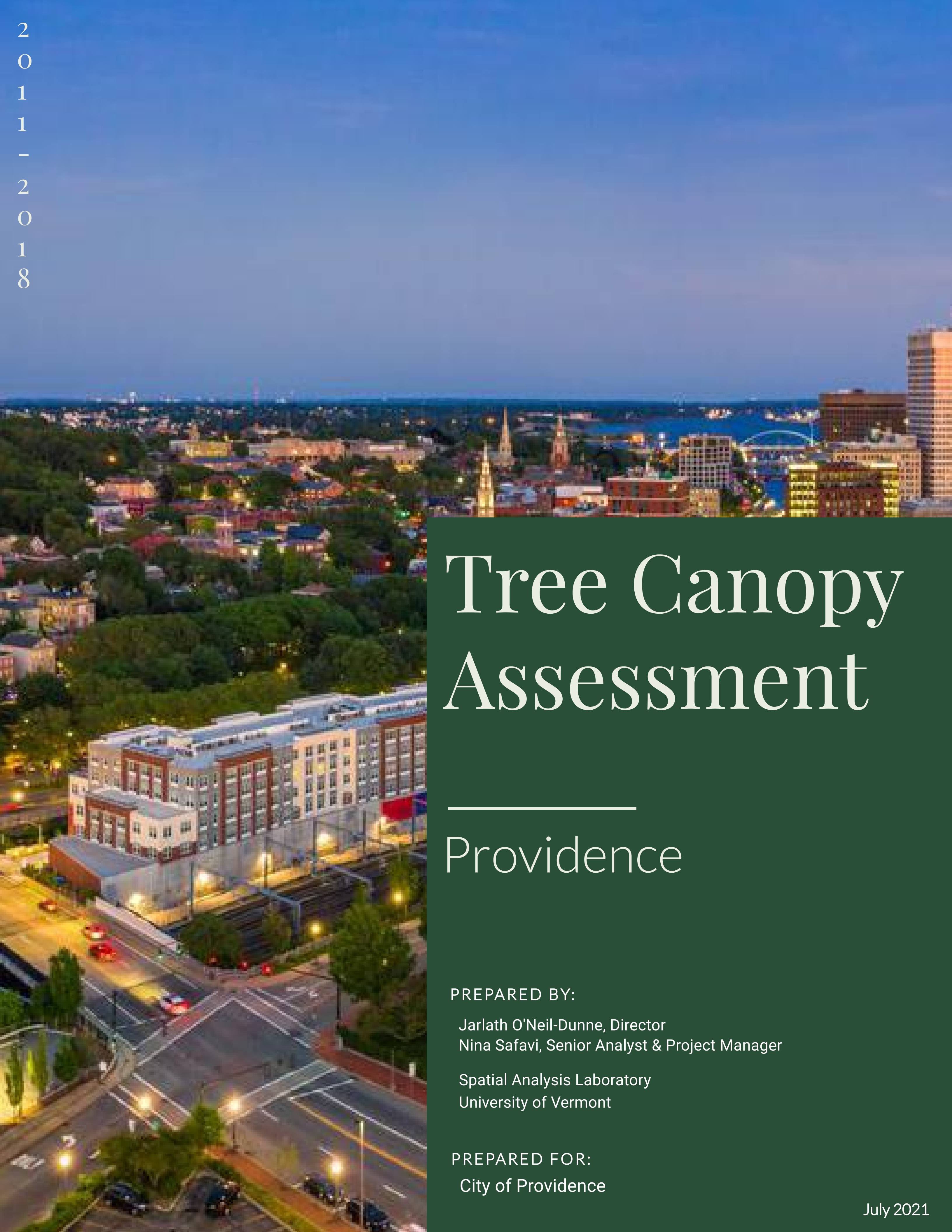

2011-2018

Tree Canopy Assessment

Providence

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PREPARED FOR:

City of Providence

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THE NEED FOR GREEN

Historically, trees have played an essential role in Providence as a way to balance the impacts of urbanization with green infrastructure. They are more important than ever as the city seeks to become more sustainable and equitable.

Trees provide essential ecosystem services. In Providence, they help mitigate many environmental challenges from stormwater runoff, to wind suppression, to reducing urban heat. Their canopies provide habitat for wildlife, transpiration reduces summer temperatures, and research shows that they can even improve social cohesion. A healthy and robust tree canopy is crucial to building a more livable city.

TREE CANOPY ASSESSMENT

For decades governments have mapped and monitored their infrastructure to support effective management of cities. That mapping has primarily focused on gray infrastructure, features such as roads and buildings. The Tree Canopy Assessment protocols were developed by the USDA Forest Service to help communities develop a better understanding of their green infrastructure through tree canopy mapping and analytics. Tree canopy is defined as the layer of leaves, branches, and stems that provide tree coverage of the ground when viewed from above. When integrated with other data, such as land use or demographic variables, a Tree Canopy Assessment can provide vital information to help governments and residents chart a greener future. Tree Canopy Assessments have been carried out for over 80 communities in North America. This study assessed tree canopy for the City of Providence over the 2011-2018 time period.

FINDINGS

Providence's has 27% tree canopy, and it has increased from 2011-2018.

Tree canopy has grown overall, but the story is more nuanced. There were 518 acres of tree canopy gained and 335 acres of tree canopy lost from 2011 to 2018.

Residential land uses had a net loss of tree canopy. This trend, if it continues, could undermine efforts to increase tree canopy in Providence.

Land use history, urban forestry initiatives, natural processes, and landowner decisions, all play a role in influencing the current state of tree canopy in the city.

Gains in tree canopy occurred predominantly on groups of trees as opposed to newly planted trees.

Street trees provide crucial ecosystems services; the gains of tree canopy within the rights-of-way is encouraging.

Tree canopy gains and losses are not evenly distributed nor similar. It varies from the location of newly planted individual trees to the clearing of patches for new construction.

The gains indicate that tree planting and preservation efforts are effective. These initiatives pay greater dividends as trees mature.

RECOMMENDATIONS

Preserving existing tree canopy is the most effective means for securing future tree canopy, as loss is an event but gain is a process.

Planting new trees in areas where tree canopy is low or in locations where there has been tree canopy removed will also help the city grow canopy.

Having trees with a broad age distribution and a variety of species will ensure that a robust and healthy tree canopy is possible over time.

Community education is crucial if tree canopy is to be maintained over time. Residents that are knowledgeable about the value and services trees provide will help the city stay green for years to come.

Integrate the tree canopy change assessment data into planning decisions at all levels of government.

Reassess the tree canopy at 3-5 year intervals to monitor change.

Tree canopy assessments require high-quality, high-resolution data. Continue to invest in LiDAR and imagery to support these assessments and other mapping needs.

Field data collection efforts should be used to compliment this assessment as information on tree species, size, and health can only be obtained through on-the-ground inventories.

TREE CANOPY BY THE NUMBERS

7 Year Summary from 2011-2018

27% OF LAND IS COVERED BY TREE CANOPY

3,221 ACRES OF LAND IS COVERED BY TREE CANOPY

TREE CANOPY IS INCREASING

163 acres of net gain of tree canopy coverage from 2011 and 2018.

1.4%

Absolute gain in tree canopy

5%

Relative gain in tree canopy

The net amount of tree canopy area gained is the equivalent of 123 football fields.

Tree canopy in Providence has increased from 2011 to 2018. Tree canopy loss is typically an event, in which the loss is nearly instantaneous. Increases in tree canopy take time. Tree canopy gain, whether due to plantings or natural growth, are slow and occur over decades.

There are three ways of measuring tree canopy change:

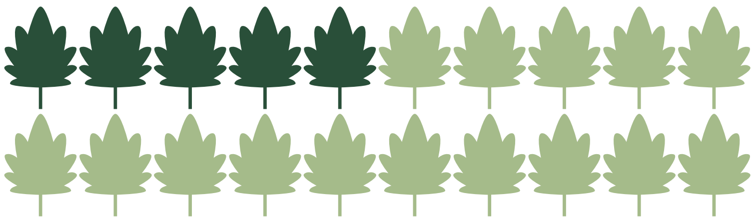
Area Change - the change in the area of tree canopy between the two time periods. Providence gained 163 acres of tree canopy between 2011 and 2018.

Relative % Change - the relative gain or loss of tree canopy using 2011 as the base year. Relative to the 2011 area of tree canopy, the city's tree canopy grew by 5%.

Absolute % Change - the percentage point change between the two time periods. Tree canopy rose from 25.8% to 27.2.% resulting in a 1.4% absolute percent increase.

TREE CANOPY METRICS

27% *of Providence's land is covered by tree canopy*



Using Geographic Information Sytems (GIS) tree canopy was summarized at various geographical units of analysis, ranging from land use and property parcel to neighborhood boundaries. These tree canopy metrics provide information on the area of Existing and Possible Tree Canopy for each geographical unit.

Existing Tree Canopy

Providence, like most cities, has an uneven distribution of tree canopy. There are some 50-acre hexagons with less than 15% tree canopy and others with nearly 100% tree canopy (Figure 1). This unequal distribution can be traced back decades and reflects everything from land use history to the location of parks. Those residents living and working in more treed areas of the east and northwestern parts of the city benefiting disproportionately from the ecosystem services that trees provide. Conversely, the densely urbanized regions, particularly the large stretch in close proximity of the Providence River and Downtown, have strikingly low amounts of tree canopy and therefore receive fewer ecosystem services.

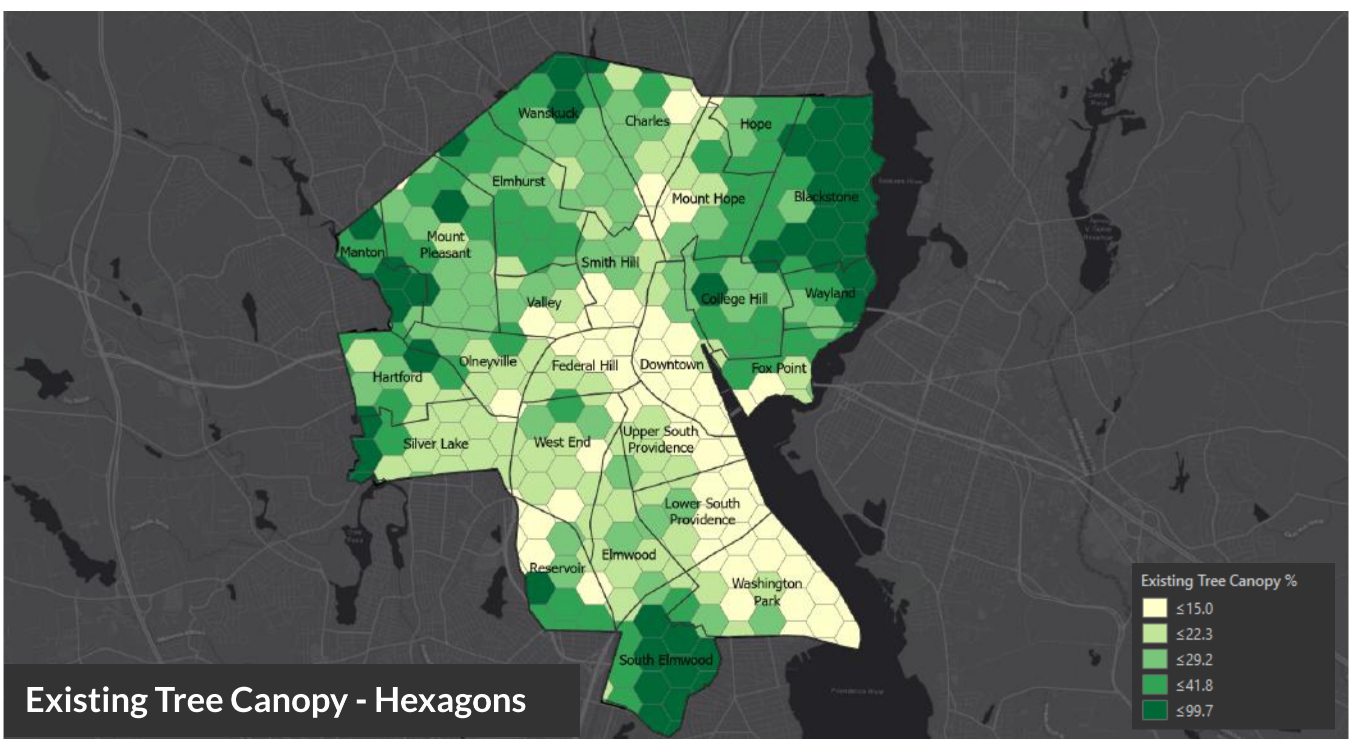


Figure 1. Existing tree canopy percentage for 2018 conditions summarized using 50-acre hexagons and overlaid with neighborhood boundaries. For each of the hexagons, the percent tree canopy was calculated by dividing the amount of tree canopy by the land area, which excludes water. Using hexagons as the unit of analysis provides a standard mechanism for visualizing the distribution of tree canopy without the constraints of other geographies that have unequal area (e.g., zip codes).

Possible New Tree Canopy

Providence has room to plant more trees. In this assessment, any areas with no trees, buildings, roads, or bodies of water are considered Possible-Vegetation, and represent locations in which trees could theoretically be established without having to remove paved surfaces. It should be noted that many other factors go into deciding where a tree can be planted and flourish, including land use, social, and financial considerations. Examples include golf courses and recreational fields. Thus, the Possible-Vegetation category should serve as a guide for further analysis, not a prescription of where to plant trees.

In the most densely urbanized portions of Providence, significantly increasing the tree canopy will be difficult; nevertheless, it remains vitally important to promote the health and number of street trees even in these areas. In heavily treed portions of the city's neighborhoods attention must be paid to ensure healthy natural regeneration of the tree canopy. The heavily urbanized areas, as well as campus green spaces and recreational fields across the city, are examples of where existing land use may make establishing new tree canopy difficult. Nevertheless, with over 1,912 acres of land (comprising 16% of the city's land base) falling into the Possible-Vegetation category, there remain significant opportunities for planting trees and preserving canopy that will improve the city's total tree canopy in the long term.

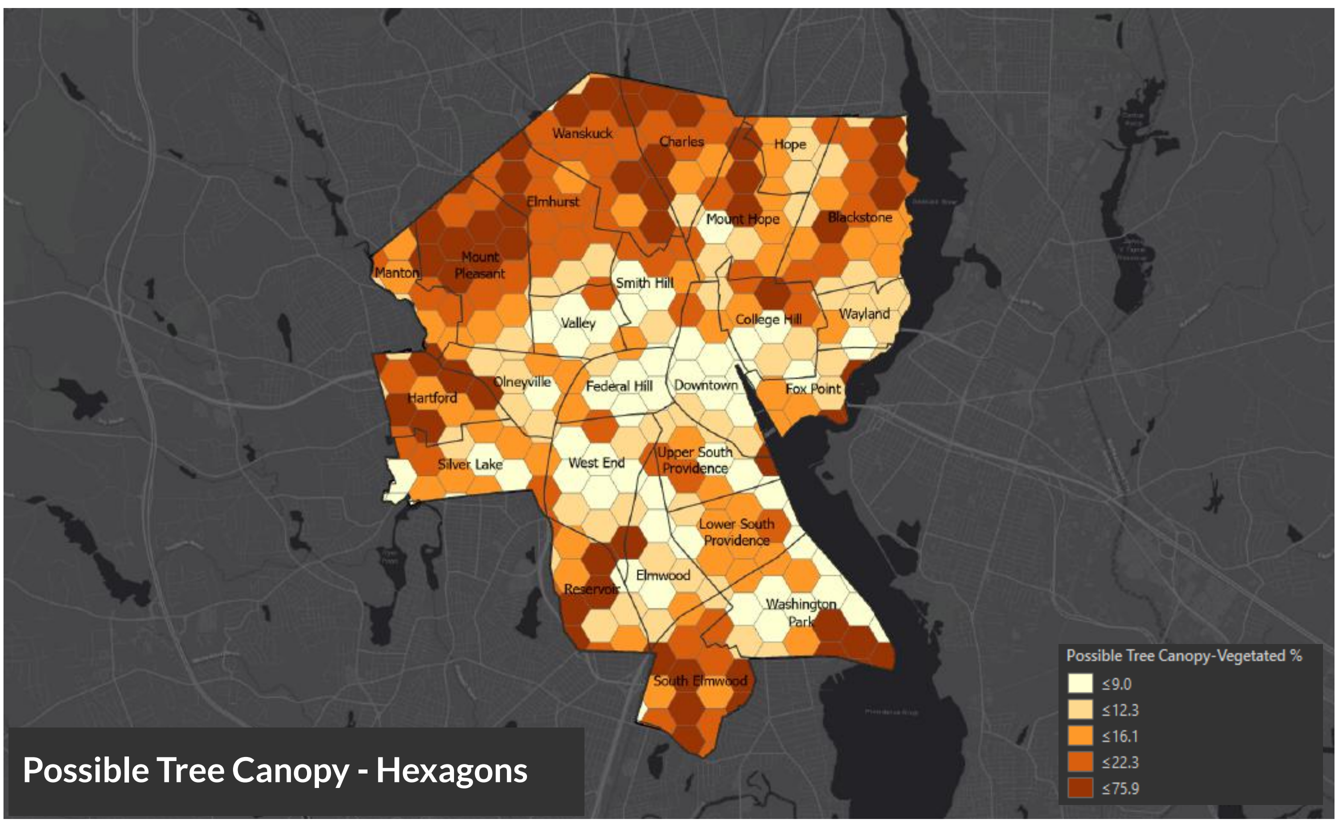
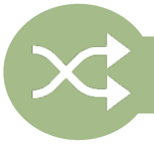


Figure 2. Possible Tree Canopy consisting of non-treed vegetated surfaces summarized by 50-acre hexagons and overlaid with neighborhood boundaries. These vegetated surfaces that are not currently covered by tree canopy represent areas where it is biophysically feasible to establish new tree canopy. It may be financially challenging or socially undesirable to establish new tree canopy on much of this land. Examples include golf courses and recreational fields. Maps of the Possible Tree Canopy can assist in strategic planning, but decisions on where to plant trees should be made based on field verification. Surface, underground, and above surface factors ranging from sidewalks to utilities can affect the suitability of a site for tree canopy planting.

 City Change Distribution

The relative tree canopy change percentage shows the magnitude of change throughout the city over the 2011-2018 time period. The relative change is calculated by taking the tree canopy area in 2018, subtracting the tree canopy area in 2011, then dividing this number by the area of tree canopy in 2011. Areas with the greatest change indicate that the canopy is markedly different in 2018 as compared to 2011. In the central part of the city, with some of the densest urbanized areas with little tree canopy, the growth of street trees resulted in a sizeable relative gain. Conversely, large removals of tree canopy due to construction resulted in substantial relative reductions in tree canopy.

Those areas with relative loss (negative values) were due to widespread removal of individual trees in areas which had below-average tree canopy to begin with, and also where there was a significant concentrated loss in areas with high levels of tree canopy.

Some notable areas of change:

- Dr. Jorge Alvarez High School & Mashapaug Commons Area - experienced a net loss. There was gain due to newly planted trees between 2011 and 2018 and loss along the river as a result of tree removals due to construction work (Figure 4).
- Blackstone area- this affluent residential neighborhood with 51% existing tree canopy, experienced gain due to new plantings and loss due to widespread tree removals on residential property (Figure 5), resulting in 0% relative gain.
- Federal Hill- this highly urbanized and centrally located neighborhood experienced relative positive change due to new trees planted between 2011 and 2018 in an area where there was little tree canopy in 2011.
- The Swan Point Cemetery experienced concentrated loss due to a large patch of tree removal.
- Rogers Williams Park - this area has substantial tree canopy, but there was widespread canopy loss in the park from 2011-2018.

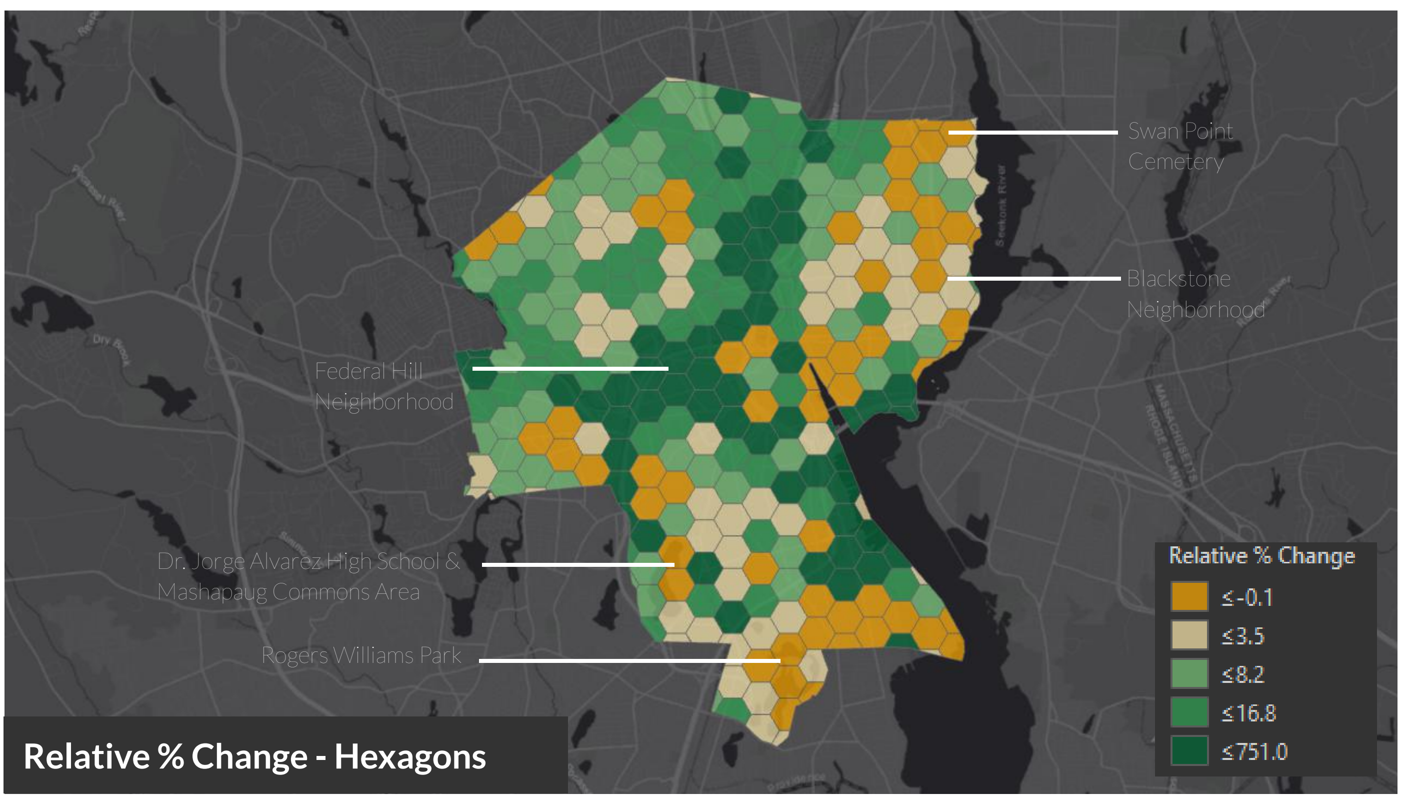


Figure 3: Tree canopy change metrics summarized by 50-acre hexagons. Relative tree canopy is calculated by using the formula (2018-2011)/2011. Negative values (orange color) indicate loss. Positive values indicate gain (darker greens indicate greater relative gain).

In Providence neighborhoods are a geographic units that most residents can easily relate to, especially the neighborhoods in which they live, work or visit most often. The city's official neighborhood geographic boundaries are a useful way to summarize tree canopy and draw comparisons between neighborhoods.

The affluent neighborhoods of Blackstone (52%), College Hill (34%) and Wayland (44%) had the most tree canopy along with Manton (45%) and South Elmwood (50%). The industrial areas along the Providence River and Downtown have the least tree canopy. The differences in canopy is the result of land use history and the built environment it has shaped. Neighborhoods with large parks and open space or those that have lower density development tend to have more canopy, while neighborhoods that are more commercial or industrial, or have higher density development tend to have less tree canopy.

All neighborhoods experienced both gain and loss within their boundaries as shown in Figure 5. The difference between the gain and loss bars gives us the relative change within each neighborhood (Figure 7 map). Overall gain outpaced loss across Providence, amounting to an overall gain in canopy from 2011-2019 of 163 acres.

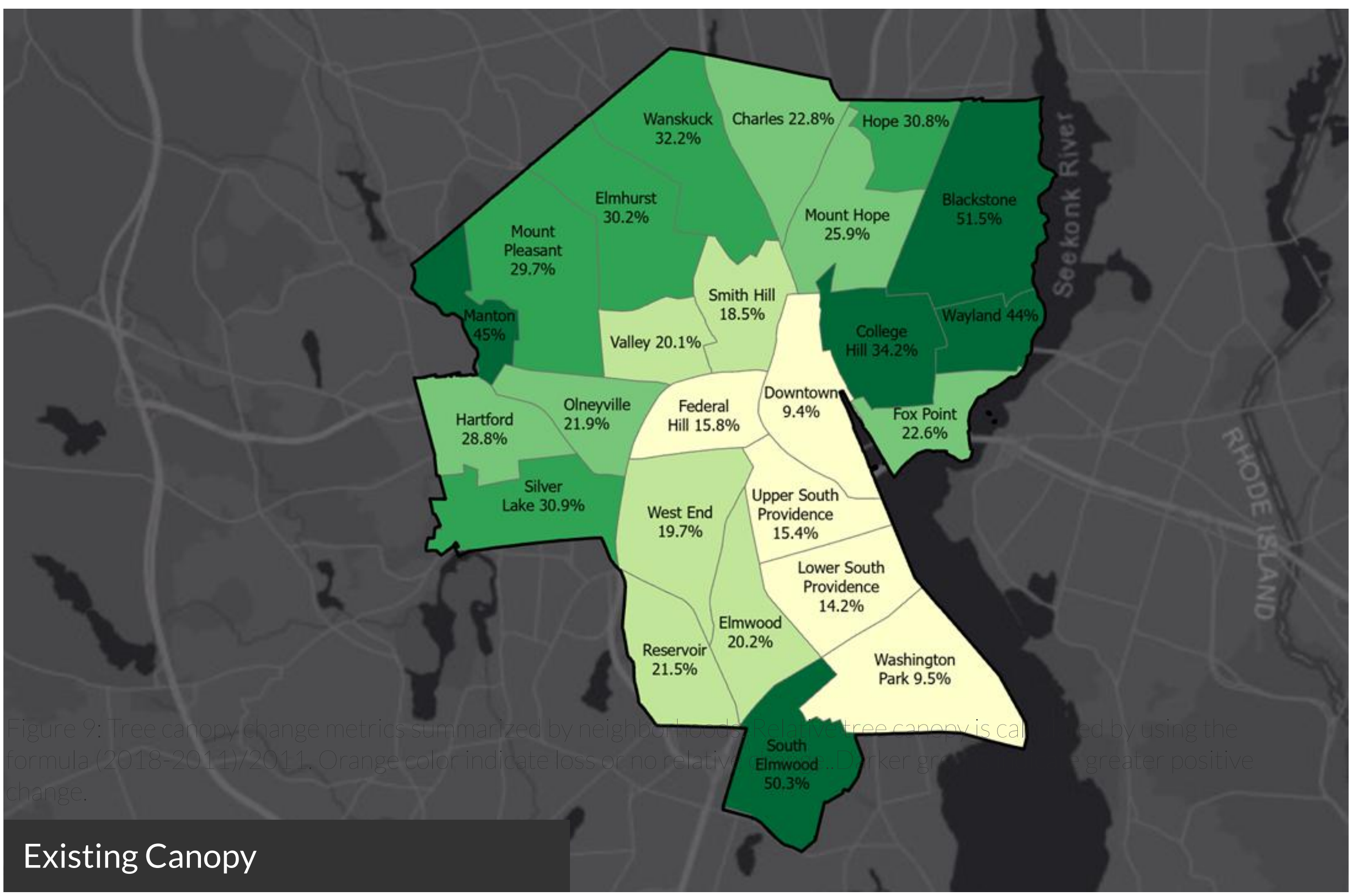


Figure 4: 2018 tree canopy cover percent summarized by neighborhood. Darker green represents more tree canopy cover and lighter tan represents less canopy cover.

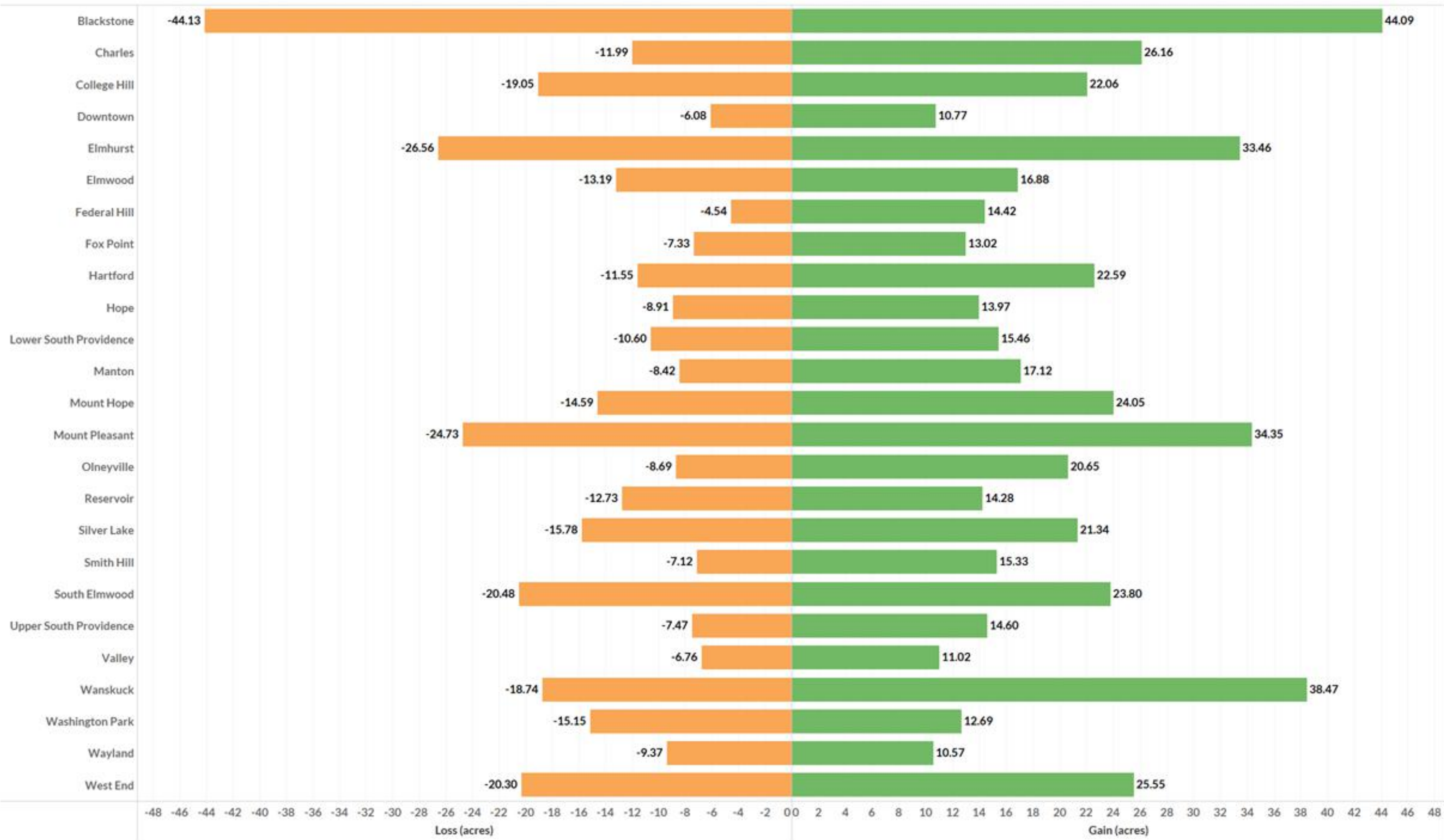


Figure 5: The area of tree canopy gain and loss in each of Providence's neighborhoods.

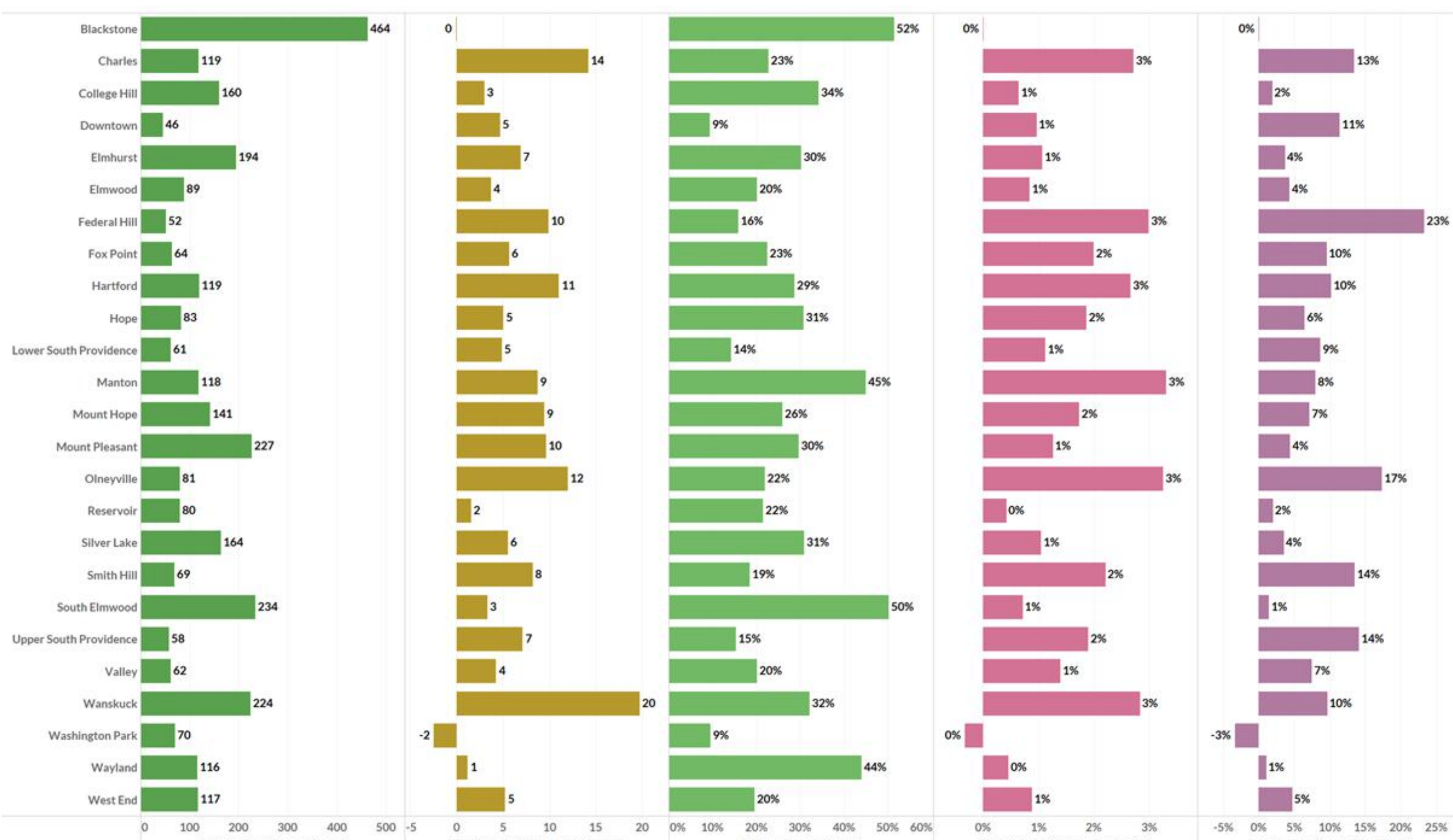


Figure 6: Existing tree canopy area, tree canopy change area, exiting tree canopy percentage, absolute percent change, relative percent change by neighborhood from 2011 to 2018.

Neighborhoods (continued)

The relative percent change by neighborhood provides an indication of the magnitude of change from 2011 to 2018. Washington Park was the only neighborhood that experienced negative relative change, with -3.4% as a result of tree removals, including a large patch in the Maritime Industrial Waterfront District. Following Washington Park, Blackstone had a net neutral (0%) relative change. All other neighborhoods had an increase in tree canopy. The city's planting efforts led to the greatest relative positive change for Federal Hill (23%), followed by many centrally located neighborhoods. All neighborhoods experienced a mix of gain and loss, and the relative change is a factor of both of these measures.

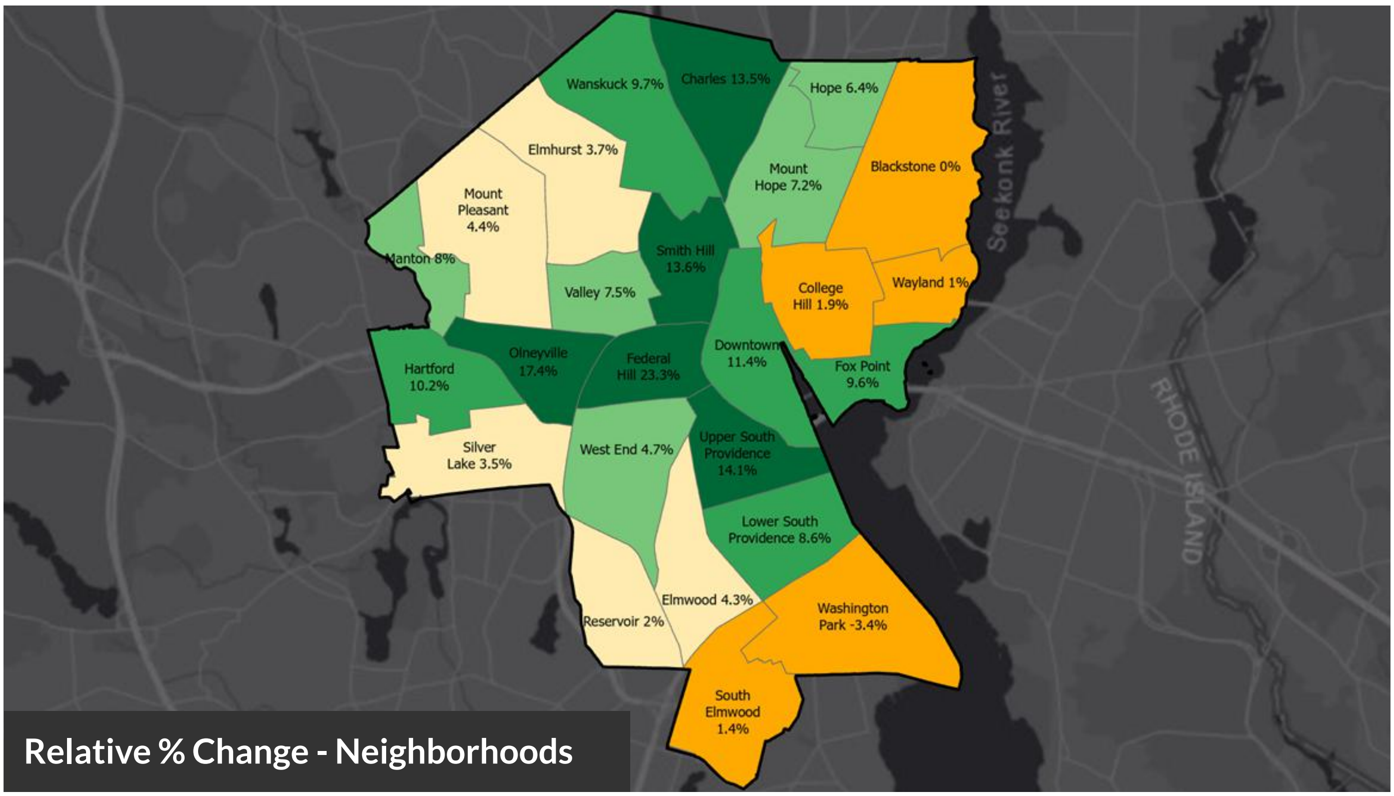


Figure 7: Tree canopy change metrics summarized by neighborhoods. Relative tree canopy is calculated by using the formula (2018-2011)/2011. Orange color indicate loss or no relative change. Darker greens indicate greater positive change.

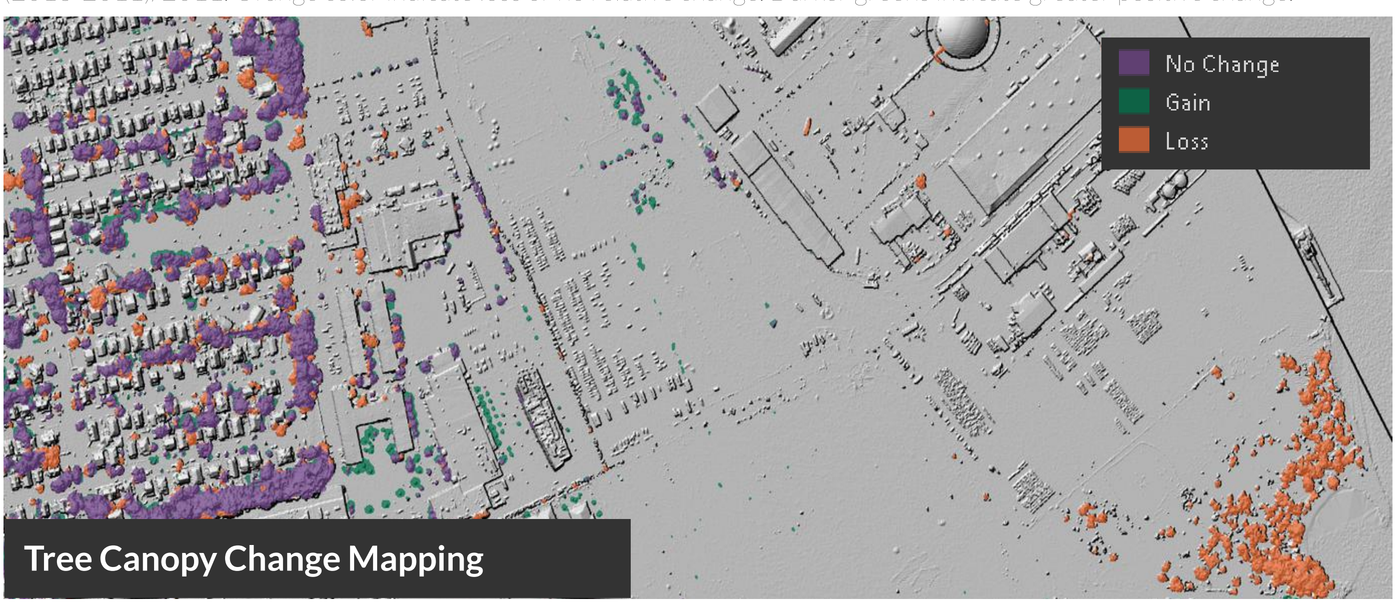


Figure 8: Tree canopy change mapping for the southeast corner of the Washington Park neighborhood near the Providence River. The majority of the loss (orange) was in the Port/Maritime Industrial Waterfront District. Gain (green) is the result of newly planted trees. Tree canopy change was mapped for the 2011-2018 time period and is overlaid on the 2018 LiDAR hillshade map.

Change Examples

Figure 9: Tree canopy change mapping for the area in the vicinity of the Dr. Jorge Alvarez High School. This area experienced a high amount of canopy loss due to removals as well as gains due to new plantings. Tree canopy change was mapped for the 2011-2018 time period and is overlaid on the 2018 LiDAR hillshade map.

Figure 10: Tree canopy change mapping for an area in the Blackstone neighborhood.. This area experienced a mix of gain and loss that amounted to a net loss due to tree removals on residential properties. Tree canopy change was mapped for the 2011-2018 time period and is overlaid on the 2018 LiDAR hillshade map.

Change Type

Change type shows connected/unconnected tree canopy and is used to differentiate stand-alone trees from groups of trees. The tree canopy was segmented into polygons approximating individual trees. Each of these polygons was then attributed with connected/unconnected based on whether they intersect any other tree polygons. Figure 6 summarized the change type into gain/loss/no change and connected/unconnected categories. Gain and loss occurred predominantly on connected canopy. There was limited gain and loss of individual trees.

Tree Canopy Change Type

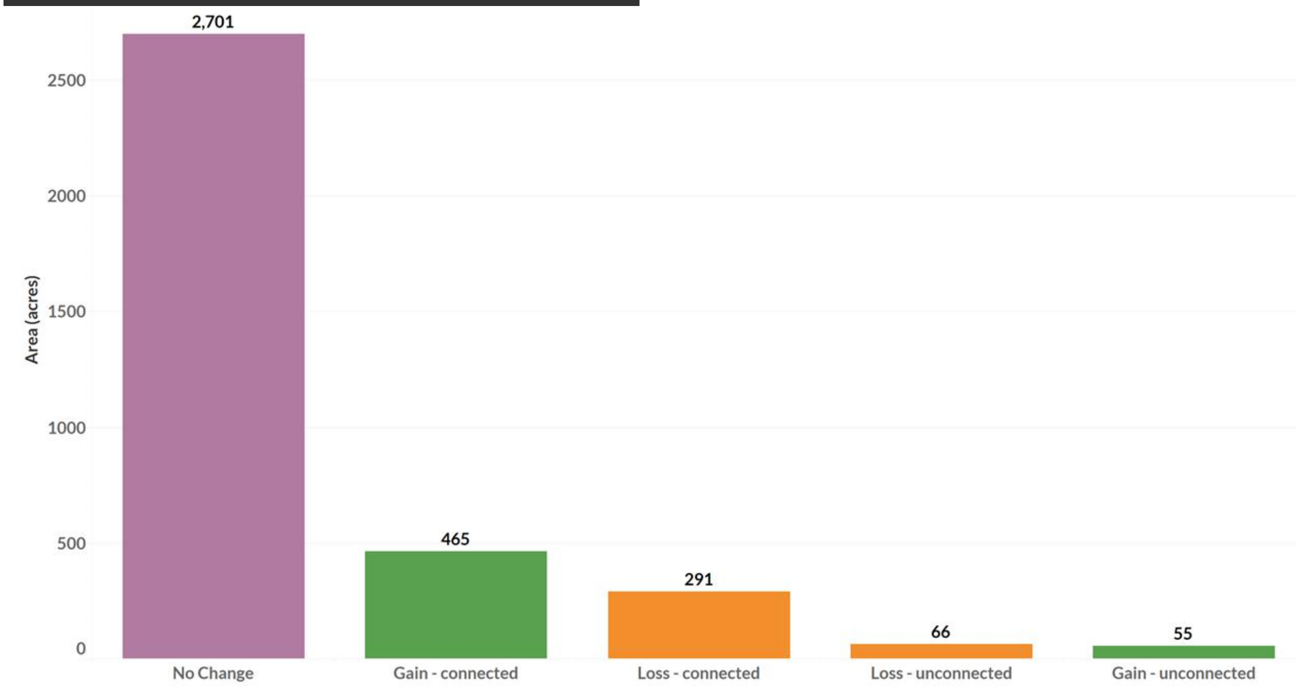


Figure 11: Tree canopy change type summarized by gain/loss/no change and connected/unconnected categories bar chart.

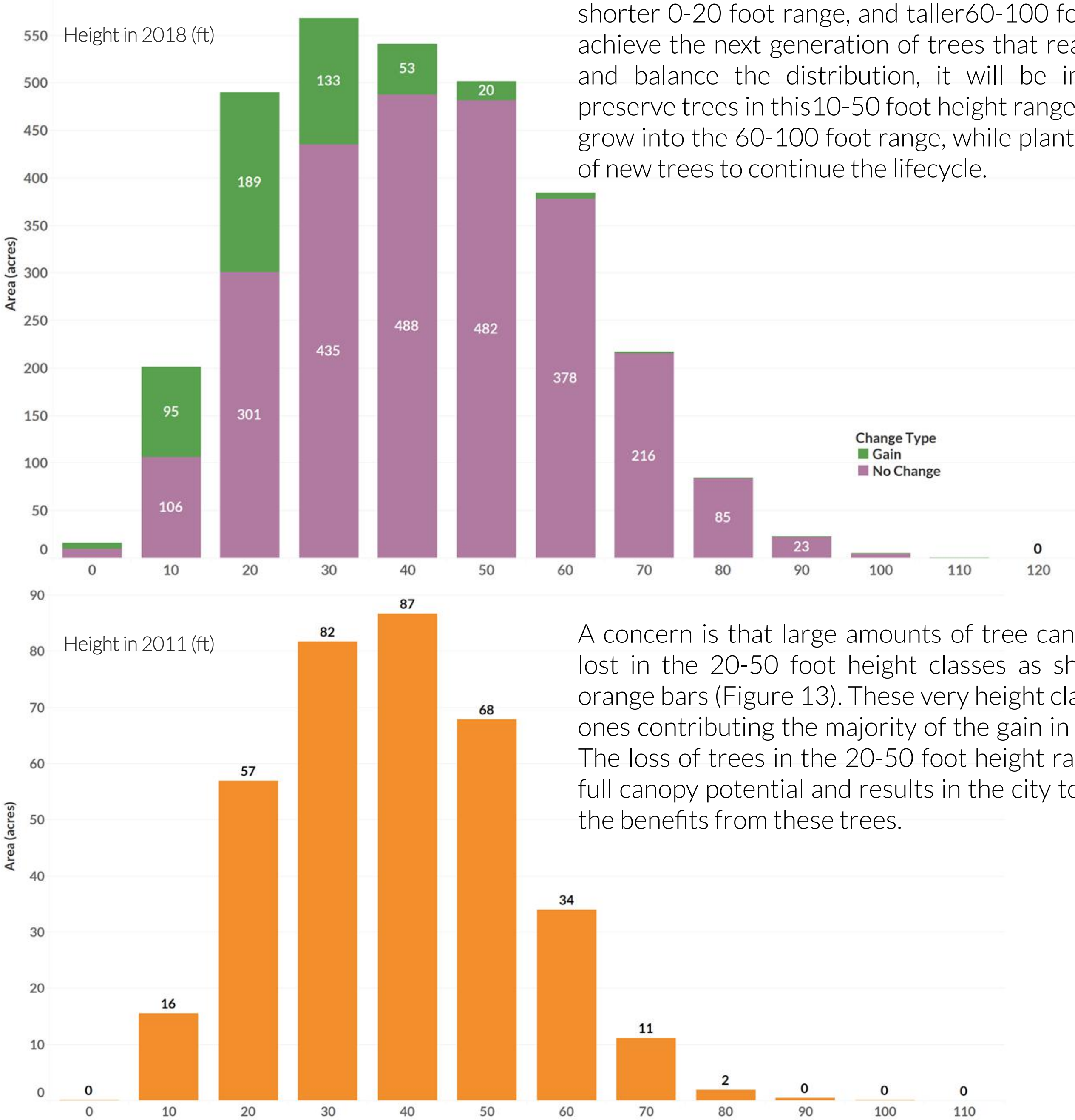
Figure 12: The tree canopy was segmented into polygons approximating individual trees. Each of these polygons was then attributed with connected/unconnected categories and summarized by gain/loss/no change.

Change Type (continued)

Shifting gears from canopy connectedness to canopy height, Figure 13 shows trees in the 10-50 foot height group experienced the most gain and loss. It is not possible to accurately infer age for a diverse urban forest from the overhead imagery and LiDAR used in this study but height can be used as a proxy. The tree canopy was segmented into polygons approximating individual trees. Each of these polygons was then attributed with the height from both the 2011 and 2018 LiDAR data. The height from the 2011 LiDAR was used to understand loss (bottom orange), whereas the height from the 2018 LiDAR was used to understand the gain (top green).

Tree Canopy Change Type Height

Diverse height structure corresponds to healthy and diverse tree age distribution across the city. Providence's has the fewest trees in both ends of the height curve, the shorter 0-20 foot range, and taller60-100 foot range. To achieve the next generation of trees that reach maturity and balance the distribution, it will be important to preserve trees in this10-50 foot height range, so they can grow into the 60-100 foot range, while planting a variety of new trees to continue the lifecycle.



A concern is that large amounts of tree canopy is being lost in the 20-50 foot height classes as shown by the orange bars (Figure 13). These very height classes are the ones contributing the majority of the gain in tree canopy. The loss of trees in the 20-50 foot height range reduces full canopy potential and results in the city to lose out on the benefits from these trees.

Figure 13: The tree canopy was segmented into polygons approximating individual trees. Each of these polygons was then attributed with the height from both the 2011 and 2018 LiDAR data. The height from the 2011 LiDAR was used to understand loss (bottom orange), whereas the height from the 2018 LiDAR was used to understand the gains (top green).

Land Use

Land use is how we, as humans, make use of the land. Land use is different from land cover. Land cover refers to the features, such as the trees, buildings, and other classes mapped as part of this study. For example, residential land use can contain tree, building, impervious, grass, and other land cover features. Land use can significantly influence the amount of tree canopy and the room available to establish new tree canopy.

This study generalized and ranked Providence's parcel data into land use categories to summarize tree canopy change metrics (Figure 11). Of the top ten parcel land uses, Residential lands experienced the most tree canopy loss of any other land use, with the majority of the loss occurring on single-family homes. While some trees on residential land use likely have reached their maximum life expectancy and were removed, factors such as construction and landowner change in preference are more likely to play a role.

The greatest aggregate gain in tree canopy took place in the ROW (right-of-way). This is an encouraging sign. Trees in the ROW face inhospitable conditions associated with their close proximity to roads. Regular salting, compaction, limited space, clearance pruning, and plow collisions are some of the challenges that limit canopy establishment and growth. Gain in the ROW is a sign of the city's effective maintenance and planting efforts between 2011 and 2018. While the ROW experienced a net gain, there was a loss of 65 acres. Street trees not only make roads more aesthetically pleasing, but they also play an important role in reducing stormwater runoff and decreasing the urban heat island effect. Keeping an eye on drivers of loss can help keep the ROW green.

Top 10 Parcel Land Uses Tree Canopy Change

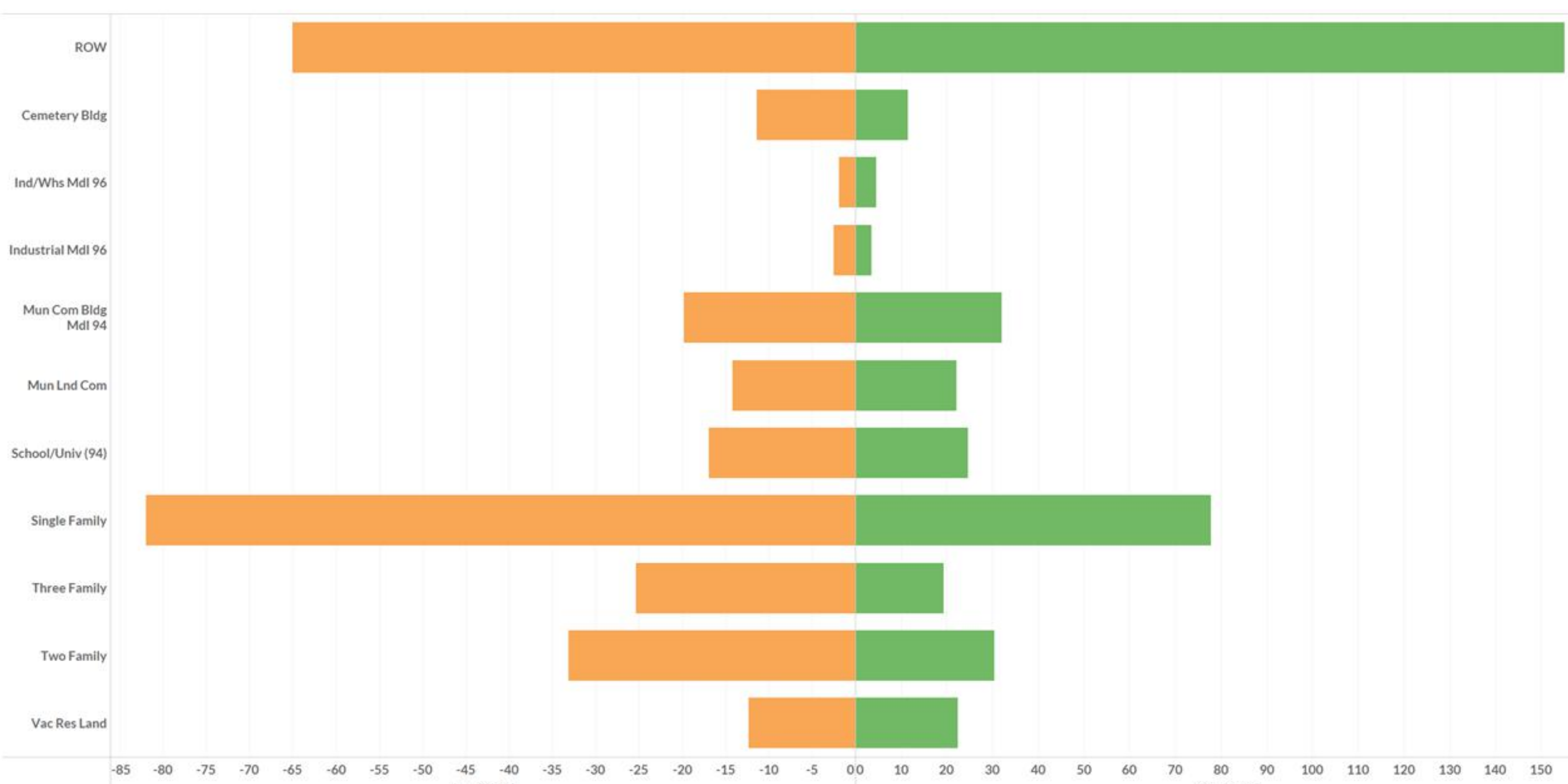


Figure 14: Tree canopy gain and loss by the top 10 largest Parcel Land Use categories in acreage.

Canopy loss on Residential land is the primary driver of canopy loss for Providence. Further insights into canopy loss on Residential area can be obtained by honing in on 1-Family, 2-Family, and 3-Family residential census categories in Figure 11. Combining these into a single "1-3 Family" category reflects Providence's largest land use by acreage. Figure 12 shows all neighborhoods experienced gain and loss in the "1-3 Family" land use, except for the Downtown.

When limiting the analysis to 1-3 Family land use, the Blackstone neighborhood was the only neighborhood where canopy loss (19 acres) outweighed gain (12 acres). Elmhurst experienced the most gain (16 acres) of all neighborhoods but was second to Blackstone in total acreage of canopy lost (13 acres). To analyze percentage change in a different format, Figure 13 shows the change in absolute and relative percentage and reveals a net positive or negative percent for each neighborhood. A majority, 17 of 25, of Providence's neighborhoods had a relative and absolute percent change loss in the 1-3 Family land use.

Given that Residential land use contributes a large total area of tree canopy, losses on residential land, if continued, will have a substantial effect on Providence's overall tree canopy. If there was no net loss of tree canopy on Residential land, Providence would have experienced a substantial net increase.

1-3 Family by Neighborhood

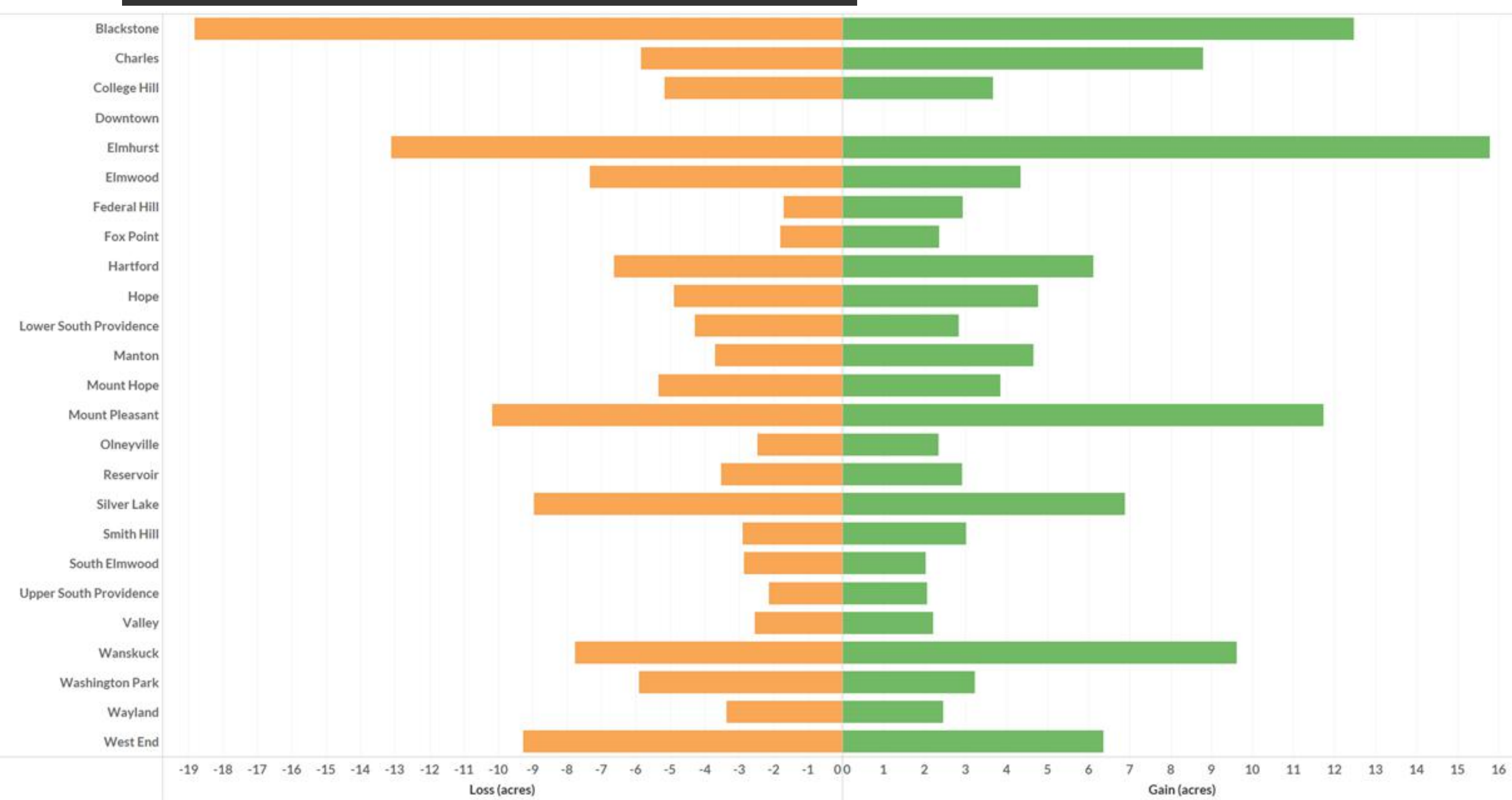


Figure 15: The area, in acres, of tree canopy change in each neighborhood of Providence broken down by land use categories.

1-3 Family by Neighborhood

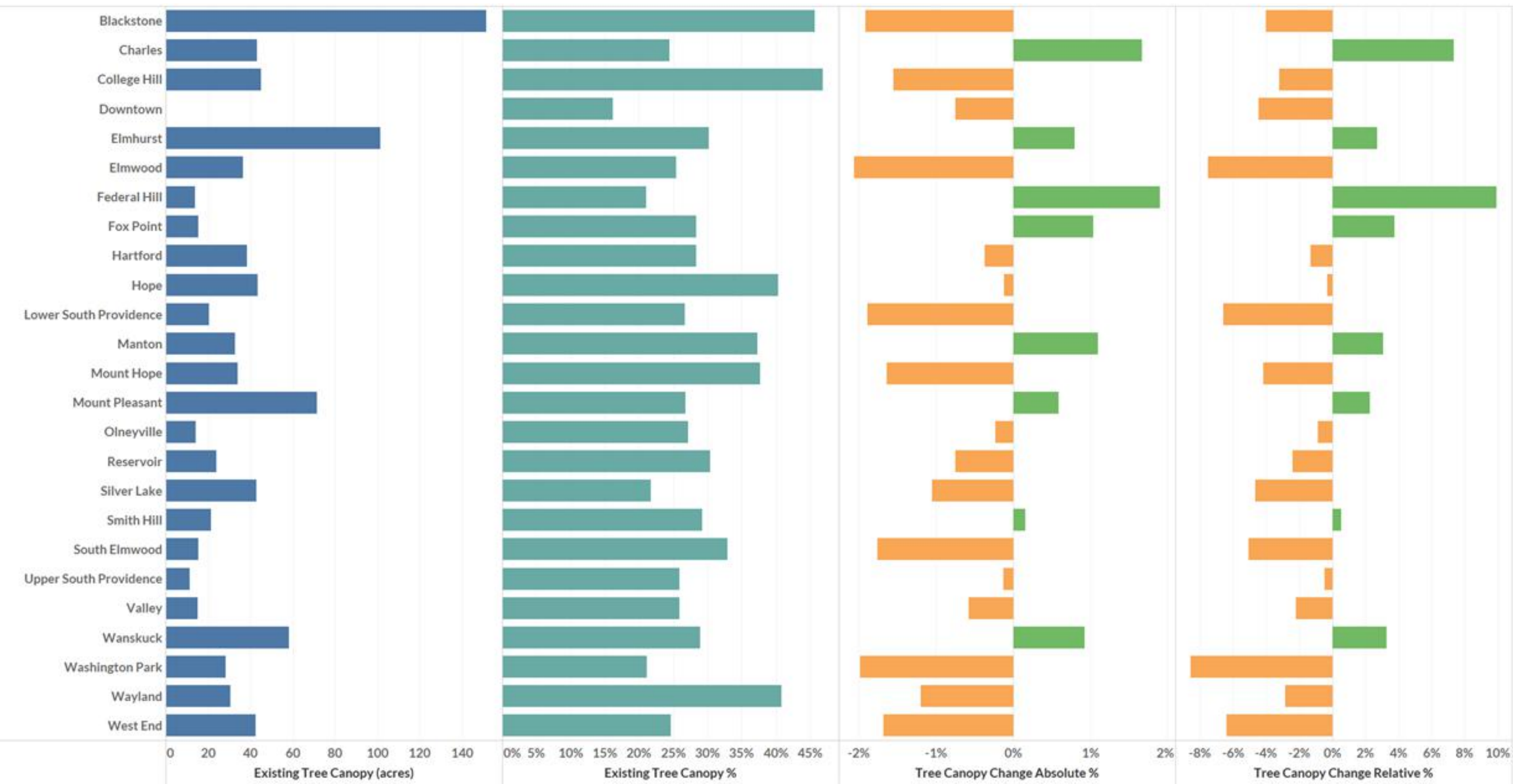


Figure 16: Existing Tree Canopy in acres, Existing Tree Canopy in %, Tree Canopy Change Absolute % and Tree Canopy Change Relative % from 2011 to 2018 by neighborhood. Gains are shown in green and losses are shown in orange.

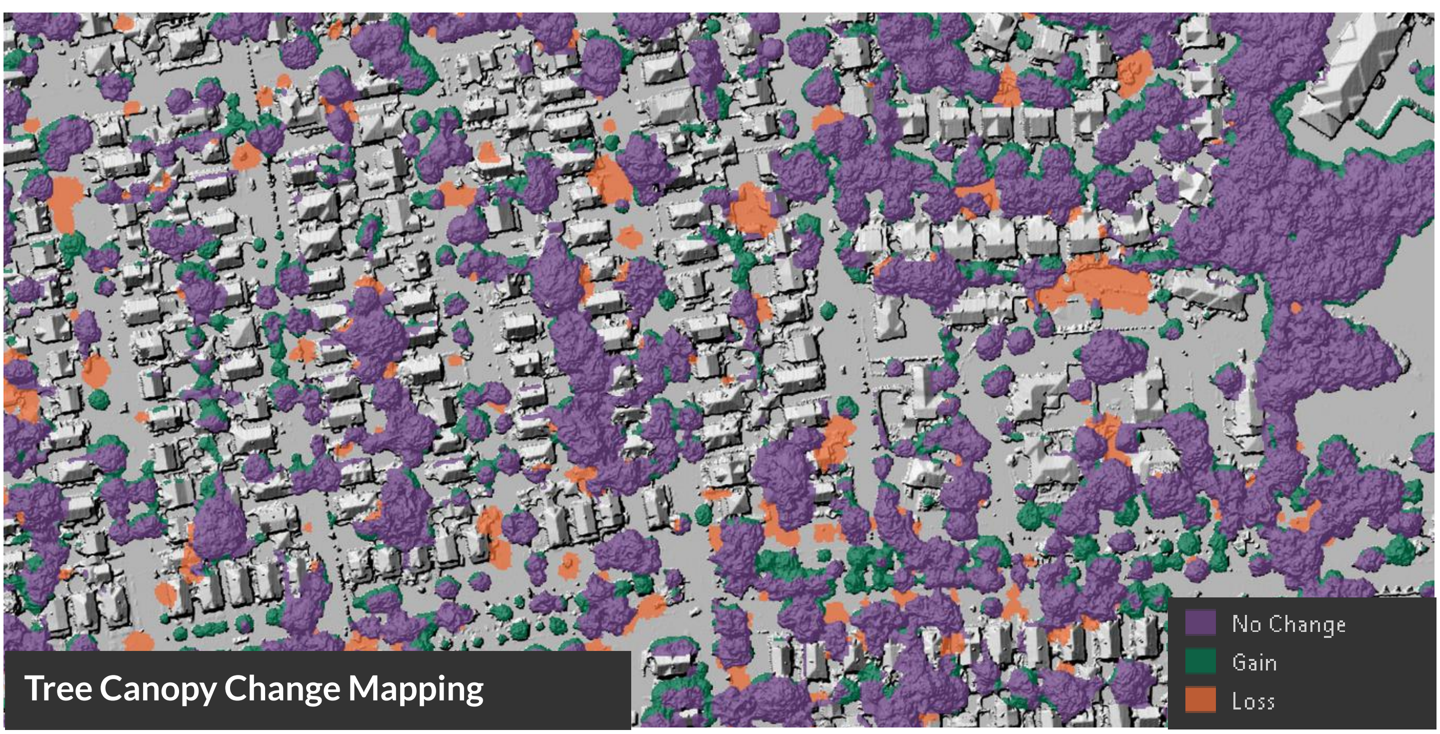


Figure 17: Tree canopy change mapping for a residential section of the Elmhurst neighborhood that experienced large acreage of gain and loss in 1-3 Family Residential land use with a 3% relative change. Tree canopy change was mapped for the 2011-2018 time period and is overlaid on the 2018 LiDAR hillshade map.

THE TREE CANOPY ASSESSMENT PROCESS

This project employed the USDA Forest Service's Urban Tree Canopy assessment protocols and made use of federal, state, and local investments in geospatial data.

Remotely sensed data forms the foundation of the tree canopy assessment. We use high-resolution aerial imagery and LiDAR to map tree canopy and other land cover features.

The land cover data consist of tree canopy, grass/shrub, bare soil, water, buildings, roads/railroads, and other impervious features.

The land cover data are summarized by various geographical units, ranging from the property parcel to the watershed to the municipal boundary.

These summaries, in the form of tree canopy metrics, are an exhaustive geospatial database that enables the Existing and Possible Tree Canopy to be analyzed.

The tree canopy metrics data analytics provide basic summary statistics in addition to inferences on the relationship between tree canopy and other variables.

The report (this document) summarizes the project methods, results, and findings.

The presentation, given to partners and stakeholders in the region, provides the opportunity to ask questions about the assessment.

Existing Tree Canopy

The tree canopy that you currently have, consisting of the leaves, branches, and stems when viewed from above.

Possible New Tree Canopy

Land where it is biophysically feasible to establish new tree canopy (excludes buildings and roads). It is easier to establish tree canopy on vegetated areas as opposed to impervious surfaces.

MAPPING THE TREE CANOPY FROM ABOVE

Tree canopy assessments rely on remotely sensed data in the form of aerial imagery and light detection and ranging (LiDAR) data. These datasets, which have been acquired by various governmental agencies in the region, are the foundational information for tree canopy mapping. Imagery provides information that enables features to be distinguished by their spectral (color) properties. As trees and shrubs can appear spectrally similar, or obscured by shadow, LiDAR, which consists of 3D height information, enhances the accuracy of the mapping. Tree canopy mapping is performed using a scientifically rigorous process that integrates cutting-edge automated feature extraction technologies with detailed manual reviews and editing. This combination of sensor and mapping technologies enabled the city's tree canopy to be mapped in greater detail and with better accuracy than ever before. From a shade tree at Roger Williams Park to a core forest patch on the banks of the Woonasquatucket River, every tree in the City was accounted for.

Tree Canopy Mapping

Figure 18: Imagery (top), LiDAR surface model (middle), and high-resolution tree canopy (bottom). By combining these datasets the land cover mapping process capitalizes on their strengths and minimizes their weaknesses. The land cover dataset is the most detailed, accurate, and current for the City of Providence.

The high-resolution land cover that forms the foundation of this project was generated from the most recent LiDAR, which was acquired in 2018. Compared to national tree canopy datasets, which map at a resolution of 30-meters, this project generated maps that were over 1000 times more detailed and better account for all of the city's tree canopy.

Land Cover Mapping

Figure 19: High-resolution land cover developed for this project.

MAPPING TREE CANOPY CHANGE

This study made use of aerial imagery and LiDAR data acquired in 2011 and 2018. LiDAR is positionally more accurate and thus served as the primary data source for determining change. The imagery was used to confirm the change detected using the LiDAR. Both LiDAR datasets were acquired under leaf-off conditions and thus tend to underestimate tree canopy slightly. The two LiDAR and imagery datasets are not directly comparable due to differences in the sensor, time of acquisition, and processing techniques employed. This study went to great efforts to reduce the errors associated with differences in the datasets to come up with the most accurate estimate of tree canopy change possible. Losses are generally easier to detect than gains as losses tend to be due to a large event, such as tree removal, whereas gains are incremental growth or new tree plantings, both of which are smaller in size.

Tree Canopy Change

Figure 20: Tree canopy change mapping for the Blackstone neighborhood in the vicinity of Swan Point Cemetery. Tree canopy change was mapped for the 2011-2018 time period and is overlaid on the 2018 LiDAR hillshade map.

Comparisons to Past Studies

A vital component of the Tree Canopy Assessment Protocols is ensuring that changes in tree canopy are attributed to actual gains and losses in tree canopy as opposed to differences in the source data. The 2011 and 2018 datasets were acquired with different specifications. Great care was put into resolving the differences in the data to ensure that tree canopy change between 2011 and 2018 reflected an actual change in the canopy as opposed to differences in the source data. A tree canopy assessment was incorporated in the 2008 State of Providence's Urban Forest Report. Data discrepancies were not accounted for between the 2008 canopy assessment and this assessment.

This assessment was carried out by the University of Vermont Spatial Analysis Lab in collaboration with the City of Providence and American Forests. The methods and tools used for this assessment were developed in partnership with the USDA Forest Service. The source data used for the mapping came from the City of Providence and the USDA. The project was funded by the City of Providence. Additional support for data analytics came from a Catalyst Award from the Gund Institute for Environment at the University of Vermont and NASA . Computations were performed on the Vermont Advanced Computing Core supported in part by NSF award No. OAC-1827314 and from the Vermont Advanced Computing Core.

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