area, and impervious areas in Kirkland's shoreline jurisdictions.

URBAN TREE CANOPY CHANGE ANALYSIS

This section presents the change analysis results which were analyzed across the same geographic assessment boundaries described above. In addition to assessing Kirkland's urban tree canopy using 2017 imagery, this study also quantified changes in urban tree canopy since it was last assessed by AMEC Environmental & Infrastructure, Inc. using 2010 Worldview-2 satellite imagery. Although the exact methods used to map land cover varied between the 2017 and 2010 studies, the resulting land cover data are comparable. Both studies used leaf-on, high-resolution aerial imagery as their primary source. The spatial resolution of the imagery in 2010 was 1.5-feet while this study used 1-meter NAIP imagery. Both studies also utilized Feature Analyst remote sensing software and an object-based image analysis (OBIA) as their primary method. To ensure an even comparison, the 2010 land cover data were reanalyzed using the current boundaries of the city, land use, census block groups, etc., and changes since 2010 were assessed at the same geographic assessment scales. Similar to the UTC and PPA assessment above, the urban tree canopy change percentages are based on land area only.

CITYWIDE URBAN TREE CANOPY CHANGE

There was a slight decrease in Kirkland's tree canopy over the 7-year study period from 2010-2017. Throughout the city, the average canopy cover decreased from 40.7 percent in 2010 to 38.3 percent in 2017. Tree canopy decreased by approximately 272 acres, yielding a 2.4 percent raw or 6 percent relative decrease since 2007. New development throughout the city was responsible for a majority of the losses in tree canopy. Some overestimation in the previous assessment was also observed.

Table 14. | Urban tree canopy change results for the City of Kirkland by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
City Boundary	11,394	100%	4,632	41%	4,361	38%	-272	-2%

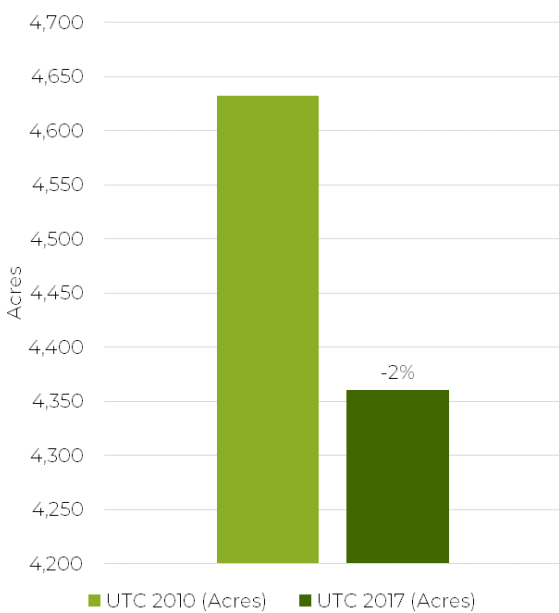


Figure 21. | Urban tree canopy change for the City of Kirkland, 2010-2017.



Figure 22. | Urban tree canopy in 2010 (yellow) compared to 2017 (green) in Downtown Kirkland.

URBAN TREE CANOPY CHANGE BY PRE-ANNEXATION CITY BOUNDARY

UTC within the pre-annexation city boundary decreased slightly. This region lost approximately 77 acres of canopy which equated to a 1 percent decrease from 36 percent to 35 percent between 2010 and 2017. This change result indicates that the majority of canopy lost in Kirkland over the study period (195 acres or 72 percent) occurred within the three annexed neighborhoods of Finn Hill, North Juanita, and Kingsgate, which were more heavily forested to begin with. The recent losses in canopy cover within the pre-annexation city boundary are a reversal of an increasing trend experienced from 2002-2010 when canopy cover increased by approximately 4 percent.

Table 15. | Urban tree canopy change results for the pre-annexation boundary by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Pre-Annexation Boundary	6,802	60%	2,448	36%	2,371	35%	-77	-1%

URBAN TREE CANOPY CHANGE BY WATERSHEDS

UTC change within the Lake-Washington Sammamish River watershed, which occupies 94 percent of the City's land area, closely mirrored the City's change result. This watershed lost approximately 239 acres of canopy which lowered its UTC by 2 percent from 41 percent in 2010 to 38 percent in 2017. The Bear Creek-Sammamish River watershed experienced a larger decrease in relation to its size. It lost approximately 33 acres of canopy, decreasing its UTC by 5 percent from 41 percent in 2010 to 36 percent in 2017. However, this watershed only occupies 6 percent of land area in Kirkland.

Table 16. | Urban tree canopy change results for Kirkland's watersheds by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Watersheds	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Bear Creek-Sammamish River	699	6%	285	41%	252	36%	-33	-5%
Lake Washington-Sammamish River	10,695	94%	4,347	41%	4,108	38%	-239	-2%
Totals	11,394	100%	4,632	41%	4,361	38%	-272	-2%

URBAN TREE CANOPY CHANGE BY LAND USES

UTC change varied slightly across Kirkland's ten King County comprehensive plan land use classes. Undesignated areas, primarily the Interstate-405 corridor, experienced the greatest loss in canopy by percentage, decreasing by approximately 4 percent from 25 percent in 2010 to 21 percent in 2017. The greatest loss in citywide canopy by acreage occurred in the Single-Family Residential class, which lost 253 acres or approximately 3 percent of their canopy from 41 to 37 percent. However, several land use classes such as Industrial/Manufacturing, Public Use/Institutional, and Parks/Open Spaces had increases in their tree canopy over the seven-year time period, and several others had little to no change.

Table 17. | Urban tree canopy change results for Kirkland’s King County land use classes by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Land Uses	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
General Commercial	602	5%	109	18%	103	17%	-6	-1%
Industrial/Manufacturing	285	2%	67	23%	72	25%	5	2%
Mixed Use Commercial/Residential	226	2%	73	32%	71	31%	-2	-1%
Multi-Family Residential	414	4%	139	33%	129	31%	-9	-2%
Office/Business Park	178	2%	49	27%	48	27%	-0	-0%
Park/Golf Course/Trail/Open Space	1,132	10%	784	69%	791	70%	7	1%
Public Use/Institutional	154	1%	48	31%	50	33%	2	1%
Single-Family Residential	8,081	71%	3,282	41%	3,029	37%	-253	-3%
Undesignated	323	3%	82	25%	67	21%	-15	-5%
Totals	11,394	100%	4,632	41%	4,360	38%	-272	-2%

Urban Tree Canopy Change by Land Uses

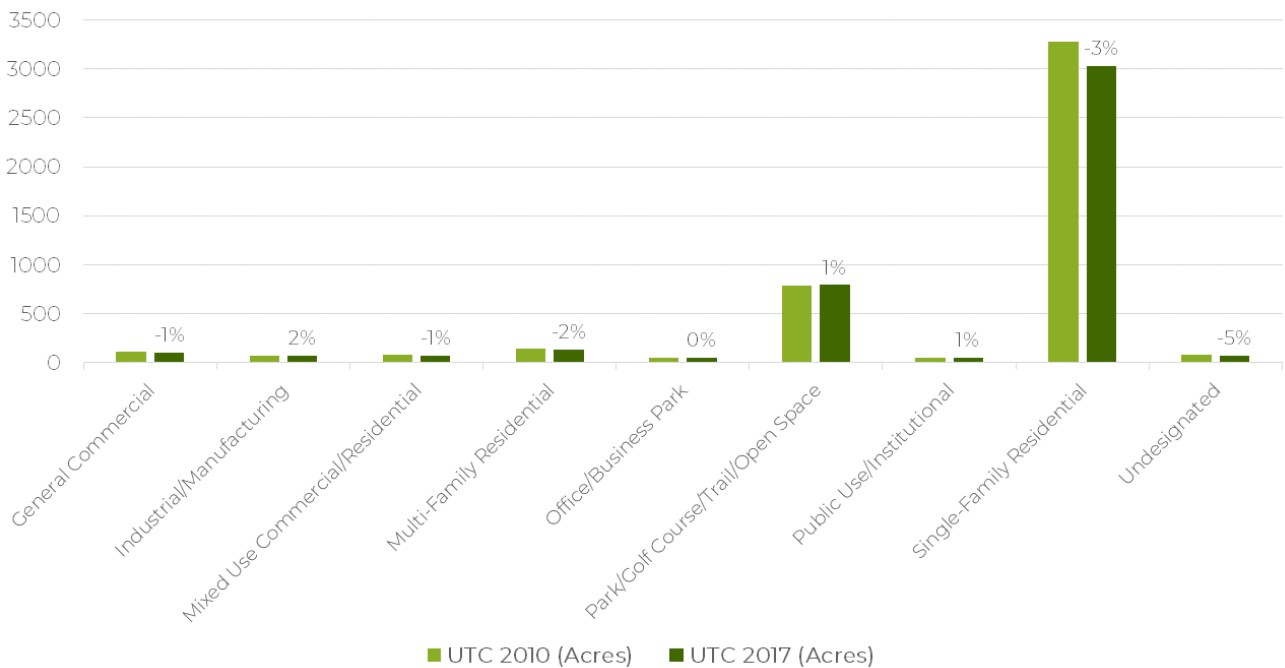


Figure 22. | Urban tree canopy change in Kirkland from 2010-2017 by county land use classes.

URBAN TREE CANOPY CHANGE BY LAND USES (CONTINUED)

Land Use Category

- Public Use/Institutional
- Office/Business Park
- General Commercial
- Industrial/Manufacturing
- Mixed Use Commercial/Residential
- Multi-Family Residential
- Single-Family Residential
- Park/Golf Course/Trail/Open Space
- Undesignated

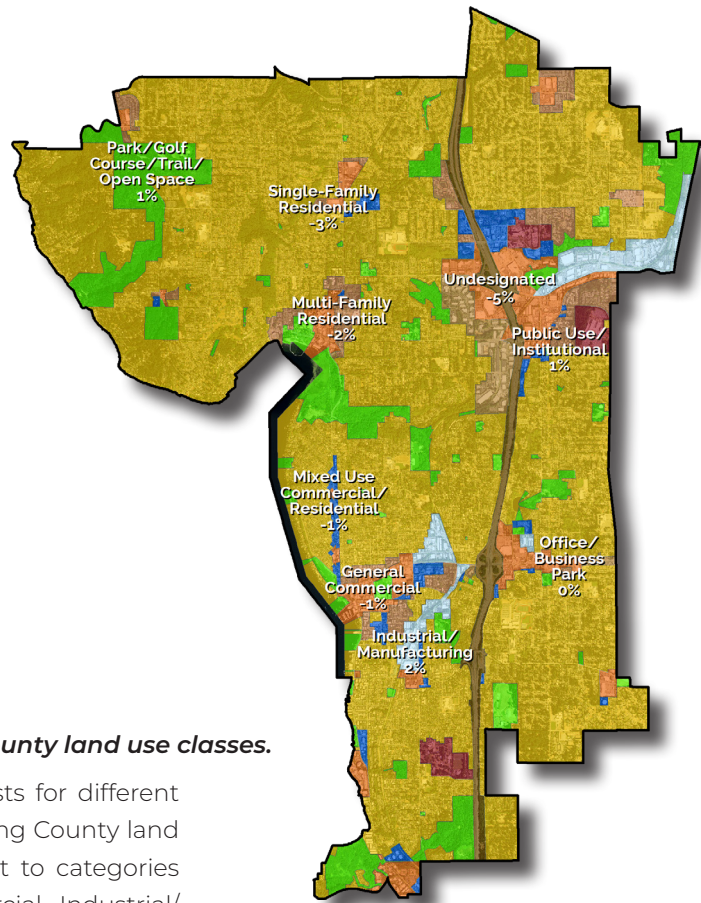


Figure 23. | Urban tree canopy change by King County land use classes.

Canopy goals were established by American Forests for different land uses in the Puget Sound region. Five of the King County land use classes analyzed in this study were equivalent to categories presented by American Forests: General Commercial, Industrial/Manufacturing, Single-Family Residential, Multi-Family Residential, and Park/Golf Course/Trail/Open Space. The City of Kirkland has not adopted American Forests' canopy goals for individual land use classes. However, comparisons between American Forests' individual land use classifications and Kirkland's UTC may provide some insight into future urban forest management decisions. In 2010, only the Park/Golf Course/Trail/Open Space category met or exceeded the American Forests' recommendations for the same land use class. Those areas had a UTC of 69 percent compared to a 25 percent standard. By 2017, another land use had exceeded American Forests' standard: Industrial areas increased from 23 percent UTC to the 25 percent standard. General Commercial, Single-Family Residential, and Multi-Family Residential areas all slightly decreased over the same time period, moving them farther away from the American Forests recommendations for the Puget Sound region. Single-Family Residential areas remained the furthest from the American Forests recommendations with 37 percent UTC compared to the target of 50 percent.

Urban Tree Canopy Change by Land Uses Compared with American Forests Goals

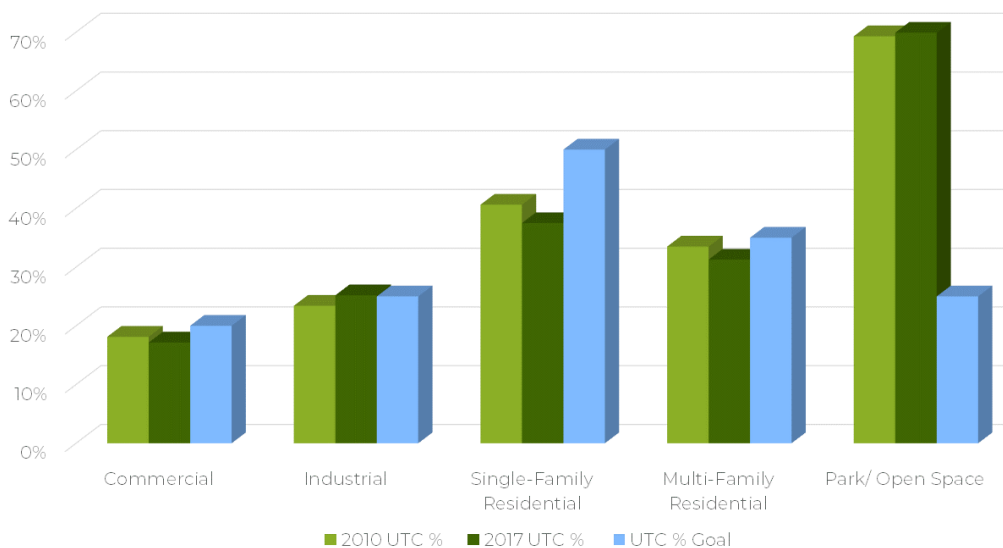


Figure 24. | Urban tree canopy change in Kirkland's five land use classes with UTC goals set in the 2010 study.

URBAN TREE CANOPY CHANGE BY NEIGHBORHOODS

Assessing Kirkland's UTC change by neighborhoods revealed more variation. Neighborhoods that experienced the greatest decreases in canopy included Kingsgate with a 6 percent loss, Juanita with 4 percent, and Finn Hill with 3 percent. Finn Hill also had the greatest decrease in canopy by acreage (85 acres) but maintained the highest UTC of any neighborhood in both 2010 (54 percent) and 2017 (50 percent). The Lakeview, Totem Lake, and Market neighborhoods all showed an increase in canopy by 2-3 percent.

Table 18. | Urban tree canopy change results for Kirkland's neighborhoods. UTC results include acres and percent of area covered by UTC in 2010 and 2017 and change in acres and percent over the seven-year period.

Neighborhoods	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Bridle Trails	610	5%	225	37%	213	35%	-12	-2%
Central Houghton	610	5%	244	40%	233	38%	-12	-2%
Everest	220	2%	87	40%	81	37%	-6	-3%
Finn Hill	2,609	23%	1,398	54%	1,313	50%	-85	-3%
Highlands	363	3%	154	43%	147	40%	-7	-2%
Juanita	1,865	16%	793	43%	712	38%	-81	-4%
Kingsgate	1,279	11%	510	40%	438	34%	-71	-6%
Lakeview	363	3%	136	37%	142	39%	6	2%
Market	291	3%	89	31%	96	33%	8	3%
Moss Bay	314	3%	77	25%	70	22%	-7	-2%
Norkirk	511	4%	171	33%	162	32%	-9	-2%
North Rose Hill	978	9%	356	36%	361	37%	5	0%
South Rose Hill	508	4%	152	30%	139	27%	-13	-3%
Totem Lake	874	8%	239	27%	254	29%	15	2%
Totals	11,394	100%	4,632	41%	4,360	38%	-272	-2%

Urban Tree Canopy Change by Neighborhoods

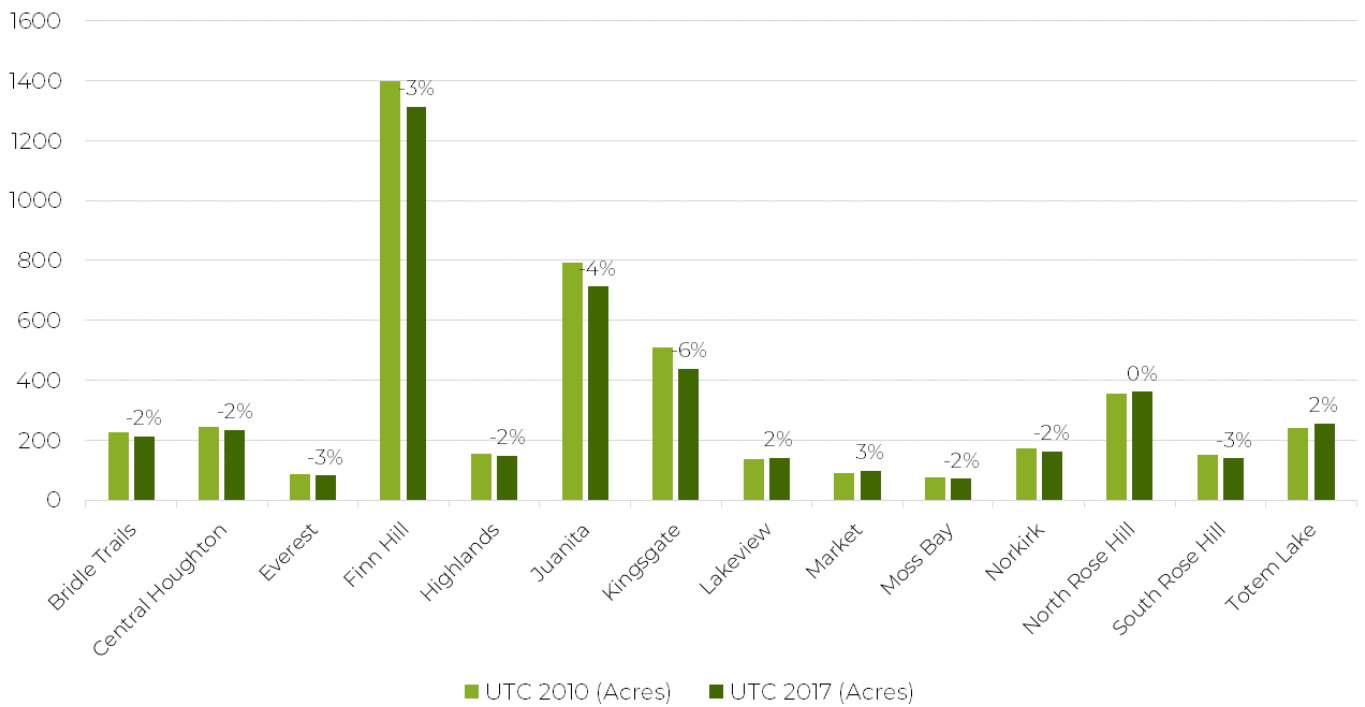


Figure 25. | Urban tree canopy change in Kirkland's neighborhoods.

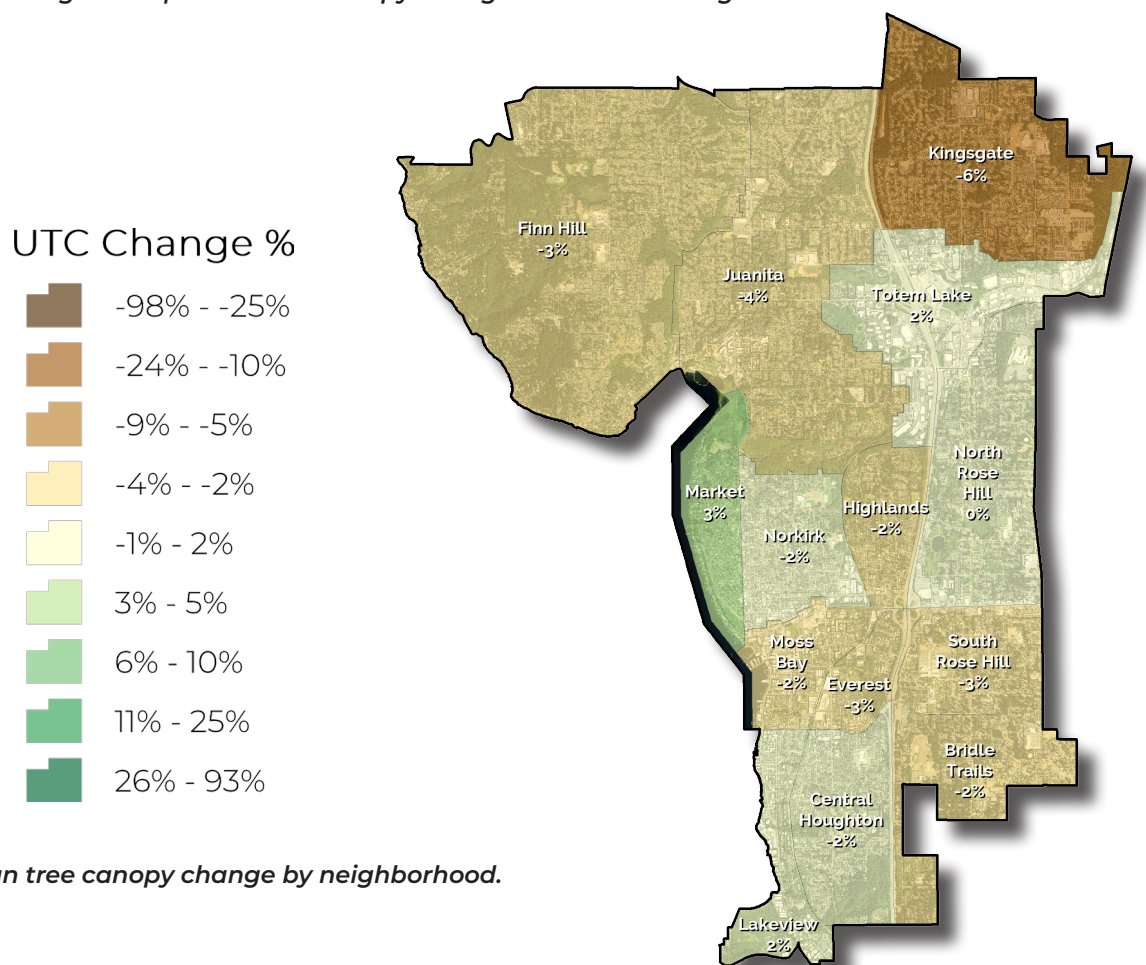


Figure 26. | Urban tree canopy change by neighborhood.

URBAN TREE CANOPY CHANGE BY DRAINAGE BASINS

Between 2010 to 2017, all of Kirkland's 15 drainage basins had a decrease in canopy except for Kirkland Slope which had no change. Holmes Point had the greatest decrease in canopy by percentage, dropping from 67 to 60 percent but maintained the highest UTC of all the drainage basins both years despite that loss. Juanita Creek had the greatest loss in UTC acres, losing 121 acres or 3 percent of its canopy.

Table 19. | Urban tree canopy change results for Kirkland's drainage basins by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Drainage Basins	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Carillon Creek	106	1%	37	35%	36	34%	-1	-1%
Champagne Creek	621	5%	292	47%	281	45%	-11	-2%
Denny Creek	803	7%	449	56%	429	53%	-20	-3%
Forbes Creek	1,824	16%	717	39%	715	39%	-2	-0%
Holmes Point	457	4%	305	67%	276	60%	-30	-6%
Houghton Slope A	376	3%	102	27%	99	26%	-3	-1%
Houghton Slope B	134	1%	48	36%	44	33%	-4	-3%
Juanita Creek	3,615	32%	1,399	39%	1,279	35%	-121	-3%
Kingsgate Slope	562	5%	239	42%	212	38%	-27	-5%
Kirkland Slope	210	2%	66	31%	66	31%	0	0%
Lower Sammamish River Valley	24	0%	11	46%	10	43%	-1	-3%
Moss Bay	1,486	13%	474	32%	444	30%	-29	-2%
South Juanita Slope	287	3%	105	36%	94	33%	-10	-4%
To Redmond	303	3%	92	30%	84	28%	-7	-2%
Yarrow Creek	577	5%	293	51%	287	50%	-6	-1%
Totals	11,385	100%	4,629	41%	4,356	38%	-273	-2%

URBAN TREE CANOPY CHANGE BY CHANGE BY CENSUS BLOCK GROUPS

18 percent of Kirkland's 80 CBGs increased their tree canopy between 2010 and 2017 and the remaining 82 percent had decreases.

56 percent of all CBGs had canopy decreases of 5 percent or less, 17 percent had decreases between 5-10 percent, and 9 percent had decreases greater than 10 percent. UTC change ranged from +10 percent in the CBG with the greatest increase to -60 percent in the CBG with the greatest loss.

For the full change analysis results by CBG, refer to the UTC Results spreadsheet.

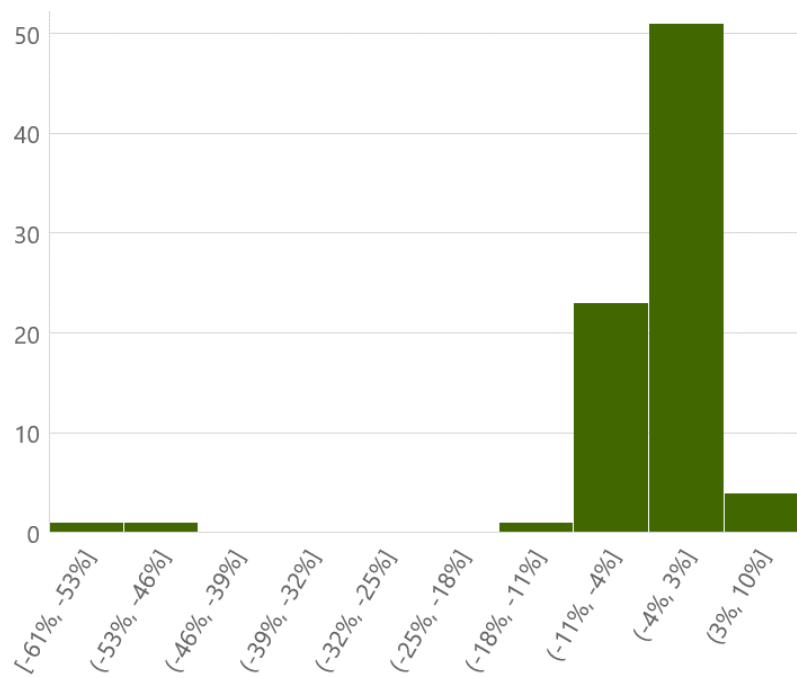


Figure 26. | Number of census block groups within UTC change ranges.

UTC Change %

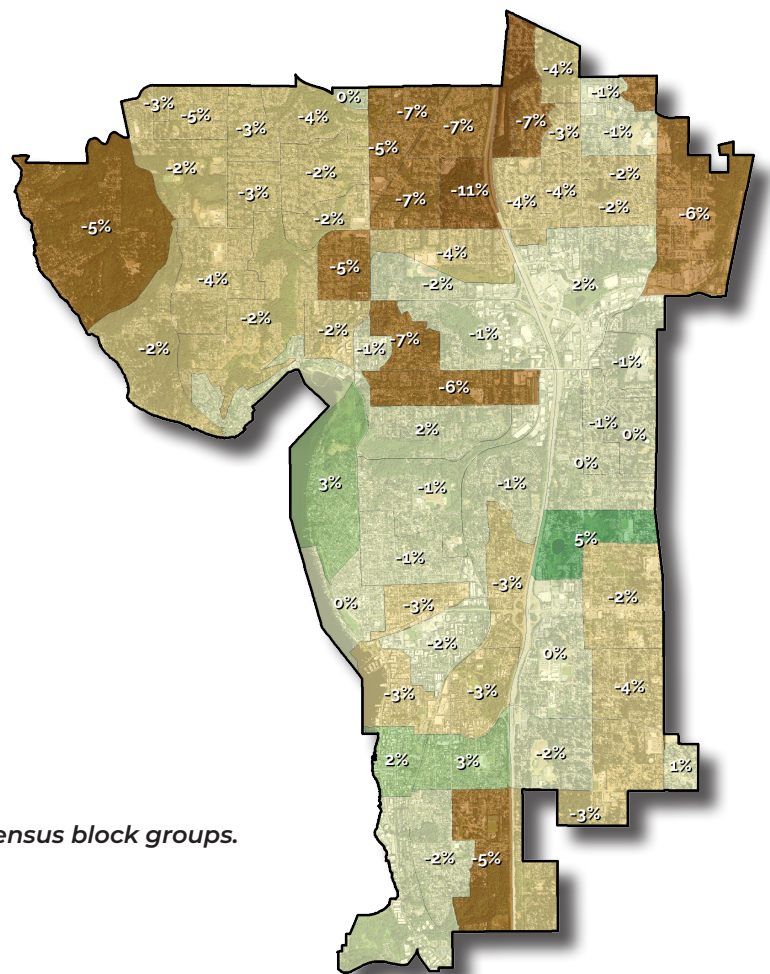
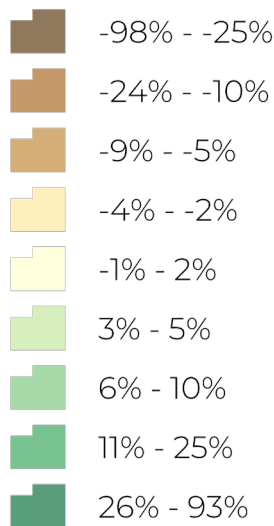


Figure 27. | Urban tree canopy change by U.S. census block groups.

URBAN TREE CANOPY CHANGE BY HOLMES POINT OVERLAY

Kirkland’s Holmes Point Overlay region had a decrease in canopy, but its UTC remained among the highest in the City. This region lost 37 acres of canopy between 2010-2017 which decreased its UTC by 6 percent from 64 to 58 percent.

Table 20. | Urban tree canopy change results for the Holmes Point overlay by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Holmes Point Overlay	651	6%	416	64%	380	58%	-37	-6%

URBAN TREE CANOPY CHANGE BY RIGHT-OF-WAY

Kirkland’s ROW experienced very little change in canopy over the seven-year assessment period. These areas lost approximately 5 acres of canopy and had a UTC of 27 percent in both 2010 and 2017.

Table 21. | Urban tree canopy change results for Kirkland’s right-of-way by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Right of Way	2,166	19%	416	64%	380	58%	-37	-6%

URBAN TREE CANOPY CHANGE BY CRITICAL AREA BUFFERS

The 100-foot buffered region around Kirkland’s lakes, streams, wetlands, and landslide areas was one of the few areas of the City that experienced an increase in canopy between 2010 and 2017. This area had an increase of 13 acres, maintaining a UTC of 60 percent throughout both years.

Table 22. | Urban tree canopy change results for Kirkland’s critical area buffers by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Critical Area Buffers (100')	2,873	25%	1,716	60%	1,729	60%	13	0%

URBAN TREE CANOPY CHANGE BY PARKS AND OPEN SPACES

UTC change in Kirkland's park and open space classes varied. General parks had an increase of 1 percent from 69 to 70 percent UTC, while UTC in open spaces decreased by 2 percent from 87 to 85 percent. Overall, UTC in all of Kirkland's park and open space areas increased by approximately 12 acres or 1 percent.

Table 23. | Urban tree canopy change results for Kirkland's parks and open space classes by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

Parks and Open Spaces	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
General Parks	943	93%	647	69%	661	70%	14	1%
Open Spaces	75	7%	65	87%	63	85%	-2	-2%
Totals	1,017	100%	712	70%	725	71%	12	1%

URBAN TREE CANOPY CHANGE BY SHORELINE JURISDICTIONS

In contrast to most of the City's area which had a slight decrease in UTC from 2010-2017, Kirkland's shoreline jurisdictions had an increase in canopy. In total, these areas gained 22 acres of canopy or 7 percent, increasing overall UTC from 39 to 46 percent.

Table 24. | Urban tree canopy change results for Kirkland's shoreline jurisdictions by acres and percent. UTC results include acres and percent of area covered by UTC in 2010 and 2017, and change in acres and percent over the seven-year period.

City of Kirkland	Land Area		UTC 2010		UTC 2017		UTC Change	
	Acres	Dist.	Acres	%	Acres	%	Acres	%
Shoreline Jurisdictions	332	3%	131	39%	153	46%	22	7%

RECOMMENDATIONS

It is clear that the City of Kirkland values its urban forest resource and wants to preserve, protect, and maintain it. One way to do this is to have a canopy assessment performed on a regular interval. The City of Kirkland has started this process by assessing their canopy in 2010 and again 2017. As the City changes, they will be able to use these recommendations to ensure that their urban forest policies and management practices continue to prioritize its maintenance, health, and growth.



**Tree canopy increased
in Kirkland's Industrial,
Parks, & Institutional
land use classes from
2010-2017.**

The City of Kirkland's 2013 Comprehensive Plan set a target of 40%. With its current canopy cover of 38%, Kirkland has fallen below this goal after reaching it in 2010. It is still within 75-100% of its citywide canopy goal which is an "optimal" indicator per the performance indicator model in the 2013 Urban Forestry Strategic Management Plan (UFSMP). The City's vegetated PPA of 21%, over 2,000 acres, provides many opportunities for future canopy expansion. Therefore, the City should put these results to work to preserve and promote its tree canopy in working towards that goal.

The results of this assessment can and should be used to encourage investment in forest monitoring, maintenance, and management; to inform codes and policies for tree retention and tree planting; to prepare supportive information for local budget requests/grant applications; and to develop targeted presentations for city leaders, planners, engineers, resource managers, and the public on the functional benefits of trees in addressing environmental issues. All data created by this study were collected and delivered in a manner that the City's GIS staff may use to conduct further analysis. The results by geographic area (such as census block group) may be particularly helpful for soliciting grant funding since they demonstrate which areas have the greatest need. The land cover data should be disseminated to diverse partners for urban forestry and other applications while the data is 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. A hyperlink to this UTC report should be provided on the City's Urban Forest, Trees and Landscaping, GIS Maps, and Kirkland Green Links and Library webpages to help engage the public. The city should also continue to incorporate tree planting, tree maintenance, and invasive removals which can be supported by these data.

Additionally, the City and its various stakeholders can utilize the results of the UTC, PPA, and change analyses to identify the best locations to focus future tree planting and canopy expansion efforts. While the City has a decent canopy coverage throughout its entire area, breaking up the results by several different geographic boundaries demonstrated that this canopy is not evenly distributed. These results can be used as a guide to determine which

RIGHTS-OF-WAY IN KIRKLAND ARE PRIME AREAS FOR INCREASING URBAN TREE CANOPY

areas would receive the greatest benefits from the investment of valuable time and resources into Kirkland's urban forest.

In terms of expanding Kirkland's canopy, the City has several potential routes to take. For example, Single-family residential areas are a good place to target future canopy expansion as they hold a large amount of PPA (72 percent of the City's total plantable

space). Rights-of-way are also good areas to target because of the additional benefits of trees in these areas for stormwater runoff mitigation, air quality improvement, and shading. Meanwhile, the Moss Bay and South Rose Hill neighborhoods have the lowest existing UTC (22 and 27 percent respectively). Therefore, land use and/or ROW could be overlaid with neighborhoods to identify single-family residential areas and rights-of-way within those neighborhoods that are lacking canopy to identify planting opportunities. An approach to review these opportunity areas should be developed including on-the-ground assessments to gauge planting site suitability.

Kirkland must integrate these data into its larger citywide planning efforts and establish set policies and guidelines for the preservation of tree canopy amidst future development. Kirkland's urban forest provides the City with a wealth of environmental, social, and even economic benefits which relate back to greater community interest in citywide initiatives and priorities. The City should use these UTC, PPA, and change metrics in combination with the results of the recent i-Tree Hydro analysis that was also performed in Kirkland to interpret where these gains would be felt most significantly and where there is still work to be done in accordance with the city's broader goals and vision for its future.



The 2013 Urban Forestry Strategic Management Plan, 2014-2019 Urban Forest Work Plan (UFWP), and 2015 Forest and Natural Areas Restoration Plan (FNARP) should be updated to include the 2018 UTC and i-Tree Hydro results. The guidelines established in the existing UFSMP, UFWP, FNARP, and other 2018 pre-approved plans should be utilized and enforced to protect tree canopy. The updated results can also be used to meet the objectives of the existing UFSMP: for example, to identify the best locations for public outreach by comparing areas with low existing canopy and high PPA, or to quantify the values, functions, and benefits of trees. To slow the loss of canopy, Kirkland Zoning Code Chapter 95 can be updated, incentives could be developed, and changes to procedures could be made in response to this study's findings.

Kirkland should also leverage its stormwater plans and regulations to promote and protect tree canopy whenever possible. Some of these include Municipal Codes 15.52.060, "Surface Water Management," which can be used to incorporate trees as best management practices for water flow control and water quality, and 15.56.060, "Qualified Rainwater Harvesting Discount," which can help to increase canopy on private property as an incentive to decrease stormwater utility fees. The UTC and i-Tree Hydro results should be incorporated into the City's Comprehensive Water Plan as they relate to canopy cover, impervious surfaces, etc., and Surface Water Master Plan (SWMP) as they relate to stormwater regulation. The SWMP also states that tree preservation and planting may be used as a low-impact development stormwater management technique (section 2.F.1), and that stormwater utility funds may be used to care for and maintain trees in the public right-of-way, fund the City's Urban Forester position, and implement of the UFMP (sections 5.B.6 and 5.C.8), so the City should continue these practices.

Comparing Tree Canopy in Nearby Communities

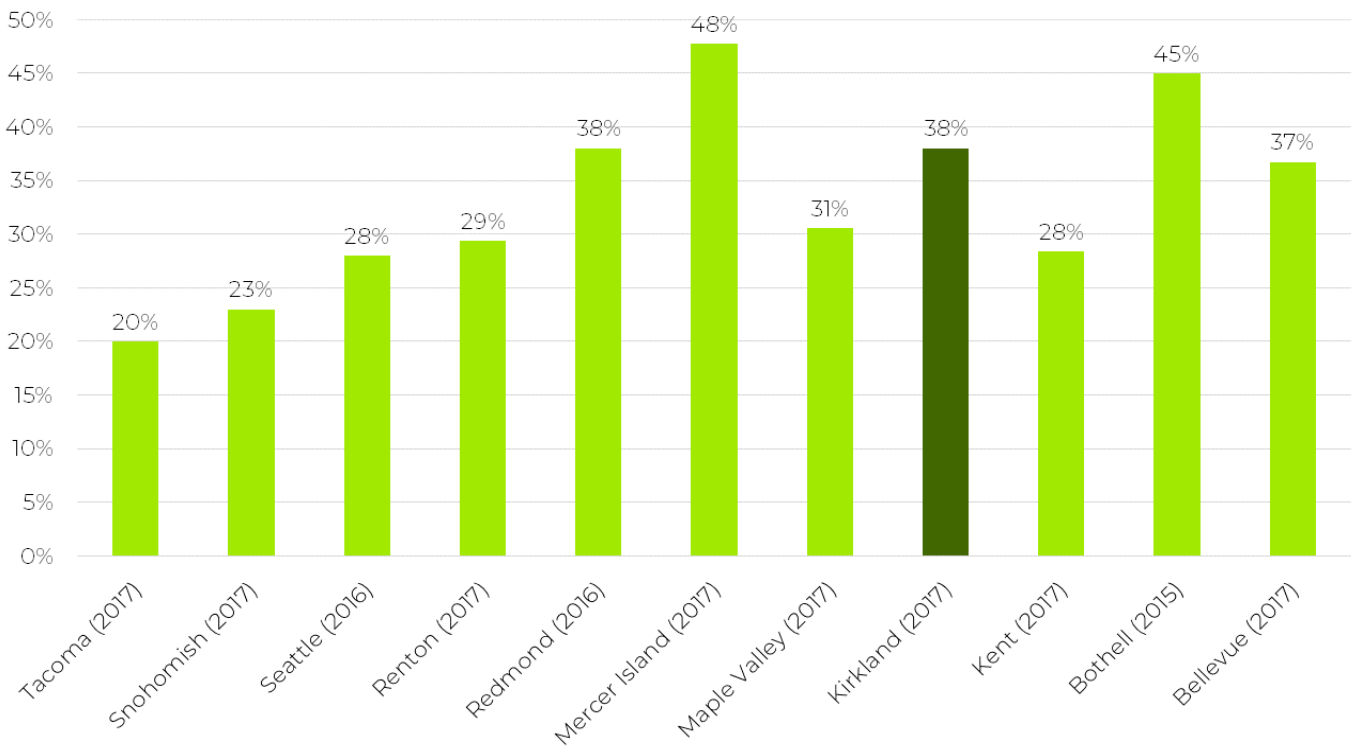


Figure 25. | A comparison of tree canopy in nearby communities.

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 2017. 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. Two hundred fifty (250) sample points, or approximately 15 points per square mile area in Kirkland (18.2 sq. miles), were randomly distributed across the study area and assigned a random numeric value.
2. Each sample point was then referenced using the NAIP 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

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 Kirkland's landscape. The error matrices 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 gray boxes along the diagonals of the matrix represent agreement between the two-pixel maps. Off-diagonal values represent the

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

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 (82 + 35 + 101 + 3 + 9 = 230 / 250 = 92 percent), and the matrix can be used to calculate per class accuracy percent's. For example, 84 points were manually identified in the reference map as Tree Canopy, and 82 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: (82/84 = .98), meaning that we can expect that ~98 percent of all 2017 tree canopy in the Kirkland, WA study area was classified as Tree Canopy in the 2017 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, 82 classification pixels intersecting reference pixels were classified as Tree Canopy, but 6 pixels were identified as Vegetation in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (82/88 = 0.93), meaning that ~93 percent 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 Kirkland in 2017. The largest sources of classification confusion exist between tree canopy and vegetation.

Table A1. | Error matrix for land cover classifications in Kirkland, WA (2017).

		Reference Data					
		Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Classification Data	Tree Canopy	82	6	0	0	0	88
	Vegetation	1	35	6	1	0	43
	Impervious	1	1	101	0	0	103
	Soil / Dry Veg.	0	0	4	3	0	7
	Water	0	0	0	0	9	9
	Total	84	42	111	4	9	250

Overall Accuracy = 92%

Producer's Accuracy		User's Accuracy	
Tree Canopy	98%	Tree Canopy	93%
Veg. / Open Space	83%	Veg. / Open Space	81%
Impervious	91%	Impervious	98%
Bare Ground / Soil	75%	Bare Ground / Soil	43%
Water	100%	Water	100%

ACCURACY ASSESSMENT RESULTS

Interpretation of the sample error matrix offers some important insights when evaluating Kirkland's urban tree canopy coverage and how land cover reported by the derived rasters and the human eye. The high accuracy of the 2017 data indicates that Kirkland's current tree canopy can be safely assumed to match the figures stated in this report (approximately 38 percent).

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 - Impervious: Paved areas void of tree canopy, excluding buildings and roads, where it is biophysically possible to establish tree canopy. Examples include parking lots and sidewalks.

Possible Planting Area - Total: The combination of PPA Vegetation area and PPA Impervious area.

Shrub: Low-lying vegetation that was classified based on interpretation of shadows and texture in vegetation. Shrubs produce little to no shadow and appeared smooth in texture compared to tree canopy.

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

Total Acres: Total area, in acres, of the assessment boundary.

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

Unsuitable Planting Area: Areas where it is not feasible to plant trees. Airports, ball fields, 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 Kirkland's urban forest. Tree canopy was generally taller than 10-15 feet tall.

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

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OCTOBER | 2018

URBAN TREE CANOPY
ASSESSMENT

KIRKLAND, WASHINGTON

