A Report on the City of Cambridge's Existing and Possible Tree Canopy

Why is Tree Canopy Important?

Tree canopy (TC) is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Tree canopy provides many benefits to communities, improving water quality, saving energy, lowering summer temperatures, reducing air pollution, enhancing property values, providing wildlife habitat, facilitating social and educational opportunities, and providing aesthetic benefits. Establishing a tree canopy goal is crucial for communities seeking to improve their green infrastructure. A tree canopy assessment is the first step in this goal-setting process, providing estimates for the amount of tree canopy currently present in a city as well as the amount of tree canopy that could theoretically be established.

How Much Tree Canopy Does Cambridge Have?

An analysis of Cambridge's tree canopy based on land cover data derived from high-resolution aerial imagery and LiDAR (Figure 1) found that 1,222 acres of the city were covered by tree canopy (termed Existing TC), representing 30% of all land in the city. An additional 35% (1,447 acres) of the city's land area could theoretically be modified (termed Possible TC) to accommodate tree canopy (Figure 2). In the Possible TC category, 19% (784 acres) of the city was classified as Impervious Possible TC and another 16% was Vegetated Possible TC (663 acres). Vegetated Possible TC, or grass and shrubs, is more conducive to establishing new tree canopy, but establishing tree canopy on areas classified as Impervious Possible TC will have a greater impact on water quality and summer temperatures.

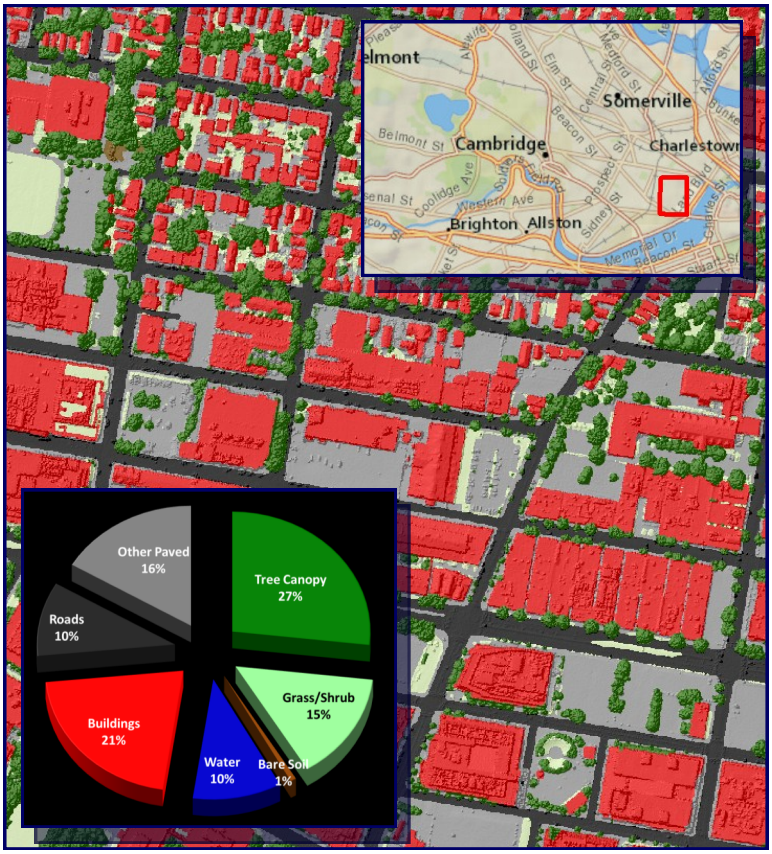


Figure 1: Land cover derived from high-resolution imagery and LiDAR for the City of Cambridge.

Project Background

The goal of the project was to apply the USDA Forest Service's TC assessment protocols to the City of Cambridge. The analysis was conducted based on year 2010 data. This project was made possible through funding from the City of Cambridge. 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 Cambridge's Community Development Department and the USDA Forest Service's Northern Research Station.

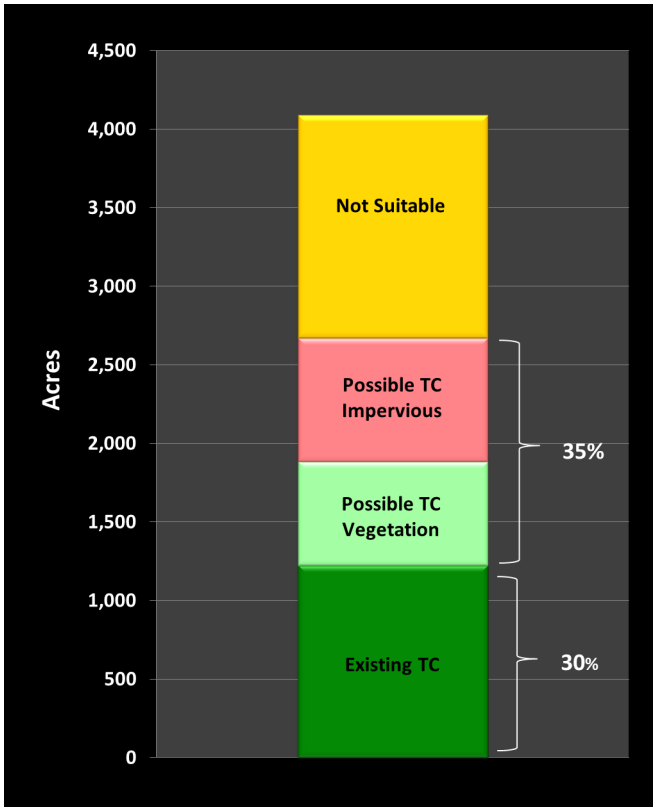


Figure 2: TC metrics for Cambridge based on % of land area covered by each TC type.

Key Terms

TC: Tree canopy (TC) is the layer of leaves, branches, and stems 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 TC: The amount of urban tree canopy present when viewed from above using aerial or satellite imagery.

Impervious Possible TC: Asphalt or concrete surfaces, excluding roads and buildings, that are theoretically available for the establishment of tree canopy.

Vegetated Possible TC: 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 Cambridge's Trees

Prior estimates of tree canopy for the entirety of the City of Cambridge (including water) from the 2001 National Land Cover Database (NLCD 2001) and the city's vegetation layer were 8% and 3% respectively, far lower than the 27% obtained in this study (the 30% estimate is a percentage of land area). The large difference is due to the fact that NLCD 2001 (Figure 3a) and the city's vegetation layer only accounted for relatively large patches of tree canopy. Using high-resolution aerial imagery (Figure 3b) and LiDAR, in combination with advanced automated processing techniques, land cover for the city was mapped with such detail that trees as short as 8ft tall were detected (Figure 3c).

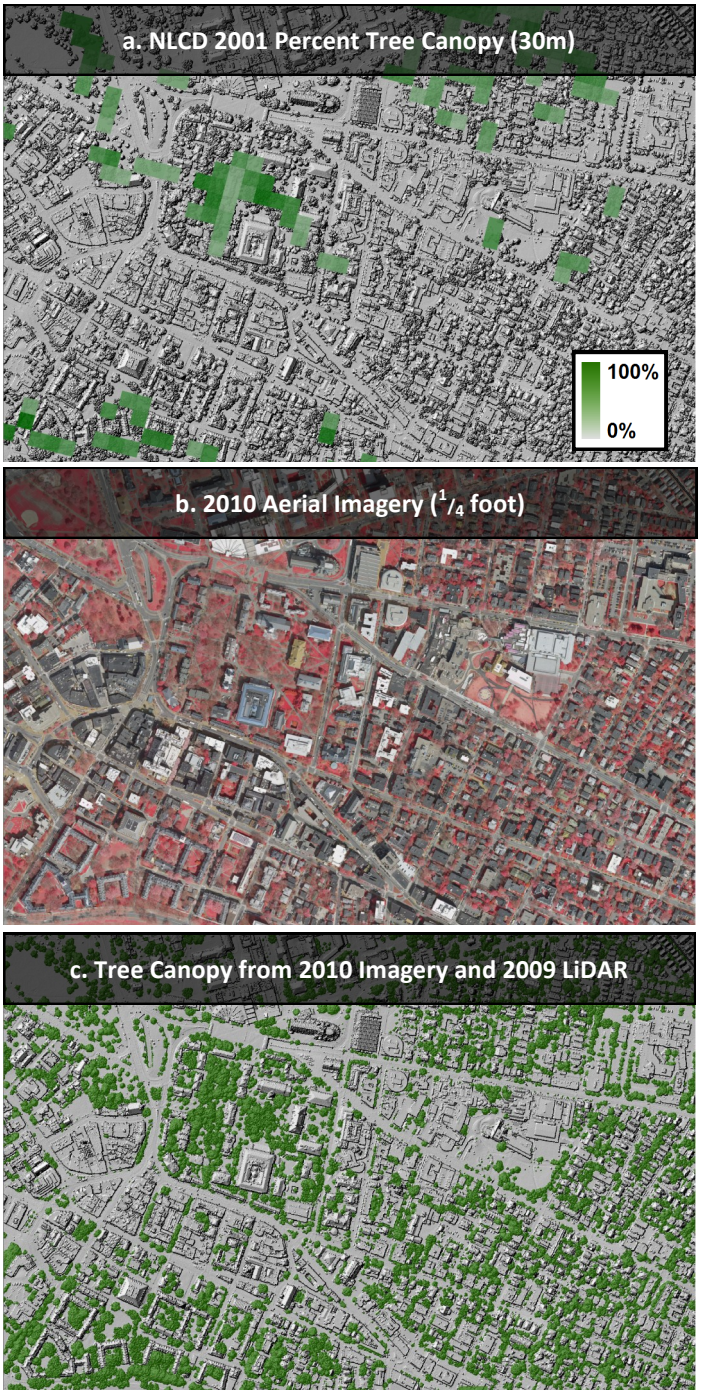


Figure 3: Comparison of NLCD 2001 (a) to high-resolution imagery (b) and tree canopy (c) derived for this study.

Parcel Summary

After land cover was mapped city-wide, Tree Canopy (TC) metrics were summarized for each property in the city's parcel database (Figure 4). 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 (TC area ÷ land area of the parcel).

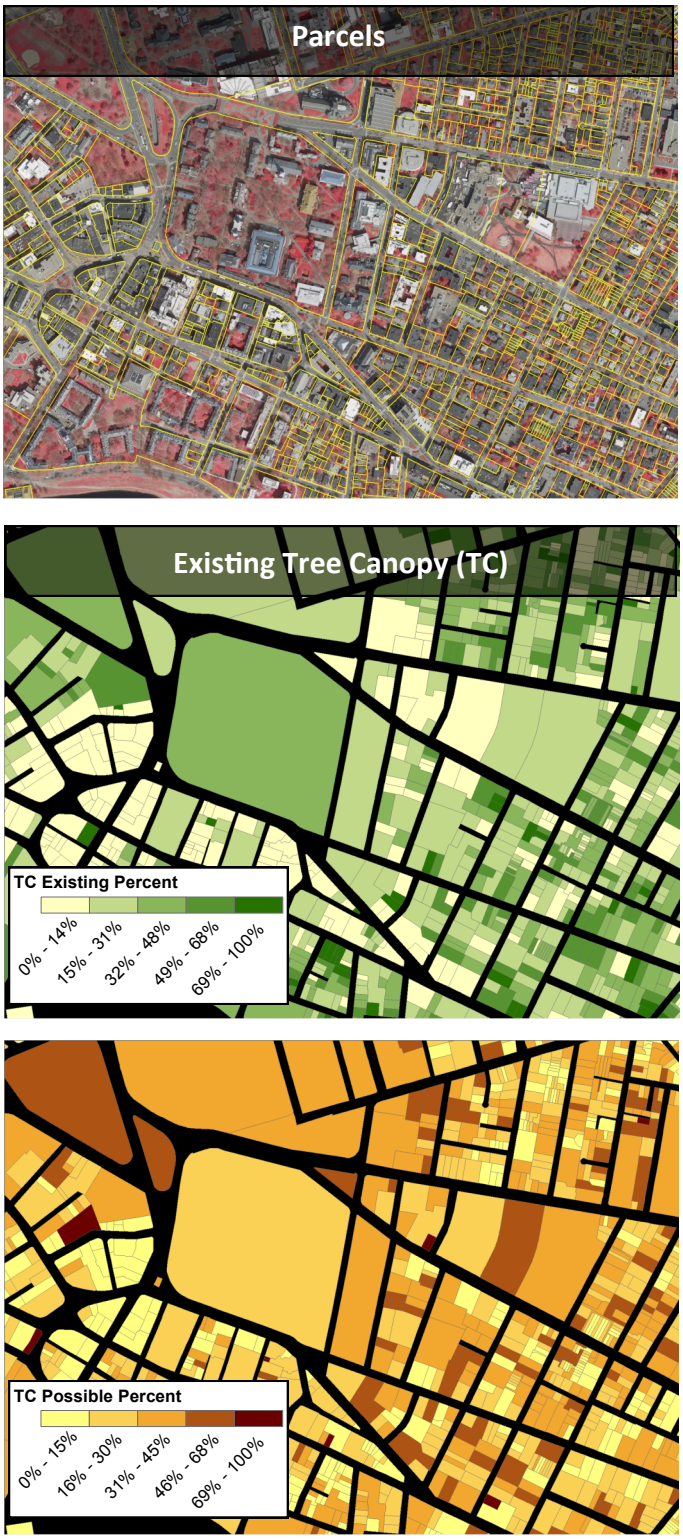


Figure 4a, 4b, 4c: Parcel-based TC metrics. TC metrics are generated at the parcel level, allowing each property to be evaluated according to its Existing TC and Possible TC.

Rights-Of-Way

Land within Cambridge can be broadly split into two categories (Figure 5), parcel land and rights-of-way. Parcel land refers to all land contained within the city's parcel database. Rights-of-Way (ROW) refers to "non-parcel" land, essentially street rights-of-way and water. The vast majority of the city's land base (79%) exists within parcels, with 21% of the city's land base within the ROW (Figure 6). Within the parcels, 30% of the land is covered by tree canopy. Within the ROW the percent of land covered by tree canopy is only slightly higher (31%). Additional tree canopy (Possible TC) could theoretically be established on 39% of all the parcel land area, but only 21% of the ROW, largely due to the presence of roads. Establishing new tree canopy within the parcel land will likely be easier as most of the Possible TC falls into the Vegetation category whereas in the ROW most of the Possible TC is in the Impervious category.

Figure 5: Parcels and ROW land division in Cambridge.

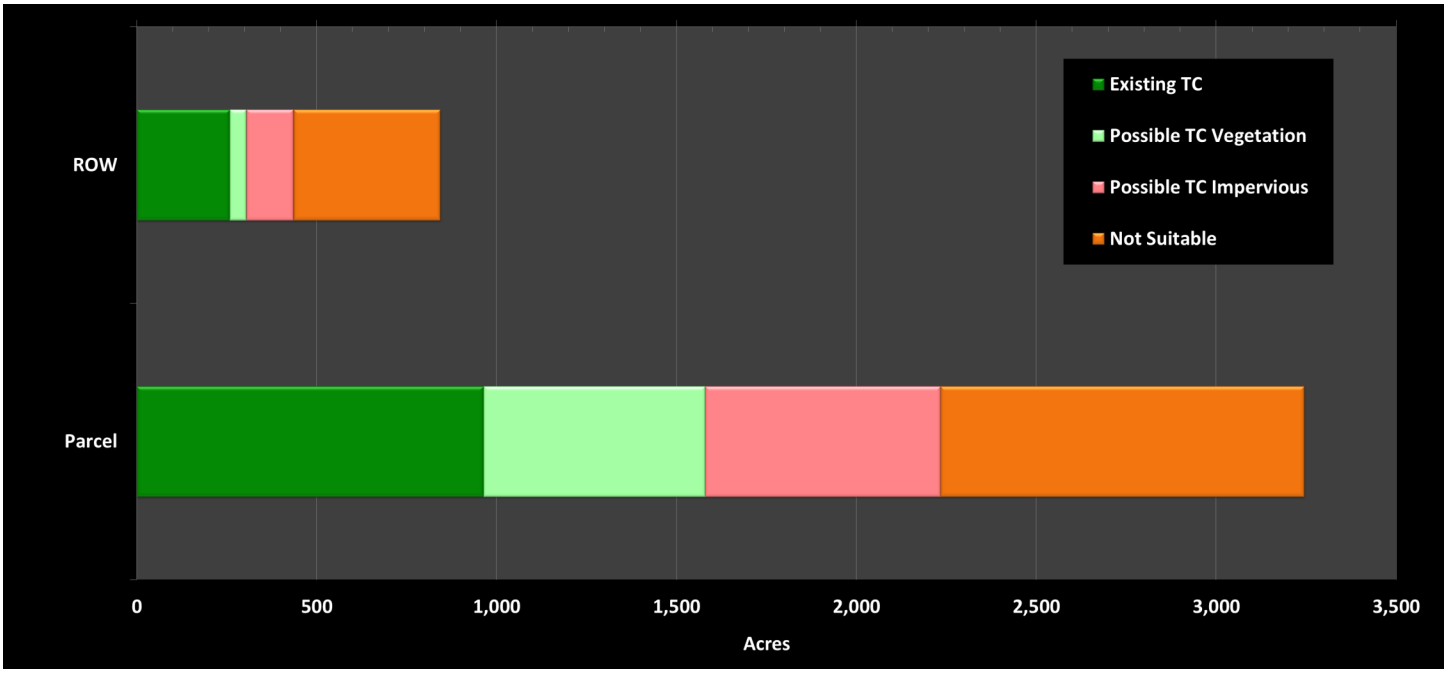


Figure 6: Tree Canopy (TC) metrics were summarized by parcels and ROW.

Land Use

Tree canopy metrics were summarized for each parcel land use category using the city's tax records. The TC metrics for the largest fourteen land use categories (excluding those parcels with no land use record) are displayed in Figures 7 and 8. Single family residential is the single largest land use category in Cambridge. 21% of the city's total tree canopy is in single family residential land use, the most of any land use category. When two family residential land use parcels are added, over 30% of the city's tree canopy can be found in either single or two family residential parcels. Condominium buildings, private universities, and improved city land uses classes are also important, with each of these land use categories contributing an additional 10% to the city's overall tree canopy. In terms of canopy coverage per land use category (% Category in Figure 8), utility authority land has 65% tree canopy coverage and single family residential land has 50% tree canopy coverage. The two office categories have only 12% and 11% of their land area covered by tree canopy. From the perspective of establishing new tree canopy (Possible TC), the improved city and vacant city have the greatest proportion of their land area available, at 61% and 56% respectively. As a percentage of all parcel land in the city it is the improved city and private universities that have the most Possible TC, accounting for 11% and 10% of all Possible TC on parcel land, respectively.

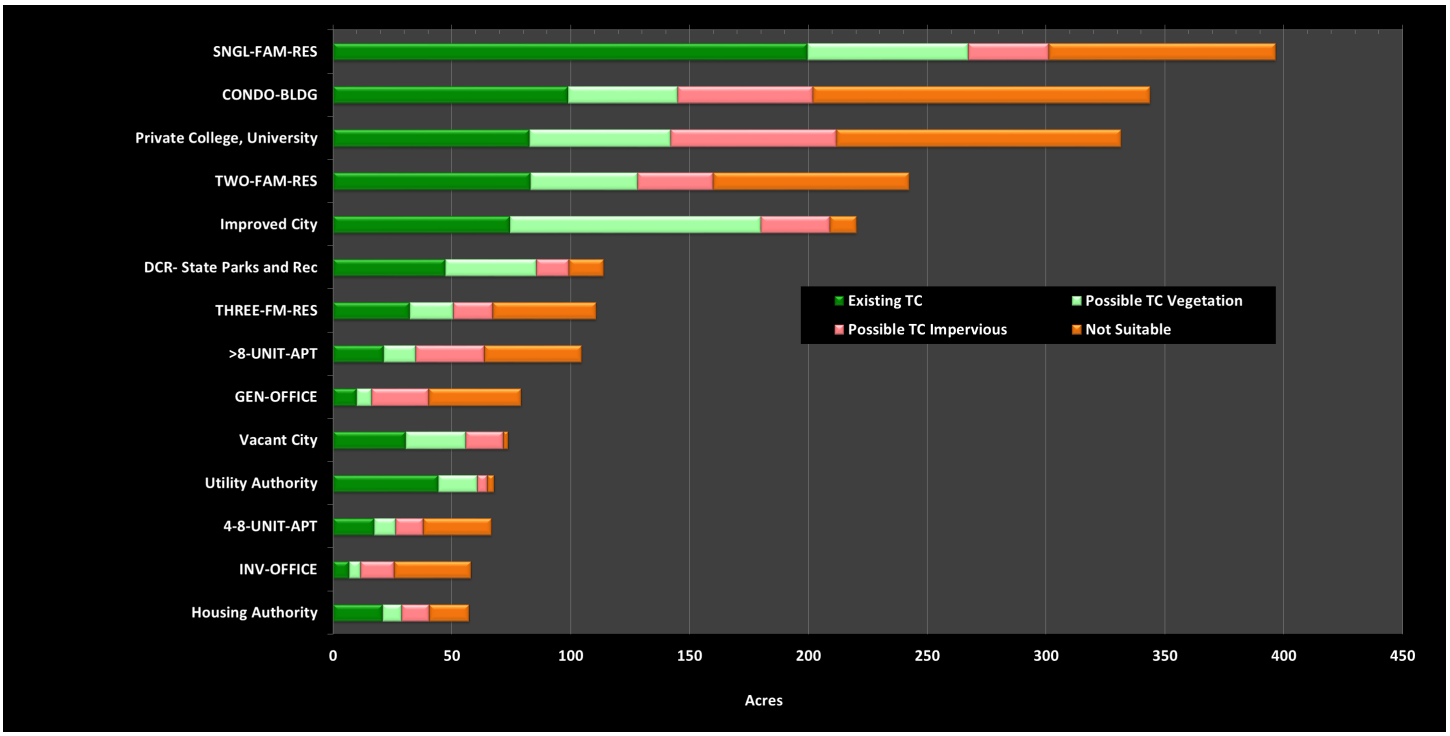


Figure 7: Tree Canopy (TC) metrics summarized for the largest fourteen land use categories.

Land Use	Existing TC			Possible TC Vegetation			Possible TC Impervious		
	% Land	% Category	% TC Type	% Land	% Category	% TC Type	% Land	% Category	% TC Type
SNGL-FAM-RES	0%	21%	0%	0%	25%	0%	0%	24%	0%
CONDO-BLDG	0%	8%	1%	1%	16%	2%	1%	28%	4%
Private College, University	0%	7%	1%	1%	19%	2%	1%	45%	5%
TWO-FAM-RES	0%	5%	0%	0%	16%	0%	0%	50%	1%
Improved City	1%	9%	5%	2%	22%	8%	4%	38%	18%
DCR- State Parks and Rec	0%	5%	0%	0%	11%	0%	0%	32%	1%
THREE-FM-RES	0%	3%	0%	0%	3%	0%	0%	25%	0%
>8-UNIT-APT	0%	21%	1%	0%	22%	0%	0%	29%	1%
GEN-OFFICE	0%	18%	1%	0%	20%	1%	0%	30%	1%
Vacant City	1%	6%	2%	3%	34%	9%	4%	46%	16%
Utility Authority	1%	14%	3%	2%	39%	7%	1%	27%	6%
4-8-UNIT-APT	0%	20%	2%	1%	28%	2%	1%	28%	3%
INV-OFFICE	1%	12%	5%	2%	24%	7%	2%	18%	7%
Housing Authority	0%	21%	0%	0%	23%	0%	0%	40%	0%

$$\text{\% Land} = \frac{\text{Area of TC type for zoning district}}{\text{Area of all land}}$$

The % Land Area value of 1% indicates that 1% of Cambridge's land area is covered by tree canopy in the vacant city land use class.

$$\text{\% Category} = \frac{\text{Area of TC type for zoning district}}{\text{Area of all land for specified land use}}$$

The % Land value of 6% indicates that 6% of land in the vacant city land use class is covered by tree canopy.

$$\text{\% TC Type} = \frac{\text{Area of TC type for zoning district}}{\text{Area of all TC type}}$$

The % TC Type value of 2% indicates that 2% of all tree canopy is in land classified as vacant city.

Table 1: Tree Canopy (TC) metrics were summarized by land use. For each land use class, TC metrics were computed as a percentage of all land in the city (% Land), as a percentage of land in the specified land use class (% Category), and as a percentage of the area for TC type (% TC Type).

Development Age

Single family residential parcels are very important in maintaining the city's Existing Tree Canopy for. An analysis of the year built data in relation to the percent exiting tree canopy reveals the development pattern of the city (Figure 8). It also point to the fact that properties containing homes built around 1920 have an unusually high percentage of tree canopy. This is likely the result of trees on those properties now reaching maturity.

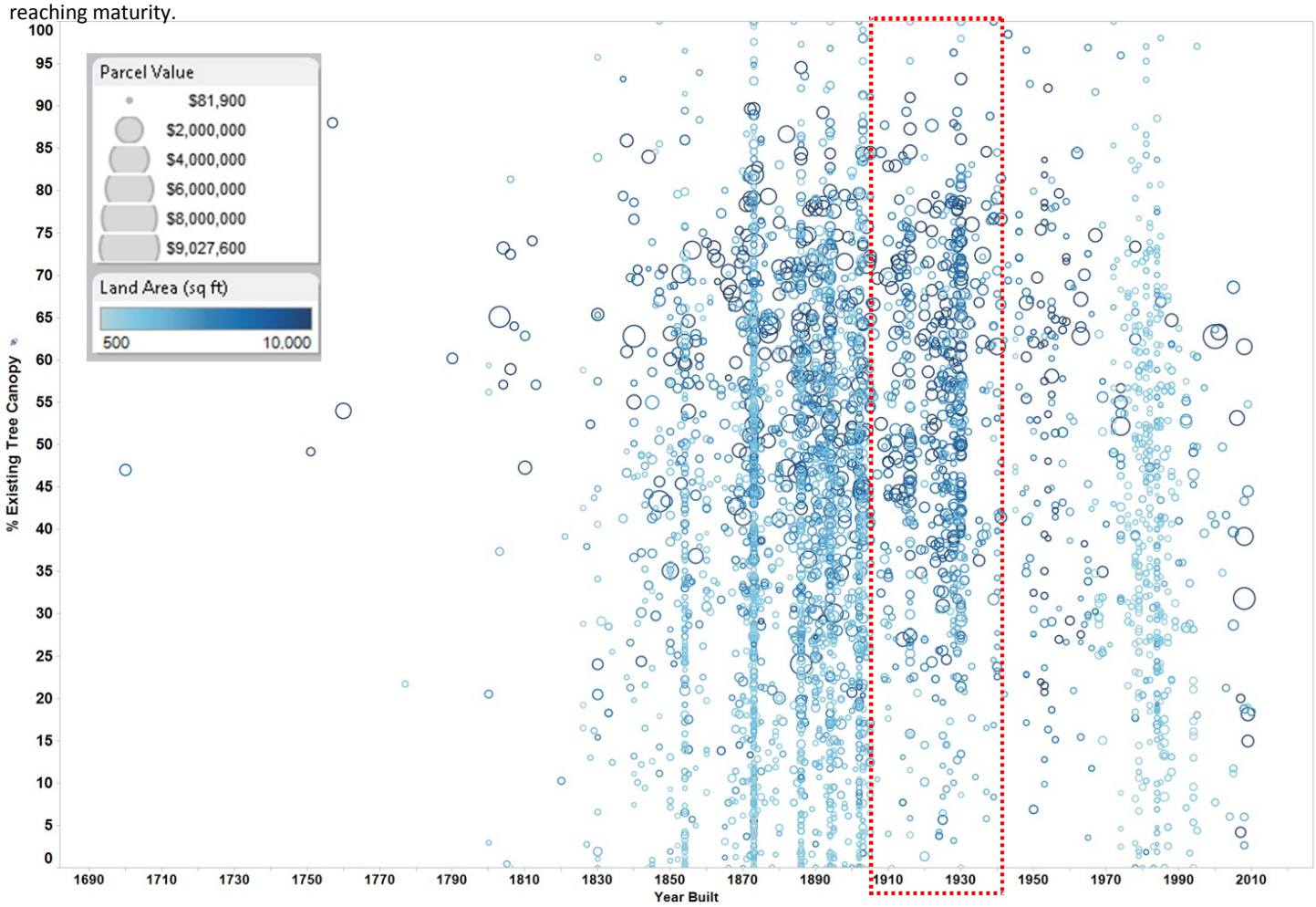


Figure 8: % Existing Tree Canopy in relation to year built, parcel value, and land area for single family residential parcels.

Sidewalks

40% of the city's sidewalks are covered by tree canopy, 10% greater than the city average. Most of the room for planting trees in the sidewalk area is Possible TC Impervious. Although establishing tree canopy in such areas is expensive there are numerous benefits to having thriving tree canopy over sidewalks including: shade and cooler temperatures for pedestrians, reduced noise, filtering of harmful pollutants from automobile traffic, and intercepting rainfall.

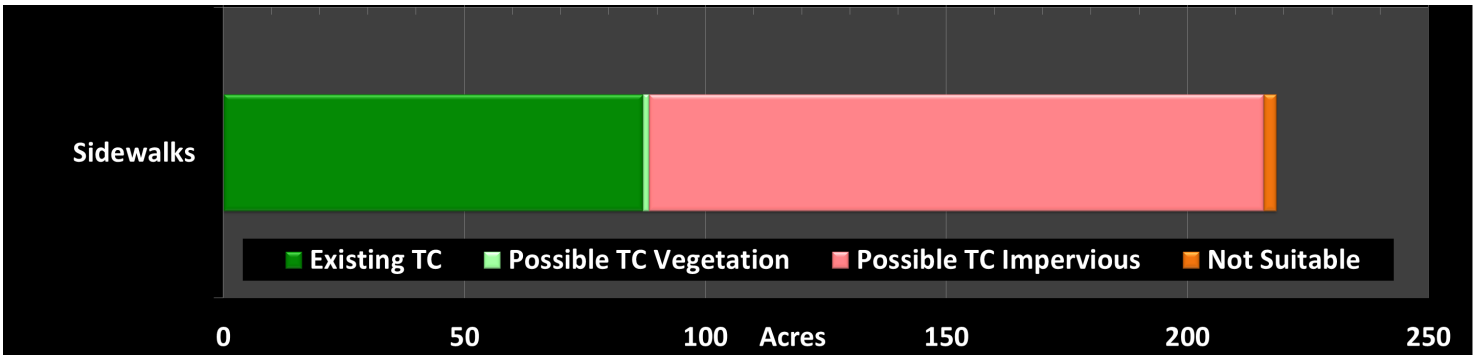


Figure 9. Existing Tree Canopy by Census block group; (b) Possible Tree Canopy by Census block group (c) Tree canopy per capita (square footage of tree canopy per person) at the Census block group; and (d) Percentage of the Census block group that is white.

Neighborhoods

Existing and Possible Tree Canopy (TC) was analyzed for each of Cambridge's thirteen neighborhoods (Figure 10). Tree canopy in the city's neighborhoods varies widely, with Neighborhood 10 having 45% of its land area covered by tree canopy and East Cambridge having 14%. Tree canopy distribution in the neighborhoods is largely a factor of land use. Neighborhood 10 is mostly residential and open spaces, whereas East Cambridge is dominated by commercial and transportation uses along with land, that as of 2010, was still being developed. Possible TC is highest in both the most northern (Cambridge Highland and North Cambridge) and southern (MIT/Area 2) neighborhoods. All three neighborhoods have a mix of non-building, non-road impervious surfaces and vegetation, that if modified, could support tree canopy. However, establishing tree canopy on many of these areas in these three neighborhoods will be challenging due to their current use (e.g. parking lots and recreational fields). Overall, Existing TC is higher and Possible TC lower, in residential neighborhoods.

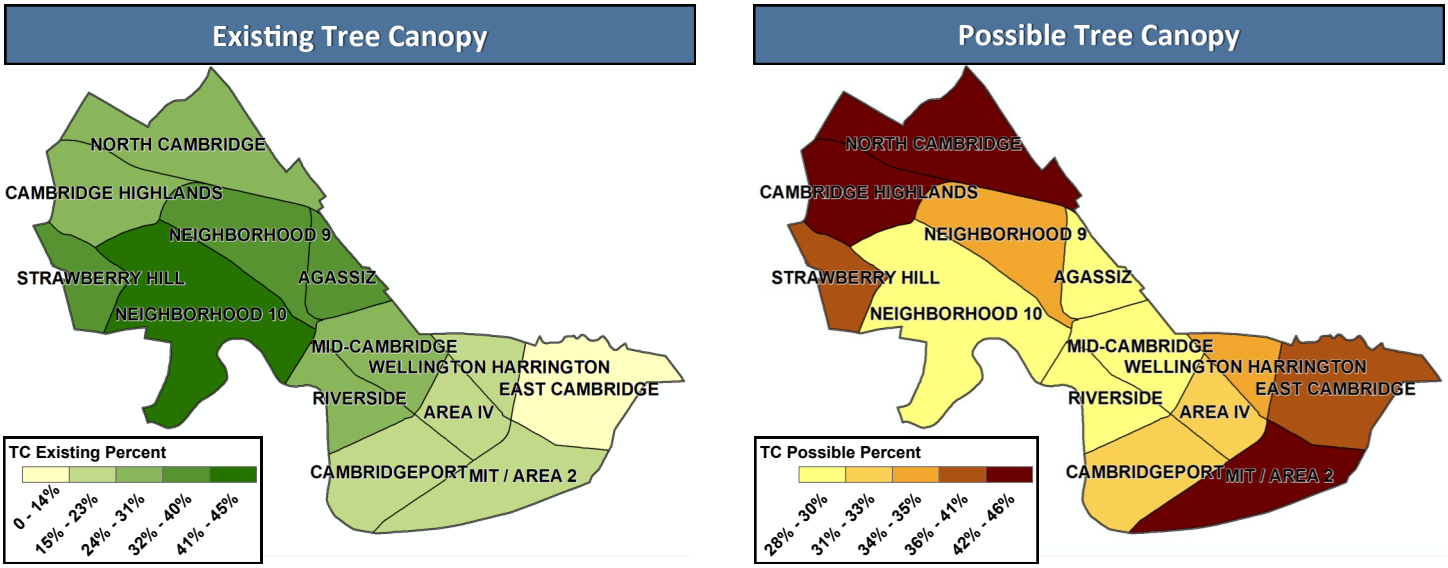
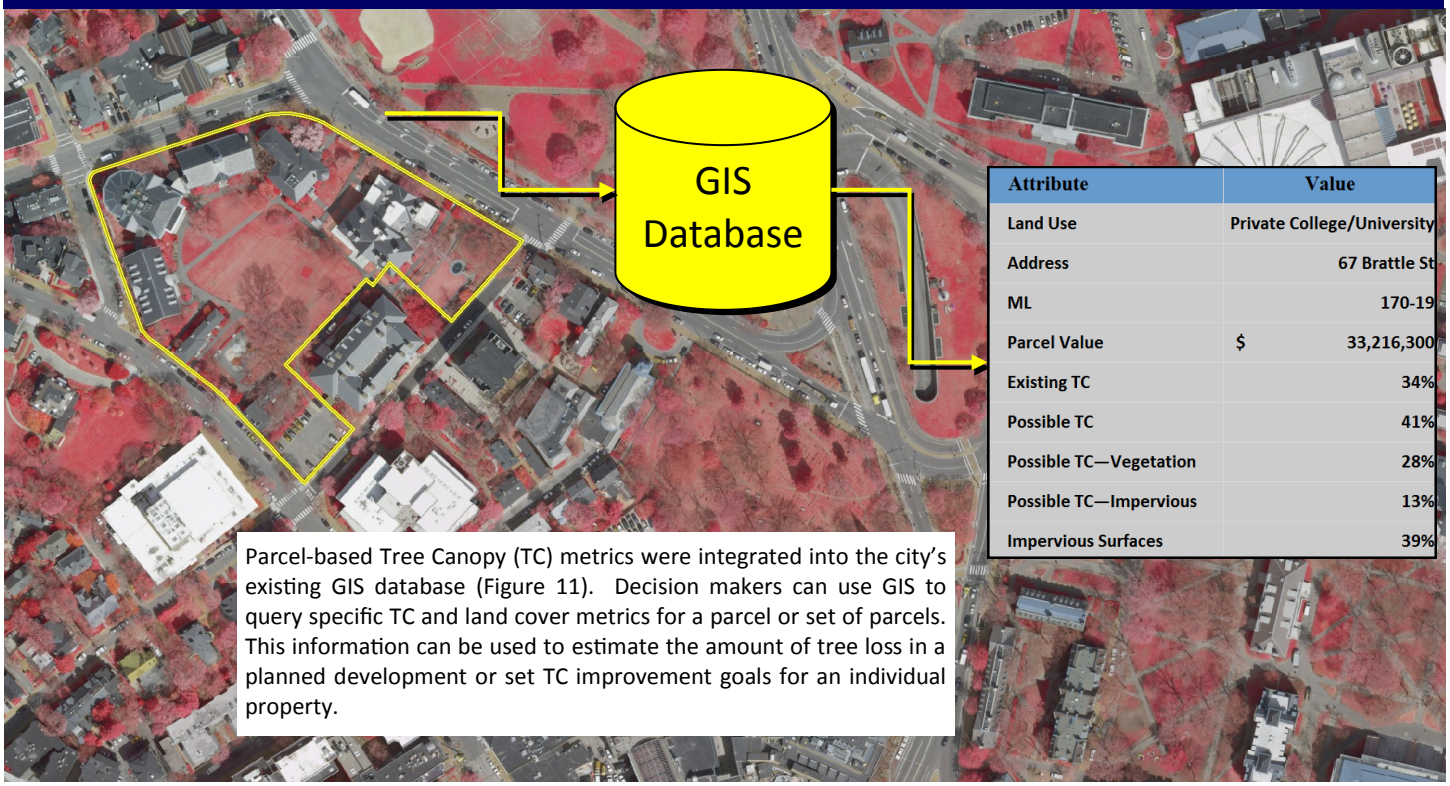


Figure 10. Existing TC (left) and Possible TC (right) as a percentage of neighborhood land area.

Decision Support



Attribute	Value
Land Use	Private College/University
Address	67 Brattle St
ML	170-19
Parcel Value	$ 33,216,300
Existing TC	34%
Possible TC	41%
Possible TC—Vegetation	28%
Possible TC—Impervious	13%
Impervious Surfaces	39%

Parcel-based Tree Canopy (TC) metrics were integrated into the city's existing GIS database (Figure 11). Decision makers can use GIS to query specific TC and land cover metrics for a parcel or set of parcels. This information can be used to estimate the amount of tree loss in a planned development or set TC improvement goals for an individual property.

Figure 11: GIS-based analysis of parcel-based TC metrics for decision support. In this example, GIS is used to select an individual parcel. The attributes for that parcel, including the parcel-based TC and land cover metrics, are displayed in tabular form providing instant access to relevant information.

Tree Canopy Opportunity Index

In addition to simple descriptive statistics, more sophisticated techniques can help identify areas of the city where tree-planting and stewardship programs would be most effective. One approach is to focus on spatial clusters of Existing and Possible TC. When a 250-foot grid network is superimposed on the land-cover map (Figure 13a), it is possible to map regions of the study area where high values of Existing TC are tightly clustered (Figure 13b). A similar map was constructed for Possible TC (Figure 13c). A single index was created by subtracting the percentage of Existing TC per grid cell from Possible TC, which produced a range of values from –1 to 1. When clustered, this tree canopy opportunity (TCO) index highlights areas with high Possible TC and low Existing TC (Figure 13d); these areas theoretically offer the best places to strategically expand Cambridge's tree canopy and to increase its many attendant benefits. As with all such analyses, however, landscape context must be evaluated before setting priorities.

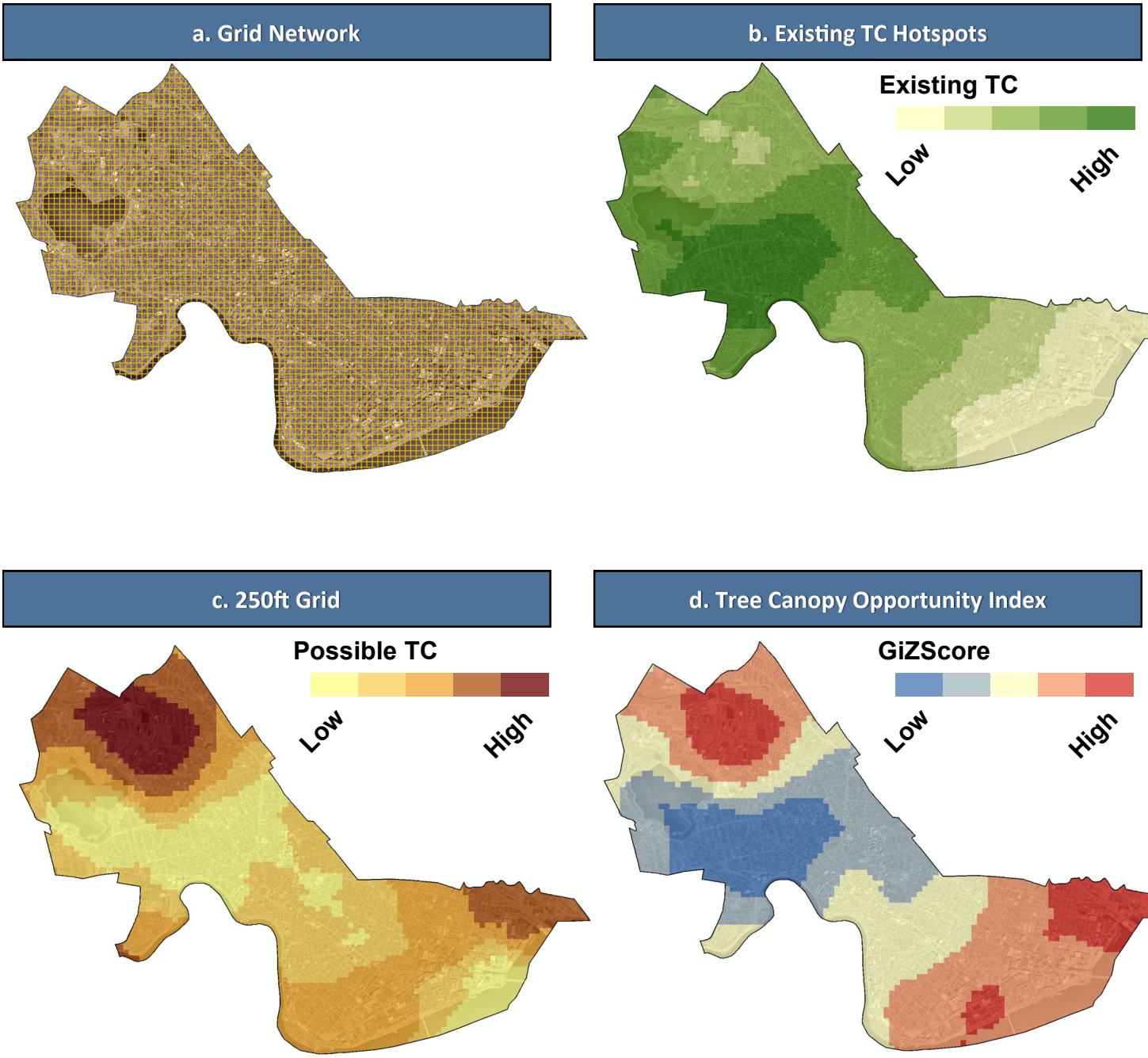


Figure 12: (a) Grid network (250-foot cells) superimposed on land-cover map for Cambridge and then used in spatial cluster analyses; (b) Spatial clustering of Existing TC in Cambridge; dark green areas are highly clustered and have high Existing TC values; (c) Spatial clustering of Possible TC in Cambridge; dark red areas are highly clustered and have high Possible TC values.; and (d) Spatial clustering of a combined index of Existing and Possible TC; red areas theoretically provide the best opportunities for expanding tree canopy.

Conclusions

- Cambridge's urban tree canopy is a vital city asset that reduces stormwater runoff, improves air quality, reduces the city's carbon footprint, enhances quality of life, contributes to savings on energy bills, and serves as habitat for wildlife.
- Although this assessment indicates that 35% of the land in Cambridge could theoretically support tree canopy, planting new trees on much of this land may not be social desirable (e.g. recreation fields) or financially feasible (e.g. parking lots). Setting a realistic goal requires a detailed feasibility assessment using the geospatial datasets generated as part of this assessment.
- With Existing and Possible TC summarized at the parcel level and integrated into the city's GIS database, individual parcels can be examined and targeted for TC improvement. Of particular focus for TC improvement should be parcels in the city that have large, contiguous impervious surfaces. These parcels contribute high amounts of runoff, which degrades water quality. The establishment of tree canopy on these parcels will help reduce runoff during periods of peak overland flow.
- Cambridge's residents are the largest "owner" of tree canopy by land use type. Programs that educate residents on tree stewardship and provide incentives for tree planting are crucial if Cambridge is going to sustain its tree canopy in the long term.
- Neighborhood and Census Block Group summaries can be used to examine the relationship between socio-economic conditions and the extent and distribution of tree canopy. These summaries can also be used to target tree planting and preservation efforts in different parts of the city.
- With residential land containing a relatively high percentage of tree canopy, the greatest opportunities for tree planting lie on city-owned and private university land.
- Geographically the greatest opportunities for increasing tree canopy lie in the northern and southern sections of the city.

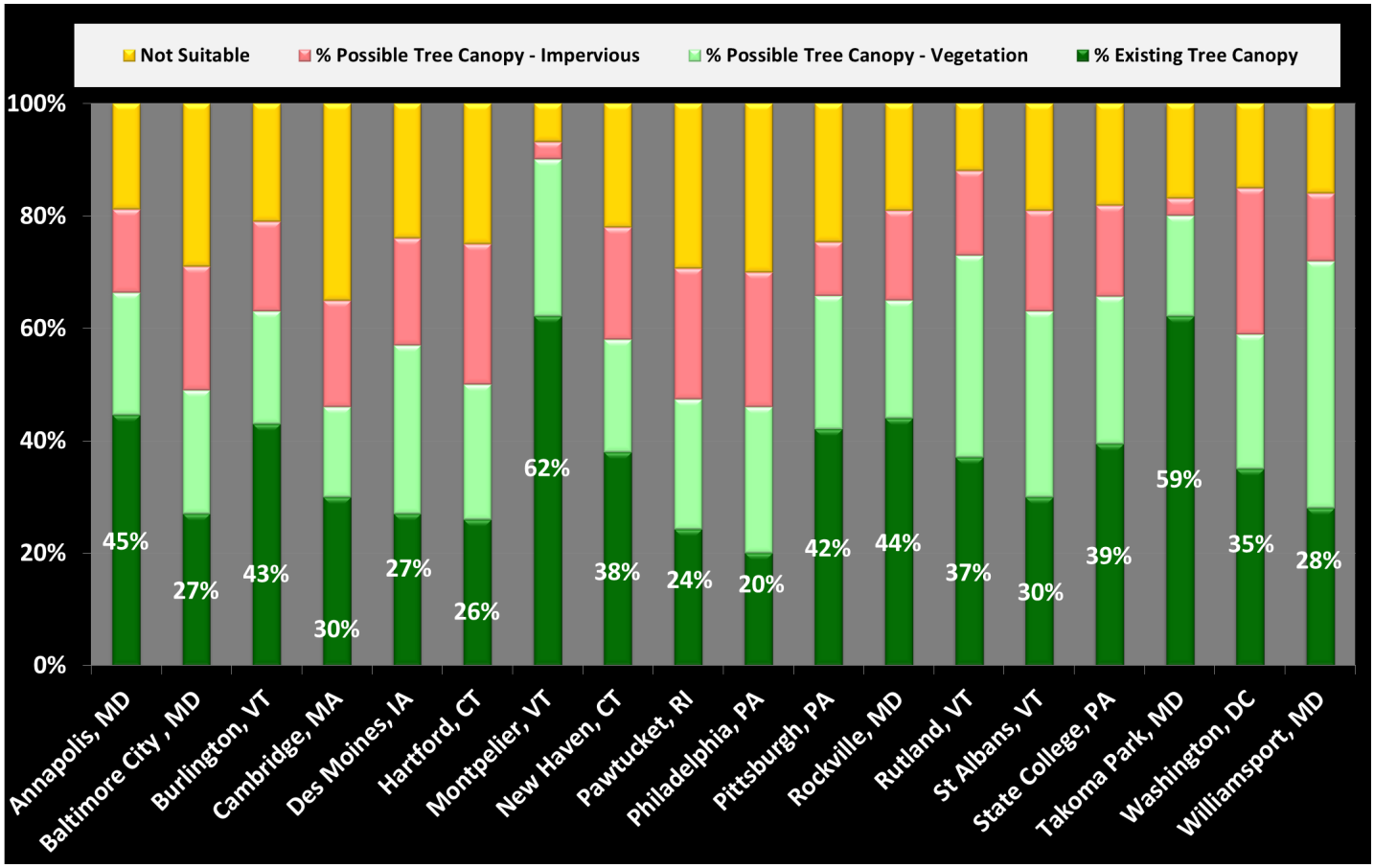


Figure 13: Comparison of Existing and Possible Tree Canopy with other selected cities that have completed Tree Canopy Assessments.

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Additional Information

Funding for the project was provided by the City of Cambridge. More information on the TC assessment project can be found at the following web site:

http://nrs.fs.fed.us/urban/utc/

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