

# An Assessment of Boston's Tree Canopy



## Why is Tree Canopy Important?

Trees provide many benefits to communities, such as improving water quality, reducing stormwater runoff, lowering summer temperatures, reducing energy use in buildings, removing air pollution, enhancing property values, improving human health, providing wildlife habitat, and aesthetic benefits<sup>1</sup>. Many of the benefits that trees provide are correlated with the size and structure of the tree canopy which is the layer of branches, stems, and leaves of trees that cover the ground when viewed from above. Therefore, understanding tree canopy is an important step in urban forest planning. A tree canopy assessment provides an estimate of the amount of tree canopy currently present as well as the amount of tree canopy that could theoretically be established. The tree canopy assessment can be used by a broad range of stakeholders to help communities plan a greener future.

<sup>1</sup>National Research Council. *Urban Forestry: Toward an Ecosystem Services Research Agenda: A Workshop Summary*. Washington, DC: The National Academies Press, 2013.

## How Much Tree Canopy Does Boston Have?

An analysis of the City of Boston, MA based on land cover data (Figure 1) derived from 2016 high-resolution aerial imagery and 2014 LiDAR found that 8,323 acres of the study area were covered by tree canopy (termed Existing TC). This represents 27% of all of the land within the City of Boston (Figure 2). An additional 41% (12,726 acres) of the city's land area could theoretically be modified to accommodate tree canopy (termed Possible Tree Canopy). Within the Possible category, 19% (5,697 acres) of total land area was classified as Vegetated Possible and another 23% (7,029 acres) as Impervious Possible. Establishing tree canopy on areas classified as Impervious Possible will have a greater impact on water quality and summer temperatures while planting on Vegetated Possible (grass/shrub), will generally be easier. 32% (9,834 acres) of the city is generally not suitable for establishing new tree canopy (buildings and roads).

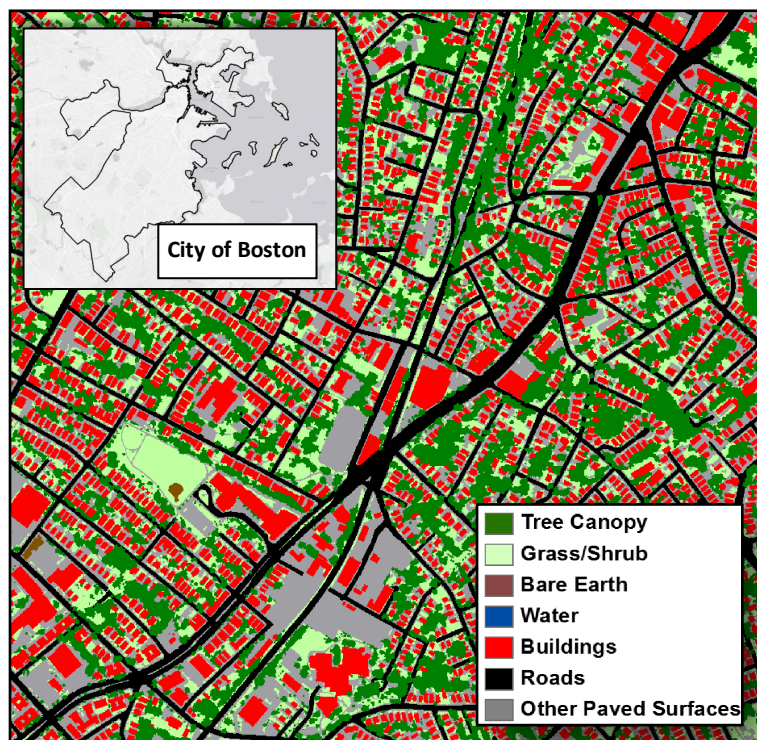


Figure 1: Study area and example of the land cover derived from high-resolution imagery for this project.

## Project Partners

This project applied the USDA Forest Service's Tree Canopy Assessment protocols to the City of Boston. The analysis was conducted using imagery and LiDAR acquired in 2016 and 2014.

The Spatial Analysis Laboratory (SAL) at the University of Vermont's Rubenstein School of the Environment and Natural Resources carried out the assessment in collaboration with the City of Boston and the Trust for Public Land.

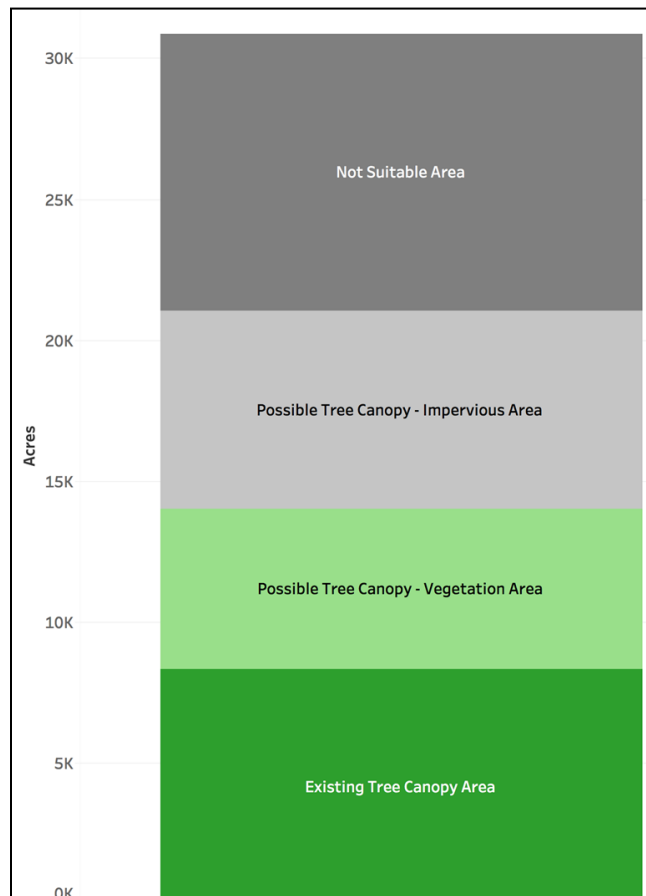


Figure 2: Tree Canopy metrics for Boston on acres of land area covered by each category.

## Key Terms

**Tree Canopy:** Tree canopy is the layer of branches, stems, and leaves of trees that cover the ground when viewed from above.

**Land Cover:** Physical features on the earth mapped from aerial or satellite imagery, such as trees, grass, water, and impervious surfaces.

**Existing Tree Canopy:** The amount of urban tree canopy present when viewed from above using aerial or satellite imagery.

**Impervious Possible Tree Canopy:** Asphalt or concrete surfaces, excluding roads and buildings, that are theoretically available for the establishment of tree canopy if improvements were made.

**Vegetated Possible Tree Canopy:** Grass or shrub area that is theoretically available for the establishment of tree canopy.

**Not Suitable:** Areas where it is highly unlikely that new tree canopy could be established (primarily buildings and roads).



## Mapping Boston's Trees

Previous estimates of Boston's tree canopy, such as the 2011 National Land Cover Database (NLCD 2011), are notably lower than the 27% obtained in this study. This large difference can be attributed to the fact that the relatively low resolution of NLCD (Figure 3a) results in only large extents of tree canopy being mapped. Using high-resolution imagery (Figure 3b) and LiDAR acquired in 2016 and 2014, land cover for Boston was mapped with such detail that individual trees as short as 8 feet were detected (Figure 3c). This new tree canopy dataset represents the most accurate accounting of tree canopy ever done for Boston. It should be noted that other estimates, such as those from NLCD, should not be used to compare tree canopy change over time in relation to this study.

**a. NLCD 2011 Percent Tree Canopy (30m)**



**b. 2016 Aerial Imagery (2ft)**



**c. Tree Canopy from 2016 Imagery**



Figure 3: Comparison of NLCD 2011 (a) to high-resolution imagery (b) and tree canopy (c) derived for this study.

## Detailed Information

Tree Canopy (TC) Metrics, produced from the land cover data, provide insight into the Existing and Possible tree canopy at various units of analysis. Existing TC and Possible TC metrics were calculated for each parcel, both in terms of total area (square footage) and as a percentage of the land area within each parcel (Tree Canopy area divided by land area of the parcel) (Figure 4). These data can be used to understand the current tree canopy and tree planting opportunities for every property in Boston.

### Parcels



### Existing Tree Canopy



### Possible Tree Canopy

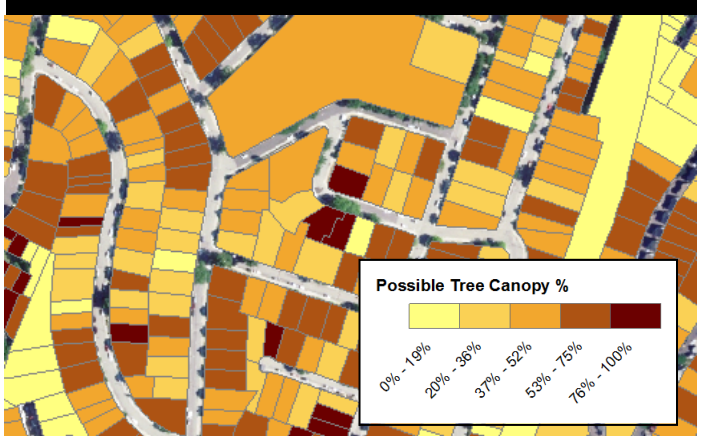


Figure 4: Comparison of existing and possible tree canopy for each property parcel in Boston.

## Land Use & Land Cover

To examine the relationship between land use and land cover, the total area for each land use class was summarized and then the percent of vegetative cover (trees, grass, shrubs) in each land use category was computed (Figure 5). This analysis provides insight into land use patterns within the city and the influence land use might have on tree canopy. Greening strategies will likely differ by land use. For example, in residential areas tree give-away programs for residents, incentive programs, and tree protection ordinances could increase canopy, while zoning regulations and design guidelines that limit the amount of impervious surfaces may be more effective in commercial areas. To better understand how to prioritize these efforts we examined the relationship between land use and vegetative cover. This analysis provides an understanding of how “green” each land use class is. The largest single land use category is Open Space followed by Residential. Unsurprisingly, Open Space also is the most green land use class, with 84% of its land covered by vegetation. At the low end, 13% of the land in the Industrial land use category is covered by vegetation.

### Percent Vegetation by Land Use Type

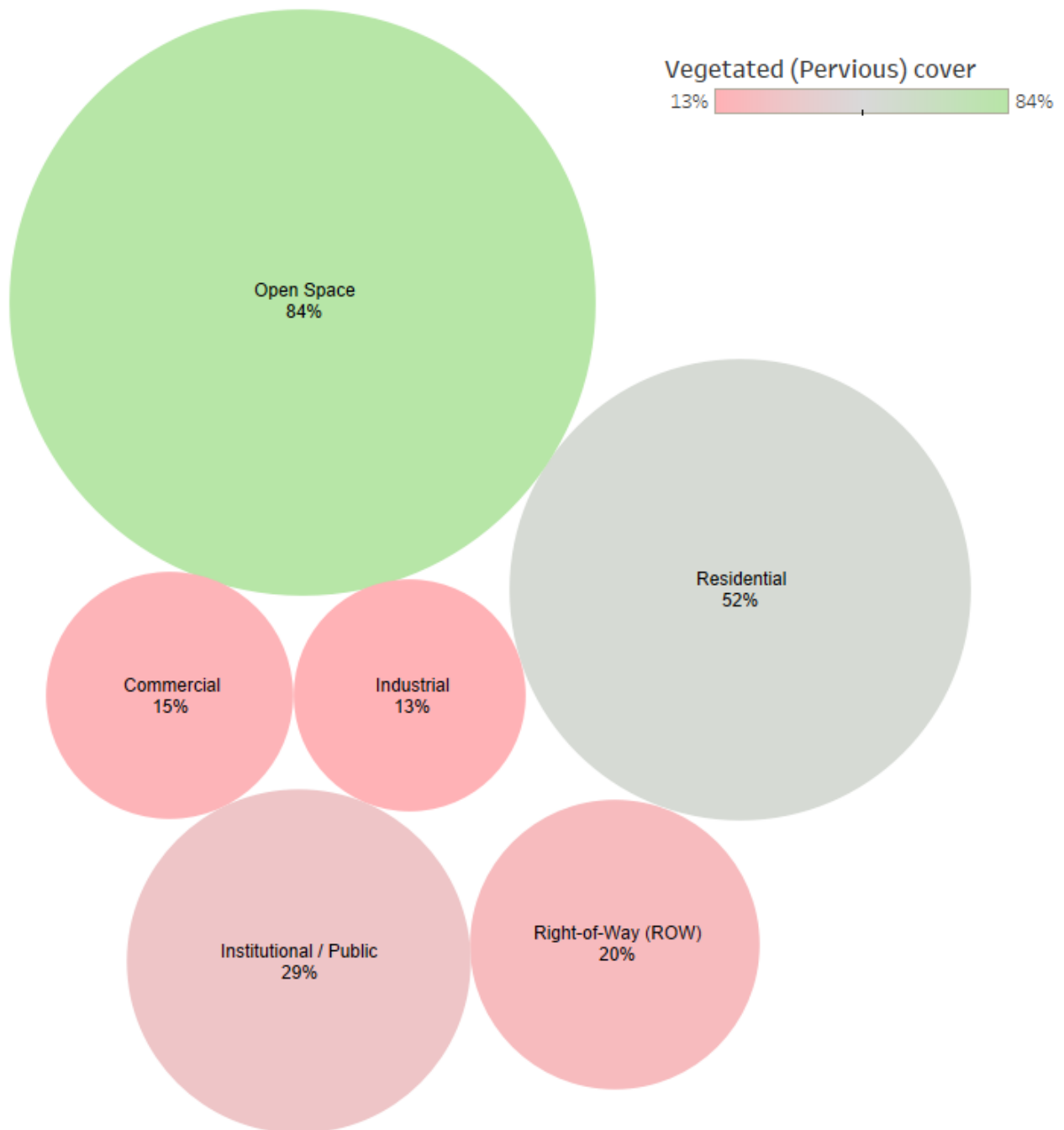


Figure 5: Percent of vegetative cover in each land use class in relation to total land area. The size of the circle represents the total land area, the color gradient represents the percentage of vegetation. Percentages are calculated based on the amount of vegetation relative to land area (i.e. water is excluded).

## Land Use Metrics

A deeper understanding of the relationship between land use, the current tree canopy, and planting opportunities can be obtained by examining the relative percentage of Existing and Possible Tree Canopy in each generalized land use category. This analysis can be used to assist in locating areas where it might be socially desirable and financially feasible to establish new tree canopy, particularly in light of Boston's ecological and climatological characteristics. Open Space is the dominant land use in Boston and thus, has the most Existing and Possible Tree Canopy by total area (Figure 6). On average, 48% of Open Space land is covered by tree canopy, which is the highest percentage out of the Land Use groups (Figure 6). Residential has the second highest percentage of tree canopy at 32%, and Open Space has the greatest percentage of its land available for establishing new tree canopy with 36% Possible Tree Canopy—Vegetation. Not surprisingly, Industrial has the least amount of tree canopy at only 8%. Overall, it is the residential and open space lands that are the most crucial for sustaining Boston's tree canopy. While policies and government initiatives can ensure tree survival on public lands, in the residential areas it will be a matter of citizen action, which can be influenced through outreach and education.

There exists thousands of acres that could theoretically support new tree canopy, but the ability to actually plant trees will largely be determined by the land use. Many areas identified as Possible Tree Canopy in Open Space lands are athletic fields or golf fairways, where adding significant tree canopy would necessitate an undesirable change of use in a dense city where recreation spaces are highly valued. Nevertheless, there exists ample opportunities to expand Boston's tree canopy across all land use types, and the data from this study can be used to help establish feasible and equitable tree canopy goals for each land use class. An approach that considers all land use types is crucial for Boston to maintain and increase its tree canopy, with governments, residents, non-profits, and the private sector all playing a role.

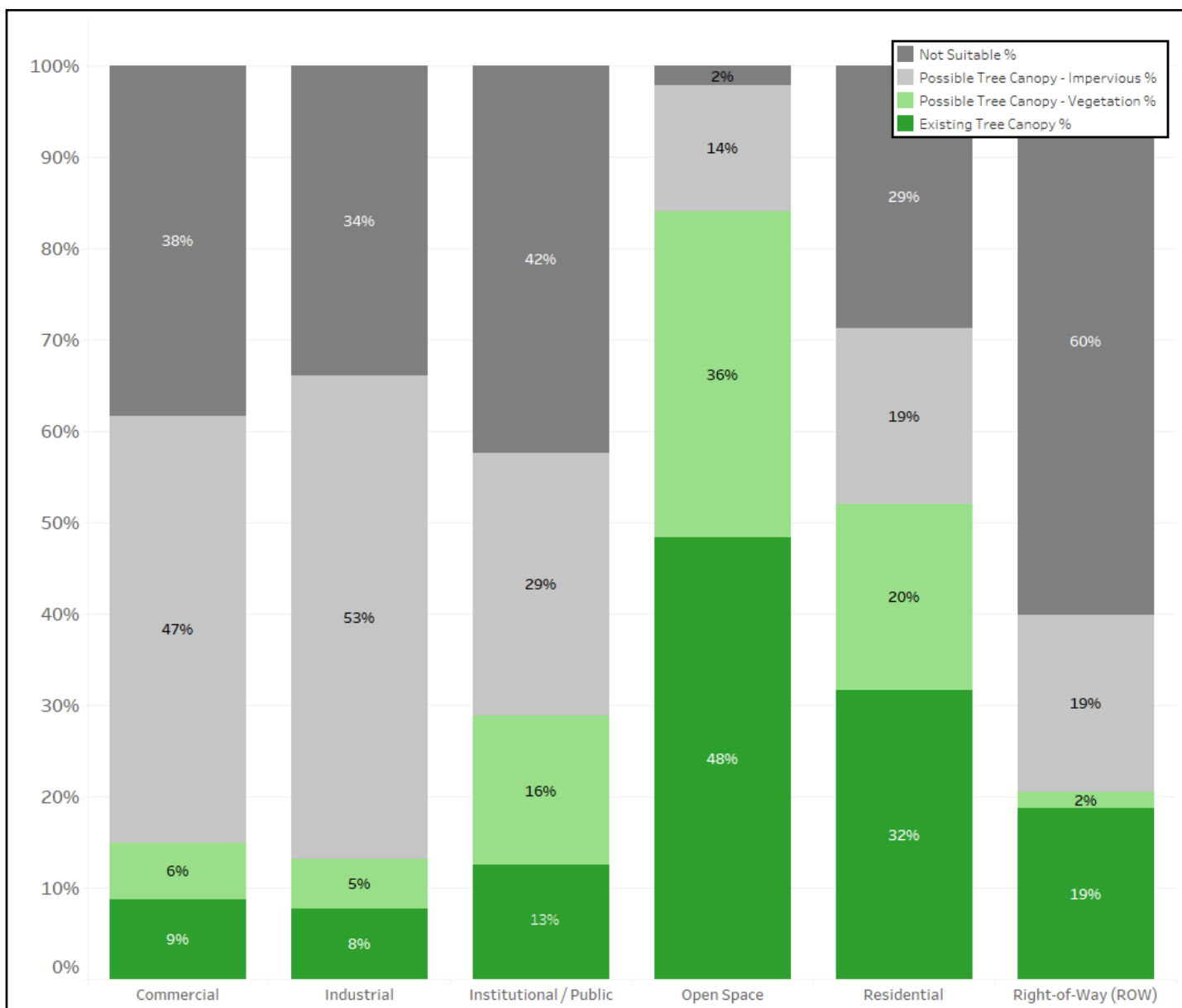


Figure 6: Tree canopy metrics derived from the parcel dataset summarized by land use.



## Urban Heat Island

Urbanized areas are typically substantially warmer than surrounding, rural locations. This effect, known as the urban heat island, has multiple negative impacts such as increased energy expenditures and higher mortality in vulnerable populations. Trees reduce ground-surface temperatures, through shading and transpiration. Impervious surfaces increase surface temperatures because they absorb and hold thermal radiation from the sun. Analysis of thermal data<sup>2</sup> (Landsat 7, August 30, 2010) illustrates this effect in Boston (Figure 7). The relationship was further confirmed by plotting surface temperature versus Existing Tree Canopy (Figure 8). The statistically significant inverse relationship between tree canopy and surface temperature provides clear evidence that trees help reduce the urban heat island effect. For example, Stony Brook Reservation in Hyde Park, which contains dense tree canopy, provides for substantially lower temperatures.

<sup>2</sup>Walawender J., Hajto M., Iwaniuk P., 2012, A new ArcGIS toolset for automated mapping of land surface temperature with the use of LANDSAT satellite data. Proc. IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 22-27 July 2012, Munich, Germany, 4371-4374, doi: 10.1109/IGARSS.2012.6350405

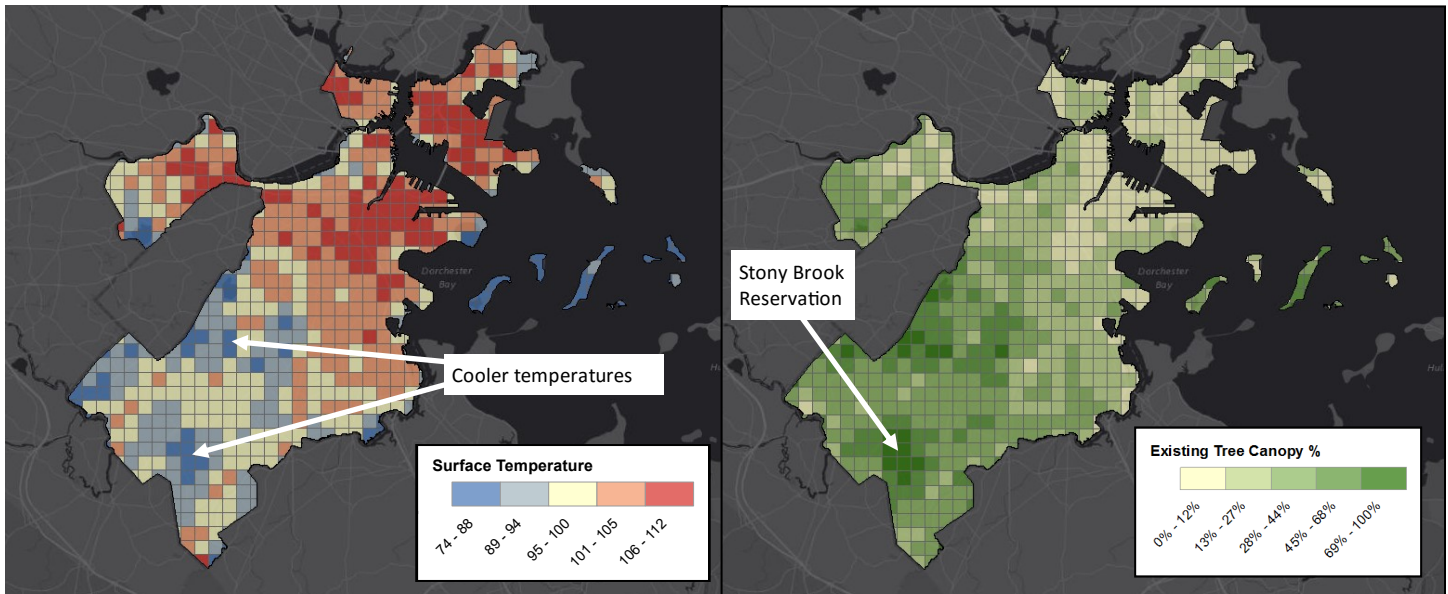


Figure 7: Surface temperature, degrees Fahrenheit on August 30, 2010 (left) in comparison with Existing Tree Canopy (right).

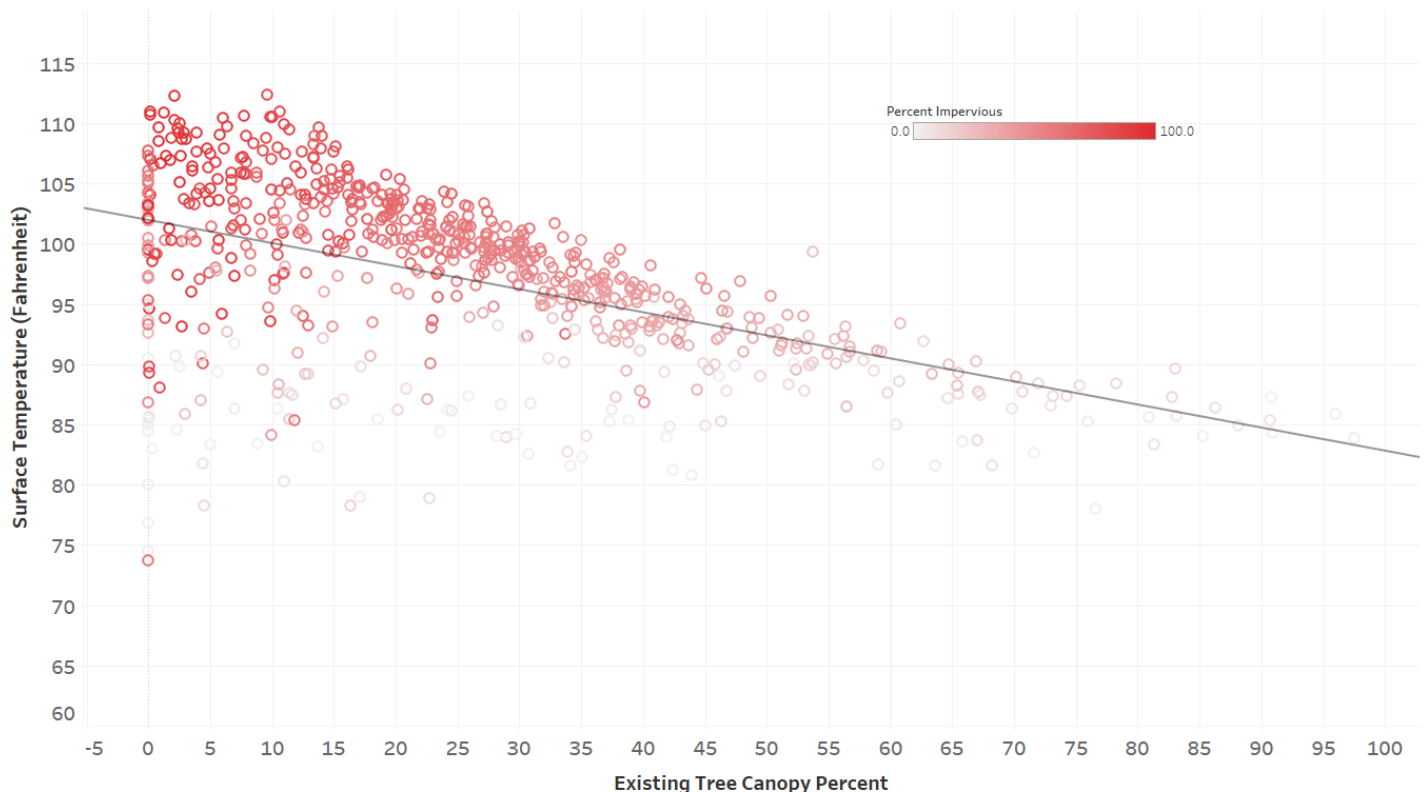


Figure 8: Surface temperature in relation to percent tree canopy. Each circle represents a 250,000 square meter grid cell. A 500 m x 500 m grid was overlaid on the region and for each grid cell the percent tree canopy, percent impervious, and average surface temperature were summarized. Surface temperature was derived from Landsat satellite imagery acquired on August 30, 2010.

## Neighborhoods

The amount of tree canopy in each neighborhood is reflective of land use and urbanization, with those neighborhoods dominated by industrial uses or in the urban core having the least tree canopy (Figure 9). Central Boston has only 8% of its land covered by tree canopy. East Boston has the least amount of tree canopy at 7% with a relatively high amount of Possible Tree Canopy (vegetation) due to Logan Airport and its predominance of tree-less grassy areas near the runways (Figure 10). Jamaica Plain has the most tree canopy cover at 46%. Neighborhoods including Roslindale, Mattapan, and Hyde Park all have at least 30% of their land covered by tree canopy — a pattern that is likely due to larger expanses of tree canopy in parks and other protected areas coupled with residential land. Neighborhoods including Charlestown, Central Boston, and South Boston all have 10% or less of their land covered by tree canopy. This trend can be traced to the proximity of these neighborhoods to the downtown area, which increases density.

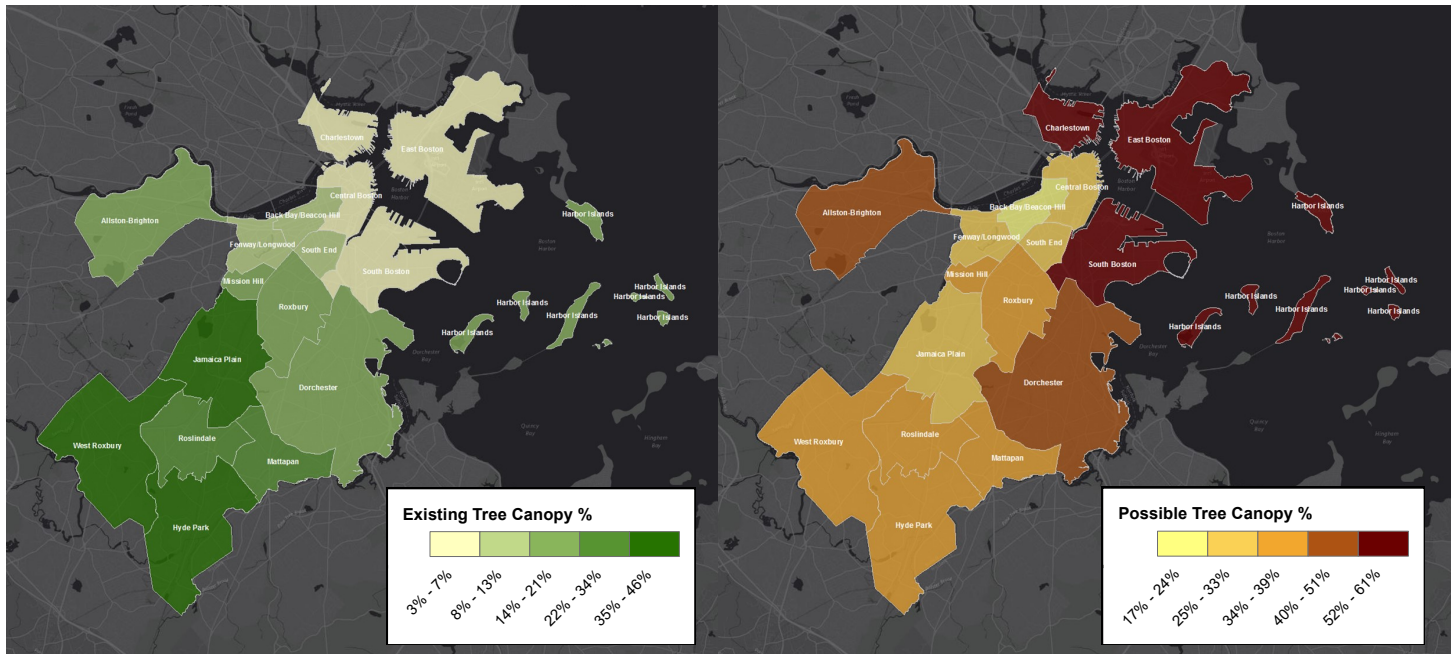


Figure 9: Percent Existing Tree Canopy by Neighborhood (left) in comparison to Percent Possible Tree Canopy (right).

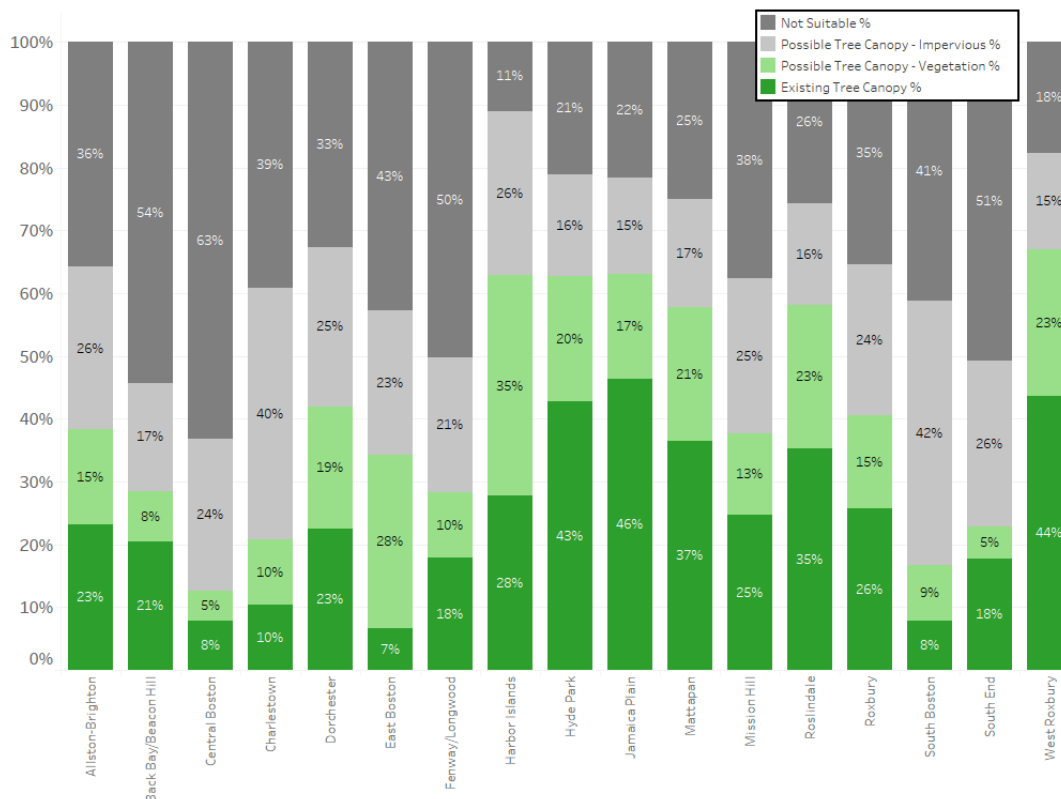


Figure 10: Tree Canopy Metrics for all Neighborhoods

## Open Space

Tree canopy varies widely in the city's 7000 acres of public and private open space. Of 992 mapped open spaces, 63 have at least 95% tree canopy, and 97 have less than 5%. The latter are primarily small plazas located near the downtown. Franklin Park, which is Boston's largest open space, has 59% tree canopy. Combining the park geospatial database with the Possible Tree Canopy estimates provided by this study could help to better establish realistic tree canopy goals that match the intended use of each park.

By ownership group, the Commonwealth of Massachusetts and Community Group/Non-Profit open spaces have the most tree canopy at 51% (Figure 11). City of Boston and Non-Public open spaces are not far behind with 48% and 46% tree canopy cover, respectively. The Federal/US ownership group has approximately one-third tree canopy and two-thirds Possible Tree Canopy. Although all 4 non-Federal/US ownership groups have close to 50% of land area classified as Possible Tree Canopy, increasing tree canopy on many of these lands might be impractical as they are historic sites or have uses that are incompatible with extensive tree canopy.

Metrics were also produced for a subset of protected open spaces (4689 acres primarily in City or Commonwealth ownership). This subset accounts for about two-thirds of total open space acreage. Existing and Possible Tree Canopy percentages for the primary ownership groups in the protected subset are similar to those found for all open spaces. Slight discrepancies between the complete and protected open space results for a given ownership group (e.g., the Commonwealth's 46% Possible Tree Canopy in all open spaces vs. 44% in protected open spaces) are due to the fact that not all of a given ownership group's open spaces are protected from development. The most noticeable differences in Existing or Possible Tree Canopy are for the Federal and Non-Public ownership groups, which represent only a tiny fraction of protected open spaces (12 and 47 acres, respectively).

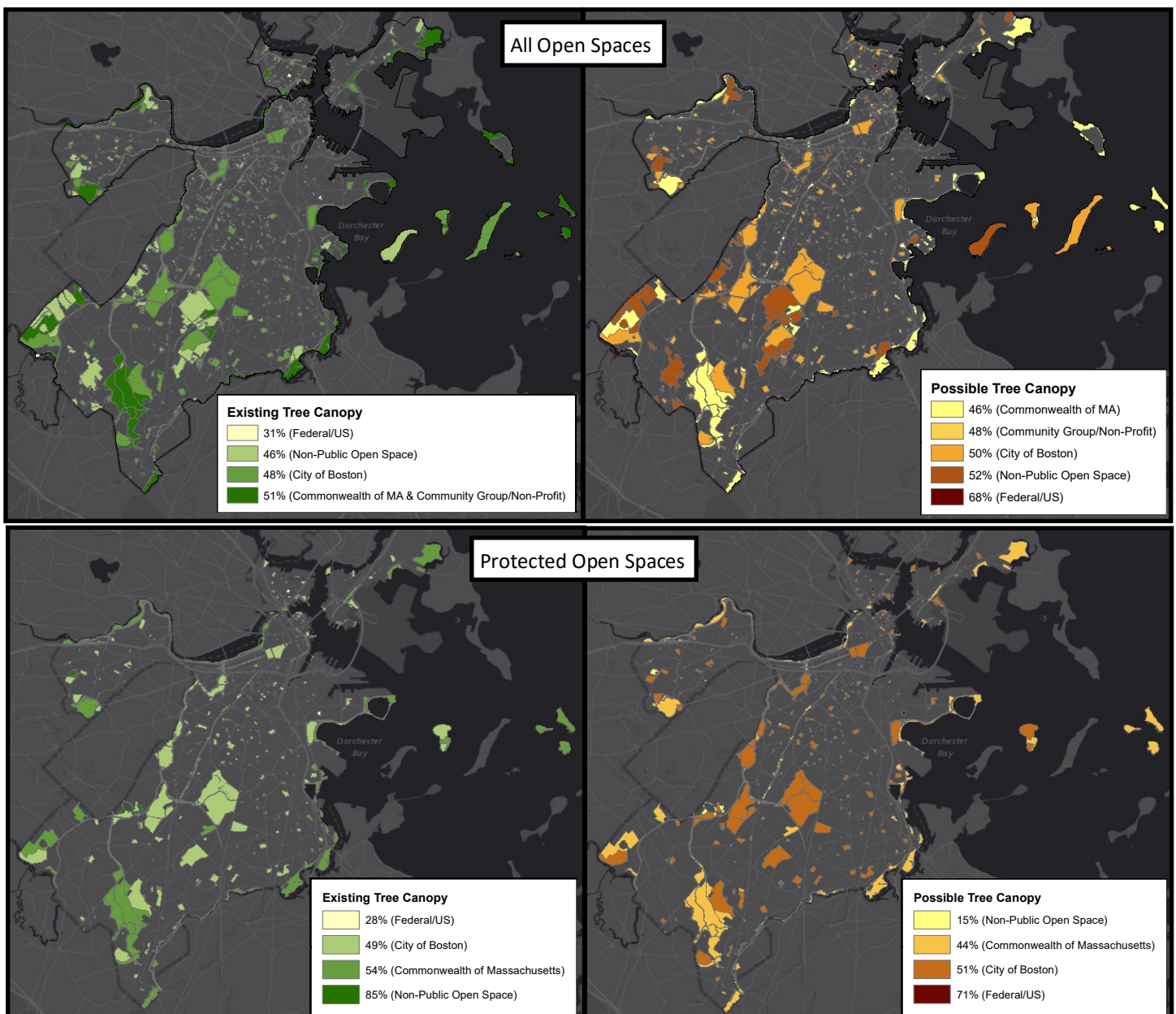


Figure 11: Percent Existing Tree Canopy and percent Possible Tree Canopy for Boston Open Space (top) and Protected Open Space (bottom).



## Rights of Way (ROW)

Tree Canopy metrics were computed by neighborhood for Boston's Rights of Way — a land use category that is roughly one-fifth Existing Tree Canopy and one-fifth Possible Tree Canopy, as noted earlier in this report. Comparing metrics for neighborhoods can help to prioritize street tree planting efforts. Although the ROW can be used to estimate the amount of tree canopy for the city's street trees, it is important to note that the mapping for this study was carried out from a top-down perspective. As a result, it was not possible to know if the actual stem of the tree fell within the ROW and was thus a street tree. Tree canopy on parcel land outside of the ROW could contribute to tree canopy within the ROW and vice versa.

Dorchester, Boston's largest neighborhood, has nearly 180 acres of its ROW classified as Possible Tree Canopy (Figure 12). This total represents 21% of the ROW in Dorchester. Other, smaller neighborhoods have lesser amounts of Possible Tree Canopy in their ROW, but these areas often represent higher percentages of each neighborhood's total ROW acreage. East Boston, for example, has 28% of its ROW classified as Possible Tree Canopy, indicating that a relatively large fraction of the ROW has potential for supporting street trees compared to other neighborhoods. The ROW in Central and South Boston are each approximately one quarter Possible Tree Canopy. Some of these neighborhoods consist primarily of the urbanized downtown area where far fewer trees exist on private land and thus street trees are the primary source of canopy. Possible Tree Canopy area ranges from 17% to 28% across all neighborhoods excluding the Harbor Islands, where the ROW is almost exclusively shoreline margins, which might not be considered appropriate areas for tree planting.

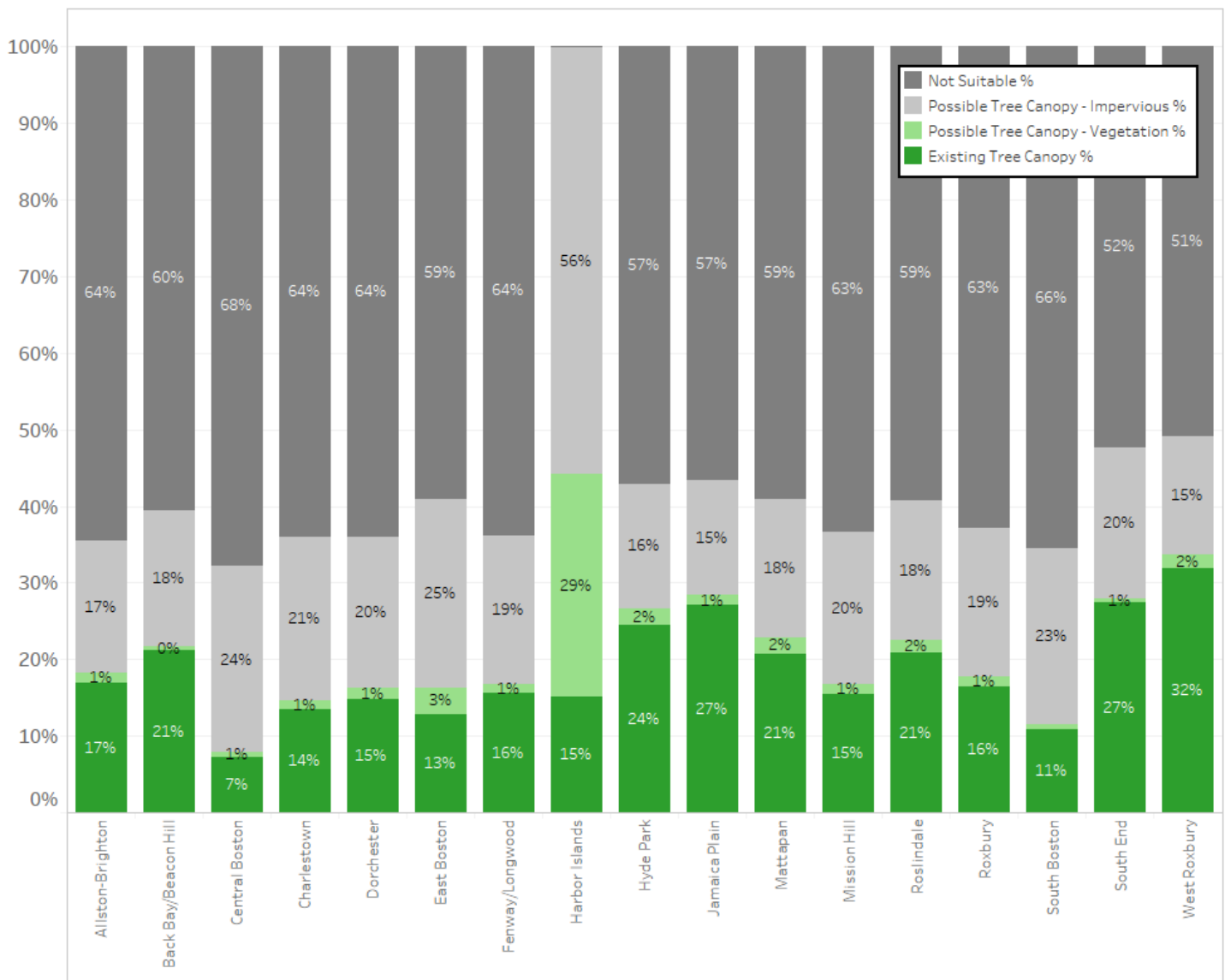


Figure 12: Tree Canopy metrics for Rights of Way summarized by neighborhood.



## Watershed

Analyzing the Existing and Possible TC by land use for each watershed allows for tree canopy planting plans to be tailored to ownership patterns in the watershed. Existing and Possible Tree Canopy were summarized for each watershed within Boston (Figure 13 and Figure 14). This watershed analysis used TribArPrioritized and IDDE watershed datasets.

In TribArPrioritized watershed dataset, Bussey Brook watershed has the highest percentage of Existing Tree Canopy at 61% (Figure 13). Millers River Watershed has the lowest percentage of Existing Tree Canopy (6%), but has a high percentage of Possible Tree Canopy (47%). The Lower Neponset River watershed also has 47% of Possible Tree Canopy.

In the IDDE watersheds, Charles River and the tiny Muddy River watersheds have the highest percentage of Existing Tree Canopy (39% and 35%; Figure 14).

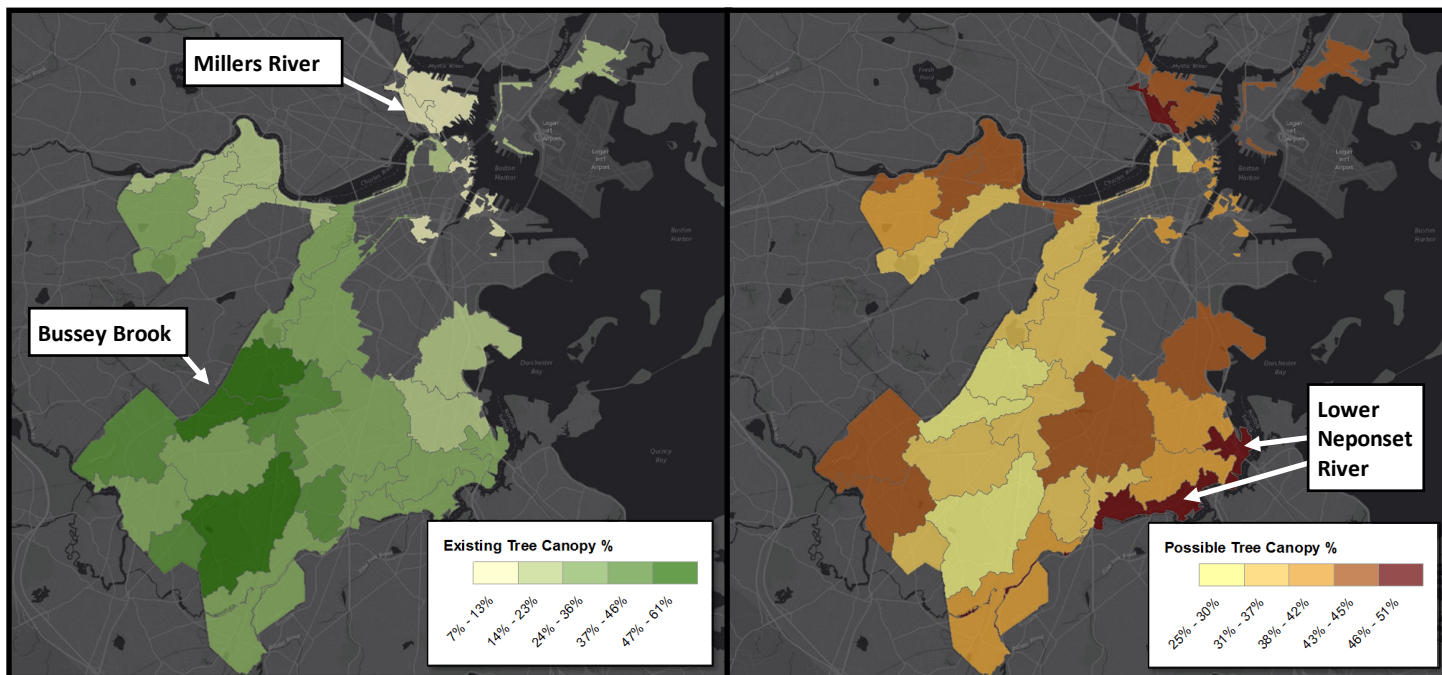


Figure 13: Percent Existing Tree Canopy by watershed in comparison to Percent Possible Tree Canopy by TribArPrioritized watersheds.

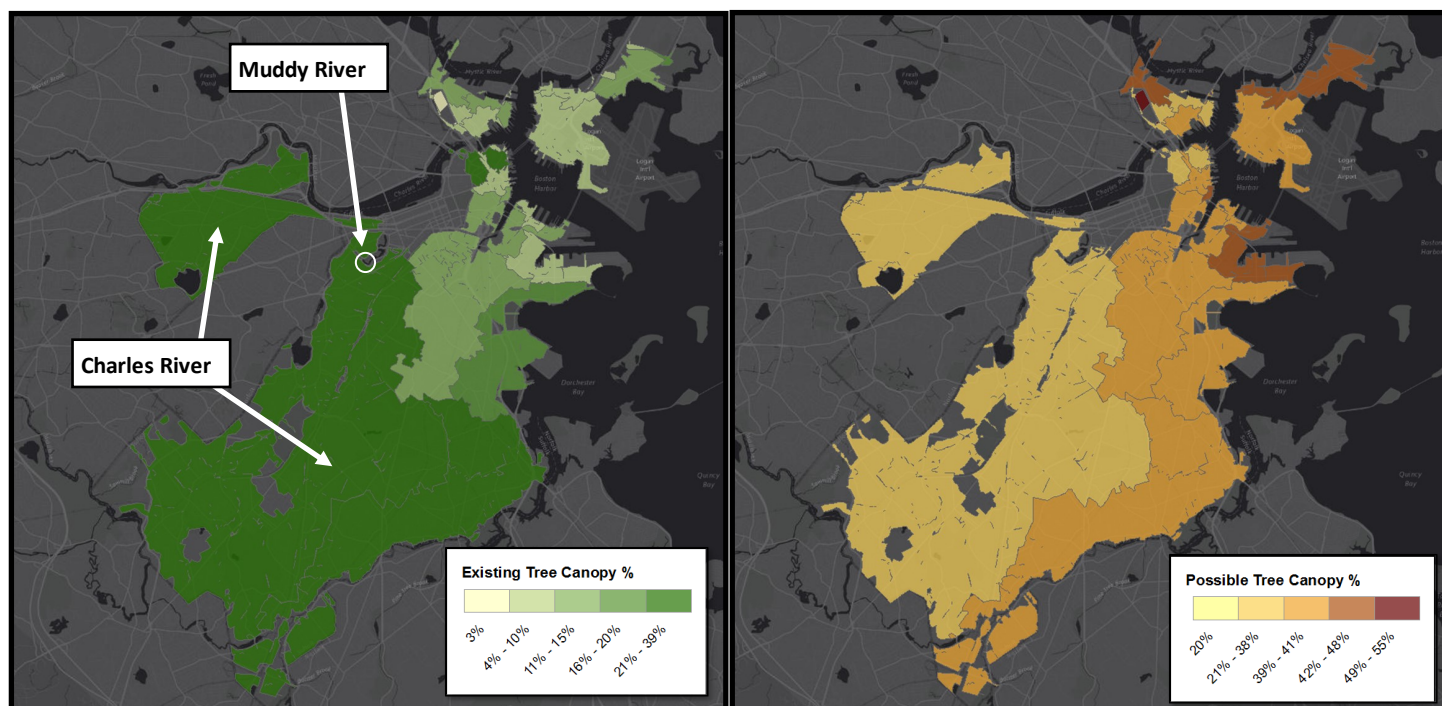


Figure 14: Percent Existing Tree Canopy by watershed in comparison to Percent Possible Tree Canopy by IDDE watersheds.



## Forest Patch Analysis

Not all tree canopy provides the same ecosystem services. Larger forested patches are associated with improved wildlife habitat and watershed health, among other positive attributes. The forest patch analysis partitions tree canopy into three classes based on their size, shape, and density: 1) small 2) medium, and 3) large. In general, small patches represent individual trees or small rows of trees, medium patches represent clumps of trees, often in suburban or agricultural settings, and large forest patches consist of forested stands, which are often associated with a duff layer (Figure 15). The majority of Boston's tree canopy is in the medium patch class (Figure 16).

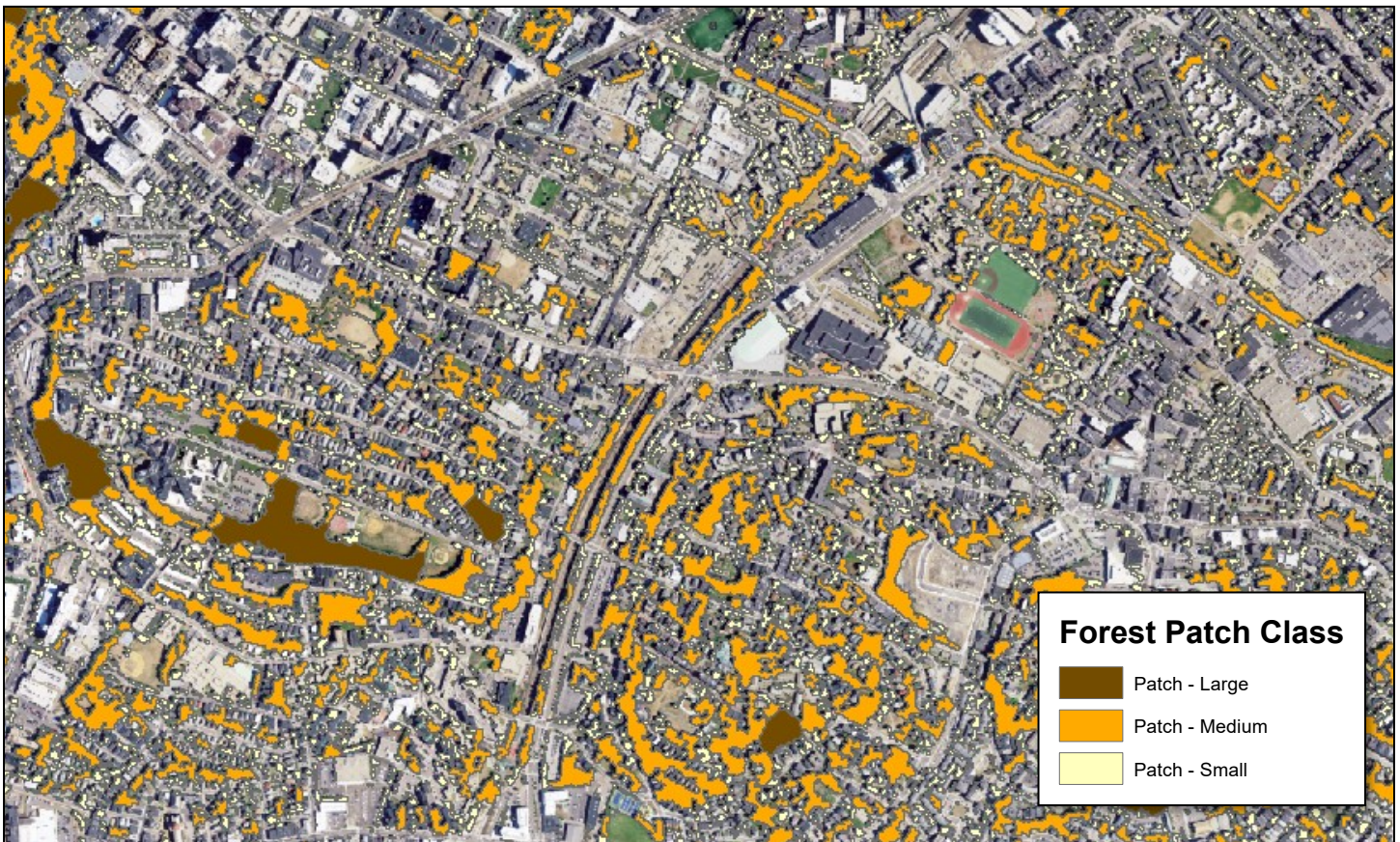


Figure 15: Forest patch classes, in which the tree canopy is subdivided into one of three categories.

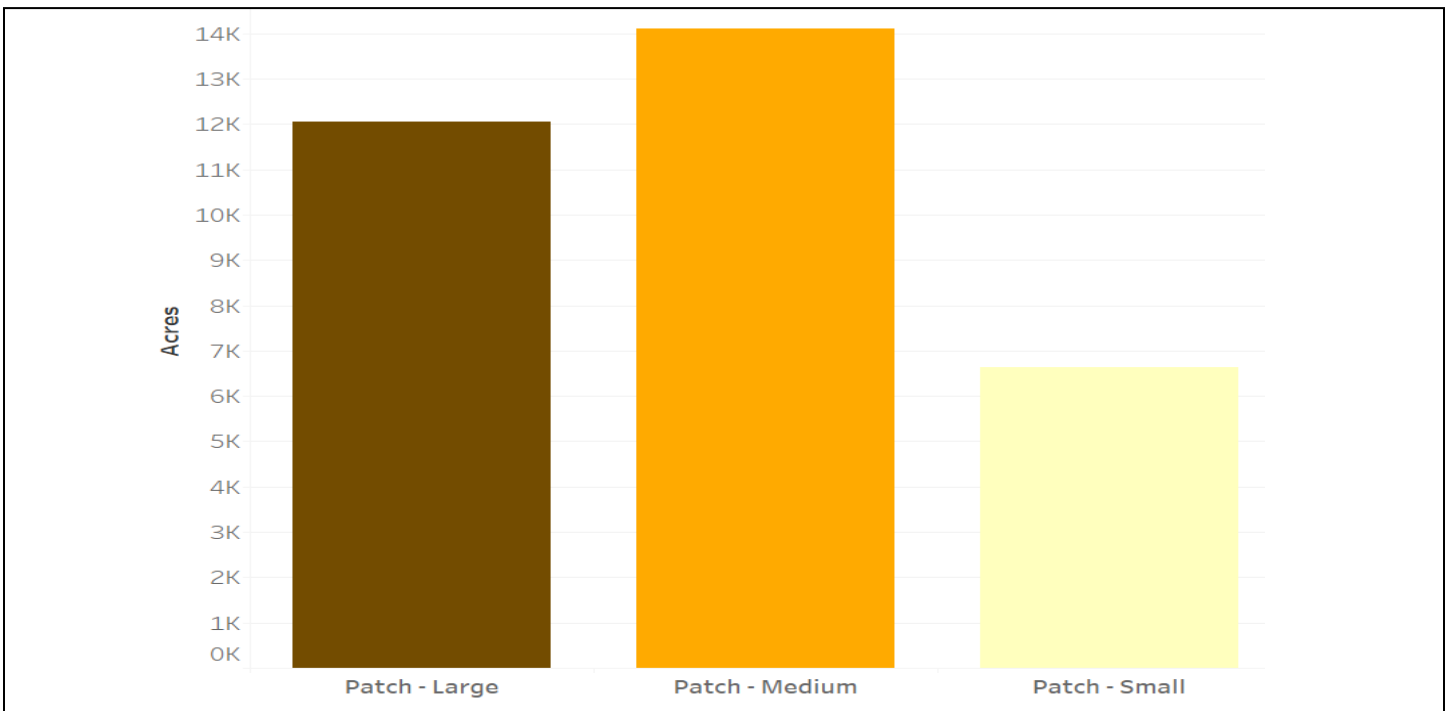


Figure 16: Number of acres each forest patch size contains



## Tree Canopy Height

Knowing the height of the tree canopy can be of value for a variety of uses, ranging from locating large trees for preservation to estimating the age of a forest stand. The tree canopy dataset was divided into polygons approximating individual trees by using a combination of high-resolution imagery and LiDAR. Each one of these polygons was then assigned average and maximum height information from the 3D LiDAR data that were collected in 2014 (Figure 17). The resulting tree polygon database can be used to visualize the tree canopy in three dimensions or to carry out various analyses, such as estimating biomass, finding the tallest trees, or computing the number of trees over 100 feet. The vast majority of trees in the city are 70 feet or less in height (Figure 18).

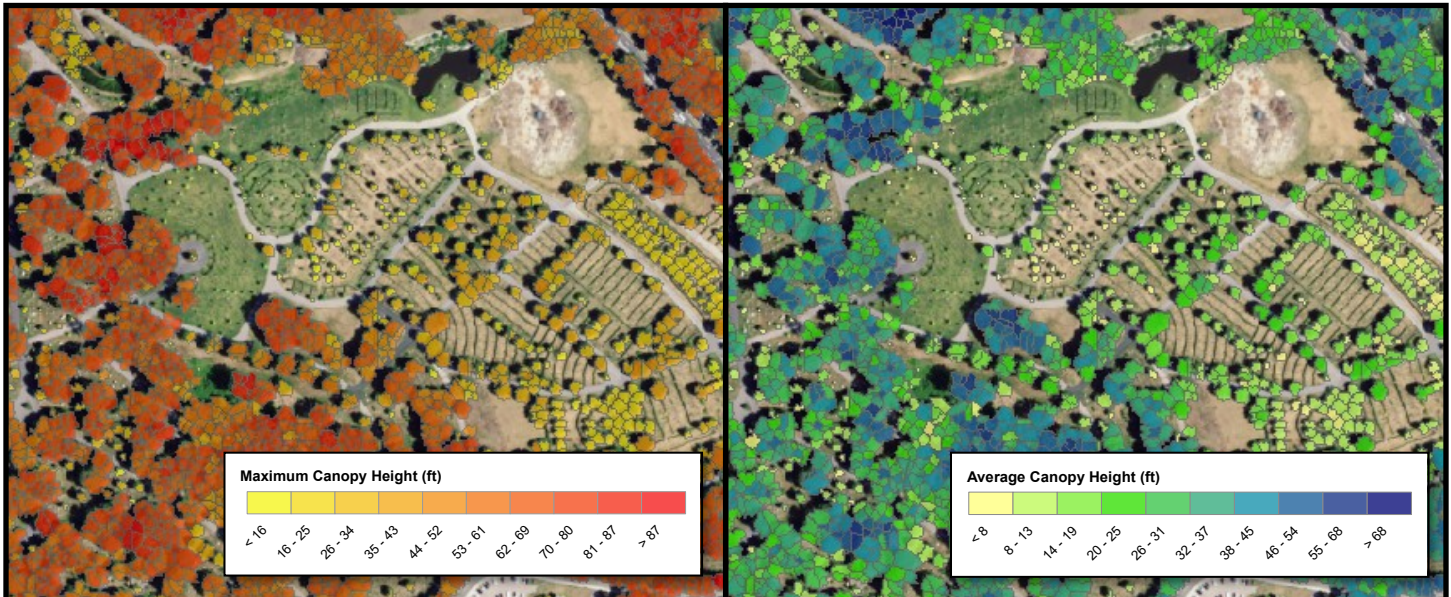


Figure 17: Maximum canopy height (Left) computed for Boston and average canopy height (right)

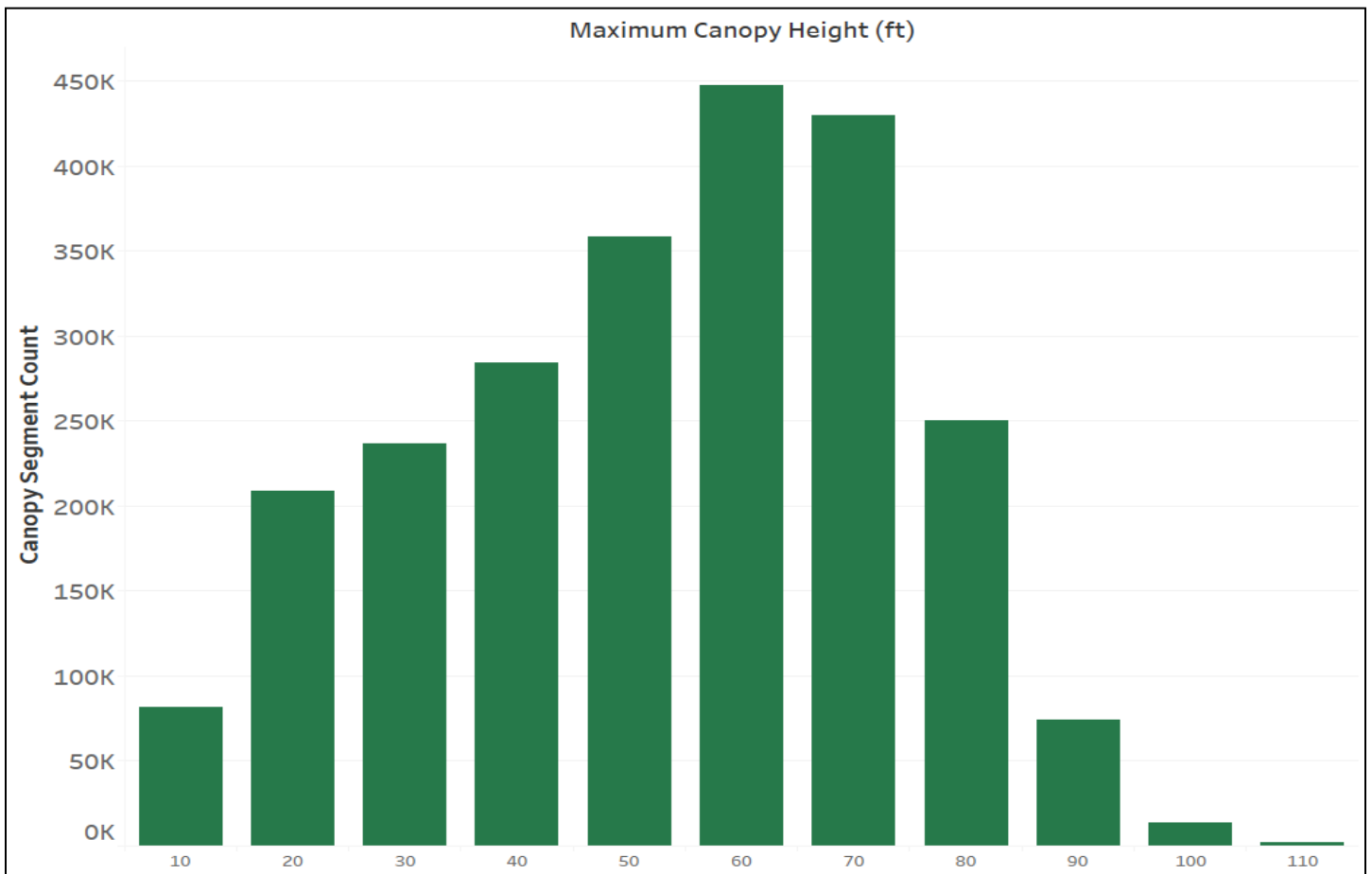


Figure 18: Count of tree canopy segments by max height class. The height of the bar reflects the number of tree canopy segments in each one of the 10 ft height classes.



## Conclusions

- This study provides the foundation for understanding the quantity, distribution, and configuration of tree canopy within Boston. It is recommended that the findings from this study be incorporated into Boston's urban forestry master planning and be used to engage urban tree canopy stakeholders.
- Tree canopy in Boston is a vital asset, providing stormwater runoff reduction, improved air quality, decreased carbon footprint, enhanced quality of life, savings on energy bills, and habitat for wildlife.
- Maintaining existing tree canopy, which allows for natural growth, is the most effective and lowest cost strategy for increasing tree canopy over time. Strategies and approaches for maintaining existing trees and establishing new ones will need to take into account local land use and demographic characteristics. This assessment provides the detailed information that can be used to help the city maintain its current tree canopy.
- The distribution of ecosystem services varies with the trees producing those services. The data from this study can be used to establish localized canopy goals and targeted plantings and conservation efforts to maximize limited resources. Selecting a specific ecosystem benefit to build an engagement campaign can increase the success in tree planting action, particularly when such an audience is already galvanized around a particular issue (e.g. engaging residents concerned about stormwater in a specific neighborhood in tree planting efforts).
- Tree canopy is correlated with lower surface temperatures. Increasing canopy cover in Boston will help reduce summer temperatures, thereby reducing energy use, improving health, and saving businesses and homeowners money by lowering energy bills. Targeting tree planting in sites with high surface temperatures would maximize these benefits.
- The configuration of tree canopy affects ecosystem services, such as wildlife habitat. Efforts to maintain larger forested areas will facilitate natural regeneration in addition to ensuring the preservation of the unique ecosystem services provided by these areas.
- The true value of the study will be realized when the analyses are used to drive specific goals to conserve existing tree canopy in addition to establishing new tree canopy.
- Future tree canopy assessments should be planned to assess changes to the tree canopy in Boston. Such assessments can provide crucial information on how effective tree planting and preservation efforts are, in addition to understanding how other factors (e.g. development) may be impacting tree canopy. Future assessments will only be made possible if continued investments are made in acquiring high-resolution, remotely-sensed imagery and LiDAR (Figure 19). It is suggested that future assessments are conducted every 5 years.

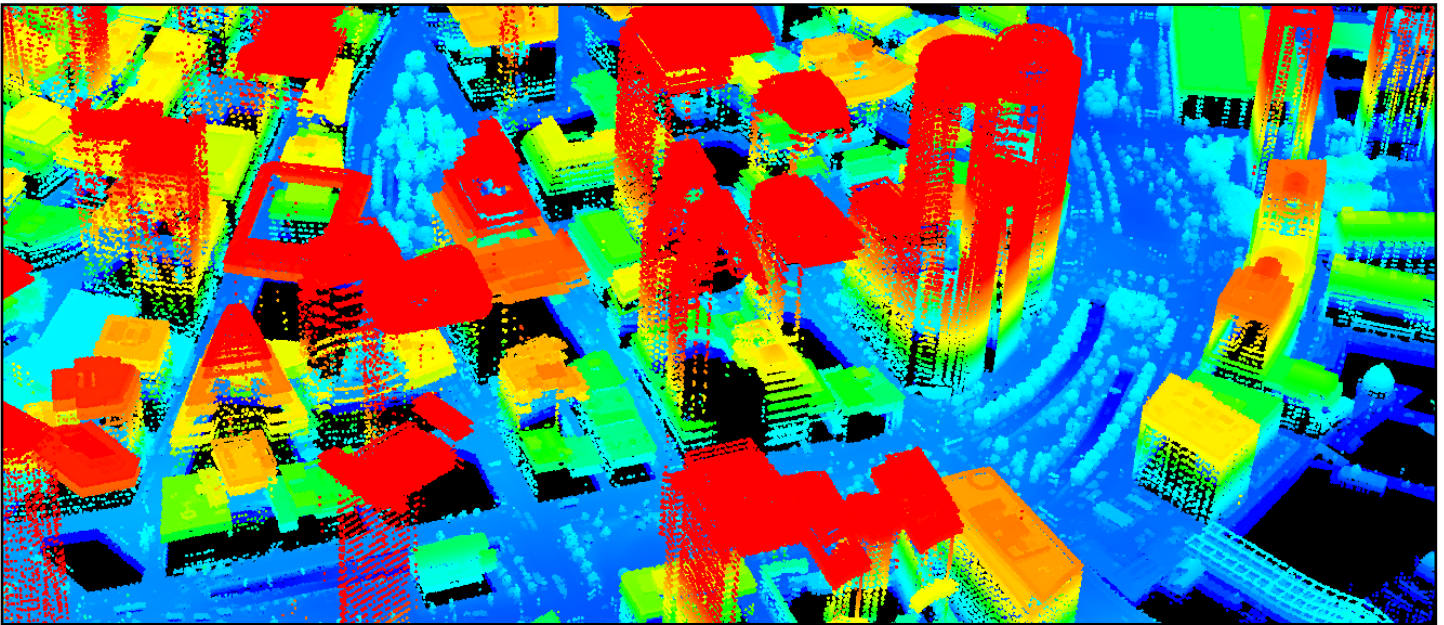


Figure 19: 3D visualization of the LiDAR collected in 2014. Without these data the accuracy and detail of the assessment would have suffered.

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### Additional Information

For more info on the Urban Tree Canopy Assessment please visit <http://nrs.fs.fed.us/urban/UTC/>

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