Tree Canopy Assessment

Burlington, Vermont

Project Team:

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THE NEED FOR GREEN

Communities are facing a host of environmental challenges, from stormwater runoff to the urban heat island effect. At the same time, communities are seeking to become more livable and sustainable to attract companies and residents while ensuring equitable access to environmental amenities.

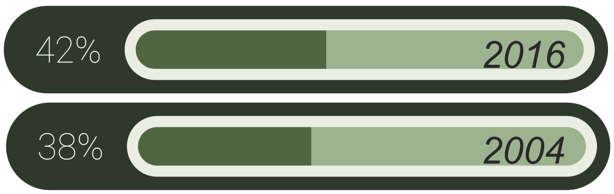
Trees provide a plethora of ecosystem services. Their canopies provide habitat for wildlife, the transpiration process reduces summer temperatures, and research shows that they can even improve social cohesion and reduce crime. A healthy and robust tree canopy is crucial to the sustainability and livability of our communities.

TREE CANOPY ASSESSMENT

For decades governments have mapped and monitored their infrastructure to support effective management. 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 data 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 property land use or demographic variables, a Tree Canopy Assessment can provide vital information to help governments and their citizens 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 Burlington over the 2004-2016 time period.

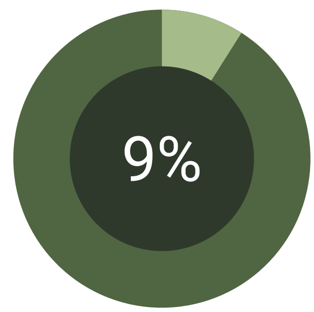
TREE CANOPY BY THE NUMBERS

Statistics



Tree canopy increased from 38% in 2004 to 42% in 2016

Burlington gained 218 acres of tree canopy (2,499 acres in 2004 to 2,717 in 2016)



Burlington's tree canopy increased by 9%

Three different, but complementary, tree canopy change metrics were calculated for this study:

Area Change - the change in the area of tree canopy between the two time periods. The city gained 218 acres of tree canopy over the twelve years.

Absolute % Change - the percentage point change between the two time periods. Tree canopy increased from 38% to 42% resulting in a 4% absolute percent change.

Relative % Change - the relative gain of tree canopy using 2004 as the base year. Relative to the 2004 amount of tree canopy, the city's tree canopy increased by 9%.

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 first Tree Canopy Assessment was completed in 2008 by the University of Vermont, using data from 2004. These data are not as detailed or as accurate as the 2016 data. Furthermore, recent improvements in the tree canopy mapping methods provided the opportunity to revisit the 2004 mapping. This re-analysis found that the 2004 mapping overestimated tree canopy, often confusing it with non-tree canopy vegetation, particularly shrubs. The 2008 study reported a city tree canopy percentage of 43%.

THE TREE CANOPY ASSESSMENT PROCESS

This project employed the USDA Forest Service's Urban Tree Canopy assessment protocols and made use of hundreds of thousands of dollars of data provided by community partners.

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 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 the street tree on Church Street to a core forest patch in the Intervale, every tree in the city was accounted for.

Figure 1: Imagery (top), LiDAR surface model (middle), and high-resolution tree canopy (bottom). The imagery was acquired under leaf-off conditions but the trees lean, making it less positionally accurate than the LiDAR. The downside of the LiDAR is that it was acquired under leaf-off conditions. 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 and accurate ever produced for the City of Burlington.

The high-resolution land cover that forms the foundation of this project was generated from the most recent LiDAR and imagery, both of which were acquired in 2014 and 2016, respectively. Compared to national tree canopy datasets, which map at a resolution of 30-meters, this project generated sub-meter maps that better account for all of the city's tree canopy.

Figure 2: High-resolution land cover developed for this project.

MAPPING TREE CANOPY CHANGE

This study made use of LiDAR data acquired in 2004 and 2014, and aerial imagery acquired in 2004 and 2016. LiDAR is positionally more accurate and thus served as the primary data source for determining change. The imagery was used to update the change mapping to the most current conditions possible (2016). Both LiDAR datasets were acquired under leaf-off conditions and thus tend to underestimate tree canopy. The 2004 LiDAR quality was not nearly to the standard of the 2014 LiDAR as the technology was relatively new in 2004. The 2004 imagery was also acquired at a time when most of the trees had yet to fully leaf-out. 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. It should also be noted that losses are generally easier to detect compared to gains. 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.

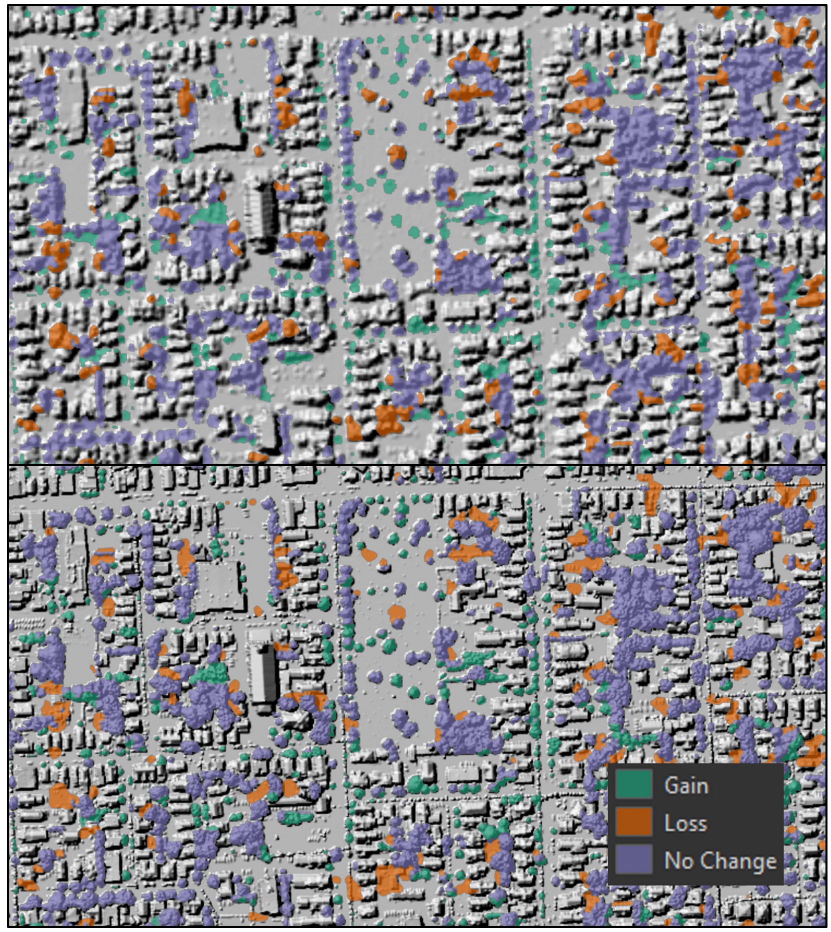


Figure 3. Tree canopy change mapping for the area bordered by North Street and Grant Street. Tree canopy change is overlaid on a LiDAR hillshade for 2004 (top) and 2016 (bottom). Rough areas generally correspond to areas with tree canopy and smooth areas are those without tree canopy.

The story of the change in Burlington's tree canopy is more complicated than one of merely an increase in the tree canopy. There have been losses, some quite substantial, but the gains stemming from natural growth and new tree plantings resulted in a net gain over the 12 years.

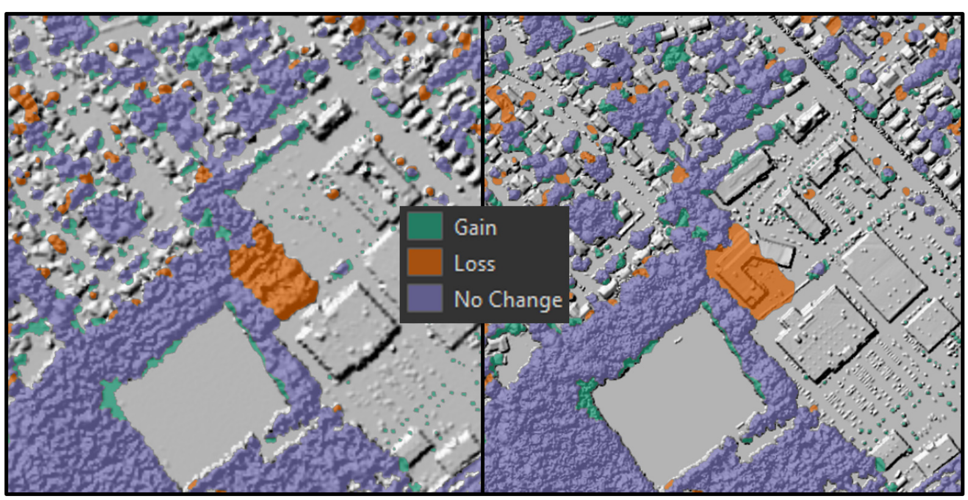


Figure 4. Tree canopy loss resulting from new construction at Thayer Commons in the New North End. Tree canopy change is overlaid on a LiDAR hillshade for 2004 (left) and 2016 (right).

TREE CANOPY METRICS

42% *Tree canopy covers 42% of all land within the City of Burlington*

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

City Existing & Possible Distribution

Tree canopy metrics were summarized for hexagons that were 40,000 square meters in size (slightly under 10 acres). Hexagons reduced the edge effects associated with square grid cells. These hexagons reveal an uneven distribution of the Existing and Possible tree canopy in Burlington. The densely urbanized downtown and agricultural fields of the Intervale have low amounts of tree canopy, whereas conserved areas and more well-established, less-dense residential areas have higher amounts of tree canopy. Vegetated areas without tree canopy (termed Possible-Vegetation) are locations in which trees could feasibly be established. Establishing new tree canopy relies on a host of land use, social, and financial considerations, and thus the Possible should serve as a guide for further analysis, not a prescription of where to plant trees. The agricultural fields of the Intervale, recreational fields, and residential lawns are all examples of where existing land uses may make establishing tree canopy unsuitable.

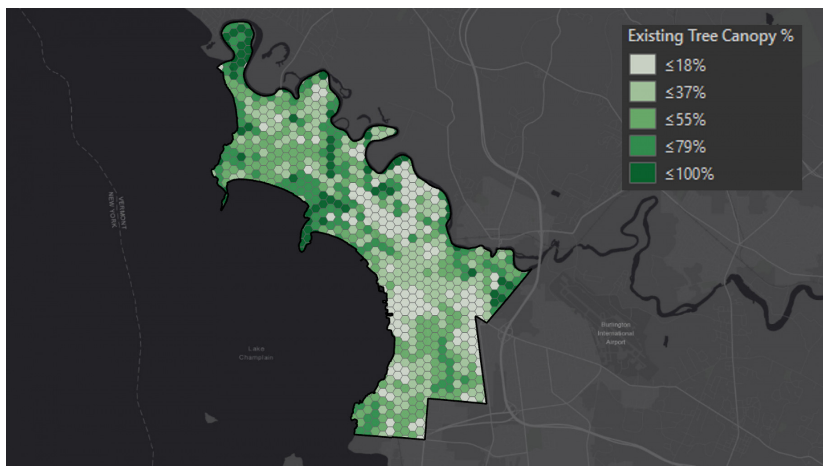


Figure 5: Existing tree canopy summarized by 40,000 square meter hexagons.

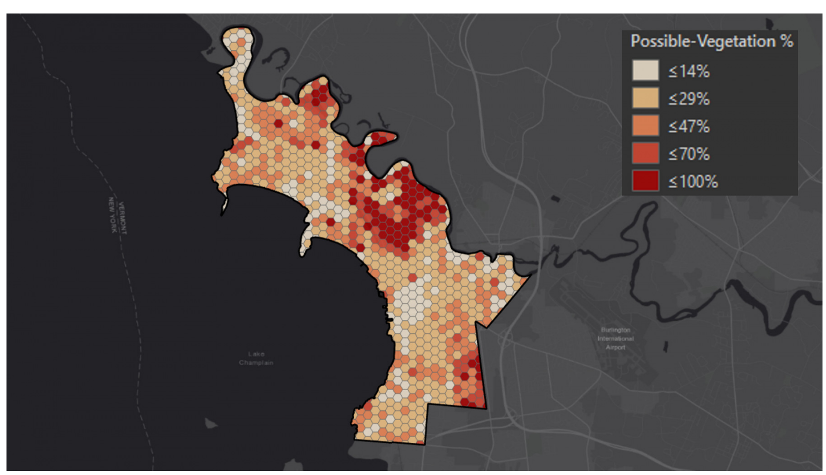


Figure 6: Possible-vegetation summarized by 40,000 square meter hexagons.

City Change Distribution

The same 40,000 square meter hexagons were used to summarize and visualize the distribution of change throughout Burlington. For each of the hexagons, the three tree canopy change metrics were calculated. This strategic view provides insight into broader patterns of tree canopy change in the city. In general, tree canopy is increasing in the northern and southern parts of the city and remaining stable or slightly decreasing in the central section. Some of the most substantial aggregate gains and losses occurred within Burlington's conserved landscapes. Natural growth, storms, insects, disease, and age are all drivers of this change. In the more urbanized areas, the losses correspond to tree removal, some of which is due to new construction whereas other removals have no apparent driving factor that could be determined.

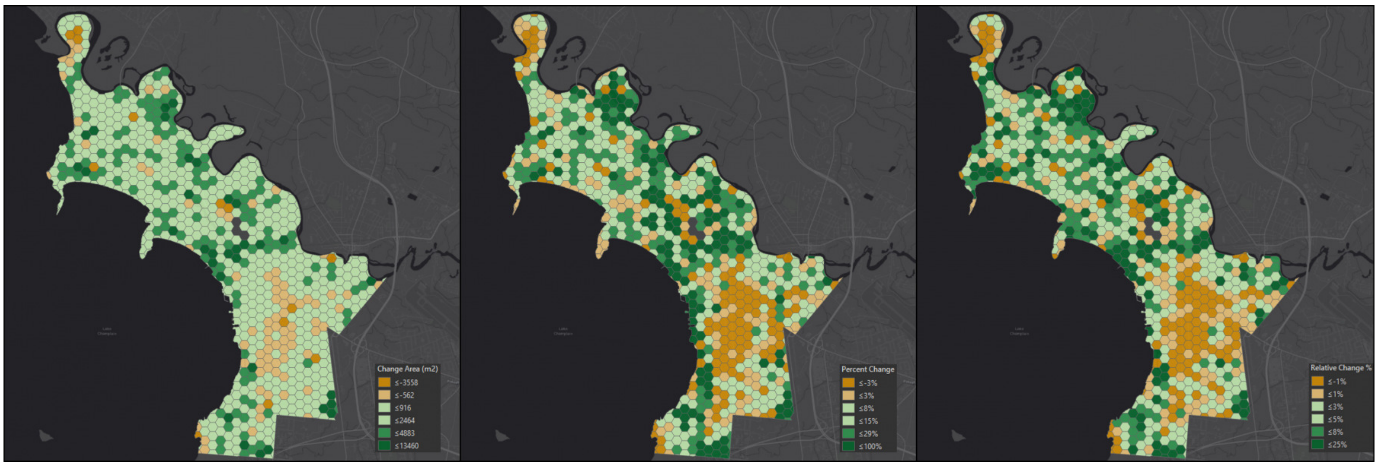


Figure 7: Tree canopy change metrics summarized by 40,000 square meter hexagons.

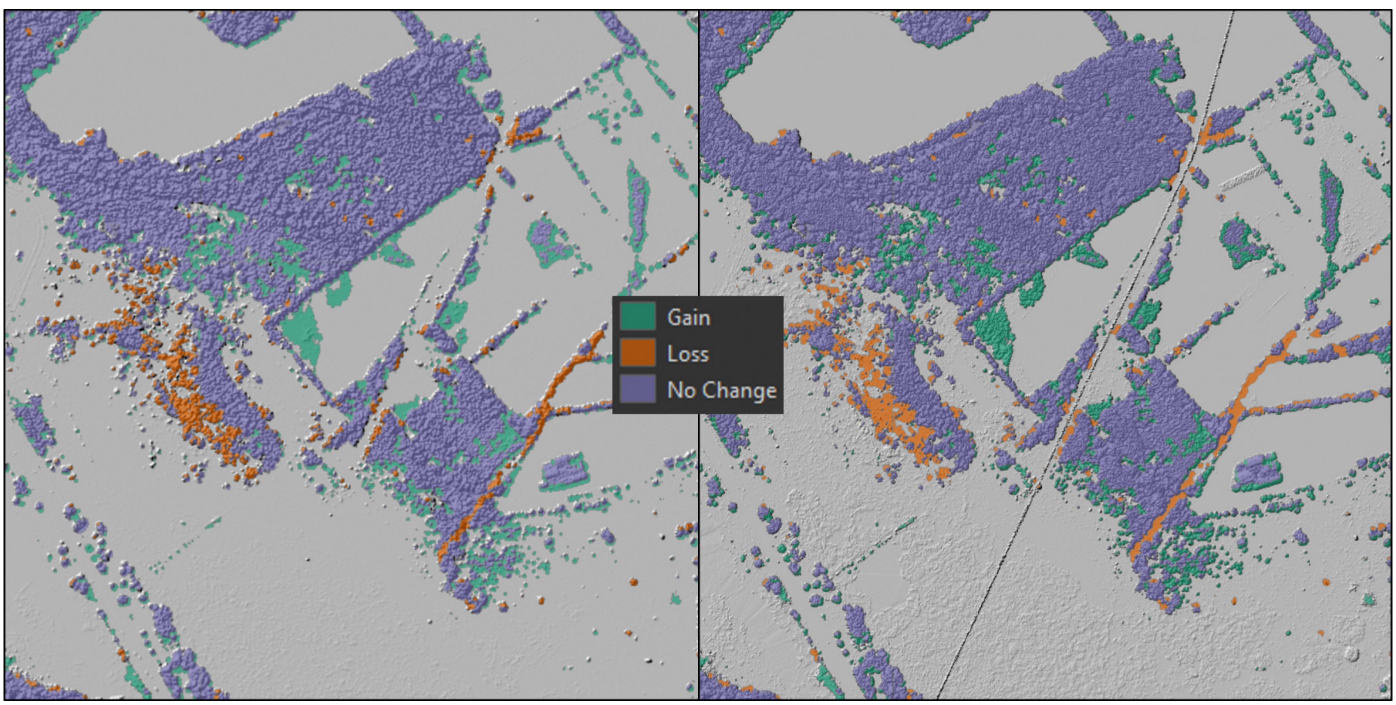
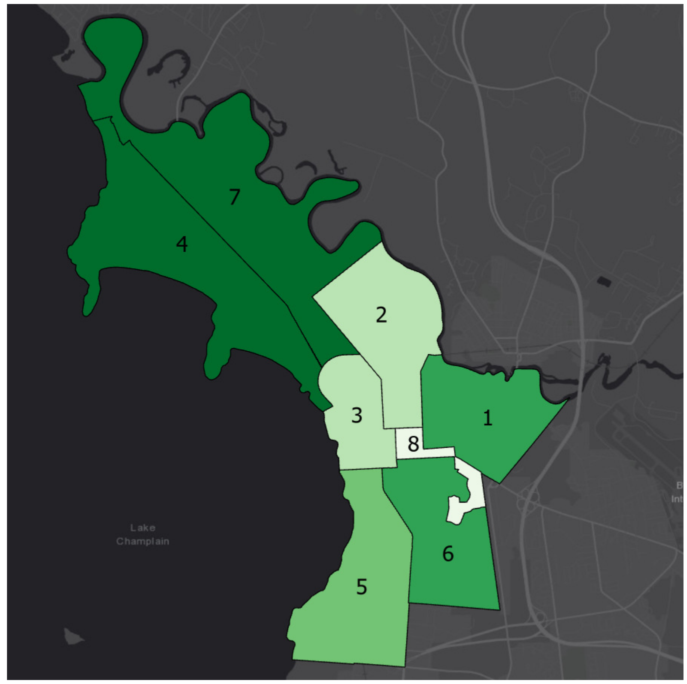


Figure 8. Tree canopy change for the Intervale in the vicinity of the Route 127 interchange. Tree canopy change is overlaid on a LiDAR hillshade for 2004 (left) and 2016 (right). Rough areas generally correspond to areas with tree canopy and smooth areas are those without tree canopy. This natural area shows how dynamic Burlington's urban forest is, with gains and losses occurring throughout the area. A multitude of factors contribute to these gains and losses.

Wards

Tree canopy varies greatly in Burlington's wards, from a low of 18% in Ward 8 to a high of 64% in Ward 4. These differences can largely be attributed to the configuration of the wards and the land use practices within the wards. Ward 8 includes some of Burlington's most dense urban areas along with portions of the University of Vermont campus that have large extents of greenspace with low tree canopy coverage. Wards 4 and 7 benefit from having the most extensive collection of large forest patches in conserved areas. When it comes to tree canopy change, the greatest aggregate gains, have occurred in Ward 5 where losses have been relatively low, and there have been notable cases of tree canopy expansion stemming from natural growth. Wards 2 and 7 experienced the most significant relative gains. Ward 6 was the only ward to experience a decline in tree canopy, much of the loss resulting from construction within the ward.



1	2	3	4	5	6	7	8
43%	29%	26%	54%	35%	39%	48%	18%

Figure 9. Existing Tree Canopy by Ward. The map shows the ward locations with darker colors indicating higher tree canopy. The corresponding table provides the percent of land in each Ward covered by tree canopy.

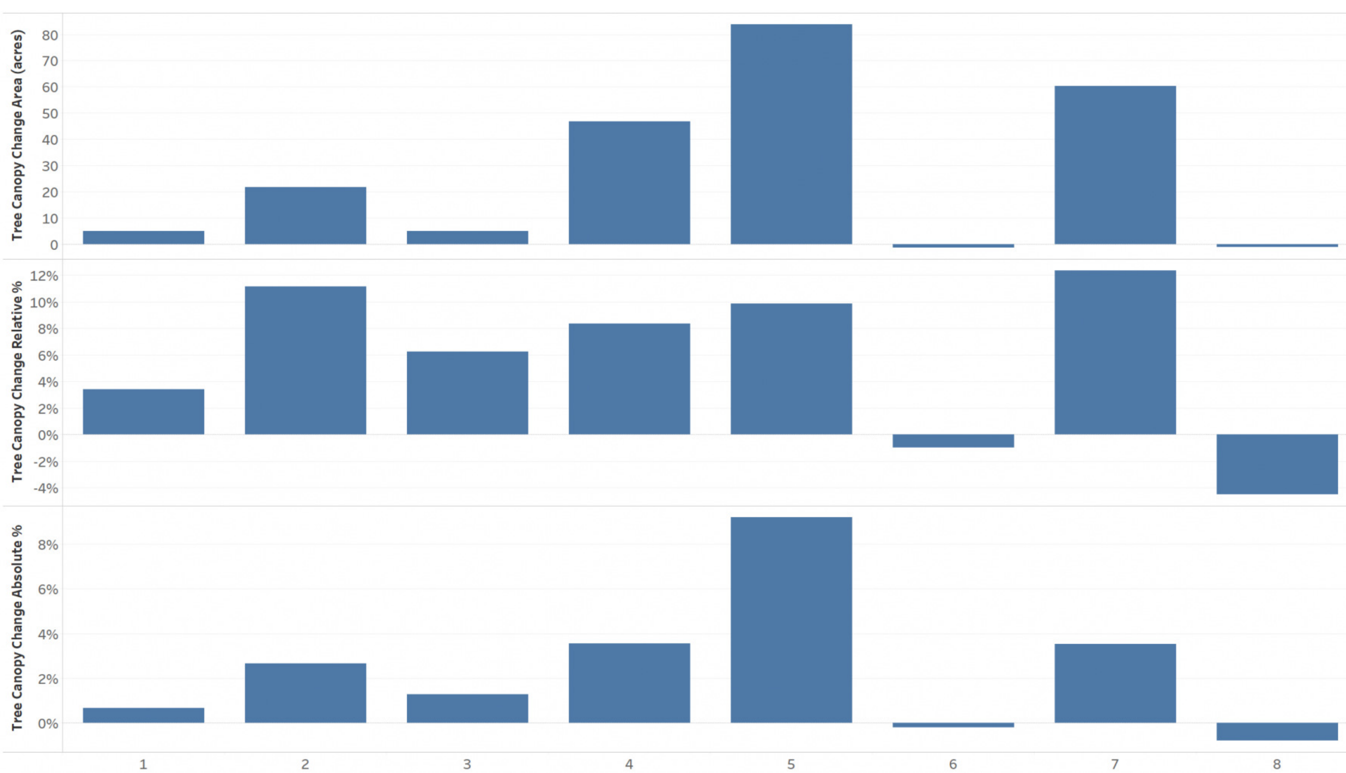


Figure 10. Tree canopy change metrics by ward.

Land Use

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. Land use is how we, as humans, make use of the land. 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 made use of Burlington's 2018 city land use dataset. Over 60% of the city's land is residential. Not surprisingly, residential land use has the highest total area of Existing Tree Canopy, accounting for over 35% off all tree canopy in the city. Although Open Space accounts for just under 17% of all land, nearly 30% of the city's tree canopy is within Open Space. Civic and Utility/Transportation (which includes the rights-of-way) round out the top four land uses in terms of total tree canopy. Civic land, which includes many of the city's parks has the most tree canopy coverage per unit area, at 50%. Residential land, at 44% coverage, has slightly more than the city average. Commercial, Industrial, and Institutional land uses have some of the lowest amounts of tree canopy coverage. All are under 30%. Most of the aggregate gains in tree canopy have occurred on Residential and Open Space lands, but the greatest relative change has been on Utility/Transportation land.

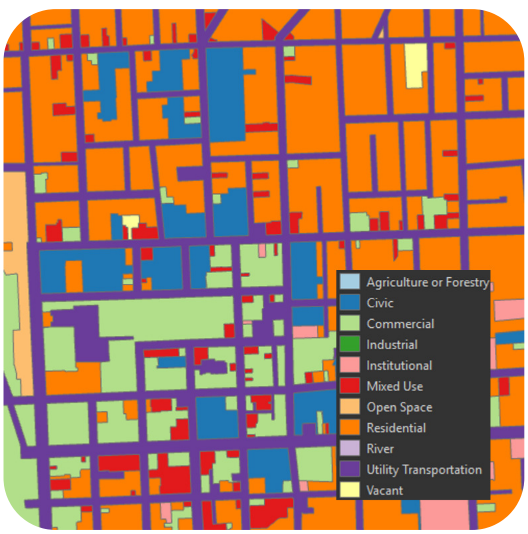


Figure 11: City land use categories.

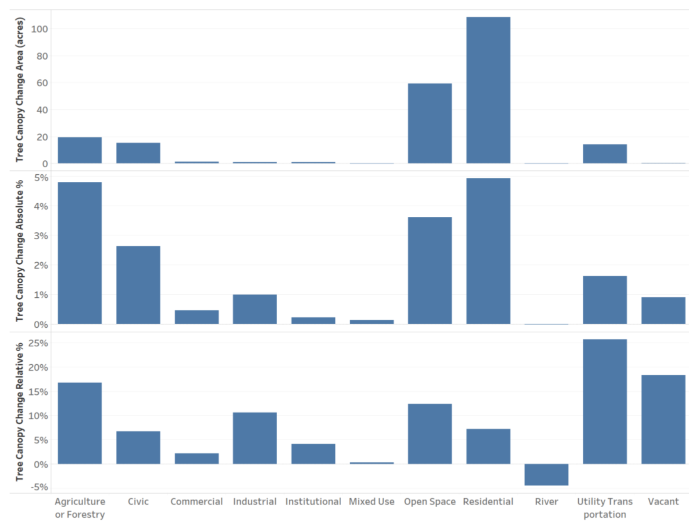


Figure 12: Tree canopy change metrics.

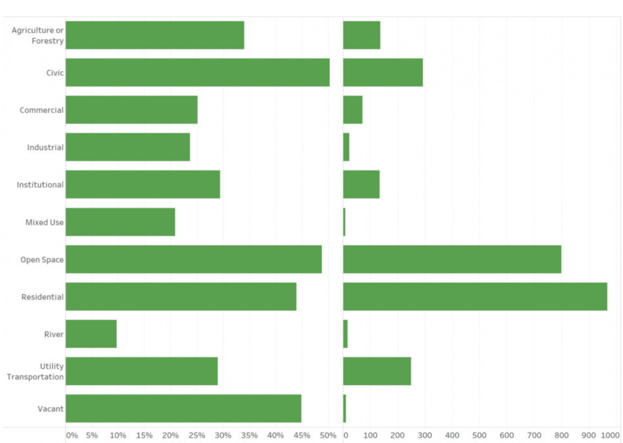


Figure 13: Existing tree canopy metrics summarized by land use.

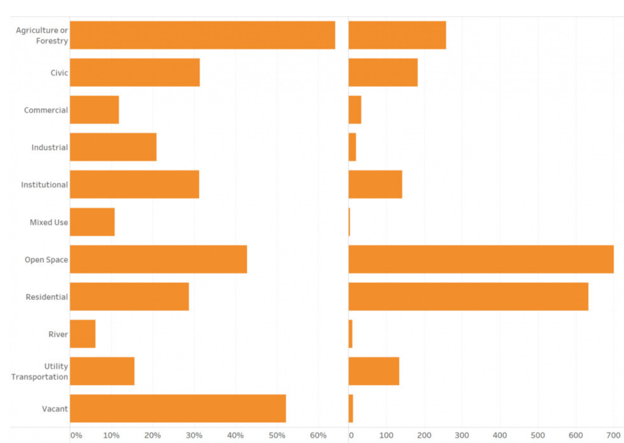


Figure 14: Possible-vegetated tree canopy metrics summarized by land use.

Ownership

The ownership analysis for this study focused on looking at four different types of land in the city: City-Owned, Other, Residential, and ROW. This dataset was a modified version of the city's 2018 land use dataset. City-Owned represents all property controlled by the city government, Residential corresponds to residential land use, ROW is the rights-of-way along roads, and other consists of all the remaining land use types. The highest aggregate gains in tree canopy across all four ownership classes have been in the Residential category. When it comes to the relative increase, the ROW experienced the most substantial gain, at 35%. This gain is a sign that the city's investments in the planting, care, and maintenance, of its street trees has paid dividends. Although the percent of land covered by tree canopy in the ROW is lower than the other categories, this is entirely understandable given the challenges of establishing and sustaining trees adjacent to streets. The ROW has the least amount of Possible-Vegetation, both as a percentage and in aggregate. Given these challenges, the expansion of tree canopy in the ROW is even more impressive. The city's residents control over 60% of the city's land and over 35% of its tree canopy. These actions of these individual landowners will play a pivotal role in the future of Burlington's tree canopy. The city can make gains on city-owned land as there are hundreds of acres where establishing new tree canopy is biologically feasible.

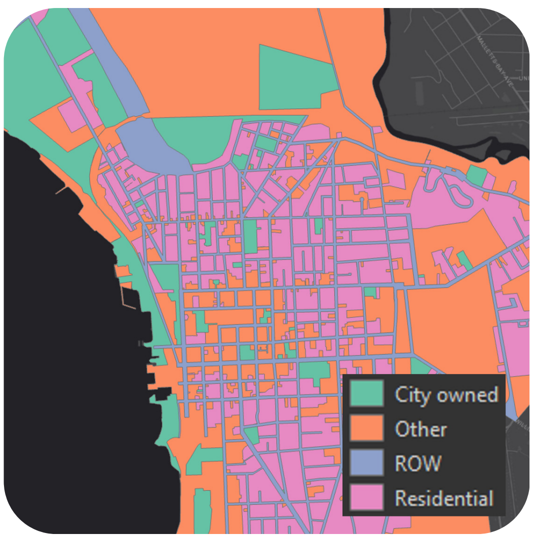


Figure 14: Ownership categories.

Figure 15: Tree canopy change metrics for ownership categories.

Figure 16: Existing tree canopy metrics summarized by ownership.

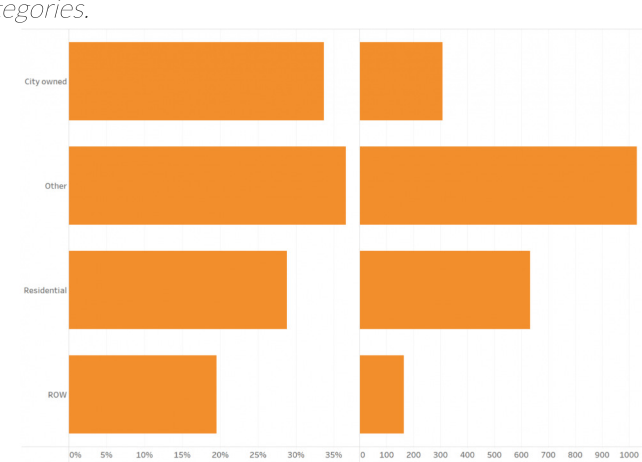


Figure 17: Possible-vegetated tree canopy metrics summarized by ownership.

Height

Canopy height is essential for understanding the vertical structure of Burlington's urban forest. To some extent, height can provide a proxy for age. The tree canopy was segmented into polygons that approximate the extent of individual trees. Each of these polygons was attributed with the height information from the LiDAR data. The taller trees tend to exist within larger patches located in the city's parks and on conserved lands. Most of the city's tree canopy is within the 10 to 25-meter height range, which is likely heavily influenced by construction date.

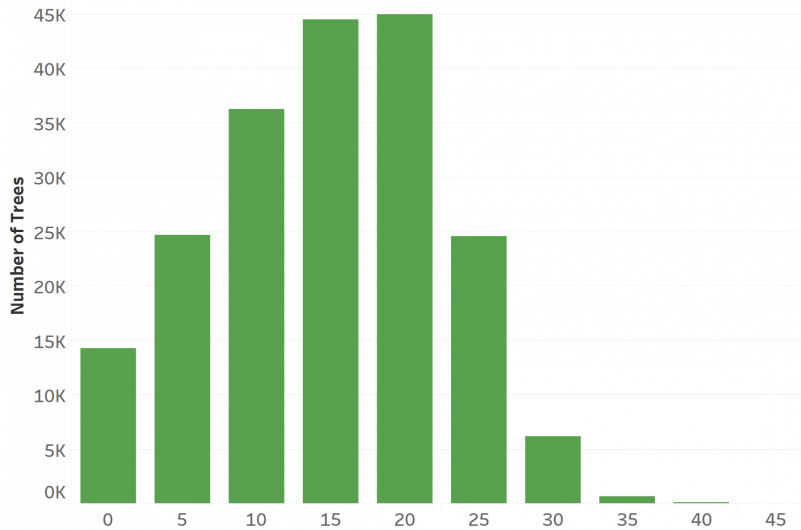


Figure 18: Histogram of the tree canopy height displaying the number of trees in each 5-meter bin.

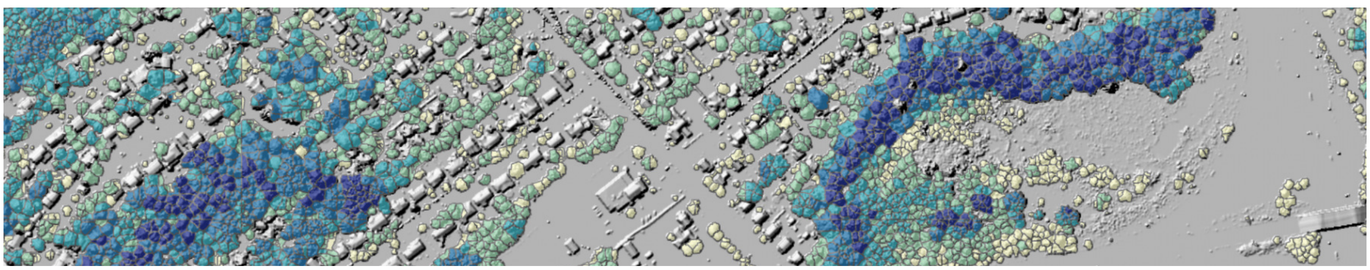


Figure 19. Example of the height classification with dark blue representing the taller canopy.

Patch

Not all tree canopy is created equal. Larger patches of tree canopy are associated with providing essential ecosystem services such as habitat for wildlife. This project used an algorithm to divide Burlington's tree canopy into three patch classes based on their morphology. Large patches generally represent core forest. Medium patches consist of either groups of a few trees or narrowly configured linear patches. Small patches consist of individual trees or clumps of small trees.

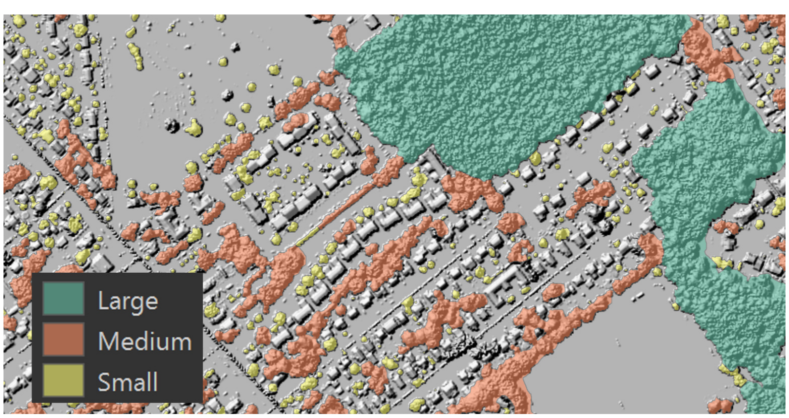


Figure 20. Example of the canopy patch classification.

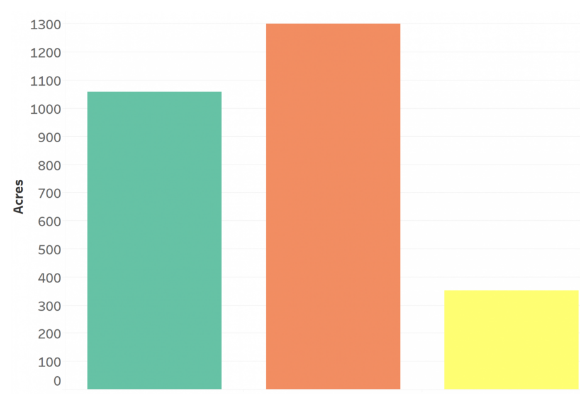


Figure 21. Total area of canopy in each patch class.

FINDINGS

Burlington's tree canopy has increased from 2004 to 2016 but there has been a mix of losses and gains throughout the the city.

Increases within the rights-of-way demonstrate the dividends paid out from the work the city has put into improving its street trees.

More tree canopy is under residential control than any other land use class. Residential areas also have the most room for new tree canopy.

Urbanization, land use, year built, and construction all play a role in influencing the current state of tree canopy in the city.

RECOMMENDATIONS

The tree canopy assessment data should be integrated into planning decisions at all levels of government.

Tree canopy should be reassessed at 5-10 year intervals to monitor change.

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

This assessment is not a replacement for field data collection on tree species, size, and health.

This assessment was carried out by the University of Vermont Spatial Analysis Lab using tools developed in collaboration with the USDA Forest Service. The City of Burlington and the Vermont Urban & Community Forestry contributed data and input to the assessment. The project was funded primarily through a grant from the Vermont Agency of Natural Resources. Additional support came from a Catalyst Award from the Gund Institute for Environment at the University of Vermont.

University of Vermont Spatial Analysis Lab

BURLINGTON PARKS RECREATION WATERFRONT

Northern Research Station USDA Forest Service

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