URBAN TREE CANOPY

ASSESSMENT

BELLEVUE,
WASHINGTON
SEPTEMBER | 2018

plan-it GEO

King Conservation District

CITY OF BELLEVUE WASHINGTON

AN ASSESSMENT OF
URBAN TREE CANOPY

BELLEVUE, WASHINGTON

> **We do not inherit the Earth from our ancestors— we borrow it from our children.**
> **-Chief Seattle**

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7,877
ACRES OF TREE CANOPY

EXECUTIVE SUMMARY

PURPOSE OF THIS ANALYSIS

The City of Bellevue is located within King County, Washington, in the Seattle metropolitan area (Figure 1). It is approximately 33.5 square miles or 21,435 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 baseline and benchmark of the City's tree canopy, assess how it has changed, and interpret the results across a range of geographic boundaries.

URBAN TREE CANOPY IN BELLEVUE

Results of this study indicated that in 2017, the city of Bellevue contained 37 percent tree canopy (or 7,877 of the city's 21,435 total acres); 2 percent shrub (343 acres); 17 percent other non-canopy vegetation (3,664 acres); 4 percent soil/dry vegetation (951 acres); 40 percent impervious (8,481 acres); and 1 percent water (120 acres). In further subdividing the impervious areas, 9 percent (1,940 acres) were roads, 12 percent (2,679 acres) were buildings, 9 percent (1,904) were parking lots, 1 percent (219 acres) were sidewalks, and 8 percent (1,740 acres) were "other impervious" areas such as driveways and trails. Of the city's 63 percent of land area not presently occupied by tree canopy, 28 percent (5,978 acres) was suitable for future tree plantings, and 35 percent (7,459) was unsuitable due to its current land use or other restraint. In further dividing the city's urban tree canopy, 39 percent was deciduous, 61 percent was evergreen, and 12 percent was overhanging impervious surfaces. Citywide, Bellevue's urban tree canopy has declined by less than 1 percent since it was last assessed in 2007.

ASSESSMENT BOUNDARIES AND ANALYSIS RESULTS

This study assessed urban tree canopy (UTC) and possible planting areas (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. Metrics were generated at the following geographies: the citywide boundary (1); HUC-12 watersheds (3); King County land use classes (12); City of Bellevue designated future land use classes (6); neighborhoods (16); drainage basins (28); schools (81); U.S. census block groups, and right-of-way areas within census block groups (89 each). Changes in canopy since 2007 were assessed within the same boundaries. Additionally, the city's current urban tree canopy was subdivided into deciduous and evergreen classes and delineated as overhanging impervious surfaces or not.

Figure 1. | Bellevue occupies approximately 33.5 square miles in King County, Washington.

RECOMMENDATIONS

The results of this analysis can be used to develop a continued strategy to protect and expand Bellevue's urban forest. Although previous studies indicated that Bellevue has lost a substantial amount of its canopy already, this study has indicated that Bellevue's trend of large canopy losses has been slowed with a loss of less than 1 percent over the last ten years, as development of undeveloped areas has slowed. However, the City has not been able to fully recover and begin restoring its canopy to its previous amounts just yet. Through management actions, strategic plantings, and protections for existing canopy informed by the UTC, PPA, and change metrics included in this report, Bellevue has an opportunity to expand its current urban tree canopy to its fullest potential.

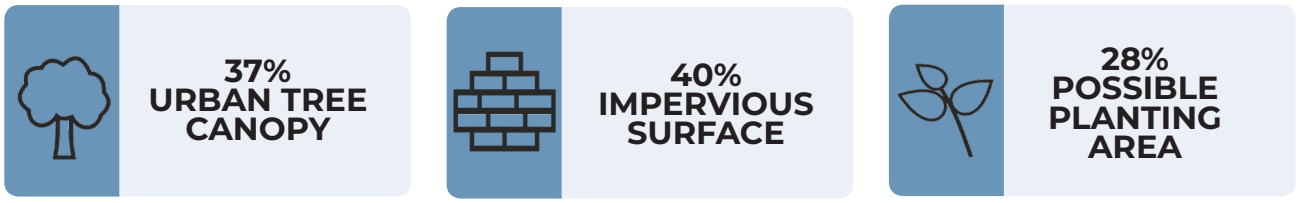

Figure 2. | Based on an analysis of 2017 high-resolution imagery, Bellevue contains 37% tree canopy, 28% areas that could support canopy in the future, and 40% total impervious areas.

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 high-resolution (1-meter) multispectral imagery from the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP) collected on 08/15/2017 and 2016 LiDAR data (8 points/m^2 density) 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 Bellevue were also incorporated into the 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 six initial land cover classes. These classes are shown in Figure 3 and described in the Glossary on page 40.

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 from 2013) were utilized to capture finer feature detail and further categorize the land cover dataset.

Figure 3. | Six (6) distinct land cover classes were identified in the 2017 tree canopy assessment: urban tree canopy, shrub, other non-canopy vegetation (such as grass), bare soil and dry vegetation, impervious (paved) surfaces, and water.

CLASSIFYING URBAN TREE CANOPY

Following the remote sensing classification and final QA/QC of the tree canopy data layer, this output was used as a mask to extract generalized tree species composition using a Normalized Difference Vegetation Index (NDVI), LiDAR height information, supervised training, and an iterative machine learning approach. Leaf-off aerial photography from Google Earth was used to obtain training and verification samples of deciduous and evergreen trees. Generalized tree species composition mapping was performed at a scale to classify larger groves of trees but not individual trees. There were no accuracy standards required or assessed for this classification. Using impervious surface data provided by the city (buildings, roads, parking lots, etc.), the amount of deciduous and evergreen tree canopy with an impervious understory was also quantified to assist with hydrologic modeling.

IDENTIFYING POSSIBLE PLANTING AREAS AND UNSUITABLE AREAS FOR PLANTING

In addition to quantifying Bellevue'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 Bellevue 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, Shrub, and Impervious classes. Wetlands were not classified in this study, however, these areas were predominately PPA outside of areas of existing UTC. Unsuitable areas, or areas where it was not feasible to plant trees due to biophysical or land use restraints (e.g. airport runways, 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 and 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 City Council and all of Bellevue'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, watersheds, designated land use classes, neighborhoods, drainage basins, schools, census block groups, and right-of-way by census block groups.

- The City of Bellevue's citywide boundary is the one (1) main area of interest over which all metrics are summarized.
- Two (2) HUC-12 watersheds intersect the city of Bellevue. Delineated by the U.S. Geological Survey, each unique 12-digit identification code represents a different subwatershed. They were analyzed to explore differences in tree canopy across a naturally-occurring geographic boundary.
- Six (6) designated land use classes were also assessed to provide detail on the current human land use configuration of the city.
- Sixteen (16) neighborhoods were assessed to quantify urban tree canopy at an easily- conceptualized scale.
- Stream corridors play an important role in urban environments. Tree canopy within 100 feet of streams was assessed.
- Since trees play an important role in storm water management, twenty-eight (28) city drainage basins were also assessed in addition to the watersheds described above.
- UTC was assessed for all of the schools in Bellevue, totaling eighty-one (81).
- Eighty-nine (89) census block groups were assessed to provide information at a small geographic scale. 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.
- In addition to the UTC throughout the census block groups' entire areas, UTC was also assessed within the Right-of-Way found within each census block group. This measure if useful for quantifying Bellevue's street trees.

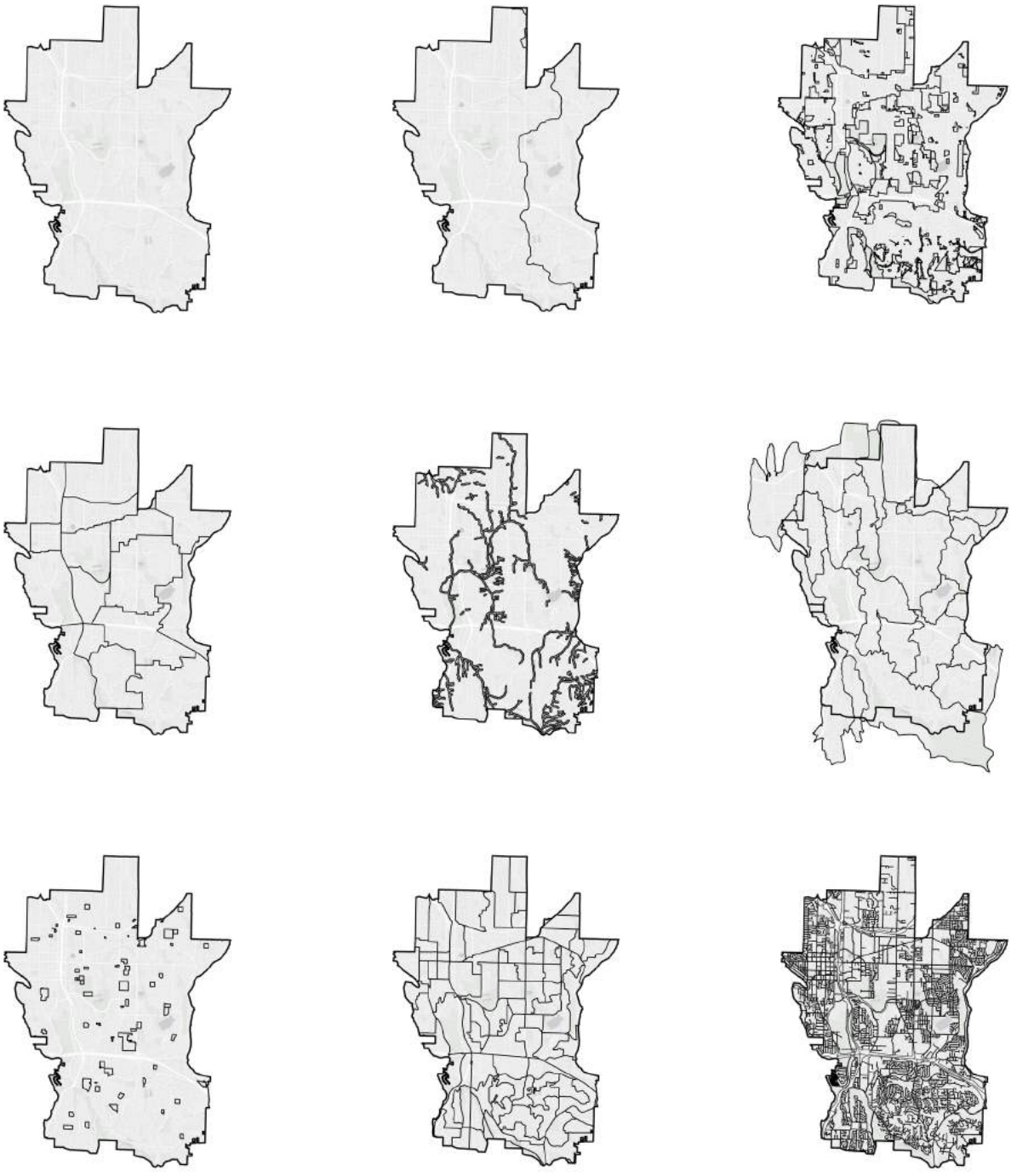

Figure 5. | Nine distinct geographic boundaries were explored in this analysis: the full city boundary, watersheds, designated land use classes, neighborhoods, stream corridors, drainage basins, schools, census block groups, and right-of-way by census block groups.

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, urban tree canopy, possible planting area, and unsuitable percentages are based on the total area of interest as opposed to land area to be consistent with the reporting of Bellevue's previous urban tree canopy assessment results.

CITYWIDE LAND COVER

In 2017, tree canopy constituted 37 percent of Bellevue's land cover; shrub was 2 percent; other non-canopy vegetation was 17 percent; soil/dry vegetation was 4 percent; impervious was 40 percent; and water was 1 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 of Bellevue was buildings, 9 percent was roads, 9 percent was parking lots, 1 percent was sidewalks, and 8 percent was "other impervious." The detailed land cover results, including impervious classifications, are presented in Figure 6.

Table 1. | Generalized land cover classification results

City Boundary	Tree Canopy	Shrub	Non-Canopy Vegetation	Impervious Surfaces	Soil & Dry Vegetation	Water
Acres	7,877	343	3,664	8,481	951	120
% of Total	37%	2%	17%	40%	4%	1%

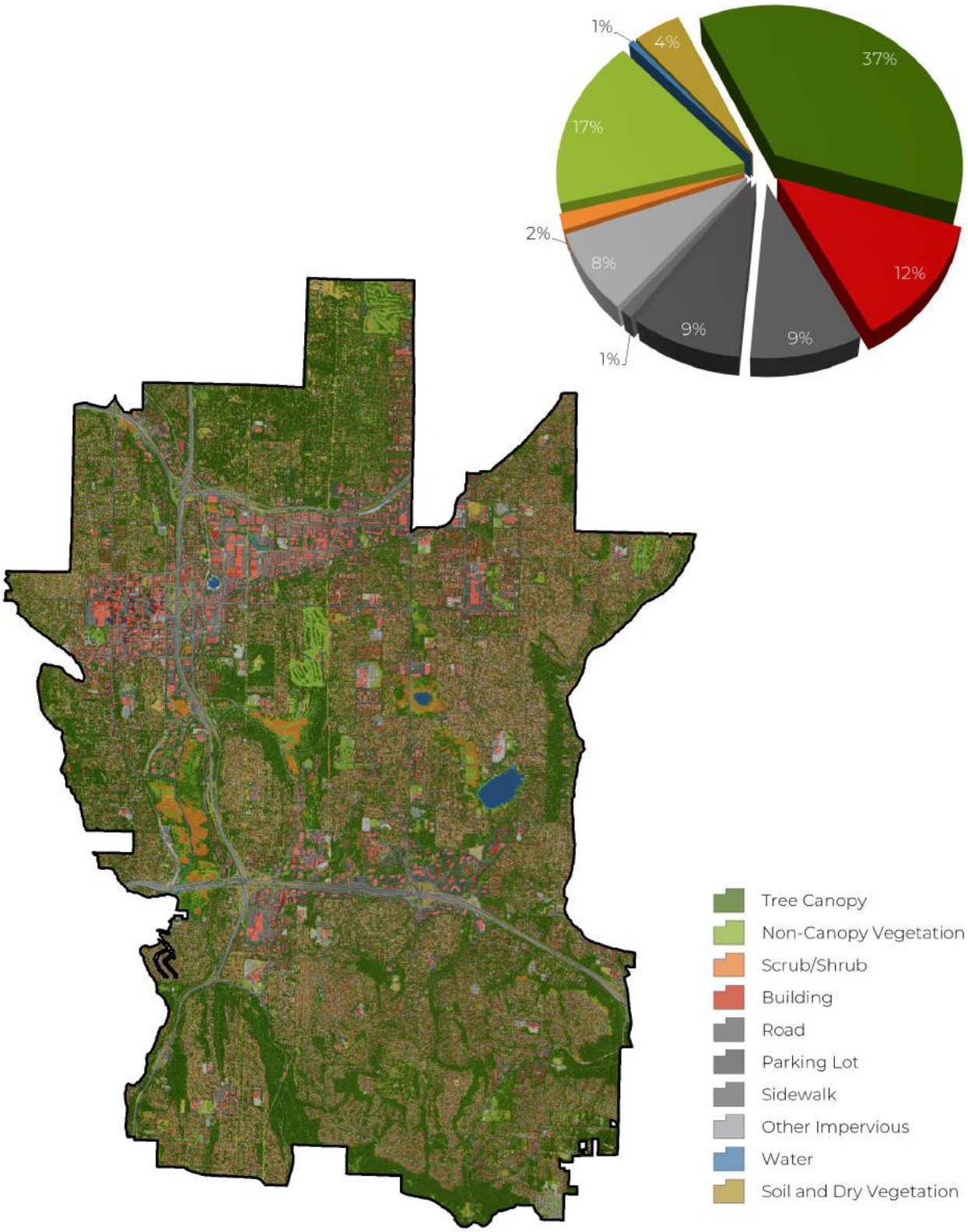

Figure 6. | Detailed land cover classes for Bellevue, Washington based on 2017 NAIP imagery and 2016 PSLC LiDAR data. (Percentages based on total acres.)

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 total area to match the previous American Forests study from 2007.

Results of this study indicate that within the city of Bellevue, 7,877 acres are covered with urban tree canopy, making up 37 percent of the city's 21,315 land acres; 5,978 acres are covered with other vegetation or impervious surfaces such as parking lots where it would be possible to plant trees (PPA), making up 28 percent of the city; and the other 7,459 acres were considered unsuitable for tree planting, making up 35 percent of the city. The unsuitable areas include recreational sports fields, golf course playing areas, buildings, roads, and areas of bare soil and dry vegetation.

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

City of Bellevue	Acres	%
Total Area	21,435	100%
Land Area	21,315	99%
UTC	7,877	37%
PPA Vegetation	3,853	18%
PPA Impervious	2,125	10%
Total PPA	5,978	28%
Unsuitable Vegetation	129	1%
Unsuitable Impervious	6,408	30%
Unsuitable Soil	922	4%
Total Unsuitable UTC	7,459	35%

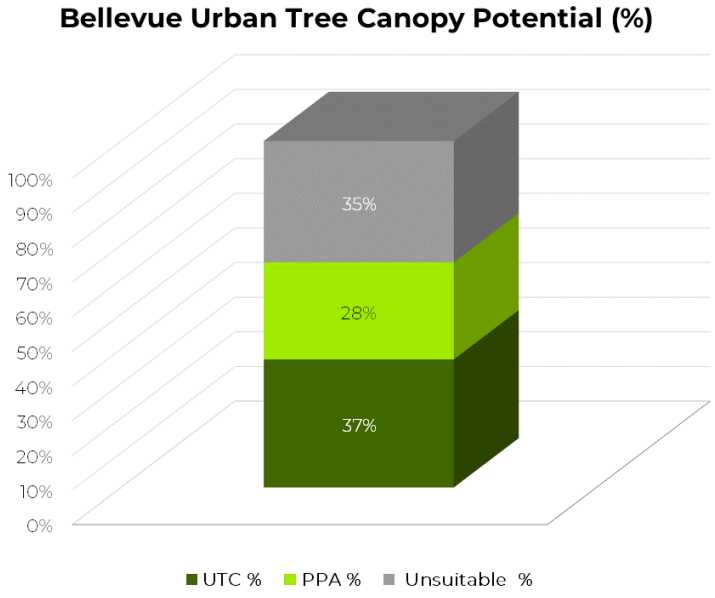

Figure 7. | Urban tree canopy, potential planting area, and area unsuitable for UTC in the city of Bellevue.

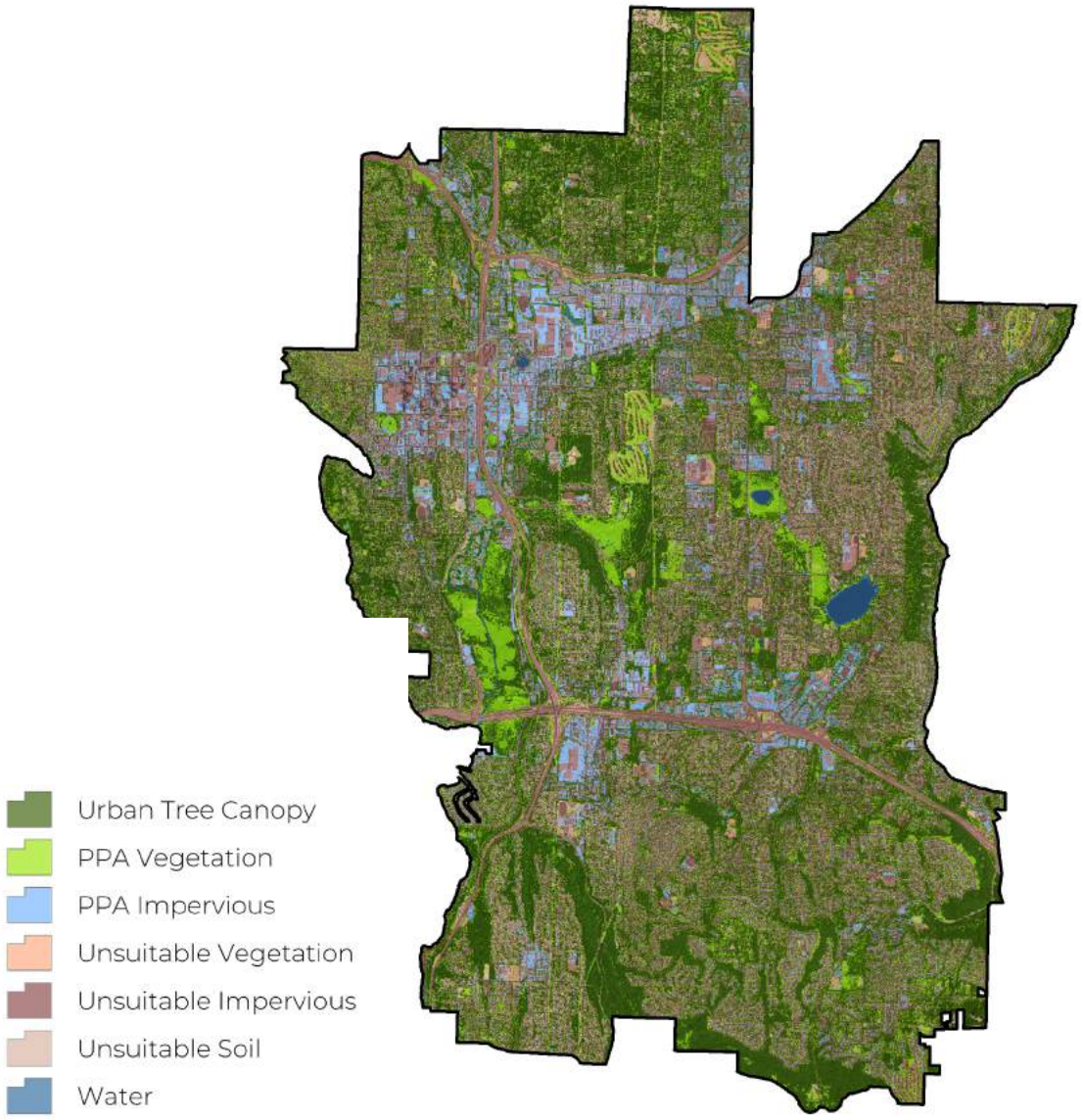

Figure 8. | Urban tree canopy, possible planting area, and area unsuitable for UTC in the city of Bellevue.

The city's 7,884 acres of urban tree canopy were further divided into several subcategories based on whether the trees were deciduous (broad-leafed) or evergreen and 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 Bellevue's UTC was predominantly evergreen, with 61 percent evergreen canopy and 39 percent deciduous canopy. In Bellevue, 12 percent of all tree canopy had an impervious understory.

Table 3. | Detailed urban tree canopy classifications.

City of Bellevue	Acres	%
Deciduous UTC	3,098	39%
Evergreen UTC	4,786	61%
UTC with Impervious Understory	941	12%

URBAN TREE CANOPY BY WATERSHEDS

Urban tree canopy metrics and possible planting areas were assessed for the 3 HUC-12 watersheds found within Bellevue (Table 4). These are the Lake Sammamish-Sammamish River watershed, which occupies a large portion of the city on the eastern side of the Sammamish River; the Lake Washington-Sammamish River watershed, which occupies the majority of the city on the western side of the Sammamish River; and the Bear Creek-Sammamish River watershed, which intersects a small portion of the northern part of the city along Bear Creek. Both of the larger watersheds' UTC closely reflected the citywide average of 37 percent. The largest watershed, Lake Washington-Sammamish River, contributed the most to both the city's overall UTC (72 percent) and PPA (74 percent).

Table 4. | Urban tree canopy assessment results by HUC-12 watershed. Columns describe the total acreage in each watershed and the distribution of the city's total area that each watershed makes up, as well as the total acres, percent of the watershed's area, and percent of the citywide total area for both UTC and PPA found within each watershed.

Watershed	Total Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Bear Creek-Sammamish River	64	0%	20	32%	0%	18	28%	0%
Lake Sammamish-Sammamish River	6,072	28%	2,208	36%	28%	1,519	25%	25%
Lake Washington-Sammamish River	15,299	71%	5,649	37%	72%	4,441	29%	74%
Totals	**21,435**	**100%**	**7,877**	**37%**	**100%**	**5,978**	**28%**	**100%**

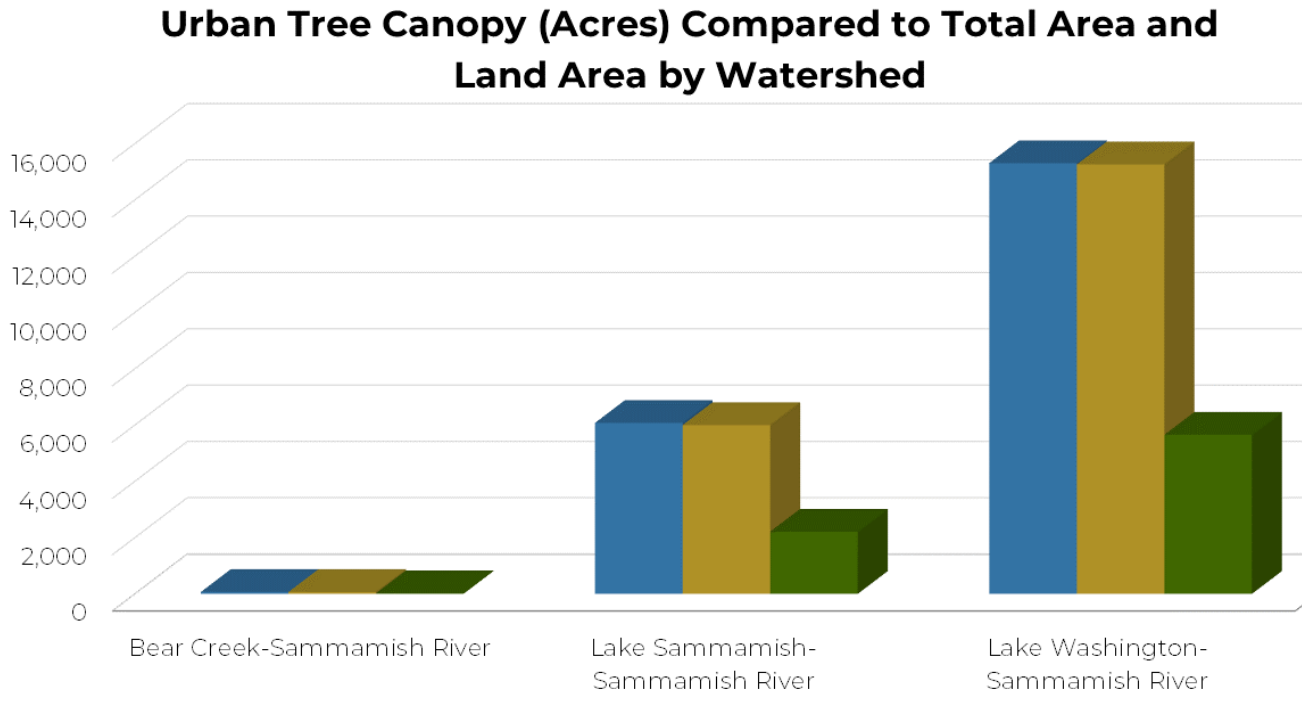

Figure 9. | Urban tree canopy in Bellevue by HUC-12 watershed.

URBAN TREE CANOPY BY DESIGNATED LAND USE

Urban tree canopy was also assessed for the City of Bellevue's designated land use classes. Parks had the highest canopy cover, with 65 percent UTC, whereas the Central Business District had the lowest at 10 percent. In terms of possible planting areas, the commercial mixed-use class had the greatest proportion, with 37 percent PPA. However, suburban residential areas contributed the greatest amounts of both UTC and PPA towards the citywide totals, making up 65 percent of all UTC and 61 percent of all PPA in Bellevue.

*Table 5. | Urban tree canopy assessment results by designated land use class.**

Designated Land Use	Total Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Central Business District	387	2%	39	10%	0%	131	34%	2%
Commercial & Mixed Use	2,747	13%	566	21%	7%	1,029	37%	17%
Industrial	220	1%	58	26%	1%	74	34%	1%
Parks	2,544	12%	1,626	64%	20%	669	26%	11%
Suburban Residential	14,131	65%	5,151	36%	65%	3,651	26%	61%
Urban Residential	1,550	7%	520	34%	7%	433	28%	7%
Totals	**21,580**	**100%**	**7,961**	**37%**	**100%**	**5,987**	**28%**	**100%**

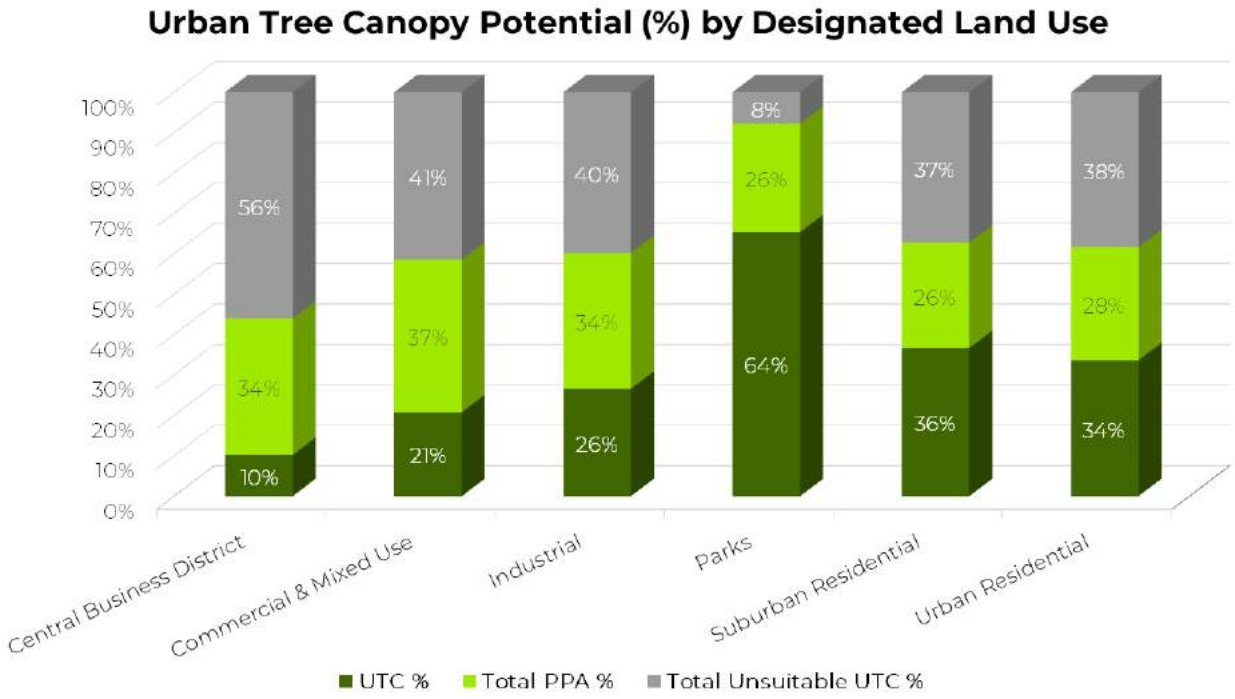

Figure 10. | Urban tree canopy, potential planting area, and area unsuitable for UTC in Bellevue by designated land use.

** Designated Land Use acreage includes the Urban Growth Area in Cougar Mountain, which is outside of city limits, but included in the Comprehensive Plan, along with a portion of Newcastle Park, which the city owns and maintains.*

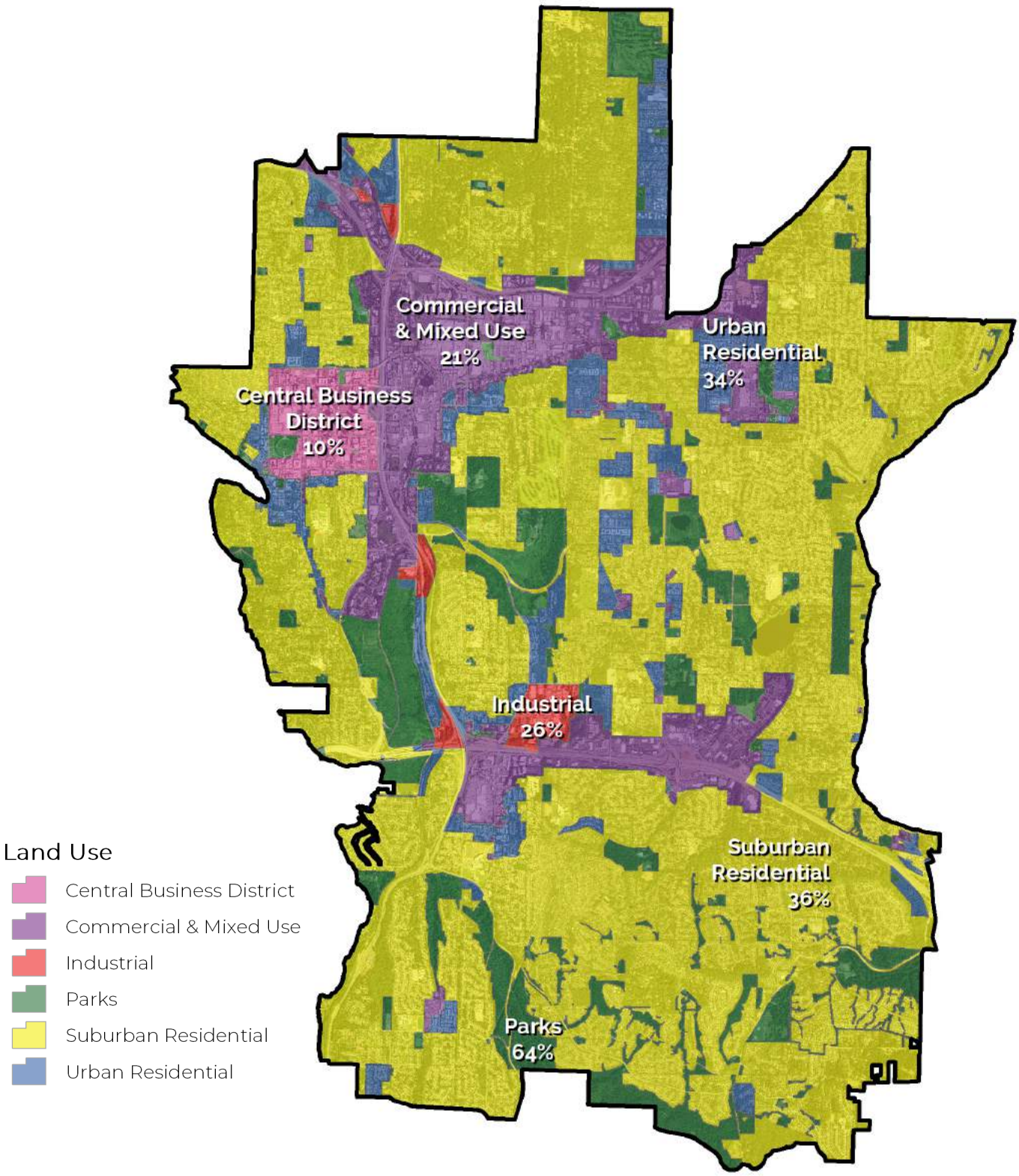

Figure 11. | Urban tree canopy in Bellevue by designated land use.

URBAN TREE CANOPY BY NEIGHBORHOODS

Urban tree canopy metrics were also assessed at the neighborhood level. This analysis revealed that Bellevue has a great deal of variation in UTC throughout the city. While some neighborhoods such as Bridle Trails and Cougar Mountain/Lakemont had nearly 50 percent canopy cover, others such as BelRed and Factoria had less than half that. Downtown had the lowest canopy cover at just 10 percent. Tree canopy in neighborhood parks, greenbelts, and open spaces is included. Some neighborhoods may be more influenced by tree canopy within these areas than others. PPA varied considerably less throughout neighborhoods with the majority remaining relatively close to the citywide average of 28 percent. The neighborhood that contributed the most to the city's overall PPA was Lake Hills, with 27 percent PPA contributing 10 percent of the city's total.

Table 6. | Urban tree canopy by neighborhood.

Neighborhood	Total Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
BelRed	963	4%	148	15%	2%	379	39%	6%
Bridle Trails	2,022	9%	977	48%	12%	559	28%	9%
Cougar Mountain / Lakemont	2,349	11%	1,155	49%	15%	573	24%	10%
Crossroads	812	4%	225	28%	3%	256	32%	4%
Downtown	432	2%	45	10%	1%	148	34%	2%
Eastgate	1,759	8%	586	33%	7%	498	28%	8%
Factoria	387	2%	83	21%	1%	126	33%	2%
Lake Hills	2,260	11%	689	31%	9%	604	27%	10%
Newport	1,706	8%	720	42%	9%	425	25%	7%
Northeast Bellevue	1,413	7%	427	30%	5%	321	23%	5%
Northwest Bellevue	1,321	6%	438	33%	6%	387	29%	6%
Somerset	1,307	6%	584	45%	7%	289	22%	5%
West Bellevue	1,683	8%	621	37%	8%	563	33%	9%
West Lake Sammamish	1,174	5%	472	40%	6%	285	24%	5%
Wilburton	1,109	5%	416	38%	5%	374	34%	6%
Woodridge	728	3%	289	40%	4%	190	26%	3%
Totals	**21,425**	**100%**	**7,875**	**37%**	**100%**	**5,977**	**28%**	**100%**

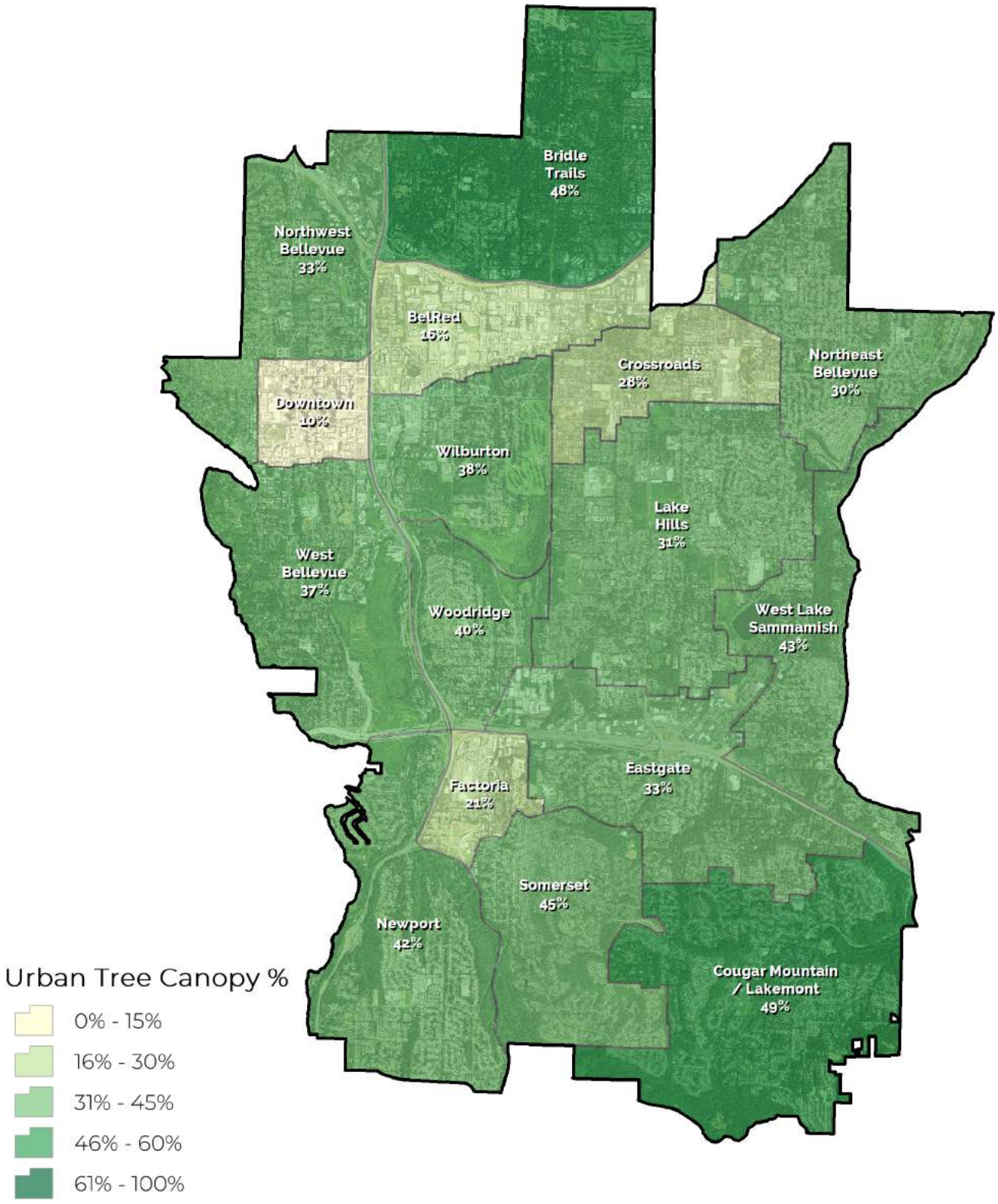

Figure 12. | Urban tree canopy in Bellevue by neighborhood.

URBAN TREE CANOPY BY STREAM CORRIDORS

Tree canopy was assessed within stream corridors. These corridors represent the area within 100 feet of a stream on both sides of the stream. Tree canopy coverage in these areas can provide enhanced wildlife habitat as well as improved water quality. Bellevue's stream corridors had an average of 58 percent tree canopy coverage. This is over 20 percent higher than the city-wide average. Possible planting area represented 25 percent of this area. Most of this PPA was on vegetated land, but there were 92 acres of impervious PPA (parking lots and sidewalks) where trees could be planted to intercept and help absorb stormwater runoff that may carry unhealthy pollutants into the streams.

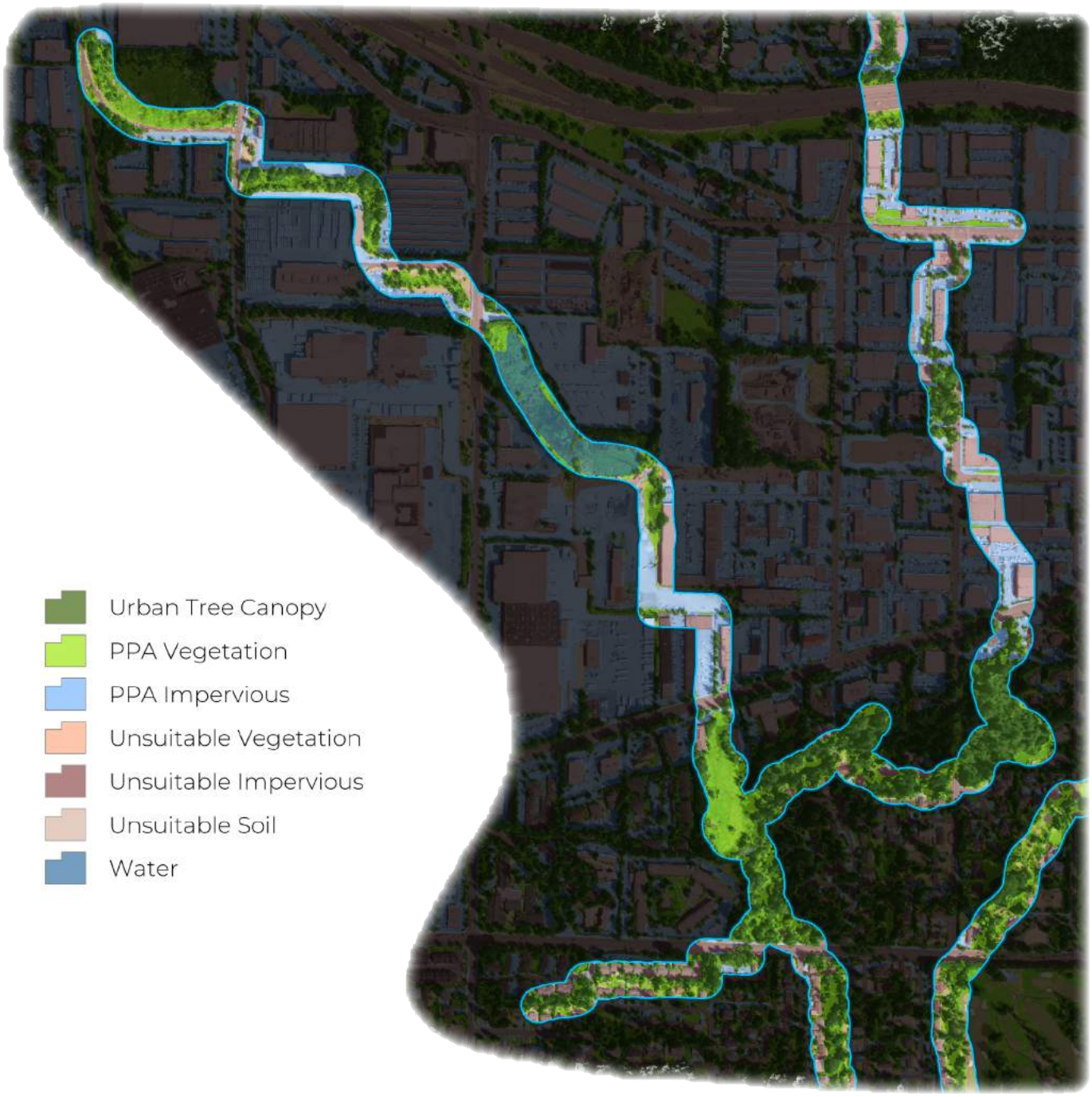

Figure 13. | Urban tree canopy and possible planting area in Bellevue's stream corridors.

URBAN TREE CANOPY BY DRAINAGE BASINS

Because of their benefits for regulating runoff, reducing flooding, and maintaining a healthy water cycle, urban tree canopy metrics were also assessed by drainage basin. This assessment boundary extended beyond the city boundary to include additional areas that drain into the Bellevue's city limits (see Figure 14). A slightly higher canopy coverage was measured when including these areas outside of Bellevue. Tree canopy coverage was 40 percent as opposed to 37 percent within the city limits. PPA remained close to the citywide an average of 28 percent while areas unsuitable for UTC dropped from the citywide average of 35 percent to 32 percent for the drainage basins.

Within the various drainage basins, there was significant variation in both UTC and PPA. UTC ranged from only 16 percent in Sturtevant Creek to 61 percent in Goff Creek, while PPA ranged from 18 percent in Coal Creek to 39 percent in the unnamed basin area. Coal Creek contributed the most of the city's overall UTC with 60 percent canopy cover contributing 21 percent of the citywide total UTC, while Kelsey Creek offered the greatest opportunities for expanding the city's canopy with 31 percent PPA contributing 12 percent of the city's total PPA.

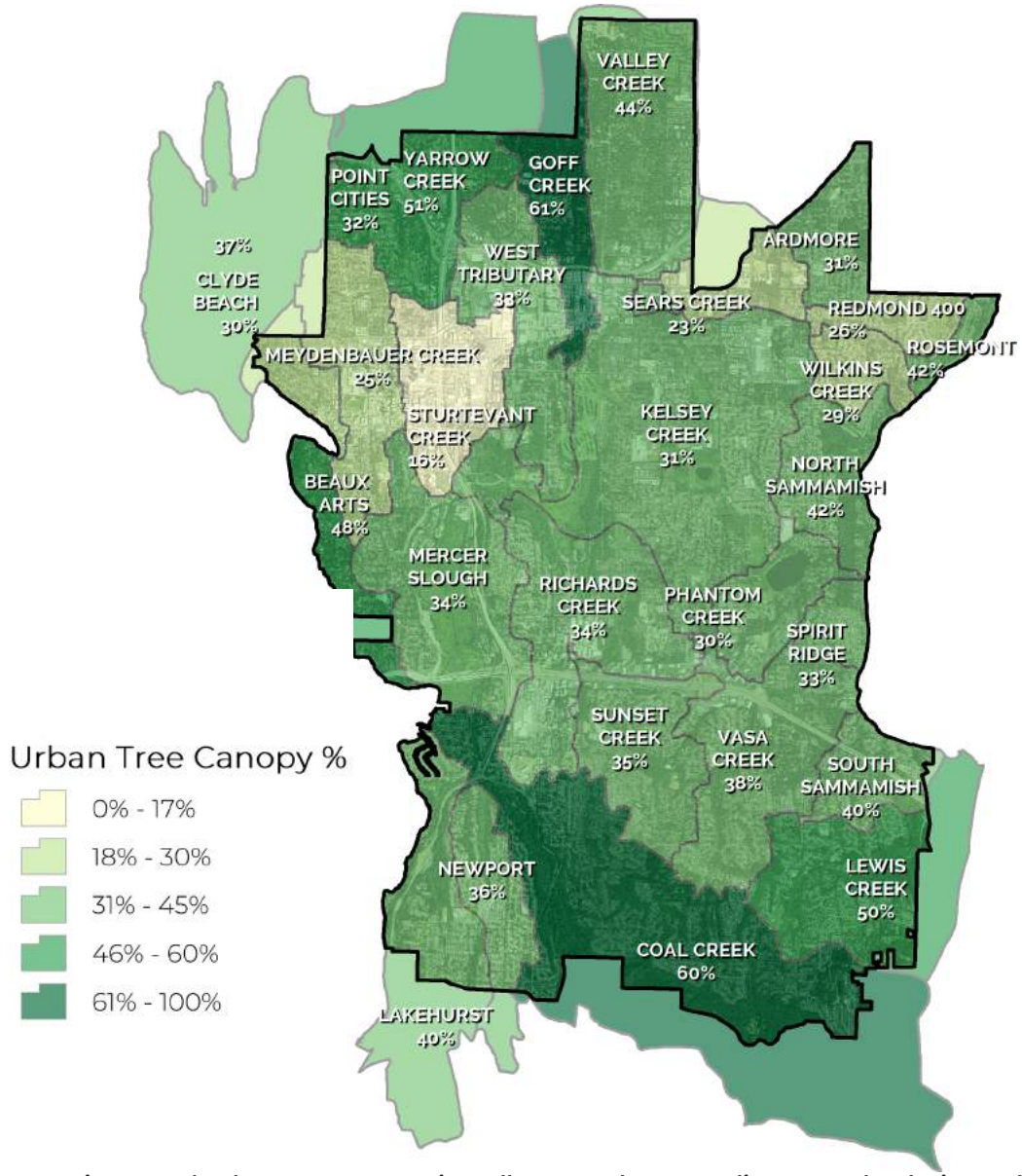

Figure 14. | Urban tree canopy in Bellevue and surrounding areas by drainage basin.

URBAN TREE CANOPY BY SCHOOLS

UTC was assessed for all 81 public and private school properties in Bellevue to determine how well the numerous benefits of the City's urban forest are reaching its next generation of residents. Overall, tree canopy on school property was substantially lower than the citywide average, at 24 percent canopy compared to the City's 37 percent. Canopy cover ranged from 0 percent at the GIX (Global Innovation Exchange) school, all the way to 78 percent at the Hillside Student Community. The average UTC for public schools was 22.5 percent, compared to 29.5 percent for private schools. These results indicate that if maintaining a healthy urban forest presence on school properties is a priority for the City, there is a lot of work to be done. The average PPA on school property slightly exceeded the citywide average at 32 percent compared to the City's 28 percent, revealing that an increase in UTC in these areas is realistically attainable.

Table 7. | Urban tree canopy by school.

Schools	UTC Acres	UTC %	Schools	UTC Acres	UTC %	Schools	UTC Acres	UTC %
AMERICAS CHILD	0.1	21%	ENATAI	2.1	24%	OPEN WINDOW	1.7	23%
ARDMORE	2.7	27%	ETON	0.5	37%	PHANTOM LAKE	1.3	14%
ASIA PACIFIC	1.6	50%	FOREST RIDGE	5.7	35%	PUESTA DEL SOL	3.9	29%
BELLEVUE COLLEGE	29.7	31%	FRENCH IMMERSION	0.5	32%	RINGDALL	4.4	24%
BELLEVUE	11.9	30%	GEMINI	0.0	2%	SACRED HEART	2.5	26%
BELLEVUE BIG PICTURE	1.6	12%	GIX	0.0	0%	SAMMAMISH	3.1	8%
BELLEVUE CHRISTIAN	2.3	28%	HAZELWOOD	4.4	32%	SHERWOOD FOREST	0.9	10%
BELLEVUE MANAGEMENT SUPPORT CTR	1.0	17%	HIGHLAND	4.1	20%	SOMERSET	3.7	37%
BELLEVUE MONTESSORI	0.7	49%	HILLSIDE	2.8	78%	SPECIALTY	0.3	33%
BELRED BILINGUAL	0.2	38%	INTERLAKE	7.5	19%	SPIRITRIDGE	2.5	27%
BENNETT	1.5	16%	INTERNATIONAL	5.6	28%	ST LOUISE	1.3	14%
CEDAR CREST	0.4	29%	INTERNATIONAL MONTESSORI	0.3	35%	ST MADELEINE	2.8	27%
CEDAR PARK CHRISTIAN	0.4	13%	JEWISH DAY	1.0	16%	ST THOMAS	0.8	14%
CHERRY CREST	6.1	60%	JING MEI	3.0	30%	STEVENSON	0.8	9%
CHESTNUT HILL	0.9	30%	JUBILEE REACH	0.8	42%	SUNSET	3.4	25%
CHINOOK	2.6	15%	LAKE HILLS	0.9	10%	TARTEEL	0.1	9%
CLYDE HILL	2.1	29%	LITTLE SCHOOL	6.8	71%	THREE CEDARS	2.1	43%
COUGAR RIDGE	2.8	27%	LIVING MONTESSORI	3.5	39%	TILLICUM	1.9	11%
EASTGATE	2.1	26%	MEDINA	0.9	16%	TYEE	4.1	18%
EASTSIDE ACADEMY	3.5	35%	MEDINA ACADEMY	0.3	16%	VERA RISDON	5.3	30%
EASTSIDE CHRISTIAN	1.6	26%	NEWPORT	4.9	12%	WILBURTON	2.1	22%
EASTSIDE MONTESSORI	0.9	29%	NEWPORT CHILDRENS	0.0	4%	WILBURTON INSTRUCTIONAL SERVICE CTR	0.8	13%
EDUCATIONAL SERVICE CTR	1.1	39%	NEWPORT HEIGHTS	2.2	24%	WOODRIDGE	1.2	12%
EMERALD HEIGHTS	2.8	53%	ODLE	2.3	12%			

URBAN TREE CANOPY BY CENSUS BLOCK GROUPS

Urban tree canopy and possible planting areas were assessed at the census block group level. This was the smallest geographic area unit analyzed that covered the entire City area and is particularly valuable for assessing the equitable distribution of tree canopy throughout the city as the block groups are linked to all demographic and socioeconomic U.S. census data. Results indicated that urban tree canopy varies substantially throughout the city, with one census block group containing only 9 percent cover and another containing as much as 90 percent. PPA also varied somewhat across the various block groups, with one containing only 7 percent PPA and another as much as 44 percent PPA. For the complete results by census block group, refer to the UTC Results Spreadsheet.

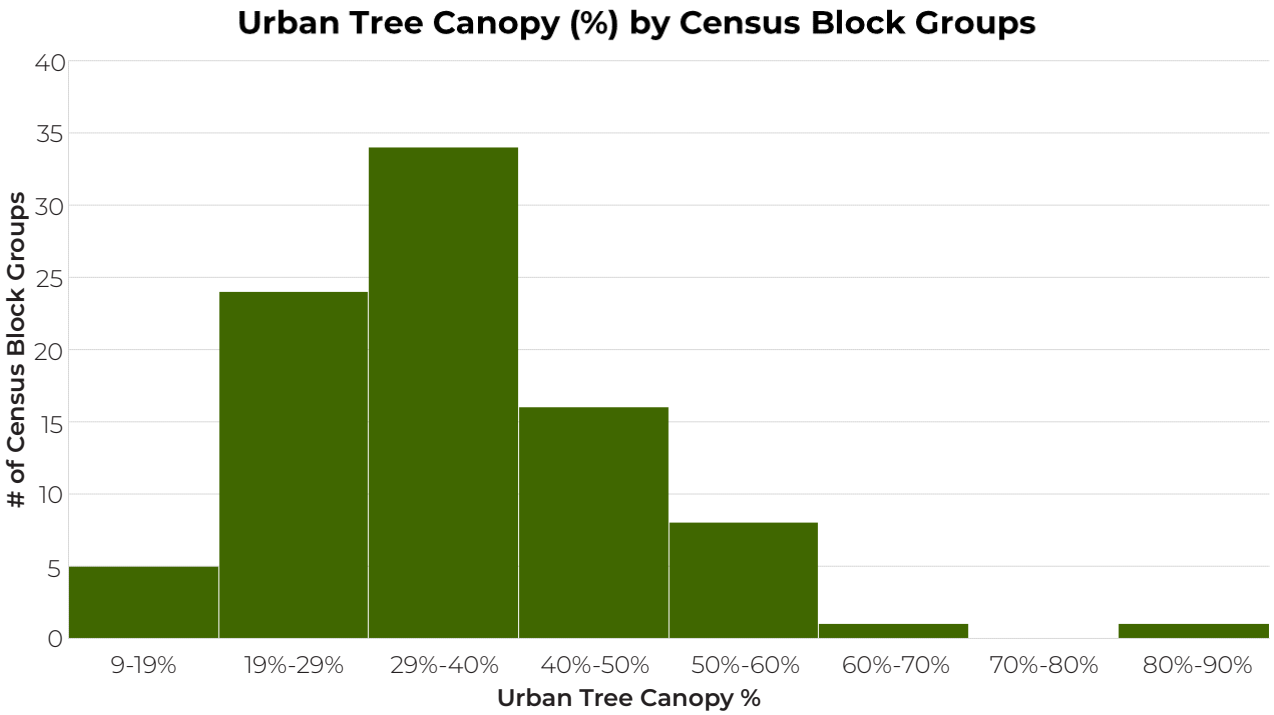

Figure 15. | Number of census block groups within percent canopy cover ranges.

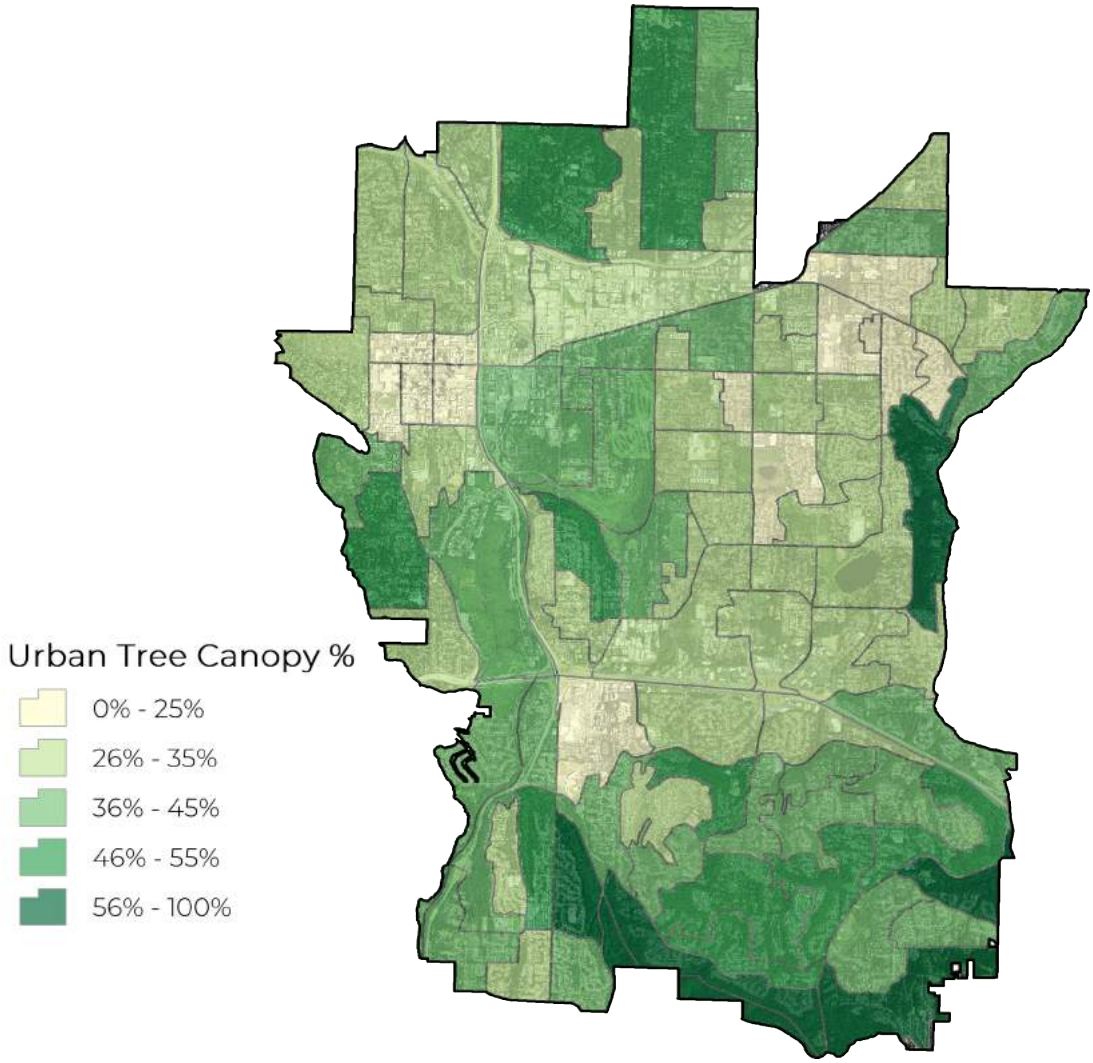

Figure 16. | Urban tree canopy in Bellevue by census block groups.

URBAN TREE CANOPY BY RIGHT-OF-WAY BY CENSUS BLOCK GROUPS

In addition to being assessed throughout each census block group's entire area, UTC was also assessed for the right-of-way areas within each census block group. Right-of-way areas include the City's sidewalks, roadways, and medians that are publicly owned and maintained. This metric is helpful for quantifying the City's street tree resources, as trees in this area provide an especially valuable service in terms of air pollution control and shading, while still tying it to a small and significant unit of measure (the census block groups). On average, Bellevue's rights-of-way had a UTC of 24 percent. This figure fell somewhat below the citywide average of 37 percent, but did not vary to as extreme of a degree as some other assessment levels, ranging from 8 percent to 46 percent.

For the complete results by census block group, refer to the UTC Results Spreadsheet.

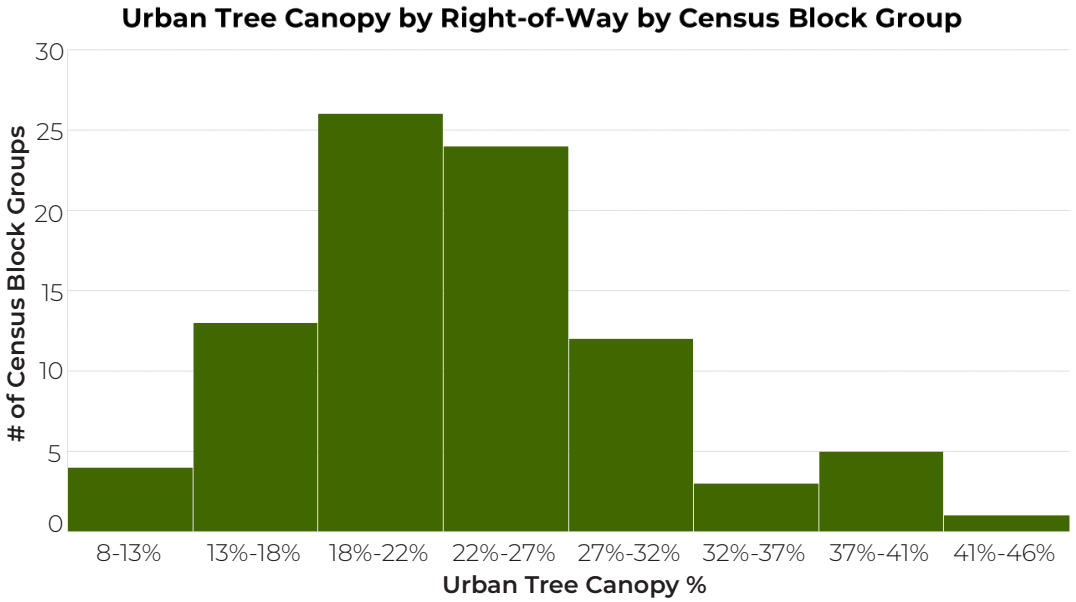

Figure 17. | Number of census block groups with right-of-way within percent canopy cover ranges.

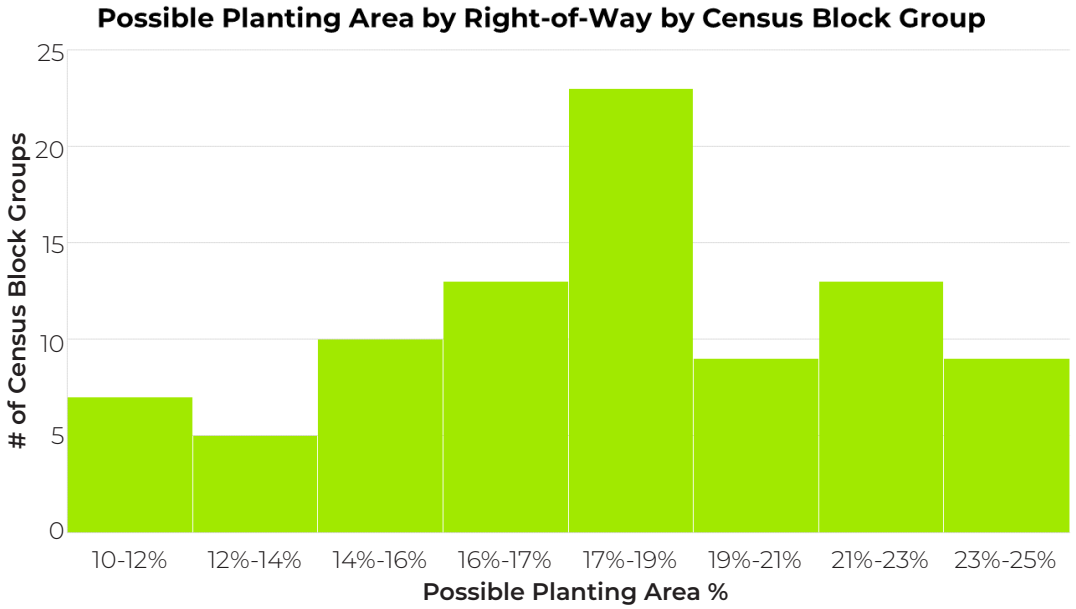

Figure 18. | Number of census block groups with right-of-way areas within percent possible planting area ranges.

QUANTIFYING ECOSYSTEM BENEFITS

Using the best available science from i-Tree tools, values were calculated for some of the benefits and functions provided by trees and forests in Bellevue. The urban forest holds millions of dollars of savings in avoided infrastructure costs, pollution reduction, and stored carbon.

AIR QUALITY

Trees produce oxygen, capture air pollutants such as particulate matter directly on their leaves, improve public health, and reduce pollution indirectly by lowering air temperatures, reducing the formation of ozone.

- The existing tree canopy in Bellevue removes 1,023,583 tons of air pollution annually, valued at $39,183,439.

STORMWATER AND WATER QUALITY

Trees and forests mitigate stormwater runoff which minimizes flood risk, stabilizes soil, reduces sedimentation in streams and marshland, and absorbs pollutants, thus improving water quality and habitats.

- On average, each acre of tree canopy in Bellevue absorbs 40,000 gallons of water. This benefit of avoided runoff is valued at roughly $360 per acre/per year. Extrapolated citywide, this means that Bellevue's existing tree canopy provides $2,843,283 in stormwater runoff benefits.

CARBON STORAGE AND SEQUESTRATION

Trees accumulate carbon in their biomass; with most species in a temperate forest, the rate and amount increase with age.

- Bellevue's trees store approximately 1,452,475 tons of carbon, valued at $51,388,889, and each year the tree canopy absorbs and sequesters approximately 28,786 tons of carbon dioxide, valued at $1,018,439.

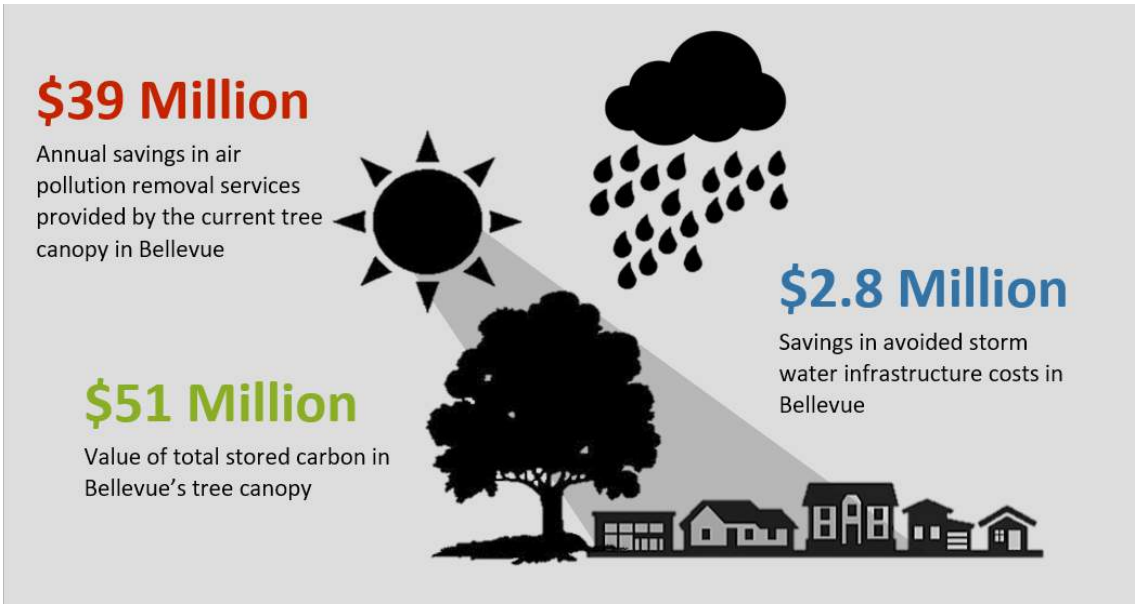

Figure 19. | Quantification of some of the monetary benefits of Bellevue's urban forest ecosystem services (based on 37% citywide tree canopy cover).

URBAN TREE CANOPY CHANGE ANALYSIS

In addition to assessing Bellevue's urban tree canopy using current 2017 imagery, this study also quantified changes in urban tree canopy since it was last assessed using 2007 imagery. Previous studies conducted in 1998 and 2008 by American Forests determined that the city was losing its valuable tree canopy and the associated ecosystem benefits that trees provide at alarming rates, with a 12 percent loss in canopy from 1986-1996 and another 9 percent loss in canopy from 1996-2006.

Although the exact methods used to map land cover varied between the 2017 and 2007 studies, the resulting land cover data are comparable. Both studies used high-resolution aerial imagery as their primary source. The spatial resolution of the imagery in 2007 was 2 feet while this study used 1 meter NAIP imagery. In those ten years, several of the geographic assessment scales had changed due to annexation, population changes, and other land use reconfigurations. To ensure an even comparison, the 2007 land cover data were reanalyzed using the current boundaries of the city, land use, census block groups, etc. While American Forests originally reported that Bellevue had 36% tree canopy cover in 2007, using the current city boundary, Bellevue had 37.6 percent cover in 2007. This increase may be due to the fact that the current city boundary now includes heavily forested areas on the southern edge of the city. Changes since that time were assessed at all of the geographic assessment scales (citywide, watersheds, land use, neighborhoods, drainage basins, and census block groups).

CITYWIDE URBAN TREE CANOPY CHANGE

Overall, this change analysis revealed that the rapid loss of canopy that occurred in previous decades has nearly ended as close to the same canopy cover over the timespan of 2007-2017 was observed. This study estimates Bellevue's urban tree canopy at an average of 36.7 percent citywide, meaning that only 0.7 percent of the city's canopy, totaling 148 acres, was lost since it was last assessed. Though still a loss, this number is a dramatic improvement from the upwards of 20 percent that was lost between 1986 and 2006. Increased efforts should be made to preserve the city's existing urban forest through revised management actions.

This study achieved 92% overall accuracy (see Appendix). With a 95% confidence interval, there was a 2.1% margin of error equating to 36.7% canopy cover +/- 2.1% or a range of 34.6% to 38.8%. Compared to 2007 coverage, there was a change of -2.8% or 1.4% taking into account the 2017 margin of error.

Table 8. | Urban tree canopy change for the City of Bellevue.

City of Bellevue	Total Area	UTC 2007		UTC 2017		UTC Change	
	Acres	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Urban Tree Canopy	21,435	8,024	37.4%	7,877	36.7%	-148	-0.7%

URBAN TREE CANOPY CHANGE BY WATERSHEDS

When the change analysis results were subdivided by HUC-12 watershed, the losses were not quite evenly distributed. The largest watershed, Lake Washington-Sammamish River, experienced only a 0.2 percent loss in canopy, whereas its counterpart, the Lake Sammamish-Sammamish River, lost 2 percent. The small Bear Creek-Sammamish River region, which had the lowest UTC in 2007 at 27 percent, actually saw an increase in canopy over the ten-year period, gaining 5 percent to reach 32 percent canopy cover.

Table 9. | Urban tree canopy change by watersheds.

Watershed	Land Area		UTC 2007		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Bear Creek-Sammamish River	64	0%	17	27%	20	32%	3	5%
Lake Sammamish-Sammamish River	6,072	28%	2,324	38%	2,208	36%	-117	-2%
Lake Washington-Sammamish River	15,299	71%	5,683	37%	5,649	37%	-34	0%
Totals	**21,435**	**100%**	**8,024**	**37%**	**7,877**	**37%**	**-148**	**-1%**

URBAN TREE CANOPY CHANGE BY DESIGNATED LAND USE

Dividing the urban tree canopy change results by the City's designated future land use categories offered some additional insights as to how Bellevue's canopy has changed over the ten-year period. As above, the Parks category had the greatest individual reduction in canopy but maintained the highest overall UTC, with an 8 percent loss from 72 to 65 percent for the 2,544 acres designated for Parks by the City of Bellevue. Differences in source datasets and mapping methodology likely impacted this canopy change statistic. In many heavily forested parks, the 2007 data showed nearly full canopy coverage. This 2017 study incorporated LiDAR data which was not available in 2007. This allowed for mapping of small gaps in the canopy scattered throughout the parks which were classified as non-canopy vegetation.

Industrial areas also had an 8 percent loss, from 34 percent to 27 percent UTC, though these areas make up only 1 percent of Bellevue's total area. Bellevue's central business district and commercial/mixed use areas had slight increases in canopy, and the suburban residential class (which makes up the majority of the city, occupying 65 percent of its total area) had no change.

Table 10. | Urban tree canopy change by City of Bellevue designated land uses.

Designated Land Use	Land Area		UTC 2007		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Central Business District	387	2%	32	8%	39	10%	7	2%
Commercial & Mixed Use	2,747	13%	540	20%	566	21%	25	1%
Industrial	220	1%	75	34%	58	27%	-17	-8%
Parks	2,544	12%	1,823	72%	1,626	65%	-197	-8%
Suburban Residential	14,131	65%	5,163	37%	5,151	37%	-12	0%
Urban Residential	1,550	7%	482	31%	520	34%	38	2%
Totals	**21,580**	**100%**	**8,116**	**38%**	**7,961**	**37%**	**-155**	**-1%**

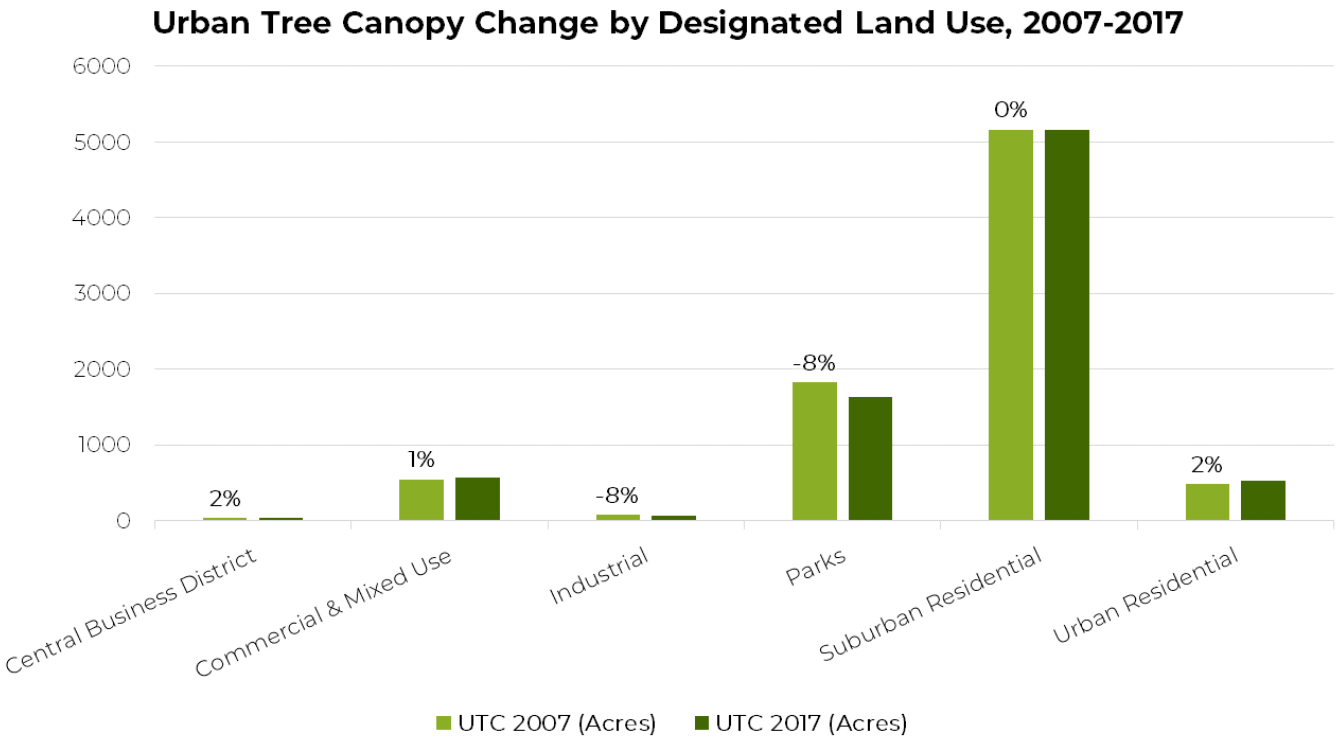

Figure 20. | Urban tree canopy change by designated land uses in Bellevue from 2007-2017.

Table 11. | Comparing urban tree canopy percentages by land use to American Forests' 2007 recommendations.

Designated Land Use	Citywide	Urban Residential	Suburban Residential	Central Business District	Commercial & Mixed Use	Industrial	Parks	ROW
2017 Canopy %	37%	34%	36%	10%	21%	26%	64%	24%
AF Recommended Canopy %	40%	35%	50%	15%	25%	25%	25%	25%
Difference in Canopy %	-3%	-1%	-14%	-5%	-4%	1%	39%	-1%

URBAN TREE CANOPY CHANGE BY NEIGHBORHOODS

Subdividing the results by neighborhoods was also very informative, revealing that almost all of the canopy loss had occurred in a small handful of neighborhoods while the rest experienced slight increases. West Bellevue had the most severe loss, with 108 acres removed equating to a 7 percent reduction in canopy. However, some of this loss can be attributed to changes in methodology related to the classifcation of heavily forested tree canopy in parks. Eastgate, West Lake Sammamish, and Wilburton each lost over 60 acres of canopy, or approximately 4-6 percent of their total canopy. Conversely, Somerset had an increase of 71 acres or 5 percent canopy cover.

Table 12. | Urban tree canopy change by neighborhoods.

Neighborhood	Land Area		UTC 2007		UTC 2017		UTC Change	
	Acres	*Dist.*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
BelRed	963	4%	147	15%	148	15%	0	0%
Bridle Trails	2,022	9%	954	47%	977	48%	23	1%
Cougar Mountain / Lakemont	2,349	11%	1,117	48%	1,155	49%	38	2%
Crossroads	812	4%	212	26%	225	28%	13	2%
Downtown	432	2%	39	9%	45	10%	6	1%
Eastgate	1,759	8%	654	37%	586	33%	-68	-4%
Factoria	387	2%	81	21%	83	21%	2	1%
Lake Hills	2,260	11%	713	32%	689	31%	-23	-1%
Newport	1,706	8%	678	40%	720	42%	42	2%
Northeast Bellevue	1,413	7%	417	29%	427	30%	10	1%
Northwest Bellevue	1,321	6%	433	33%	438	33%	5	0%
Somerset	1,307	6%	513	39%	584	45%	71	5%
West Bellevue	1,683	8%	729	42%	621	37%	-108	-7%
West Lake Sammamish	1,174	5%	539	46%	472	40%	-67	-6%
Wilburton	1,109	5%	477	43%	416	38%	-61	-6%
Woodridge	728	3%	320	44%	289	40%	-31	-4%
Totals	**21,425**	**100%**	**8,022**	**37%**	**7,875**	**37%**	**-148**	**-1%**

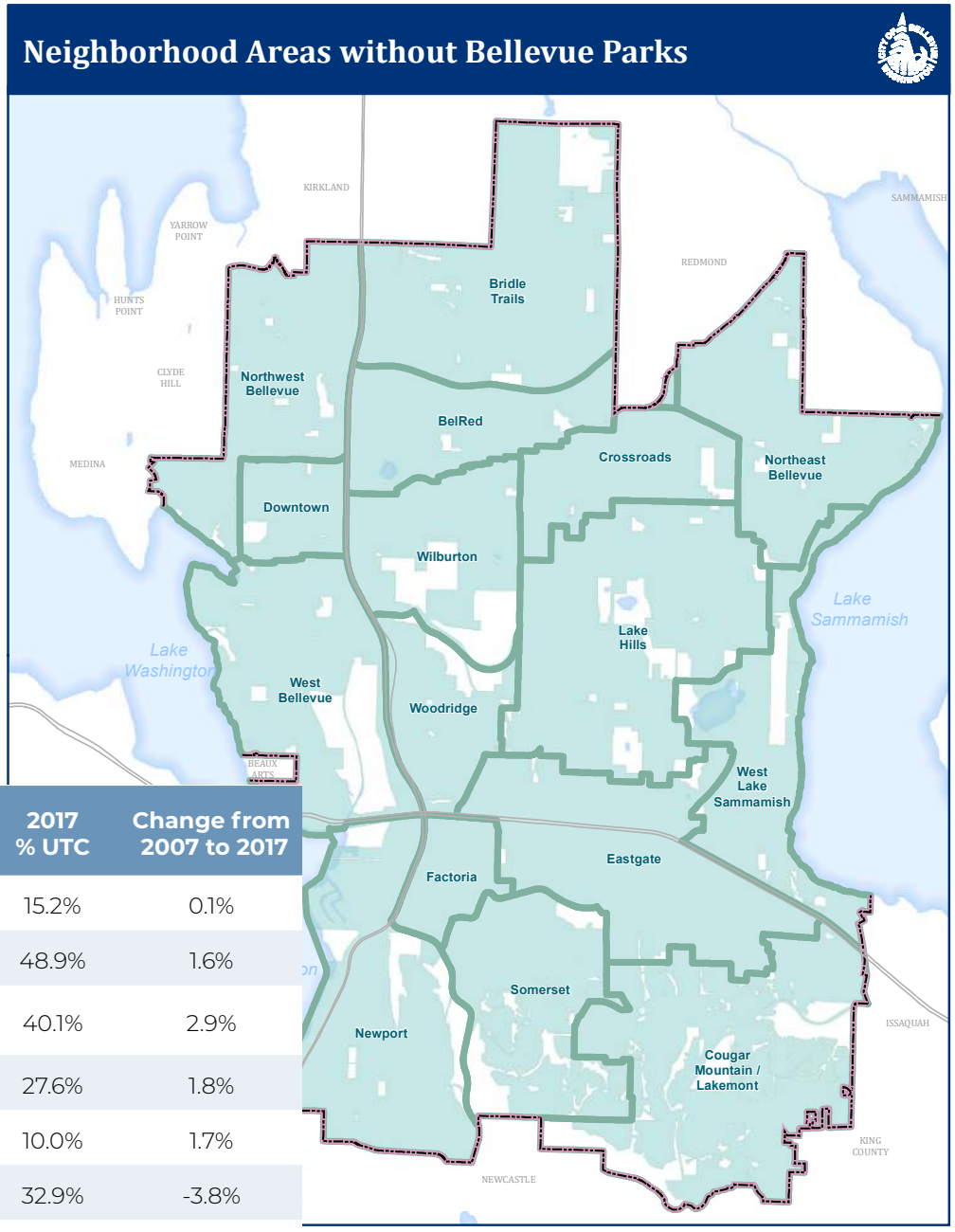

Figure 21. | Bellevue's neighborhoods minus parks.

Neighborhood Areas Minus Bellevue Parks	2007 % UTC	2017 % UTC	Change from 2007 to 2017
BelRed	15.1%	15.2%	0.1%
Bridle Trails	47.4%	48.9%	1.6%
Cougar Mountain / Lakemont	37.2%	40.1%	2.9%
Crossroads	25.8%	27.6%	1.8%
Downtown	8.2%	10.0%	1.7%
Eastgate	36.7%	32.9%	-3.8%
Factoria	20.8%	21.4%	0.6%
Lake Hills	29.3%	28.9%	-0.4%
Newport	30.8%	34.6%	3.9%
Northeast Bellevue	26.3%	27.7%	1.4%
Northwest Bellevue	32.3%	32.8%	0.5%
Somerset	27.8%	34.9%	7.2%
West Bellevue	40.1%	35.4%	-4.7%
West Lake Sammamish	40.6%	36.0%	-4.6%
Wilburton	31.4%	30.0%	-1.4%
Woodridge	39.2%	35.0%	-4.2%
Totals	**32.9%**	**33.1%**	**0.2%**

Table 13. | Urban tree canopy change by neighborhoods minus park lands. Bellevue's parks consist of heavily forested areas. Because of differences in methodology between 2007 and 2017 studies, tree canopy in parks showed significant change. This table removes parks from neighborhoods to show that tree canopy coverage has been steady over the last ten years in Bellevue's neighborhoods.

URBAN TREE CANOPY CHANGE BY CHANGE BY STREAM CORRIDORS

Within Bellevue's stream corridors, there was a 7 percent decrease in tree canopy cover. This is 6 percent greater than the citywide average. These corridors provide a variety of important ecosystem services including, but not limited to, wildlife habitat, water quality, and stormwater runoff, so It is important to maintain the existing tree canopy in these areas.

URBAN TREE CANOPY CHANGE BY CHANGE BY DRAINAGE BASINS

Of the city's 28 drainage basins, 13 experienced losses in canopy, 10 experienced gains, and 5 experienced little to no change. The most significant loss in canopy occurred in the Mercer Slough, which lost 8 percent of its canopy over the ten-year period, while the Newport basin had a 6 percent gain. Refer to the UTC Results spreadsheet for the full change assessment results by drainage basin.

URBAN TREE CANOPY CHANGE BY SCHOOLS

Urban tree canopy on Bellevue's 81 school properties closely reflected the citywide average, with a 1 percent decrease overall. Wilburton had the greatest reduction in canopy, losing 6 of its 8 acres from 2007-2017 (equating to a 60 percent loss). At the other end of the spectrum, Bellevue Children's School more than tripled its canopy over the same time period, increasing their UTC from .07 to .33 acres or by 19 percent. For the full change results by schools, refer to the UTC Results spreadsheet.

URBAN TREE CANOPY CHANGE BY CENSUS BLOCK GROUPS

Perhaps the most informative unit of analysis for the change analysis was the census block groups. As the smallest geographic unit, this assessment revealed changes in canopy at the finest scale. Some block groups lost as much as 11 percent of their canopy while others gained exactly that much. Losses in canopy tended to be concentrated near the center of the city, while the northern and southern edges experienced more increases. Refer to the UTC Results spreadsheet for the full change assessment results by census block groups.

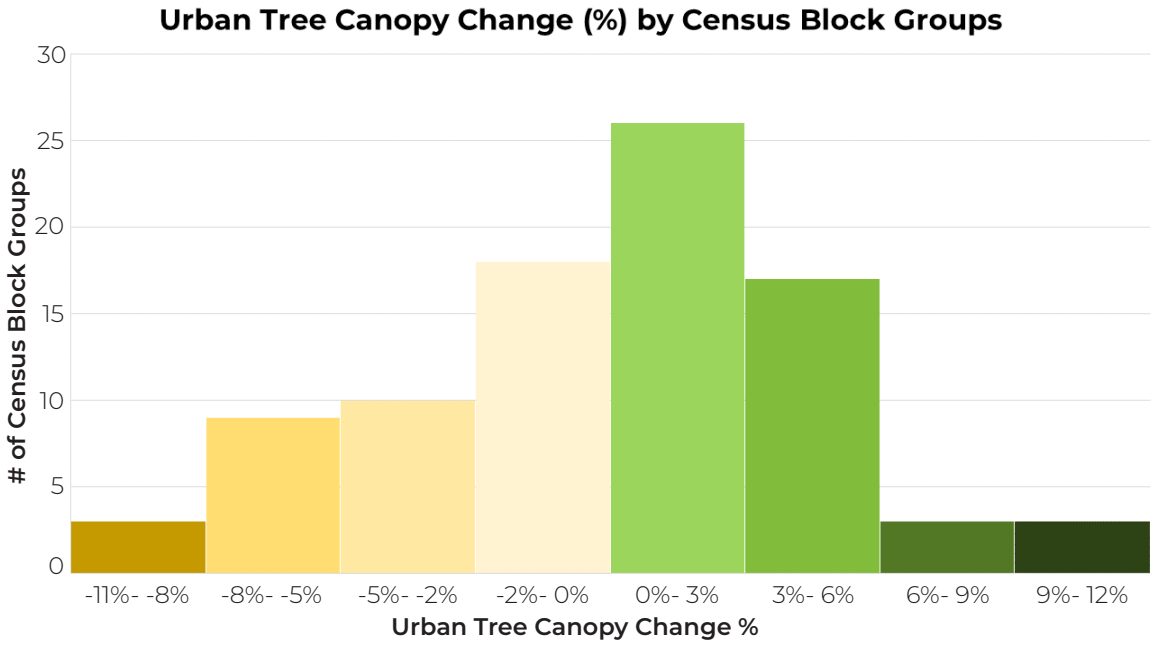

Figure 22. | Number of census block groups within percent canopy cover change ranges.

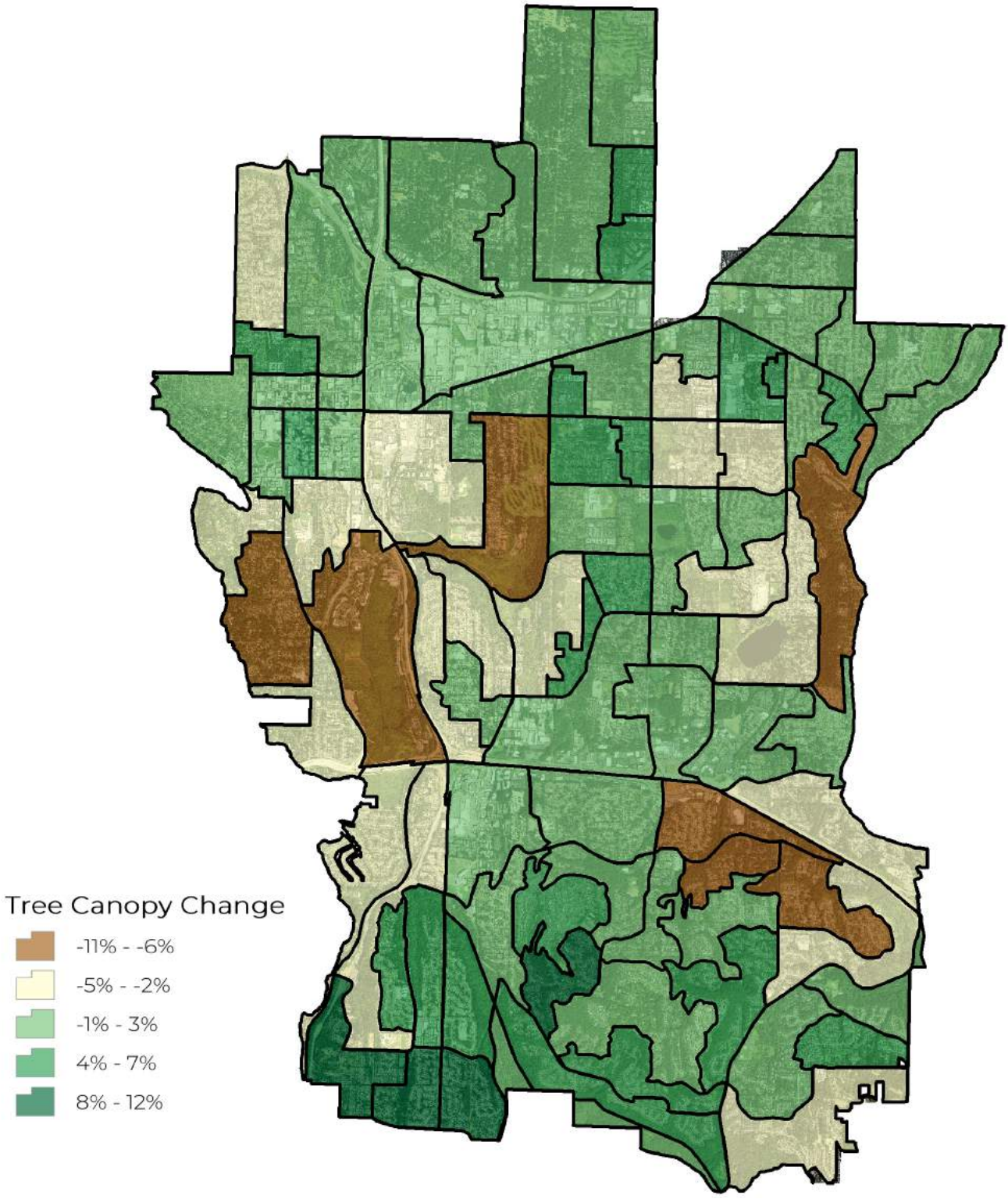

Figure 23. | Urban tree canopy change by census block groups from 2007-2017.

URBAN TREE CANOPY CHANGE BY RIGHT-OF-WAY CENSUS BLOCK GROUPS

Again, changes in UTC were assessed for only the right-of-way areas within each census group, in addition to within the full census block group areas. Interestingly, these areas had an overall 5 percent increase in canopy, in contrast to the citywide average of -1 percent. UTC change for the right-of-way areas within each census block group varied, with the greatest decrease at -15 percent and the greatest increase at 18 percent. Refer to the UTC Results spreadsheet for the full change results by right-of-way by census block group.

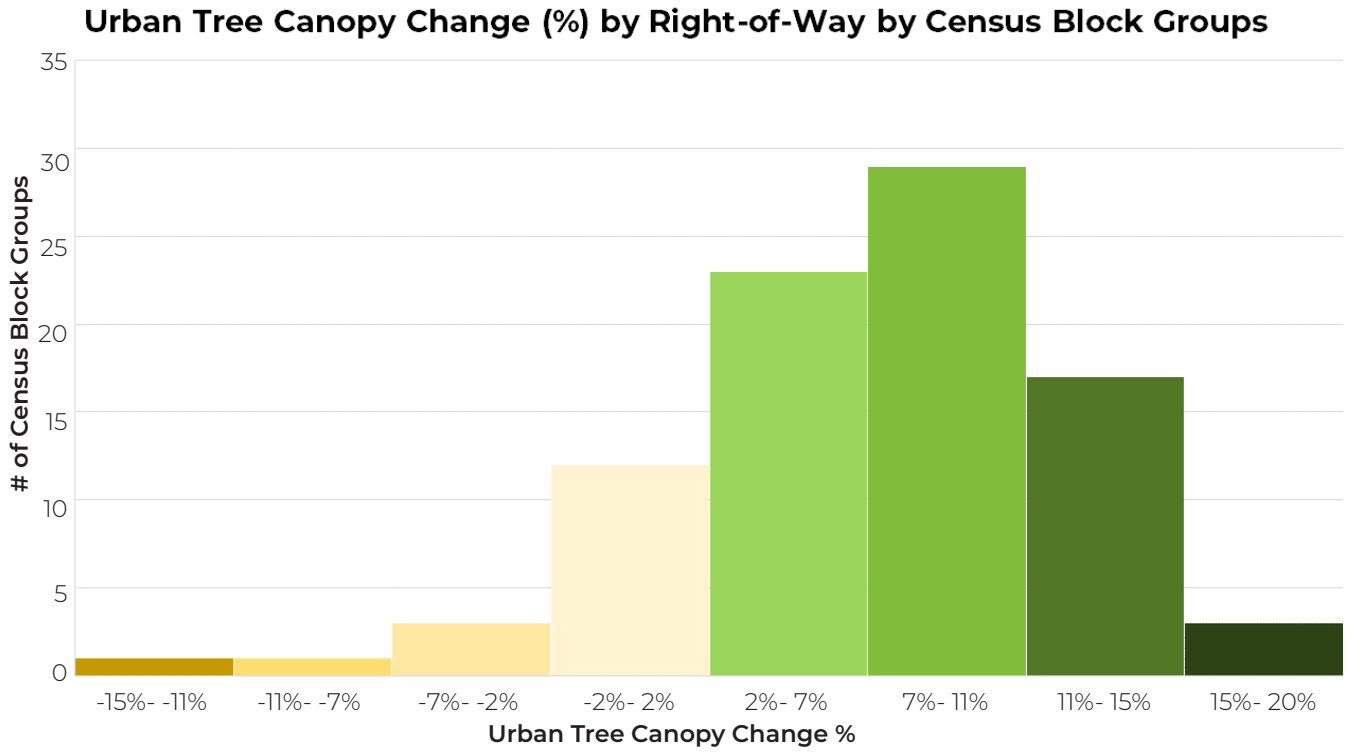

Figure 24. | Number of census block groups by right-of-way within percent canopy cover change ranges.

TREE CANOPY CORRELATIONS

The urban forest is an integral part of the character of Bellevue for all those that live, work, and visit the city. Benefits of trees are referred to as "ecosystem services" and describe the ways that urban forests impact our lives and the environment. To further guide and assist city planning efforts, the correlations between tree canopy cover and several socioeconomic and demographic factors were analyzed. Using data from the U.S. Census Bureau at the census block group level, racial and ethnic diversity, income levels, and home values were compared with the percentage of canopy cover. Correlations were identified for each factor analyzed indicating areas in greatest need of ecosystem services provided by the urban forest.

One trend showed that census block groups where a large percentage of the population are part of racial and ethnic minority groups had less than the average city-wide tree canopy cover. In areas where minorities made up more than half of the population, canopy coverage was 7% less than the city-wide average. The least diverse census block groups (>75% white) had slightly above average canopy cover (38%).

The rate of poverty showed a negative correlation with tree canopy coverage. In areas where 10% or more of the population was below the poverty line or "underserved", the average canopy coverage was 26%, 10% lower than the city-wide average. Census block groups where 10% or less of the population was below the poverty line, the average canopy coverage was equivalent to the city-wide average.

There was a positive correlation in Bellevue between tree canopy cover and median home values. For areas with median home values less than the city-wide average (~$550,000), tree canopy coverage was 5% less than the city-wide tree canopy cover average. Census block groups with home values greater than the city's average had canopy coverage rates over 2% higher than the city-wide average.

Table 14 - Tree canopy rates by various demographic and socioeconomic factors.

	Bellevue Citywide Tree Canopy	More Than 50% Minority Population	Less Than 25% Minority Population	> 10% Under-served Population	< 10% Under-served Population	Greater Than Average Home Values	Less Than Average Home Values
Tree Canopy %	37%	30%	38%	26%	37%	39%	32%
Difference from City average	-	-7%	1%	-11%	0%	2%	-5%

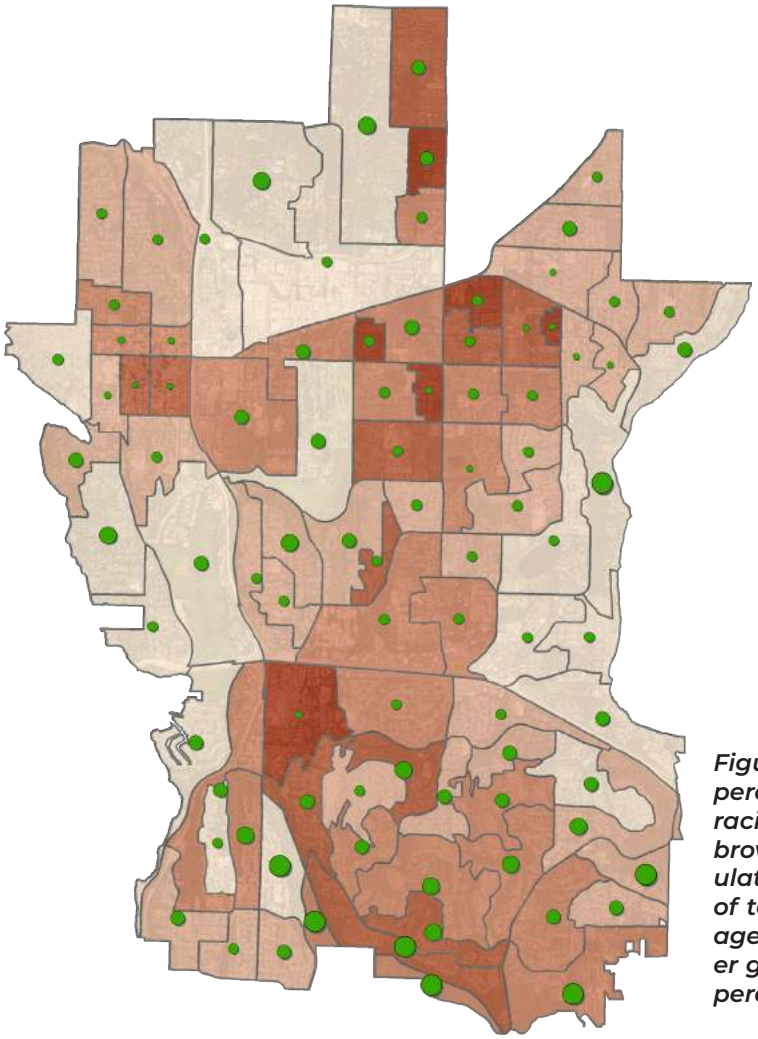

Figure 25. | Census block groups showing the percentage of the population that are part of racial and ethnic minority groups. The darker brown colors represent higher minority population percentages, while the lighter shades of tan represent lower. Tree canopy percentages are illustrated by the green circles. Larger green circles represent higher tree canopy percentages.

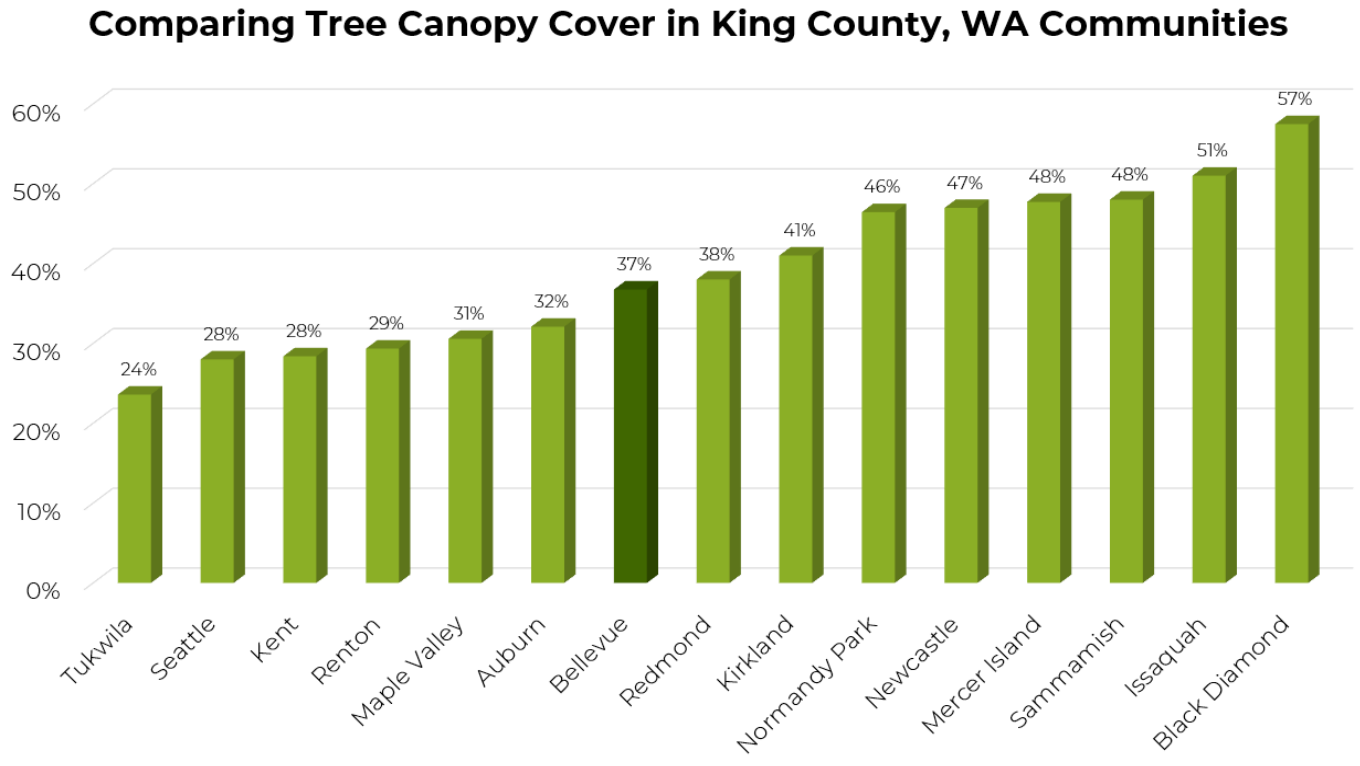

Figure 26. | A comparison of tree canopy in 15 cities in the surrounding area.

RECOMMENDATIONS

To preserve, protect, and maintain Bellevue's tree canopy, the City should continue having a tree canopy assessment performed on a regular interval. As the City changes, they will be able to use these recommendations to ensure that their urban forest policies and management practices prioritize its maintenance, health, and growth. Bellevue'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. These updated results can be used to interpret where these gains have been 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 results of this assessment can and should be used to encourage investment in forest monitoring, maintenance, and management; 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. 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.

72% of the city's tree canopy is in suburban and urban residential land use areas.

Bellevue's 37% tree canopy falls short of the City's comprehensive plan goal of a 40% tree canopy, which is also a best practice recommendation from American Forests. In the 2007 study, American Forests provided the following recommendations for tree canopy in different land use types:

- Urban Residential: 35%
- Suburban Residential: 50%
- Central Business District: 15%
- Commercial and Mixed Use: 25%
- Industrial: 25%
- Parks: 25%
- Right-of-Way: 25%

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 reductions in canopy coverage occurred city-wide in previous decades, breaking up the results by several different geographic boundaries demonstrated that the recent gains have not been evenly distributed. These results can be used as a guide to determine which areas would receive the greatest benefits from the investment of valuable time and resources into Bellevue's urban forest.

SUBURBAN RESIDENTIAL NEIGHBORHOODS ARE PRIME AREAS FOR INCREASING TREE CANOPY

Urban residential designated land use areas saw an increase in tree canopy coverage of about 2.5%. These areas have a higher population density than their suburban residential counterparts. Therefore, an increased tree canopy coverage in these areas will provide benefit to a larger number of residents. In 2007, American Forests recommended that Bellevue's urban residential areas should have a canopy goal of 35%. Tree canopy coverage in 2017 was estimated at just under 34%. The city should continue to focus on these areas by making use of the available PPA (433 acres or 28%) on both vegetated surfaces (13%) as well as impervious surfaces (15%) such as parking lots for apartment complexes.

Suburban residential areas experienced very little net change in tree canopy coverage between 2007 and 2017, however, some neighborhoods experienced a greater loss of trees than others. American Forests recommended that tree canopy coverage expand to 50% in these areas, however, that figure stands at about 36%. The city should focus on community outreach and education programs to better inform citizens and private land holders of the environmental, social, and financial benefits that trees provide and consider other strategies to help preserve and grow the tree canopy.. Tree giveaways and tree planting programs can be developed to further promote new tree plantings. Since a majority of Bellevue is considered suburban residential land, these areas provide the greatest opportunity to increase tree canopy cover throughout the city. There is ample room for growth, with 26% of these areas being considered possible planting areas.

Schools within the Bellevue school district are prime areas for increasing tree canopy. In 2017, there was 24% tree canopy coverage. Since 2007, tree canopy coverage on all school properties was stable showing just a small loss of 7 acres. There was also 29% PPA in open vegetated areas as well as parking lots and sidewalks. Sports fields and play areas were excluded from PPA. School tree planting programs are a great way to teach students why trees matter while also empowering them to take action and improve conditions in their neighborhood.

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. An accuracy assessment was performed on both land cover datasets – one derived from the previous AMEC study in 2007 and another from this study – to evaluate both their individual accuracy and how they compare to each other.

The classification accuracy error matrices illustrated in Figures 24 and 25 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 both 2007 and 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. Six hundred and thirty two (632) sample points, or approximately 18 points per square mile area in Bellevue (33.5 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 Bellevue’s landscape. The error matrices shown in Figure 24 and 25 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.

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(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.

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 (using the 2017 matrix in Figure 21 as an example, 214 + 103 + 205 + 22 + 38 = 582 / 632 = 92 percent). At the 95% confidence interval, there is a 2.1% margin of error.

The matrix can be used to calculate per class accuracy percent's. For example, 227 points were manually identified in the reference map as Tree Canopy, and 214 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: (214/227 = .94), meaning that we can expect that ~94 percent of all 2017 tree canopy in the Bellevue, 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, 233 classification pixels intersecting reference pixels were classified as Tree Canopy, but 16 pixels were identified as Vegetation, 2 were identified as soil/dry vegetation, and 1 pixel was identified as Impervious in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (214/233 = 0.92), meaning that ~92 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 Bellevue in 2017. The largest sources of classification confusion exist between tree canopy and vegetation.

Reference Data

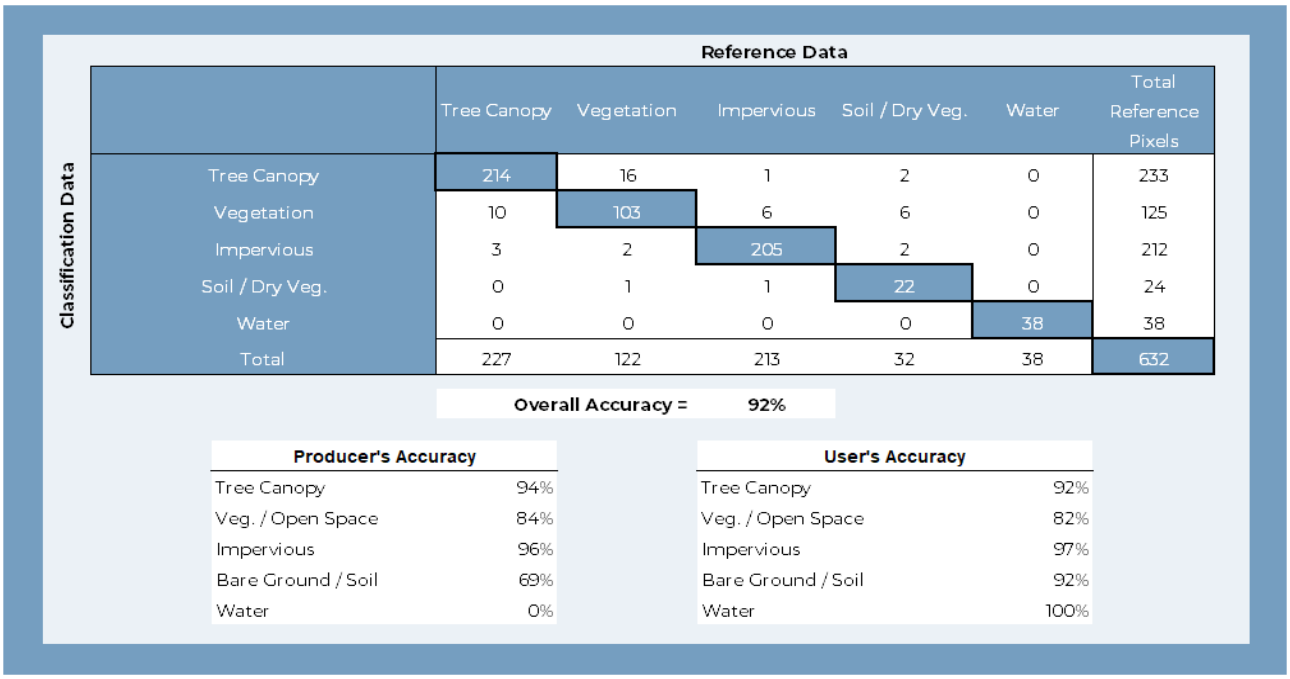
Classification Data	Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	230	18	14	0	0	262
Vegetation	33	102	29	0	0	164
Impervious	7	7	200	0	1	215
Soil / Dry Veg.	0	0	2	1	0	3
Water	0	0	0	0	21	21
Total	270	127	245	1	22	665

Overall Accuracy = 83%

Producer's Accuracy	
Tree Canopy	85%
Veg. / Open Space	80%
Impervious	82%
Bare Ground / Soil	100%
Water	0%

User's Accuracy	
Tree Canopy	88%
Veg. / Open Space	62%
Impervious	93%
Bare Ground / Soil	33%
Water	100%

Figure 27. | Error matrix for land cover classifications in Bellevue, WA (2007).



Classification Data	Reference Data: Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	214	16	1	2	0	233
Vegetation	10	103	6	6	0	125
Impervious	3	2	205	2	0	212
Soil / Dry Veg.	0	1	1	22	0	24
Water	0	0	0	0	38	38
Total	227	122	213	32	38	632

Overall Accuracy = 92%

Producer's Accuracy	
Tree Canopy	94%
Veg. / Open Space	84%
Impervious	96%
Bare Ground / Soil	69%
Water	0%

User's Accuracy	
Tree Canopy	92%
Veg. / Open Space	82%
Impervious	97%
Bare Ground / Soil	92%
Water	100%

Figure 28. | Error matrix for land cover classifications in Bellevue, WA (2017).

ACCURACY ASSESSMENT RESULTS

Interpretation of the sample error matrix offers some important insights when evaluating Bellevue'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 Bellevue's current tree canopy can be safely assumed to match the figures stated in this report (approximately 37 percent). However, the slightly lower accuracy of the 2007 data indicates that the previously stated canopy amount of 38 percent may have been slightly under- or over-reported. Specifically, the results indicate that in 2007, only 85 percent of tree canopy on the ground may have been captured in the classification map (producer's accuracy), while only 88 percent of points identified as tree canopy may have truly been tree canopy.

I-TREE HYDRO STORMWATER ANALYSIS

i-Tree Hydro is a tool designed to simulate the impacts that tree canopy cover, impervious surfaces, and other land cover types have on the hydrological cycle. Users of the tool can make use of existing input datasets provided by i-Tree or they can incorporate their own data for hourly weather, streamflow, and elevation (either a Digital Elevation Model [DEM] or one of Hydro's pre-formatted topographic index files). One or many different land cover scenarios can be defined in order to estimate the impact on stormwater runoff. Reports detailing these impacts can be exported. Additional parameters can be configured such as soil texture and conductivity. However, these variables are recommended for more advanced users. The default regional values that are provided should be sufficient for the average user.

For the purposes of this study, a simplified version of the model was used utilizing only pre-existing data already available in i-Tree Hydro. A topographic index was chosen to represent the area of interest (see Appendix 2, page 47 of the i-Tree Hydro User's Manual for more information on topographic indexes). Baseline land cover conditions created by this tree canopy assessment were incorporated. To create an alternate land cover scenario, all existing tree canopy was removed and converted to herbaceous or impervious land cover to show a drastic case where all canopy cover in Bellevue was removed. The results, provided in total stormwater runoff over a specified period of time, can help natural resource managers and urban planners engage in meaningful discussions to better describe the impacts of land cover changes in their cities. The results in Figure 1, below, are presented as raw numbers (cubic feet) and a percent change (%) from the base case scenario. At the time of publication, Plan-It Geo is engaged in a comprehensive analysis of the i-Tree Hydro tool's applications in western Washington. This project will provide much more detailed modeling scenarios and offer guidance on best practices. This project is anticipated to be completed in 2019.

Table 15. | Stormwater runoff values using existing the existing land cover and an alternate scenario where all tree canopy was removed.

Land Cover	Base (%)	Alternate (%)	Change (%)
Tree Canopy	36.8%	0.0%	-36.8%
Pervious Under Tree Canopy	32.5%	0.0%	-32.5%
Impervious Under Tree Canopy	4.4%	0.0%	-4.4%
Shrub	1.6%	1.6%	0.0%
Herbaceous	17.1%	49.5%	32.4%
Water	0.6%	0.6%	0.0%
Impervious	39.6%	43.9%	4.3%
Soil	4.4%	4.4%	0.0%
Streamflow Predictions	**Base (m^3)**	**Alternate (m^3)**	**Change (%)**
Total Flow	12,348.8	12,635.0	2.0%
Base Flow	1,258.0	1,277.3	2.0%
Pervious Runoff	5,978.0	6,187.5	4.0%
Impervious Runoff	5,112.8	5,170.1	1.0%

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. They are generally between 5 and 10 feet tall.

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, 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 Bellevue’s urban forest. Tree canopy is generally taller than 10-15 feet tall.

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

SEPTEMBER | 2018

URBAN TREE CANOPY

ASSESSMENT

BELLEVUE, WASHINGTON

plan-it GEO

King Conservation District

CITY OF BELLEVUE WASHINGTON