URBAN TREE CANOPY

ASSESSMENT

NORMANDY PARK, WASHINGTON

NOVEMBER | 2018

King Conservation District

plan-it GEO

City of Normandy Park

AN ASSESSMENT OF
URBAN TREE CANOPY

NORMANDY PARK, WASHINGTON

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

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TABLE OF CONTENTS

740
ACRES OF TREE CANOPY

EXECUTIVE SUMMARY

PURPOSE OF THIS ANALYSIS

The City of Normandy Park is located within King County, Washington, in the Seattle metropolitan area (Figure 1). It is approximately 2.5 square miles or 1,622 acres, of which 1,593 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 was to provide a baseline and benchmark of the City's tree canopy and interpret the results across a range of geographic boundaries.

URBAN TREE CANOPY IN NORMANDY PARK

Results of this study indicated that in 2017, the city of Normandy Park contained 46 percent tree canopy (or 740 of the city's 1,622 total acres); 29 percent non-canopy vegetation (462 acres); 3 percent soil/dry vegetation (46 acres); 21 percent impervious surfaces (345 acres); and 2 percent water (29 acres). Existing urban tree canopy covered 46 percent of Normandy Park's land area (740 of the city's 1,593 land acres). Of the city's 54 percent of land area not presently occupied by tree canopy, 29 percent (456 acres) was suitable for future tree plantings, and 25 percent (391) was unsuitable due to its current land use or other restraint. In further dividing the city's urban tree canopy, 19 percent was deciduous, 81 percent was evergreen, and 12 percent was overhanging impervious surfaces.

ASSESSMENT BOUNDARIES

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; HUC-12 watersheds (2); county land use classes (6); census block groups (9); critical environmental areas (10); city-owned areas (49); and parcels (2,563). Additionally, the city's urban tree canopy was subdivided into deciduous and evergreen classes and delineated as overhanging impervious surfaces or not.

Figure 1. | Normandy Park occupies approximately 2.5 square miles in King County, Washington.

RECOMMENDATIONS

The results of this analysis can be used to develop a continued strategy to protect and expand Normandy Park's urban forest. Normandy Park should use these UTC and PPA metrics to inform management actions to ensure that its trees are able to provide the city with valuable environmental, ecological, economic, and social benefits far into the future. By comparing where the city's canopy is currently lacking with the greatest opportunities for future tree plantings, Normandy Park can generate the maximum benefits possible.

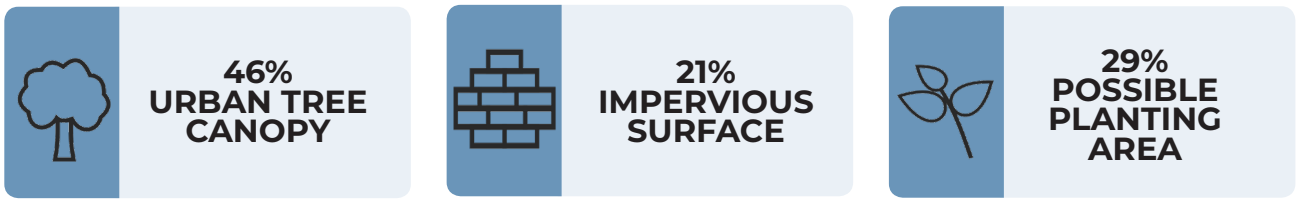


Figure 2. | Based on an analysis of 2017 high-resolution imagery, Normandy Park contains 46% tree canopy, 29% areas that could support canopy in the future, and 21% total impervious areas.

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.

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 Normandy Park were also incorporated into the analysis.

MAPPING LAND COVER

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

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.

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 overhanging impervious surfaces was also quantified to assist with hydrologic modeling.

IDENTIFYING POSSIBLE PLANTING AREAS AND UNSUITABLE AREAS FOR PLANTING

In addition to quantifying Normandy Park'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 Normandy Park that was not existing tree canopy coverage was classified as either possible planting area (PPA) or unsuitable for planting. Possible planting areas were derived from the Non-Canopy Vegetation class. Unsuitable areas, or areas where it was not feasible to plant trees due to biophysical or land use restraints (e.g. 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 and Unsuitable Vegetation, Unsuitable Impervious, Unsuitable Soil, and Total Unsuitable.

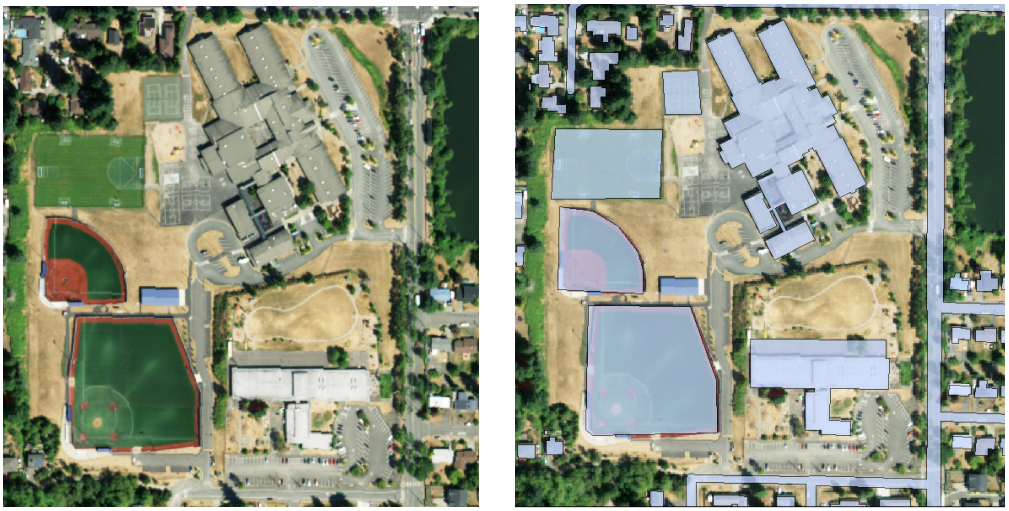


Figure 4. | Vegetated areas where it would be biophysically feasible for tree plantings but undesirable based on their current usage (left) were delineated in the data as "Unsuitable" (right). These areas included recreational sports fields, golf courses, and other open space.

DEFINING ASSESSMENT LEVELS

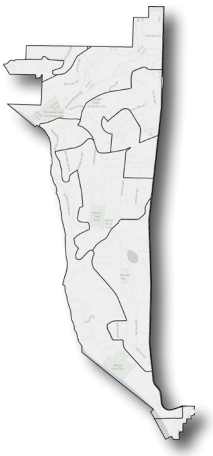
In order to best inform the City Council and all of Normandy Park's various stakeholders, urban tree canopy and other associated metrics were tabulated across a variety of geographic boundaries (Figure 5). These boundaries include the city boundary, watersheds, land use classes, census block groups, critical environmental areas, city-owned areas, and parcels.

- The City of Normandy Park'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 Normandy Park. 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) King County land use classes were analyzed to assess differences in tree canopy across different human uses of land.
- Nine (9) 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.
- Trees also provide innumerable environmental benefits such as preventing erosion, offering a habitat for wildlife species, and cleaning the air and water, therefore ten (10) critical areas were assessed. These included designated erosion and landslide areas, floodplains, and wetlands.
- City-owned areas were analyzed to help the city interpret how it is doing at maintaining its urban forest on the land the city itself manages, and totaled forty-nine (49).
- The smallest unit of analysis was parcels, of which there were over two thousand (2,563) total. This is helpful for assessing the canopy on an individual piece of property.

City of Normandy Park

Watersheds

Land Uses



Census Block Groups

Critical Areas

City-Owned Areas

Parcels

Figure 5. | Seven distinct geographic boundaries were explored in this analysis: the full city boundary, watersheds, land use classes, census block groups, critical areas, city-owned areas, and parcels.

STATE OF THE CANOPY AND KEY FINDINGS

This section presents the key findings of this study including the land cover base map and canopy 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 46 percent of Normandy Park's land cover; non-canopy vegetation was 29 percent; soil/dry vegetation was 3 percent; impervious was 21 percent; and water was 2 percent. These generalized land cover results are presented below in Table 1 and in Figure 6.

Table 1. | Generalized land cover classification results for the City of Normandy Park, WA.

City Boundary	Total Area	Tree Canopy	Non-Canopy Vegetation	Impervious Surfaces	Soil & Dry Vegetation	Water
Acres	1,622	740	462	345	46	29
% of Total	100%	46%	29%	21%	3%	2%

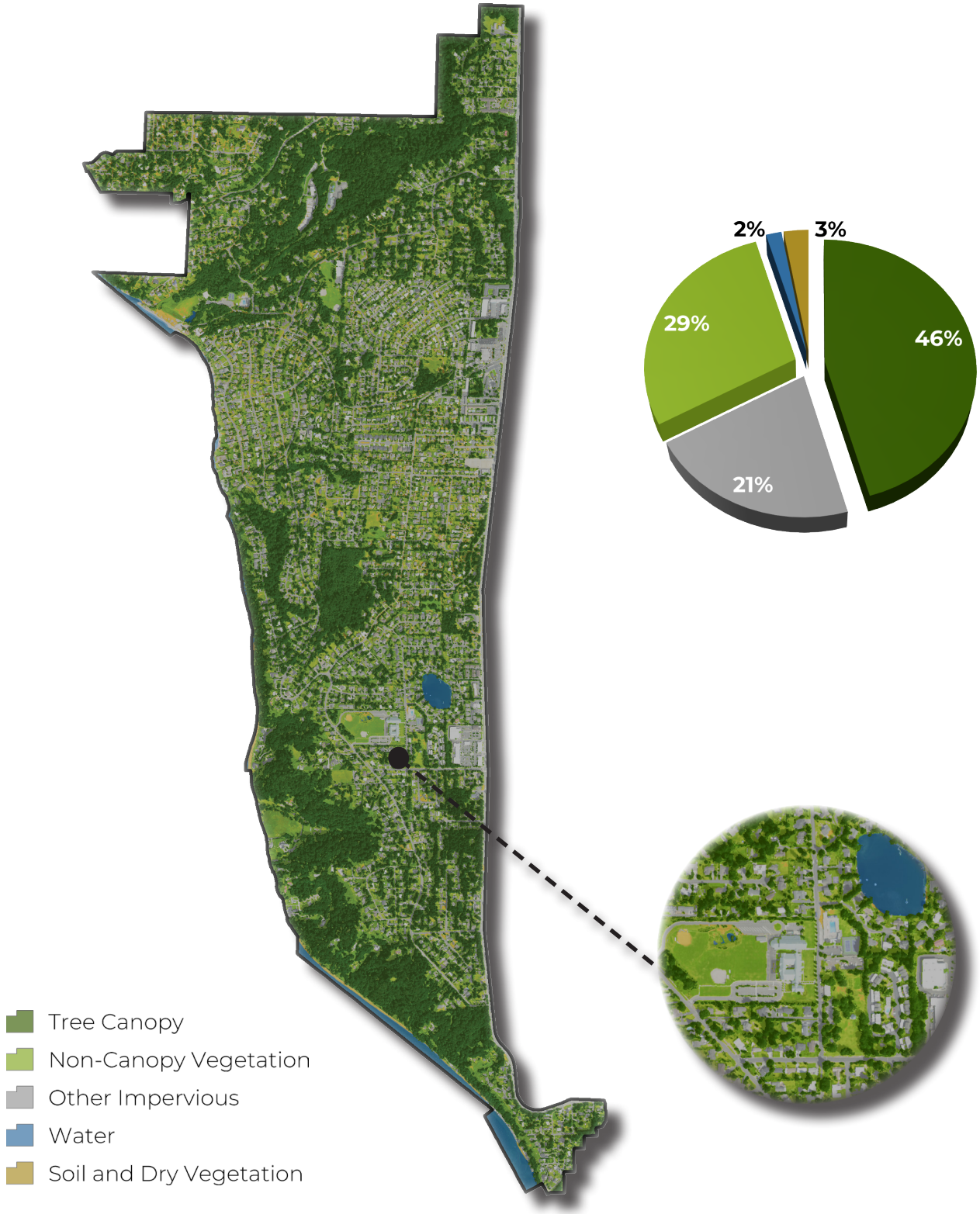


Figure 6. | Land cover classes for Normandy Park, Washington based on 2017 NAIP imagery and 2016 PSLC LiDAR data. (Percentages based on total acres.)

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. 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 Normandy Park, 740 acres are covered with urban tree canopy, making up 46 percent of the city's 1,593 land acres; 456 acres are covered with other vegetation where it would be possible to plant trees (PPA), making up 29 percent of the city; and the other 391 acres were considered unsuitable for tree planting, making up 25 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.

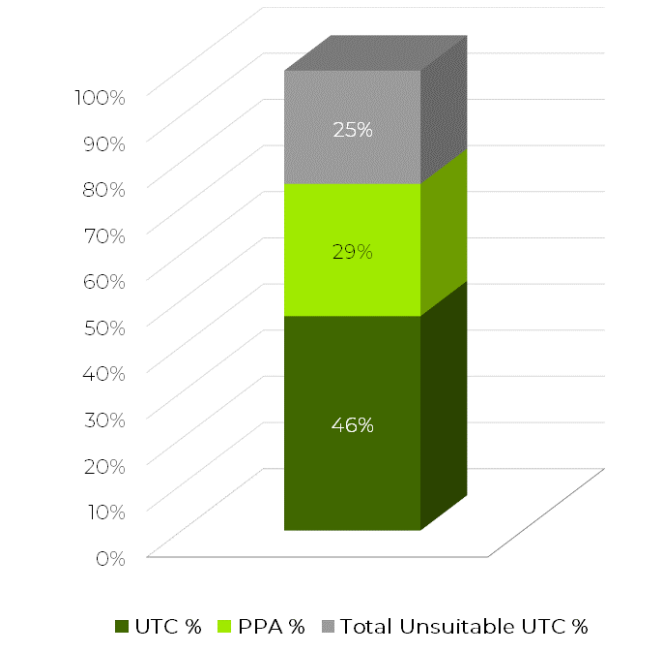


Figure 7. | Urban tree canopy, potential planting area, and area unsuitable for UTC in the City of Normandy Park.

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

City of Normandy Park	Acres	%
Total Area	1,622	100%
Land Area	1,593	98%
Urban Tree Canopy	740	46%
Possible Planting Area	456	29%
Unsuitable Vegetation	6	<1%
Unsuitable Impervious	345	22%
Unsuitable Soil	46	3%
Total Unsuitable Areas	391	25%

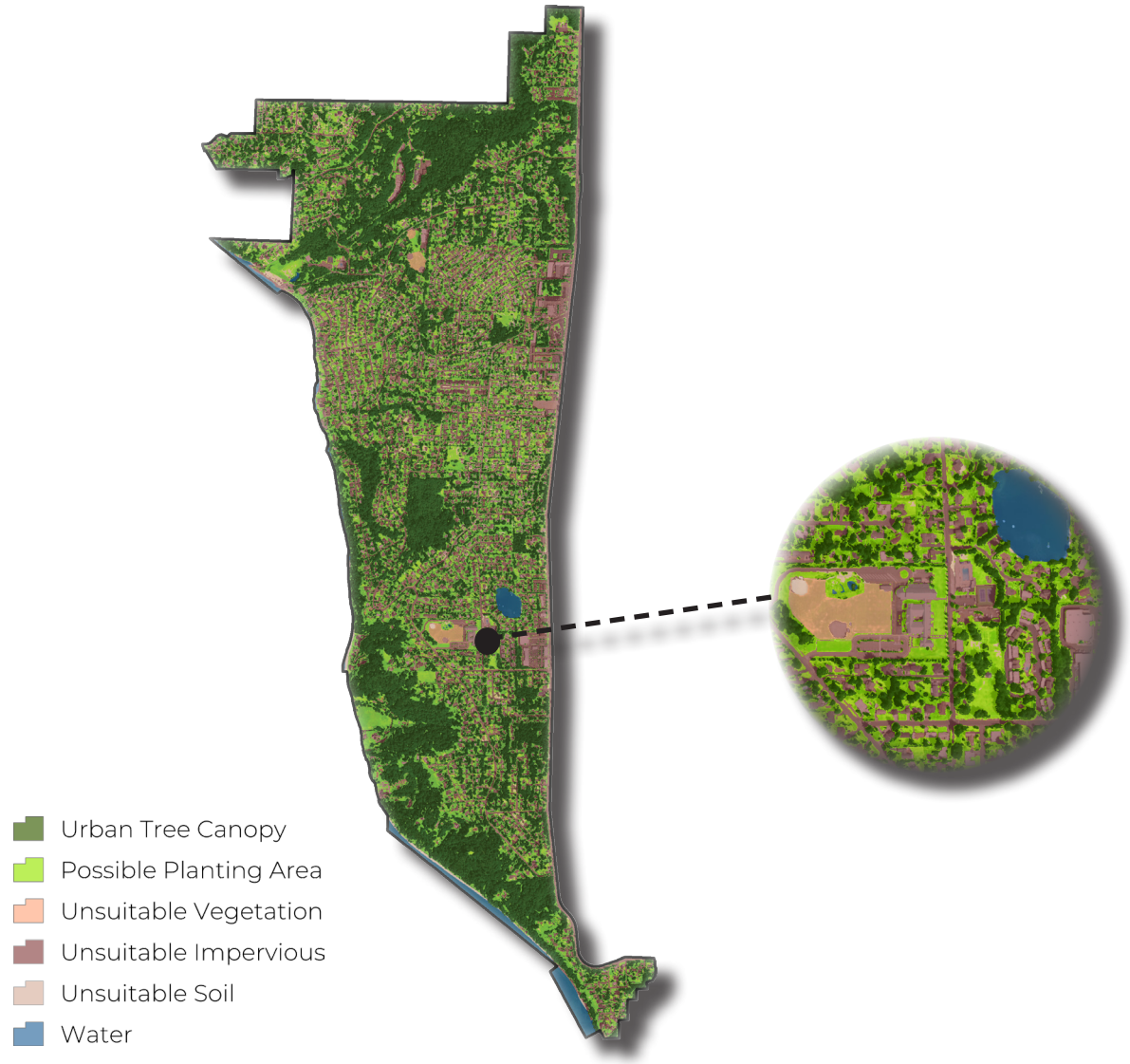


Figure 8. | Urban tree canopy, possible planting area, and area unsuitable for UTC in the City of Normandy Park.

The city's 740 acres of urban tree canopy was further divided into several subcategories based on whether the trees were deciduous (broad-leafed) or evergreen and whether they had an impervious or a 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 city's UTC was significantly dominated by evergreen trees with 81 percent evergreen canopy and 19 percent deciduous canopy. In Normandy Park, 12 percent of all tree canopy had an impervious understory.

Table 3. | Detailed urban tree canopy classifications.

City of Normandy Park	Acres	%
Deciduous Urban Tree Canopy	142	19%
Evergreen Urban Tree Canopy	598	81%
Tree Canopy with Impervious Understory	86	12%

URBAN TREE CANOPY BY WATERSHEDS

UTC and PPA were assessed for the two HUC-12 watersheds found within Normandy Park (Table 4). These are the Miller Creek-Frontal East Passage, which occupies most of the city's area, and the Puget Sound, which intersects a very small portion of the city along its western boundary (i.e. the coastline). The Miller Creek-Frontal East Passage watershed's UTC metrics were similar to those of the full city boundary, with 47 percent canopy cover and 29 percent possible planting area. The coastal Puget Sound watershed had only 24 percent UTC and 12 percent PPA while most (63 percent) of its area was unsuitable for UTC, likely because it is predominantly a shoreline.

Table 4. | Urban tree canopy assessment results by watersheds. 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.*
Miller Creek-Frontal East Passage	1,587	1	738	0	1	456	0	1
Puget Sound	6	0.3%	1	24%	0.2%	0.7	12%	0.1%
Totals	**1,593**	**100%**	**740**	**46%**	**100%**	**456**	**29%**	**100%**

URBAN TREE CANOPY BY LAND USES

UTC and PPA were assessed for the city's six different land use categories found within the King County comprehensive plan land use data layer (Table 5). The parks class had the highest percentage of canopy cover with 69 percent, while the general commercial class had the lowest at 18 percent. General commercial areas also had the lowest PPA at 9 percent whereas single-family residential areas had the greatest percentage of PPA, 32 percent. The single-family residential class contributed the greatest proportion of the citywide totals of UTC (74 percent) and PPA (81 percent), indicating that this land use provides the city with most of its existing urban forest resource as well as its greatest opportunities for future urban forest expansion.

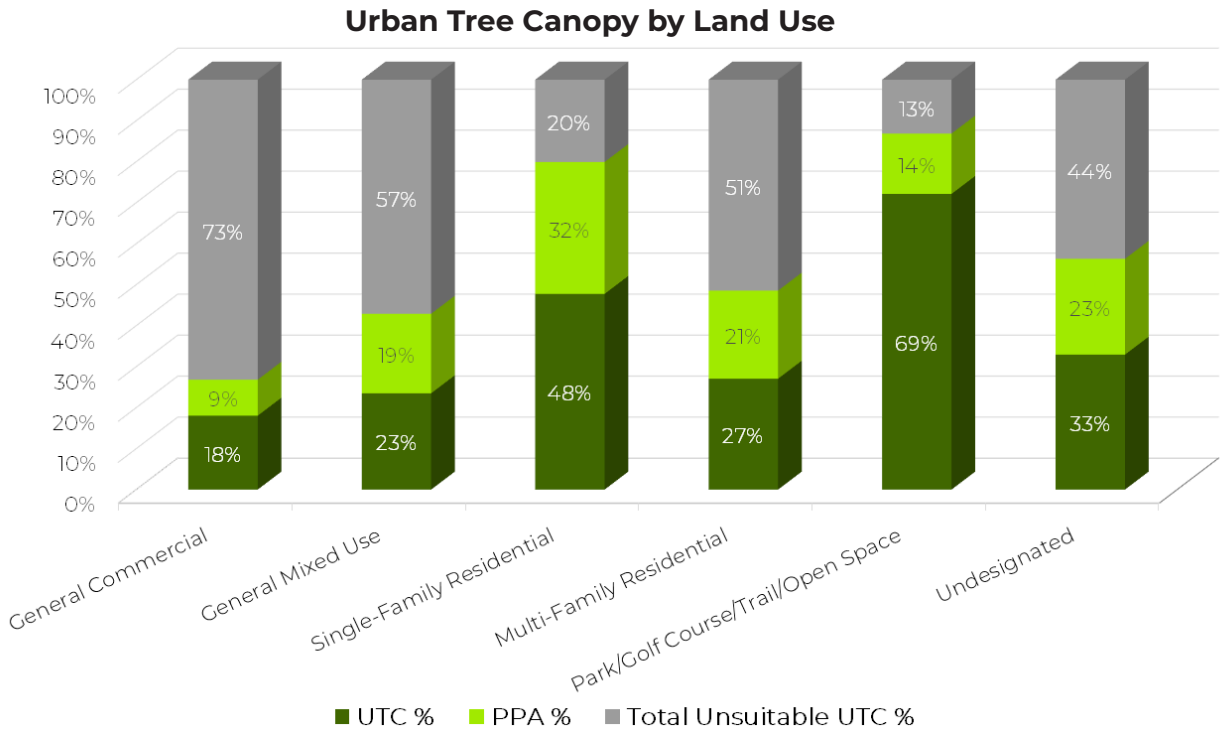
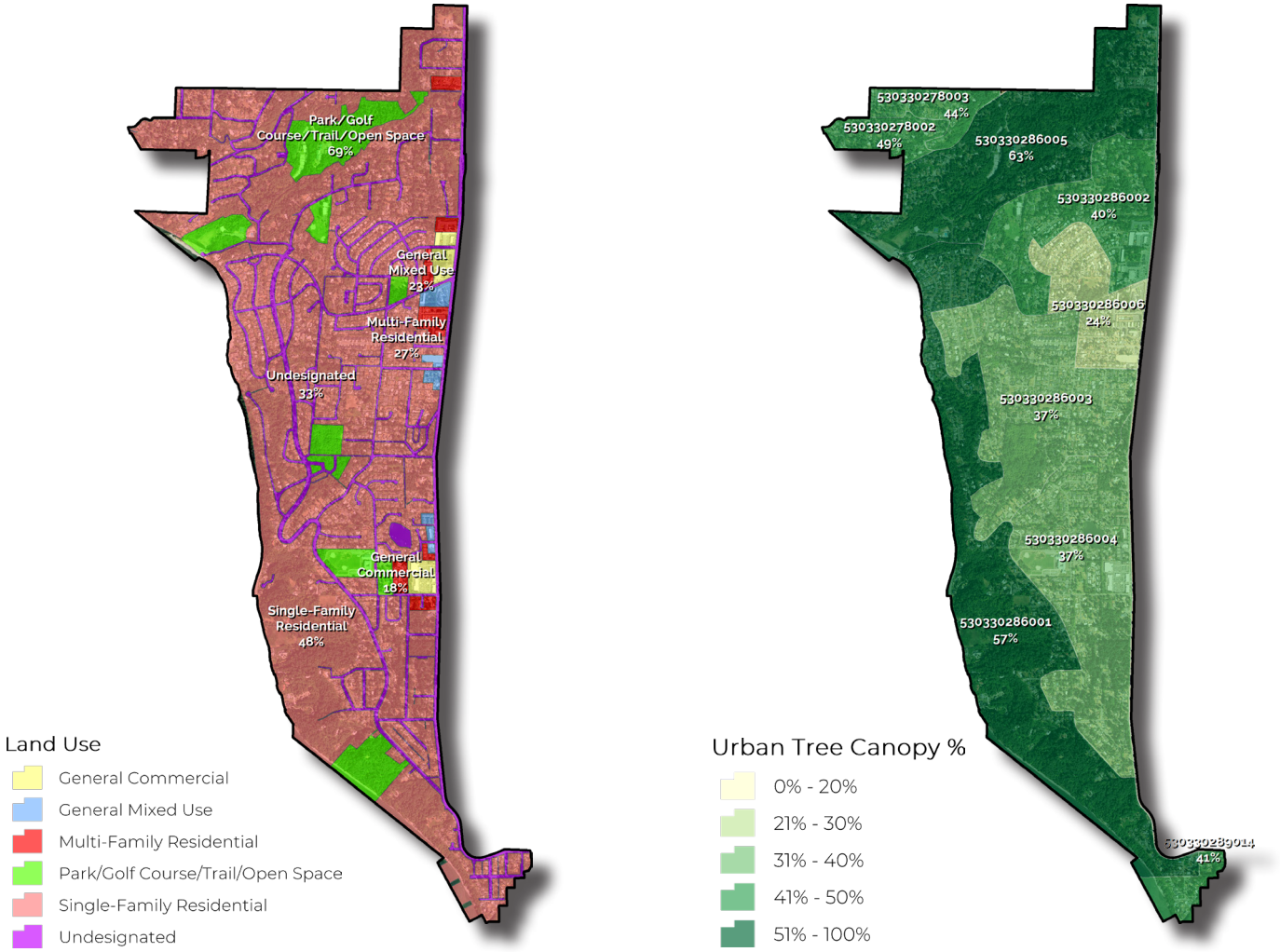


Figure 9. | Urban tree canopy, potential planting area, and area unsuitable for UTC by land use.

Table 5. | Urban tree canopy assessment results by land use. UTC and PPA results include acres, percent of area covered by UTC or PPA (%), and distribution of the city's total UTC or PPA within each land use (dist.).

Land Use	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	Dist.	Acres	%	Dist.	Acres	%	Dist.
General Commercial	19	1%	3	18%	0%	2	9%	0%
General Mixed Use	14	1%	3	23%	0%	3	19%	1%
Single-Family Residential	1,149	72%	549	48%	74%	370	32%	81%
Multi-Family Residential	30	2%	8	27%	1%	6	21%	1%
Park/Golf Course/Trail/Open Space	140	9%	96	69%	13%	20	14%	4%
Undesignated	237	15%	78	33%	11%	55	23%	12%
Totals	**1,590**	**100%**	**738**	**46%**	**100%**	**456**	**29%**	**100%**



Figures 10 and 11. | Urban tree canopy in Normandy Park by county land uses (left) and census block groups (right).

URBAN TREE CANOPY BY CENSUS BLOCK GROUPS

UTC and PPA were assessed at the census block group (CBG) level. This unit of measure is particularly valuable for assessing the equitable distribution of tree canopy throughout the city as the CBGs are linked to all demographic and socioeconomic U.S. Census data. Results indicated that tree cover varies substantially throughout the city and ranged from 24 percent UTC in the lowest CBG to 63 percent in the greatest. PPA varied less dramatically across the various block groups and ranged from 22 percent in the CBG with the least PPA (which was also incidentally the CBG with the highest existing UTC) to 34 percent in the CBG with the greatest PPA.

Urban Tree Canopy Compared to Total Area and Land Area by Census Block Groups

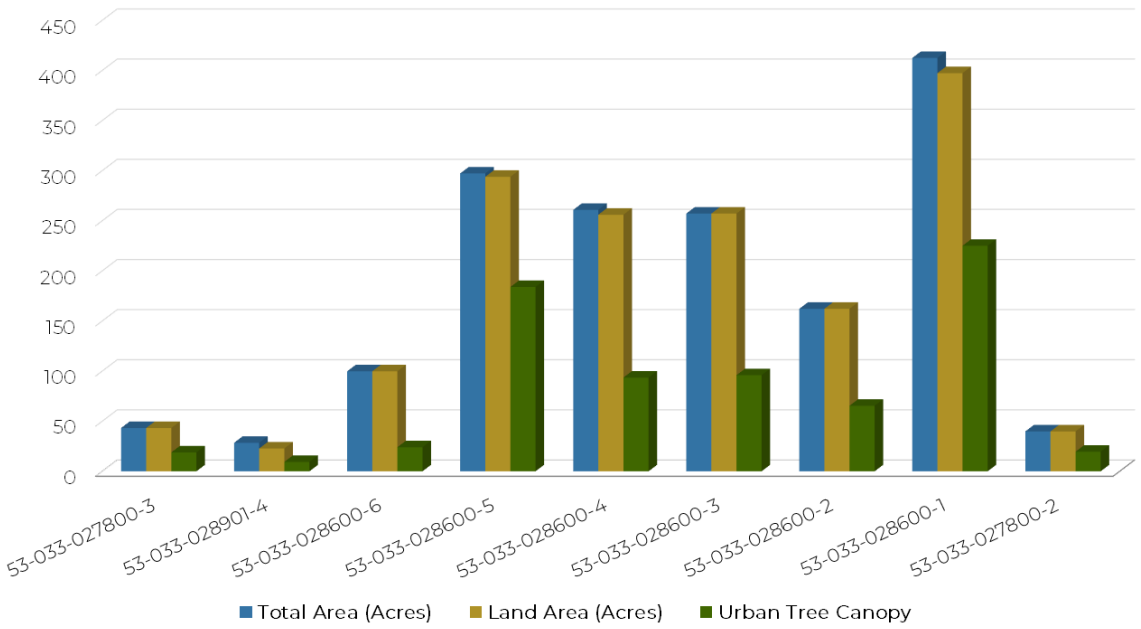


Figure 12. | Urban tree canopy, land area, and total area by census block groups.

Table 6. | Urban tree canopy assessment results by census block groups. 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 CBG (dist.).

Census Block Groups	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
53-033-027800-3	43	3%	19	44%	3%	14	32%	3%
53-033-028901-4	23	1%	9	41%	1%	7	33%	2%
53-033-028600-6	100	6%	24	24%	3%	32	32%	7%
53-033-028600-5	294	19%	184	63%	25%	66	22%	15%
53-033-028600-4	256	16%	94	37%	13%	79	31%	17%
53-033-028600-3	257	16%	96	37%	13%	87	34%	19%
53-033-028600-2	162	10%	65	40%	9%	47	29%	10%
53-033-028600-1	397	25%	225	57%	31%	107	27%	24%
53-033-027800-2	40	3%	20	49%	3%	12	31%	3%
Totals	**1,572**	**100%**	**736**	**47%**	**100%**	**453**	**29%**	**100%**

URBAN TREE CANOPY BY CRITICAL AREAS

While trees offer many environmental benefits when planted in any location, they are especially valuable in sensitive areas such as floodplains, wetlands, and areas prone to erosion or landslides due to their ability to help regulate the movement of water and retain sediments. For this reason, UTC and PPA were assessed in all of Normandy Park's critical environmental areas (including two erosion areas, four floodplain areas, three landslide areas, and one wetland area). Overall, UTC in these areas was much higher than the citywide average with an overall UTC of 74 percent. Two of the landslide areas had a UTC over 80 percent and one floodplain area (<1 acre in size) had complete canopy coverage (100 percent). Only one of the ten critical areas had a UTC below the citywide average—an erosion area with 35 percent UTC.

Table 7. | Urban tree canopy assessment results by critical areas. 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 area (dist.).

Critical Areas	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Erosion Area 630-670	176	75%	137	78%	79%	30	17%	72%
Erosion Area 652-687	1.4	1%	0.5	35%	0%	0.5	36%	1%
Floodplain Area 171-47	45	19%	30	66%	17%	9	19%	21%
Floodplain Area 246-57	0.01	0%	0.0	100%	0%	0.0	0%	0%
Floodplain Area 261-58	0.7	0%	0.2	35%	0%	0.2	23%	0%
Floodplain Area 280-59	2.55	1%	1.3	50%	1%	0.4	17%	1%
Landslide Area 138-132	0.1	0%	0.1	92%	0%	0.0	8%	0%
Landslide Area 139-133	6.2	3%	3.3	53%	2%	1.9	30%	5%
Landslide Area 153-88	1.2	1%	1.0	82%	1%	0.2	18%	1%
Wetland Area 723-709	0.5	0%	0.3	55%	0%	0.0	2%	0%
Totals	**233**	**100%**	**173**	**74%**	**100%**	**42**	**18%**	**100%**

URBAN TREE CANOPY BY CITY-OWNED AREAS

Much like the critical environmental areas, UTC in Normandy Park's 49 city-owned areas exceeded the city's average with 83 percent average canopy cover in these areas. Only six city-owned areas had a UTC below the citywide average, while another six had 100 percent cover. For the full results by city-owned areas, refer to the UTC Results spreadsheet.

Table 8. | Urban tree canopy assessment results by city-owned areas. 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 area (dist.).

City-Owned Areas (Aggregated)	Land Area		Urban Tree Canopy			Possible Planting Area		
	Acres	*Dist.*	*Acres*	*%*	*Dist.*	*Acres*	*%*	*Dist.*
Combined total	96	6%	80	83%	11%	9	10%	2%

URBAN TREE CANOPY BY PARCELS

In addition to the subset of parcels owned by the city, UTC and PPA metrics were calculated for all of the city's 2,563 individual parcels. Short of quantifying every single tree, this unit of measure provides the finest possible scale at which to interpret the results, defining UTC and PPA metrics for every piece of public or privately-owned property within the city boundary. (Note that the analysis of city-owned areas described in the previous section focused specifically on the parcels owned and managed by the City of Normandy Park.)

The analysis by parcels also revealed differences in the distribution of canopy cover throughout the city. 7 percent of parcels had a UTC of 10 percent or less, and 24 percent had a UTC of 20 percent or less. However, 57 percent had a UTC of 30 percent or greater, and 29 percent had a UTC of 50 percent or greater. 30 parcels were entirely covered in canopy (100 percent UTC), while 37 had no UTC at all (0 percent). The average UTC of parcels was below the citywide average of 46 percent at 39 percent, indicating that most parcels have a lower UTC and the city's value is boosted up by fewer parcels with very high UTC. For the full UTC results by parcel, refer to the Parcels data included in this project's data deliverables.

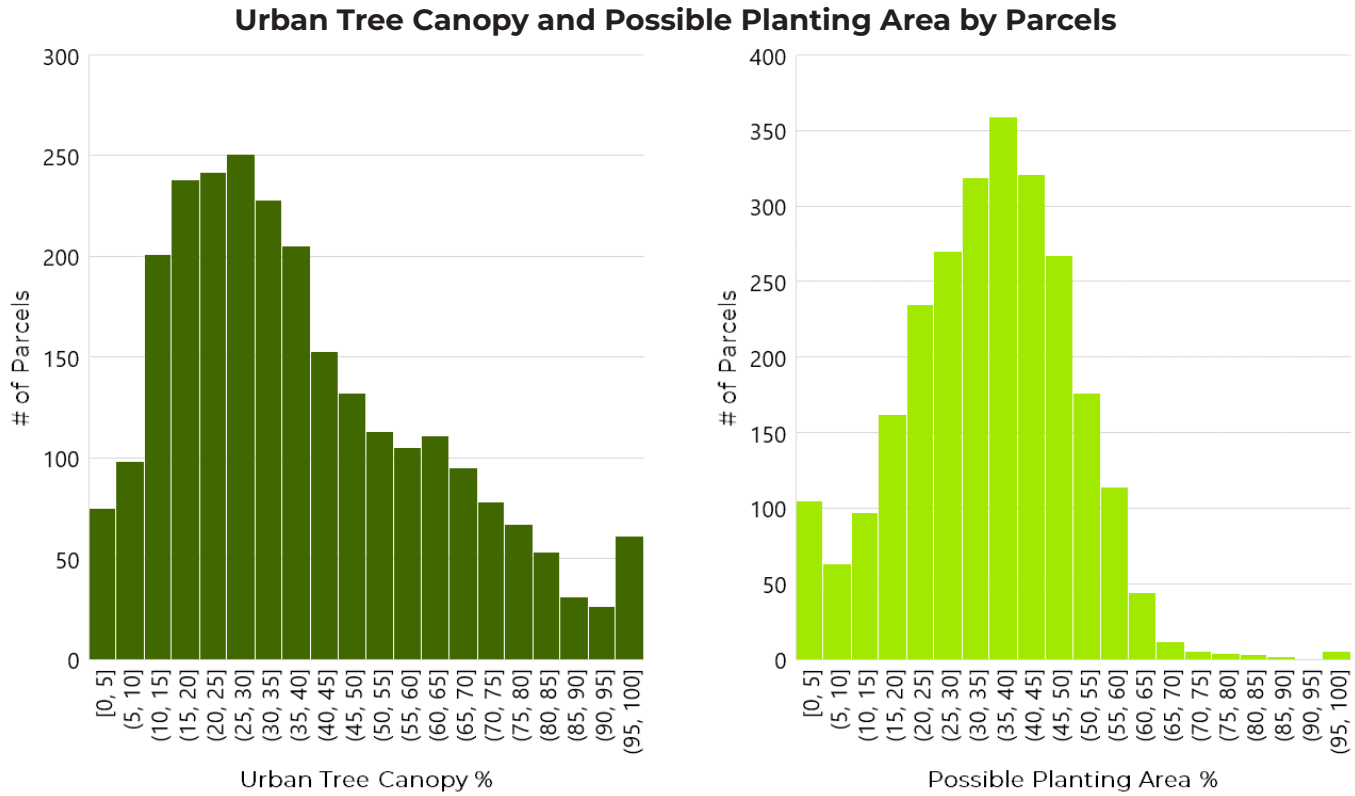


Figure 13. | Urban tree canopy (left) and possible planting area in Normandy Park by U.S. census block groups.

RECOMMENDATIONS

It is clear that the City of Normandy Park 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 Normandy Park has started this process by assessing their canopy in 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.

In 2017, Normandy Park had 46% existing urban tree canopy and 21% possible planting area.

The City should put these results to work to preserve and promote tree its canopy. 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. The information from this study can help establish canopy cover goals for the short- and long-term.

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 high amount of canopy coverage throughout its entire area, breaking up the results by several different geographic boundaries demonstrated that this canopy is not evenly distributed throughout the City's area. For example, out of all of Normandy Park's Census Block Groups, #53-033-028600-3 has a relatively low existing tree canopy (37%) but the highest percentage of PPA Vegetation (34%). This information could be overlaid with the land use layer to identify the best opportunities for planting trees. If increasing canopy citywide is the goal, the greatest opportunities for planting trees reside in the Single-Family Residential land use areas. Normandy Park should conduct outreach and education workshops to inform the public of the benefits of trees and proper tree planting and maintenance to motivate increased canopy in these areas.

IDENTIFY AREAS WITHIN CENSUS BLOCK GROUP *#53-033-028600-3* FOR FUTURE TREE PLANTINGS.

Additionally, Normandy Park assessed its city-owned parcels and found their average UTC to be well above the citywide average (83%), but this was not the case for all individual city-owned parcels. The city should utilize the data to identify city-owned land with low tree canopy and high PPA.

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 Normandy Park's urban forest. In addition to the examples above, the City can also use the provided Canopy Planner tool to explore a wide range of targeted, in-depth planting scenarios based on several prioritization criteria. Canopy Planner allows stakeholders to visualize existing land cover and create custom weighted priority planting maps.

A nation-wide analysis conducted by USFS researchers stated that under ideal conditions, forested states such as Washington could achieve a canopy cover of 40-60%. With its current canopy of 46%, Normandy Park is well within this ideal range, and with its PPA of 29% is poised to continue this trend even further. Normandy Park'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 urban forest should therefore be considered in the City's future planning processes, such as during their implementation of the 2017 Parks, Recreation & Open Space Plan.

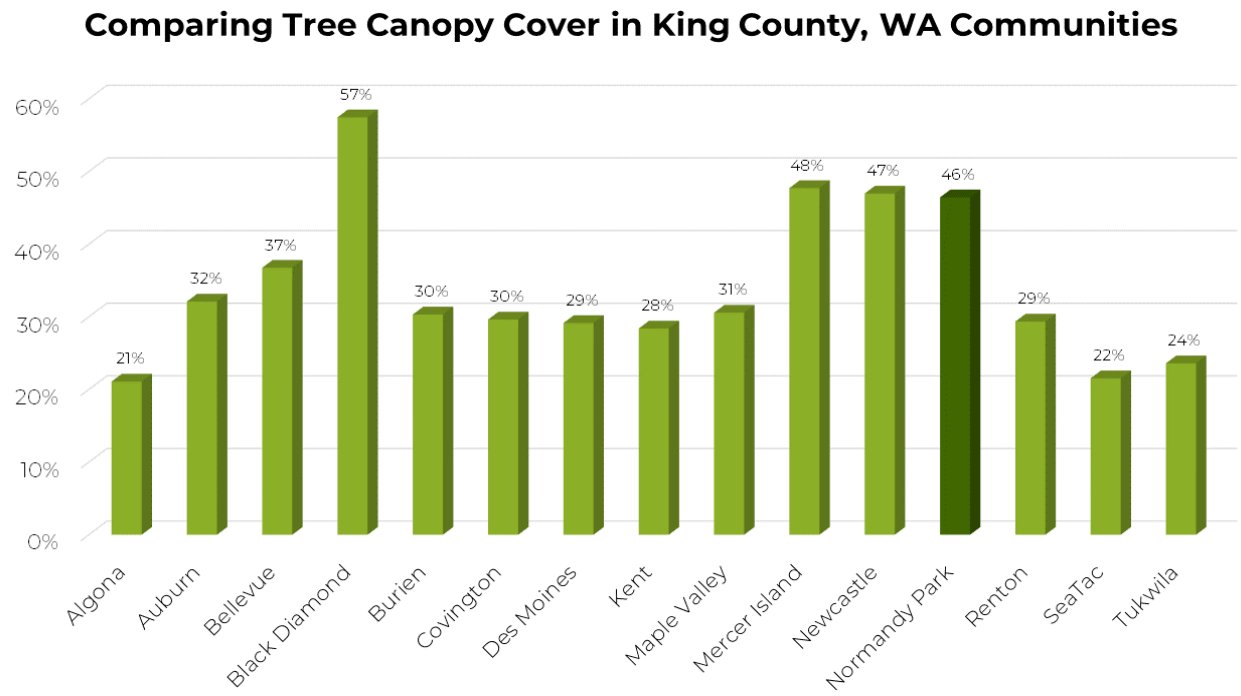


Figure 14. | A comparison of tree canopy in all 15 cities mapped in the 2017 South King County UTC Assessment.

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. Fifty (50) sample points, or approximately 15 points per square mile area in Normandy Park (2.5 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 Normandy Park'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

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.

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 (24 + 8 + 12 + 1 + 2 = 47 / 50 = 94 percent), and the matrix can be used to calculate per class accuracy percent's. For example, 25 points were manually identified in the reference map as Tree Canopy, and 24 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: (24/25 = .96), meaning that we can expect that ~96 percent of all 2017 tree canopy in the Normandy Park, 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, 24 classification pixels intersecting reference pixels were classified as Tree Canopy, but two pixels were identified as Vegetation in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (24/26 = 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 Normandy Park in 2017. The largest sources of classification confusion exist between tree canopy and vegetation.

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

Classification Data	Reference Data: Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	24	2	0	0	0	26
Vegetation	1	8	0	0	0	9
Impervious	0	0	12	0	0	12
Soil / Dry Veg.	0	0	0	1	0	1
Water	0	0	0	0	2	2
Total	25	10	12	1	2	50

Overall Accuracy = 94%

Producer's Accuracy	
Tree Canopy	96%
Veg. / Open Space	80%
Impervious	100%
Bare Ground / Soil	100%
Water	100%

User's Accuracy	
Tree Canopy	92%
Veg. / Open Space	89%
Impervious	100%
Bare Ground / Soil	100%
Water	100%

ACCURACY ASSESSMENT RESULTS

Interpretation of the sample error matrix offers some important insights when evaluating Normandy Park'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 Normandy Park's current tree canopy can be safely assumed to match the figures stated in this report (approximately 46 percent).

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 Normandy Park 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 Table A2, 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 A2. | Stormwater runoff values using existing the existing land cover and an alternate scenario where all tree canopy was removed. (Continued on next page.)

Land Cover	Base (%)	Alternate (%)	Change (%)
Tree Canopy	45.6%	0.0%	-45.6%
Pervious Under Tree Canopy	40.4%	0.0%	-40.4%
Impervious Under Tree Canopy	5.2%	0.0%	-5.2%
Shrub	0.0%	0.0%	0.0%
Herbaceous	28.5%	68.9%	40.4%
Water	1.8%	1.8%	0.0%
Impervious	21.3%	26.5%	5.2%
Soil	2.8%	2.8%	0.0%

Streamflow Predictions	Base (m^3)	Alternate (m^3)	Change (%)
Total Flow	870.8	896.0	3.0%
Base Flow	134.6	138.2	3.0%
Pervious Runoff	381.4	395.4	4.0%
Impervious Runoff	354.7	362.4	2.0%

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.

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 Normandy Park'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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URBAN TREE CANOPY

ASSESSMENT

NORMANDY PARK, WASHINGTON

King Conservation District

plan-it GEO

City of Normandy Park