

A Report on the City of Philadelphia'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 city 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.

Project Background

The goal of the project was to apply the USDA Forest Service's TC assessment protocols to the City of Philadelphia. The analysis was conducted based on year 2008 data. This project was made possible by an America Recovery and Reinvestment Act (ARRA) grant through the USDA Forest Service's Northern Research Station. This analysis of Philadelphia's tree canopy (TC) was conducted in collaboration with Philadelphia Parks & Recreation and the Northern Research Station. The Spatial Analysis Laboratory (SAL) at the University of Vermont's Rubenstein School of the Environment and Natural Resources carried out the assessment.

How Much Tree Canopy Does Philadelphia Have?

An analysis of Philadelphia's tree canopy based on land cover data derived from high-resolution aerial imagery and LiDAR (Figure 1) found that 16,884 acres of the city were covered by tree canopy (termed Existing TC), representing 20% of all land in the city. An additional 49% (42,451 acres) of the city could theoretically be modified (termed Possible TC) to accommodate tree canopy (Figure 2). In the Possible TC category, 24% (20,821 acres) of the city was classified as Impervious Possible TC and another 25% was Vegetated Possible TC (21,630 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.

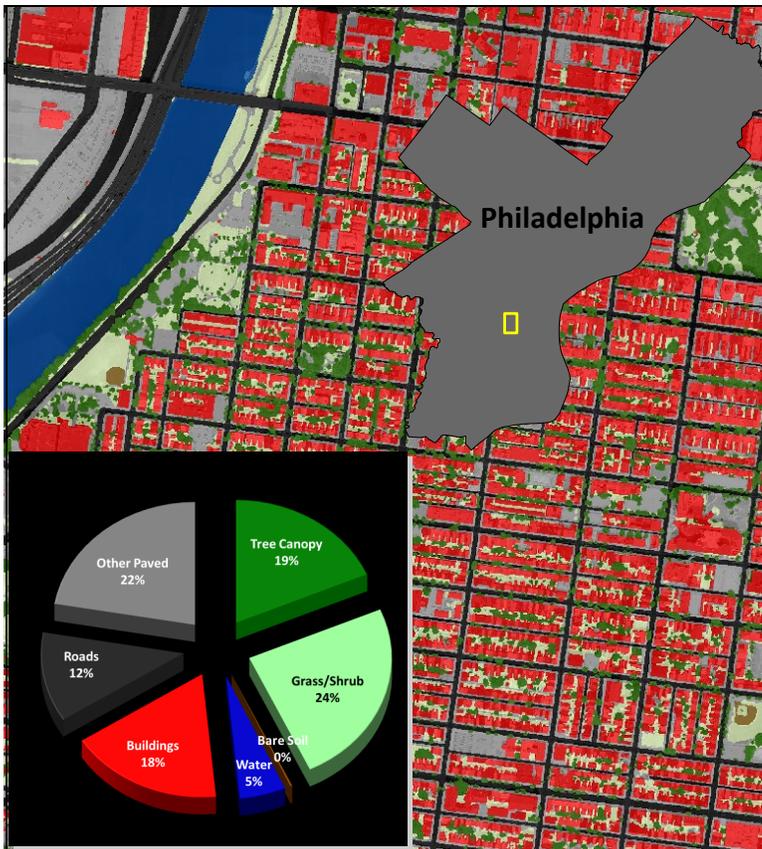


Figure 1: Land cover derived from high-resolution aerial imagery for the City of Philadelphia.

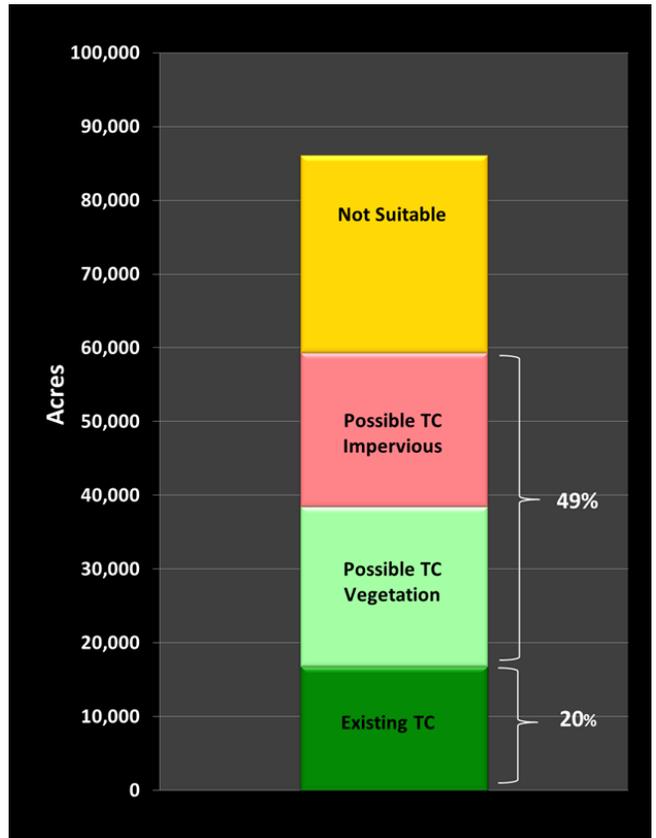


Figure 2: TC metrics for Philadelphia based on % of land area covered.

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.

Mapping Philadelphia's Trees

Prior to this study, the only comprehensive remotely-sensed estimates of tree canopy for Philadelphia was from the 2001 National Land Cover Database (NLCD 2001). While NLCD 2001 is valuable for analyzing land cover at the regional level, it is derived from relatively coarse, 30-meter resolution satellite imagery (Figure 3a). Using high-resolution aerial imagery and LiDAR acquired in 2008 (Figure 3b), in combination with advanced automated processing techniques, land cover for the city was mapped with such detail that trees as short as 6ft tall were detected (Figure 3c). NLCD 2001 estimated a mean percent tree canopy of 10% for Philadelphia largely because it failed to capture many isolated trees.



Figure 3a, 3b, 3c: Comparison of NLCD 2001 to high-resolution land cover.

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 and as a percentage of the land area within each parcel (TC area ÷ land area of the parcel).

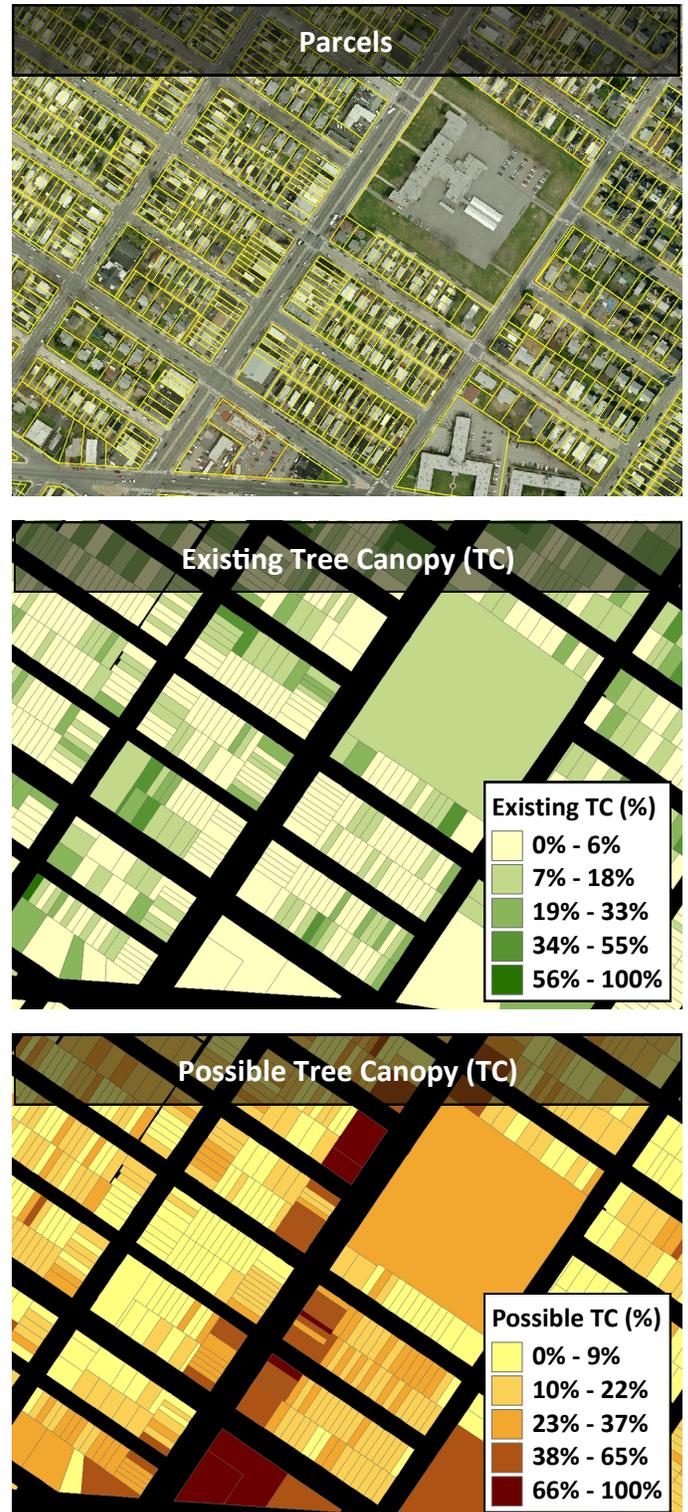


Figure 4a, 4b, 4c: Parcel-based TC metrics. TC metrics are generated at the parcel level, allowing each property to be evaluated according to its Existing TC and Possible TC.

Zoning

An analysis of Existing and Possible tree canopy by zoning category was conducted using the city's current zoning layer (Figure 5, Table 1). For each zoning district, Tree Canopy (TC) metrics were calculated as a percentage of all land in the city (% Land), as a percentage of land area in the specified zoning category (% Category), and as a percentage of the area for TC type (% TC Type). Areas zoned as "Recreation" have the largest amount of tree canopy of any category with 35% of all tree canopy. They also have the largest percentage of their area covered by tree canopy (58%). Both of the "Single Family" zoning categories have 21% of all of the tree canopy within zoned land. "Single Family Twin/Row" areas have most of the land available to support tree plantings, with 32% of the Vegetated Possible TC and 22% Impervious Possible TC of all

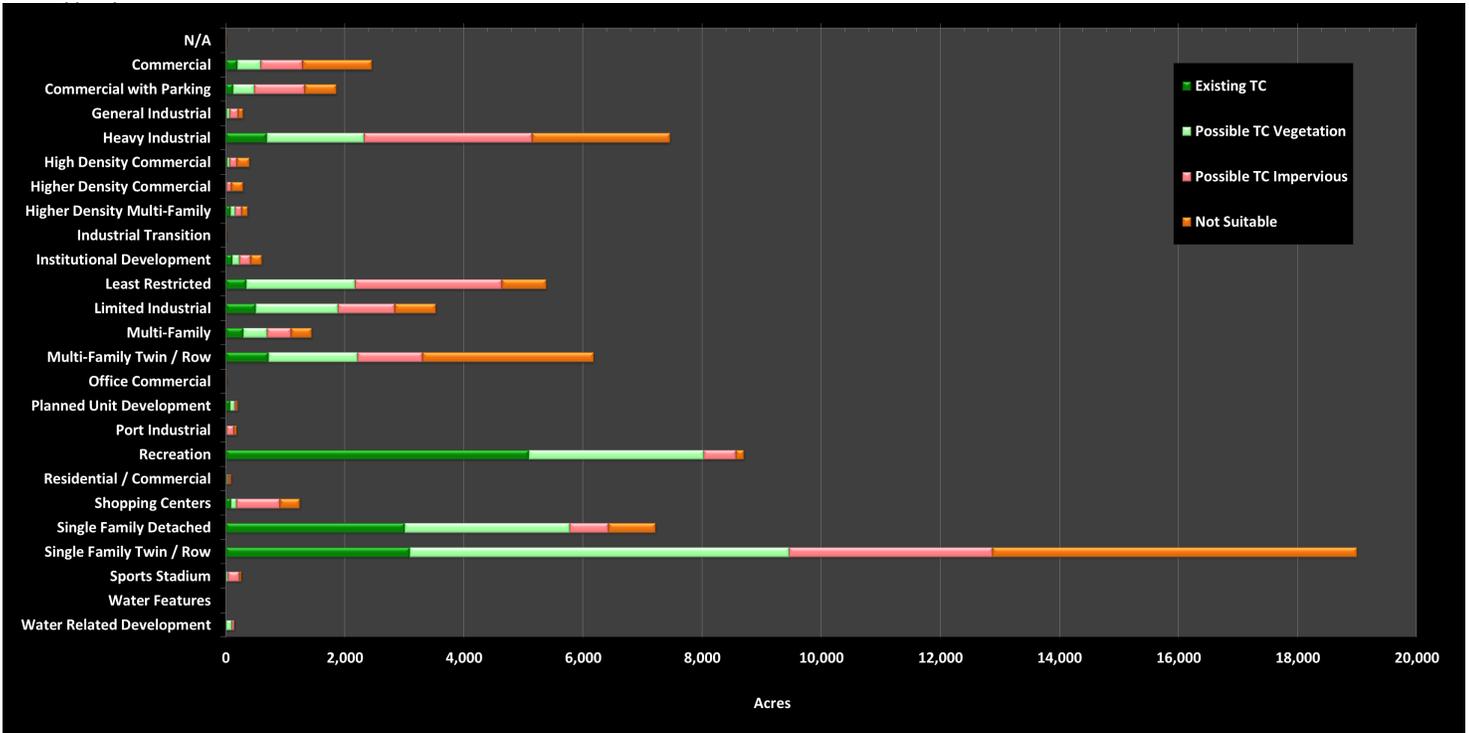


Figure 5: Tree Canopy (TC) metrics summarized by zoning class.

Land Use	Existing TC			Possible TC Vegetation			Possible TC Impervious		
	% Land	% Category	% TC Type	% Land	% Category	% TC Type	% Land	% Category	% TC Type
N/A	0%	21%	0%	0%	25%	0%	0%	24%	0%
Commercial	0%	8%	1%	1%	16%	2%	1%	28%	4%
Commercial with Parking	0%	7%	1%	1%	19%	2%	1%	45%	5%
General Industrial	0%	5%	0%	0%	16%	0%	0%	50%	1%
Heavy Industrial	1%	9%	5%	2%	22%	8%	4%	38%	18%
High Density Commercial	0%	5%	0%	0%	11%	0%	0%	32%	1%
Higher Density Commercial	0%	3%	0%	0%	3%	0%	0%	25%	0%
Higher Density Multi-Family	0%	21%	1%	0%	22%	0%	0%	29%	1%
Industrial Transition	0%	2%	0%	0%	31%	0%	0%	41%	0%
Institutional Development	0%	18%	1%	0%	20%	1%	0%	30%	1%
Least Restricted	1%	6%	2%	3%	34%	9%	4%	46%	16%
Limited Industrial	1%	14%	3%	2%	39%	7%	1%	27%	6%
Multi-Family	0%	20%	2%	1%	28%	2%	1%	28%	3%
Multi-Family Twin / Row	1%	12%	5%	2%	24%	7%	2%	18%	7%
Office Commercial	0%	21%	0%	0%	23%	0%	0%	40%	0%
Planned Unit Development	0%	36%	1%	0%	35%	0%	0%	14%	0%
Port Industrial	0%	5%	0%	0%	2%	0%	0%	66%	1%
Recreation	8%	58%	35%	4%	34%	15%	1%	6%	3%
Residential / Commercial	0%	13%	0%	0%	17%	0%	0%	34%	0%
Shopping Centers	0%	7%	1%	0%	8%	0%	1%	59%	5%
Single Family Detached	4%	42%	21%	4%	38%	14%	1%	9%	4%
Single Family Twin / Row	5%	16%	21%	9%	34%	32%	5%	18%	22%
Sports Stadium	0%	2%	0%	0%	10%	0%	0%	74%	1%
Water Features	0%	0%	0%	0%	0%	0%	0%	0%	0%
Water Related Development	0%	6%	0%	0%	57%	0%	0%	29%	0%

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

The % Land Area value of 8% indicates that 8% of Philadelphia's land area is covered by tree canopy in the Recreation zoning 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 58% indicates that 58% of land in the Recreation zoning 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 35% indicates that 35% of all tree canopy is in land zoned as Recreation

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

Land Use

The Delaware Valley Regional Planning Commission (DVRPC) maintains a comprehensive land use layer for the region. For this study the DVRPC land use data were aggregated into twelve general categories. Existing and Possible tree canopy was summarized for the twelve aggregated land use classes (Figure 6, Table 2). For each land use class, Tree Canopy (TC) metrics were calculated as a percentage of all land in the city (% Land), as a percentage of land area in the specified zoning category (% Category), and as a percentage of the area for TC type (% TC Type). The vast majority of the city's land base (42%) is residential land. It is thus not surprising that a large percentage of the city's overall tree canopy (35%) falls within residential land use. This is only second to those areas classified as "wooded," which account for 37% of the city's total tree canopy. Most of the land available to plant trees (Possible Tree Canopy) in the city is also in residential areas (36%). Within this space the land is relative evenly divided between grassy areas (Possible Tree Canopy—Vegetation) (40%) and paved surfaces (Possible Tree Canopy—Impervious) (31%). Parking and manufacturing, and vacant land use types all follow residential in terms of the total land area considered to be Possible Tree Canopy, but in the parking and manufacturing land use classes most of the Possible Tree Canopy is on impervious land, which would require a considerable amount of site improvement. On vacant land, 58% of the land is considered to be Possible Tree Canopy—Vegetation (grass and shrubs), where it would be more cost effective to establish new tree canopy.

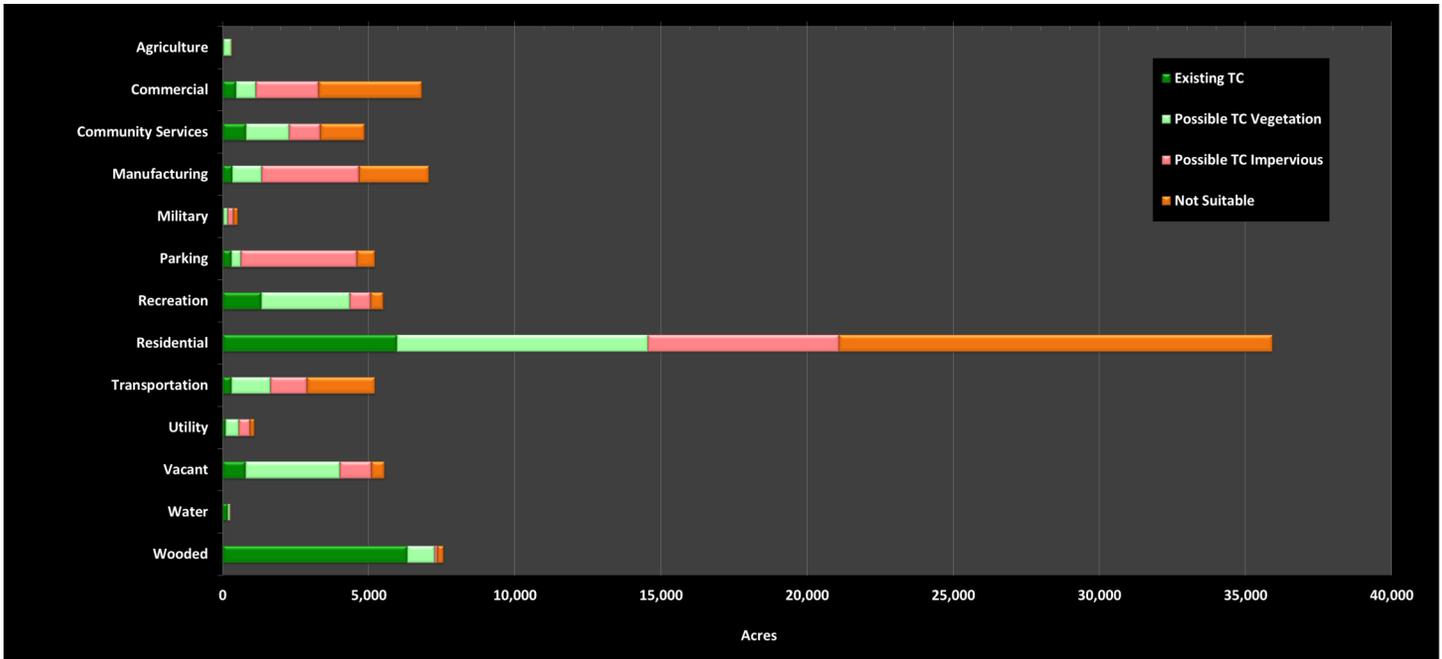


Figure 6: Tree Canopy (TC) metrics summarized by land use.

Land Use	Existing TC			Possible TC Vegetation			Possible TC Impervious		
	% Land	% Category	% TC Type	% Land	% Category	% TC Type	% Land	% Category	% TC Type
Agriculture	0%	10%	0%	0%	83%	1%	0%	6%	0%
Commercial	1%	7%	3%	1%	10%	3%	3%	32%	10%
Community Services	1%	16%	5%	2%	31%	7%	1%	22%	5%
Manufacturing	0%	5%	2%	1%	14%	5%	4%	47%	16%
Military	0%	6%	0%	0%	27%	1%	0%	36%	1%
Parking	0%	6%	2%	0%	6%	1%	5%	76%	19%
Recreation	2%	24%	8%	4%	55%	14%	1%	13%	3%
Residential	7%	17%	35%	10%	24%	40%	8%	18%	31%
Transportation	0%	6%	2%	2%	26%	6%	1%	24%	6%
Utility	0%	10%	1%	1%	41%	2%	0%	34%	2%
Vacant	1%	14%	5%	4%	58%	15%	1%	20%	5%
Water	0%	58%	1%	0%	30%	0%	0%	8%	0%
Wooded	7%	83%	37%	1%	12%	4%	0%	1%	0%

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

The % Land Area value of 7% indicates that 7% of Philadelphia's land area is covered by tree canopy in the Residential zoning 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 17% indicates that 17% of land in the Residential zoning 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 35% indicates that 35% of all tree canopy is in land zoned as Residential.

Table 2: 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 zoning district (% Category), and as a percentage of the area for TC type (% TC Type).

Parks Analysis

Existing and Possible Tree Canopy (TC) was analyzed for the Fairmount Park lands (Figure 6). As expected, these lands have relatively high existing tree canopy, with parks such as Wissahickon Valley Park having over 86% of its land area covered by tree canopy. The assessment does reveal potential opportunities to increase coverage. For example, Pennypack on the Delaware has 87% of its land available for tree planting. While maintaining open spaces for recreation is an important social consideration, there still exists room for establishing new tree canopy.

Existing Tree Canopy

Possible Tree Canopy

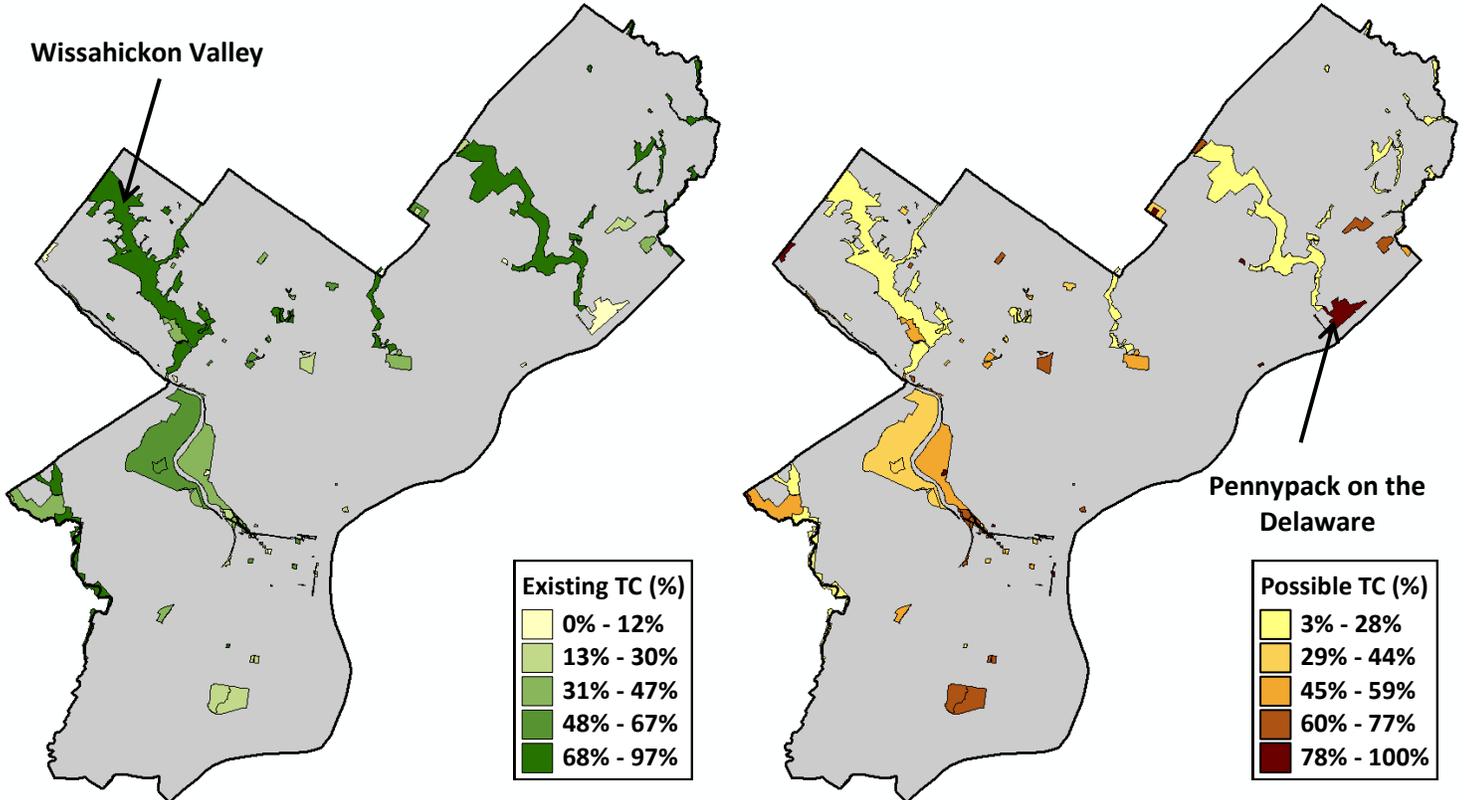
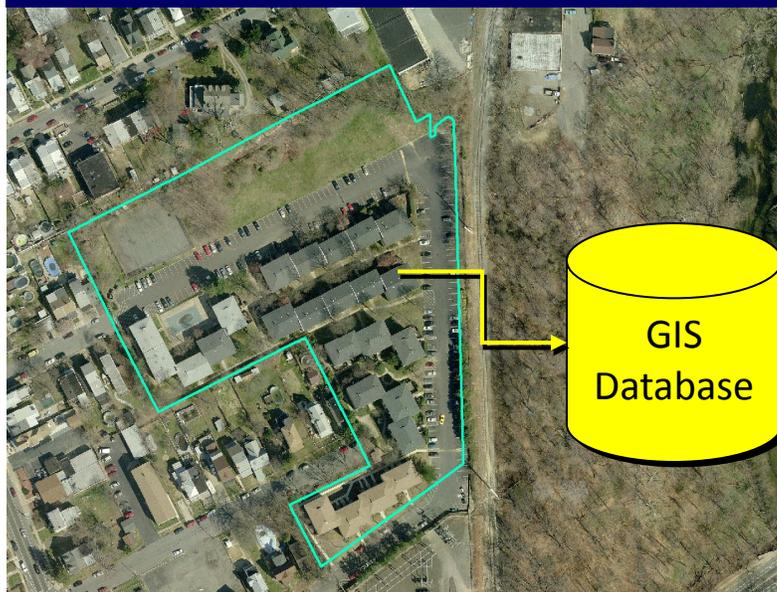


Figure 7 Existing TC (left) and Possible TC (right) as a percentage of land area by park.

Decision Support



Parcel-based Tree Canopy (TC) metrics were integrated into the city's existing GIS database (Figure 7). Decision makers can use GIS to query specific TC and land cover metrics for a parcel or set of parcels. For example, 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.

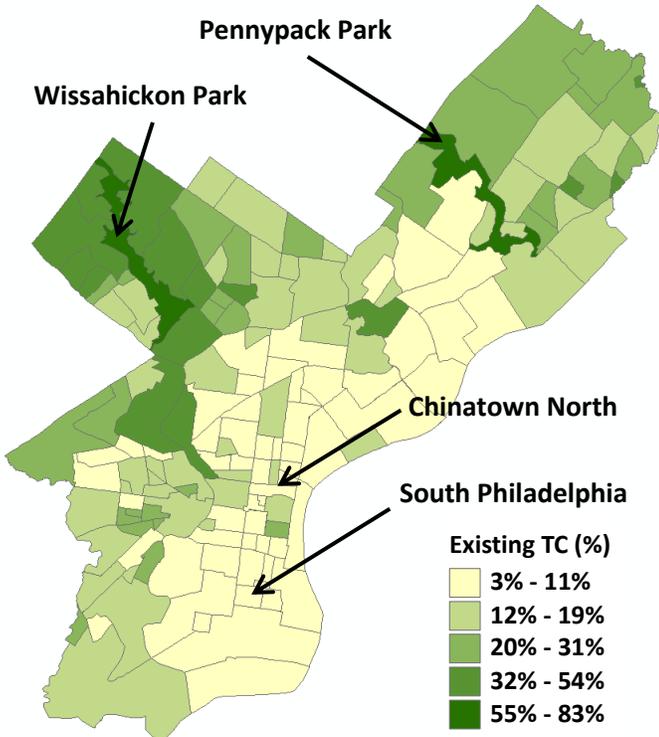
Attribute	Value
Building Description	Residential Condo
Address	8030 Ditman Street
TENCODE	2866008030
Existing TC	29%
Possible TC	31%
Possible TC—Vegetation	23%
Possible TC—Impervious	8%
Impervious Features	48%

Figure 8: 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.

Neighborhood Analysis

The neighborhoods of Wissahickon Park and Pennypack Park have the highest Existing Tree Canopy at 83% and 81% respectively. Chinatown North, and South Philadelphia have the lowest percentage of their land covered by tree canopy at 3%. The Navy Yard, Eastwick, and Bridesburg have the highest percentage of their land available for tree canopy, with Possible Tree Canopy values of 76%, 72%, and 70% respectively.

Existing Tree Canopy



Possible Tree Canopy

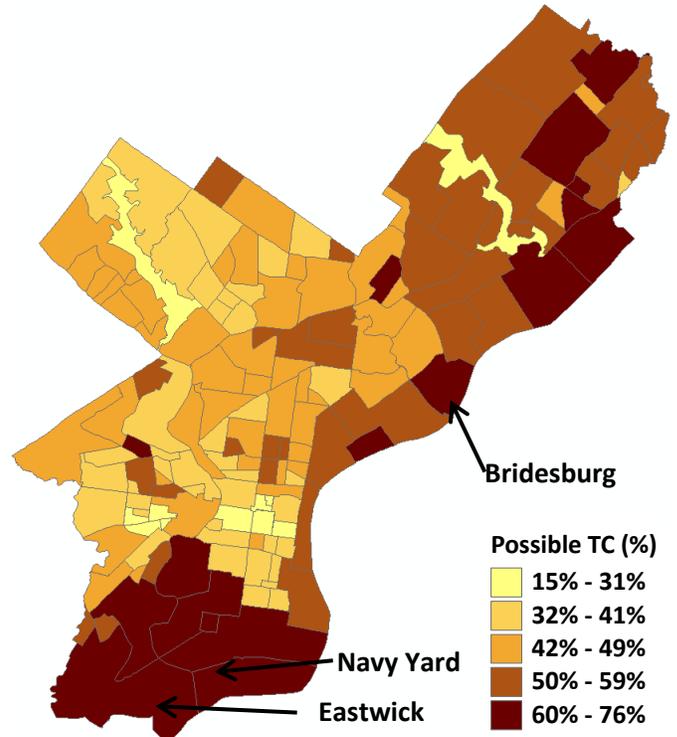
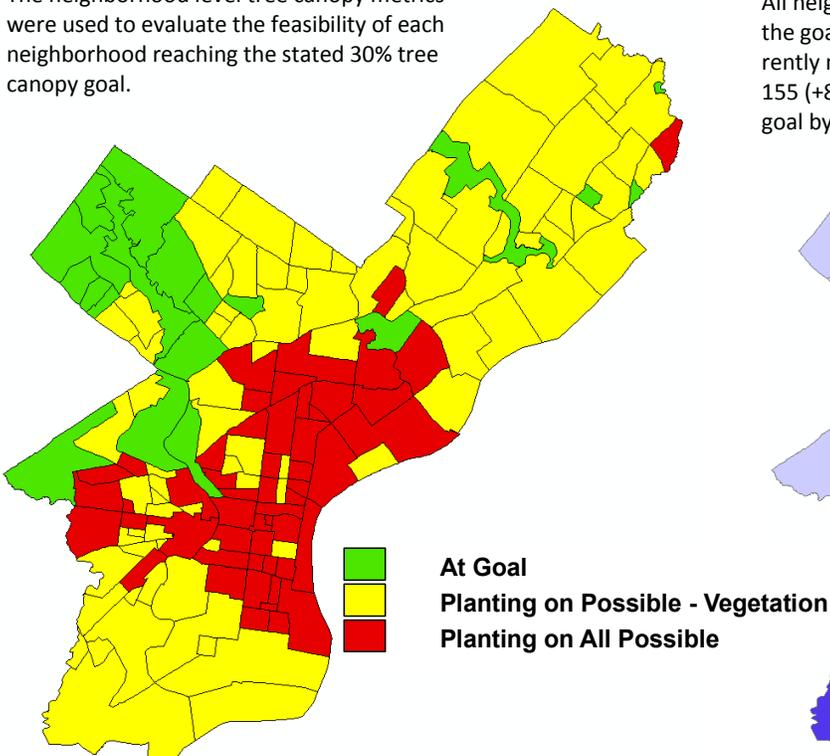


Figure 9. Existing TC (left) and Possible TC (right) as a percentage by neighborhood.

Ability to Achieve Goal

The neighborhood level tree canopy metrics were used to evaluate the feasibility of each neighborhood reaching the stated 30% tree canopy goal.



% Increase to Meet Goal

All neighborhoods could theoretically meet the goal. 19 out of 155 neighborhoods currently meet or exceed the 30% goal. 102 of 155 (+83) neighborhoods could meet the goal by planting on vegetated land.

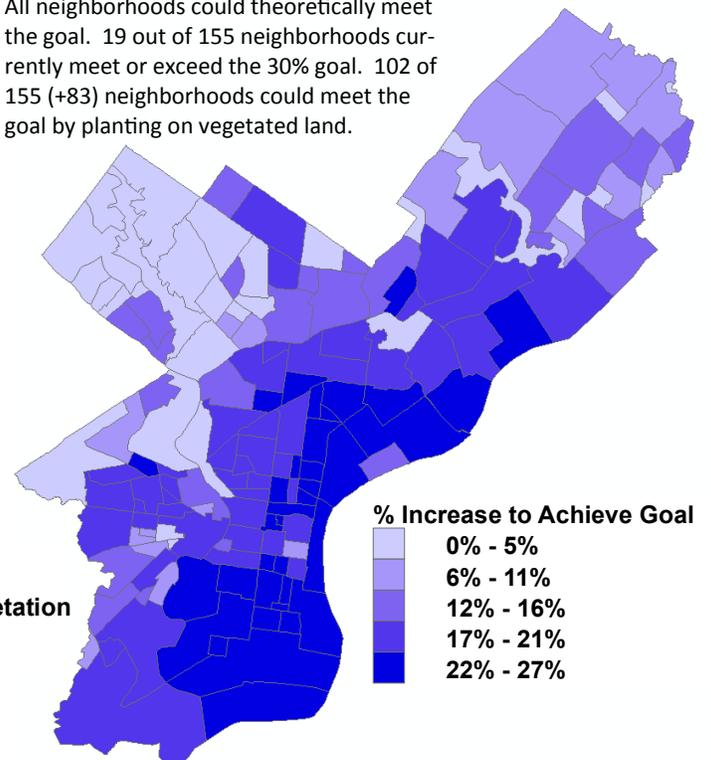


Figure 10. Ability to achieve the 30% goal based on land available (left) and % tree canopy increase needed to reach goal (right).

Planning Districts Analysis

Planning Districts that contain parks, such as the Central Northeast, Upper Northwest, Lower Northwest, and West Park have the highest percentage of their land covered by Existing Tree Canopy. Possible Tree Canopy as a percent of land is highest in the Planning Districts in the southern most part of the city, but the presence of the airport and industry reduces the feasibility of establishing tree canopy of all of the land considered to be “possible.”

Existing Tree Canopy

Possible Tree Canopy

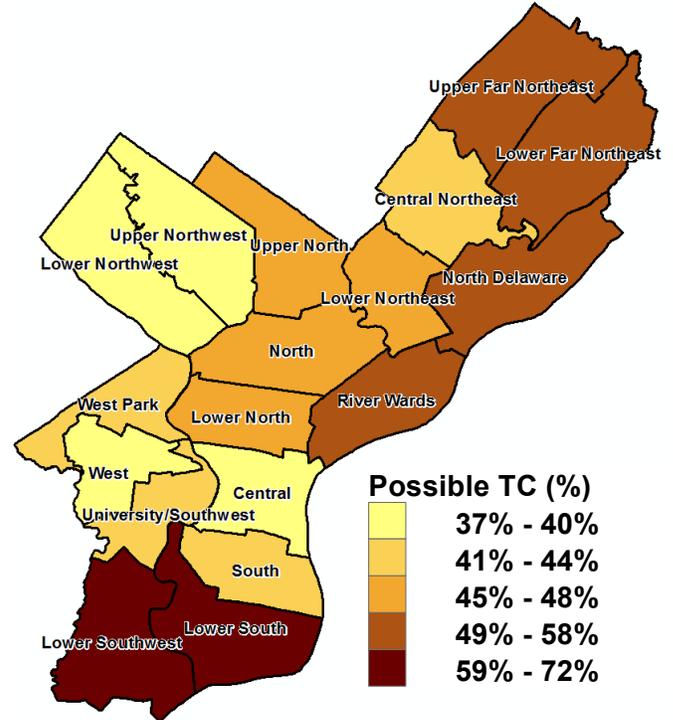
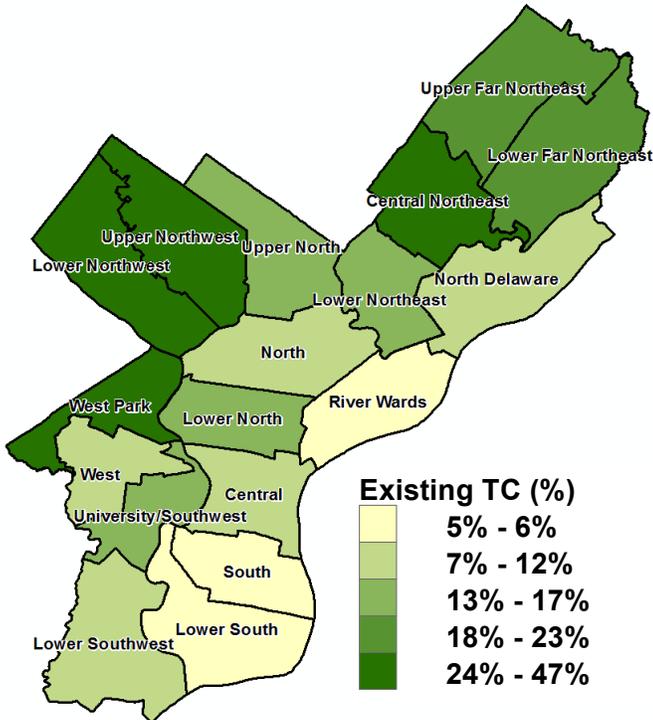


Figure 11: Existing TC (left) and Possible TC (right) as a percentage by planning districts.

Parcel Billing Class Analysis

Tree Canopy (TC) metrics were computed for all ten billing classes within the City’s GIS parcel database. Parcels assigned to the “Exempt Park” class have the highest percentage of their land covered by tree canopy (80%) and “Row” parcels have the lowest (8%). “Non Residential” parcels have the highest percentage of their land available for the establishment of new tree canopy (63%)

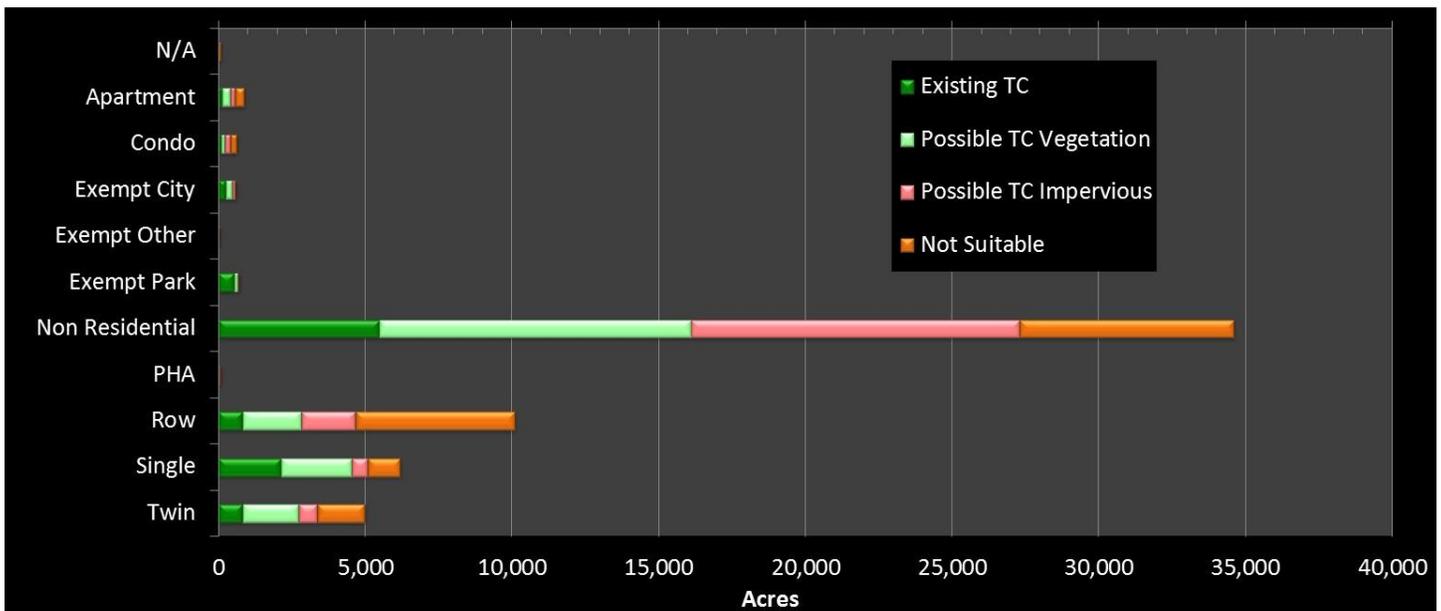


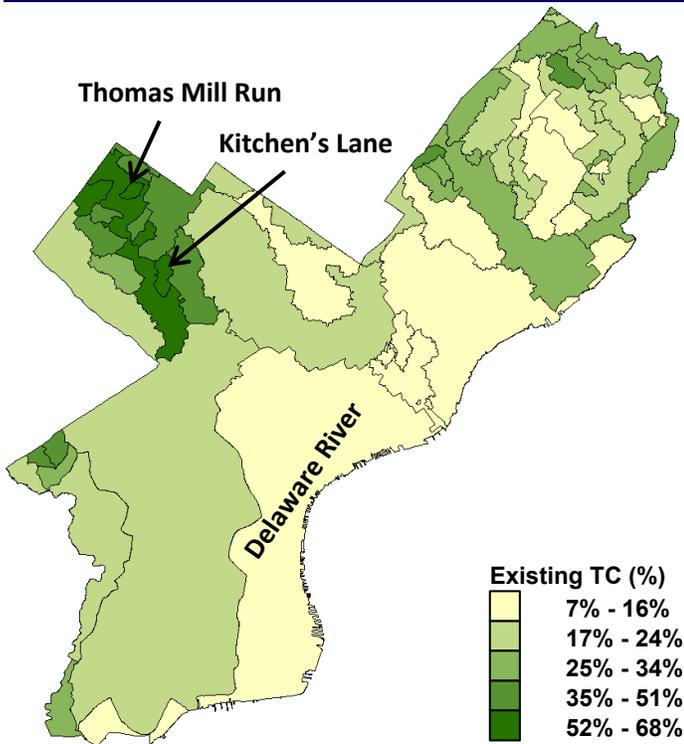
Figure 12: TC metrics summarized by parcel billing class.

Subwatershed Analysis

Tree canopy metrics were computed for the portions of subwatersheds within the city boundary. The Thomas Mill Run and Kitchen's Lane, both very small subwatersheds, at 104 acres and 234 acres respectively, have the highest percentage of their land area covered by tree canopy at 68%. The Delaware River subwatershed, which is the largest in the city, has the lowest percentage of its land area covered by tree canopy at 7%. However, it is the Black Lake Run and Byberry Creek (unnamed trib 'B') that have the highest percent Possible Tree Canopy at 66%. Of the city's 58 watersheds, 48 have less than 45% of their land area covered by tree canopy, the amount of Goetz et al. (2003) associated with a "good" stream health in the mid-Atlantic region. (Ranking includes: poor, fair, good, and excellent).

Goetz, S. J., R. K. Wright, A. J. Smith, E. Zinecker, and E. Schaub. 2003. IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region. *Remote Sensing of Environment* 88, no. 1: 195-208.

Existing Tree Canopy



Possible Tree Canopy

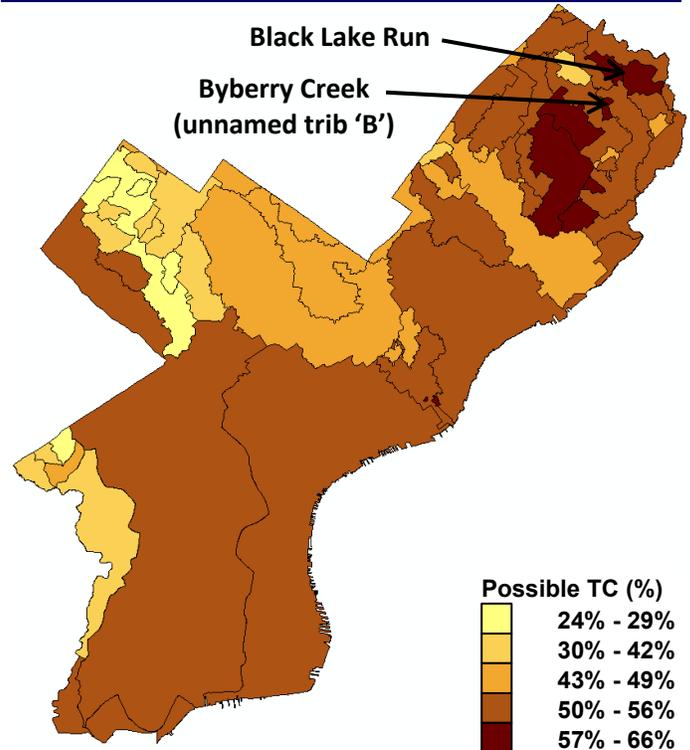


Figure 13: Existing TC (left) and Possible TC (right) as a percentage of area for each subwatershed.

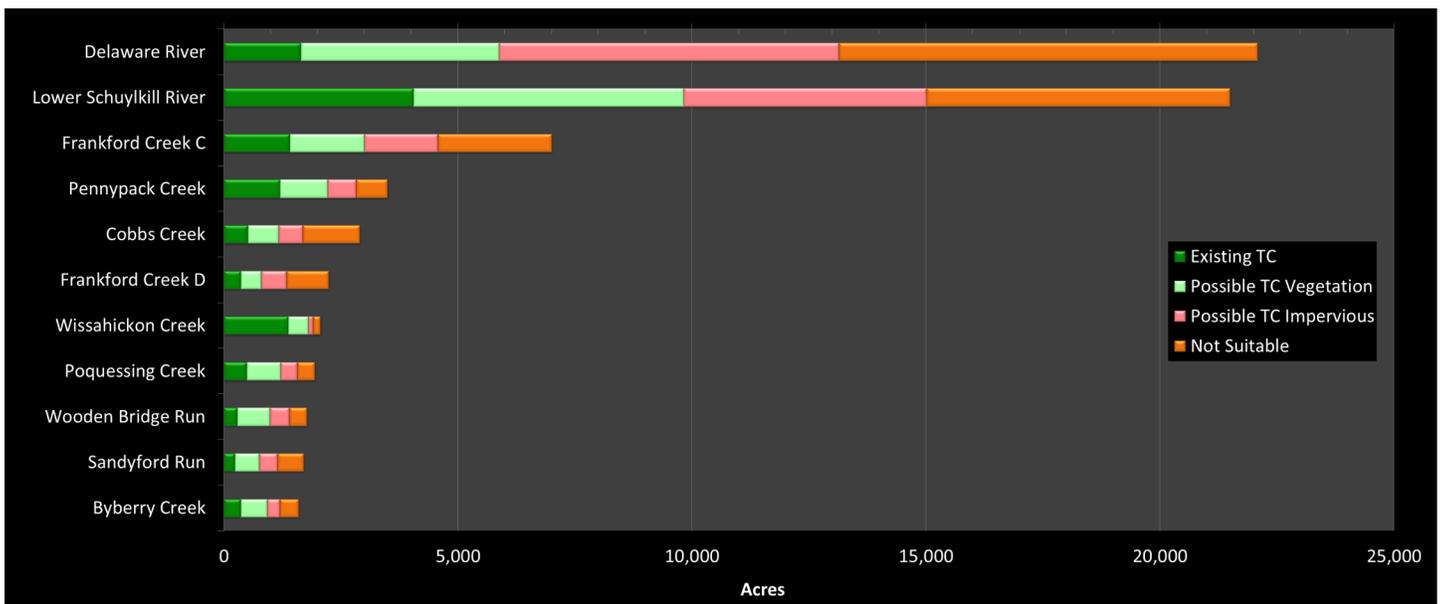


Figure 14. Graphical representation of the tree canopy metrics for the ten largest subwatersheds by land area.

Zip Code Analysis

Tree canopy metrics were computed for all zip codes. Higher amounts of Existing Tree Canopy are clustered in both the northern and western parts of the city. Zip codes with highest amounts of Possible Tree canopy tend to be found in the southern portions of the city and along the eastern edge.

Existing Tree Canopy

Possible Tree Canopy

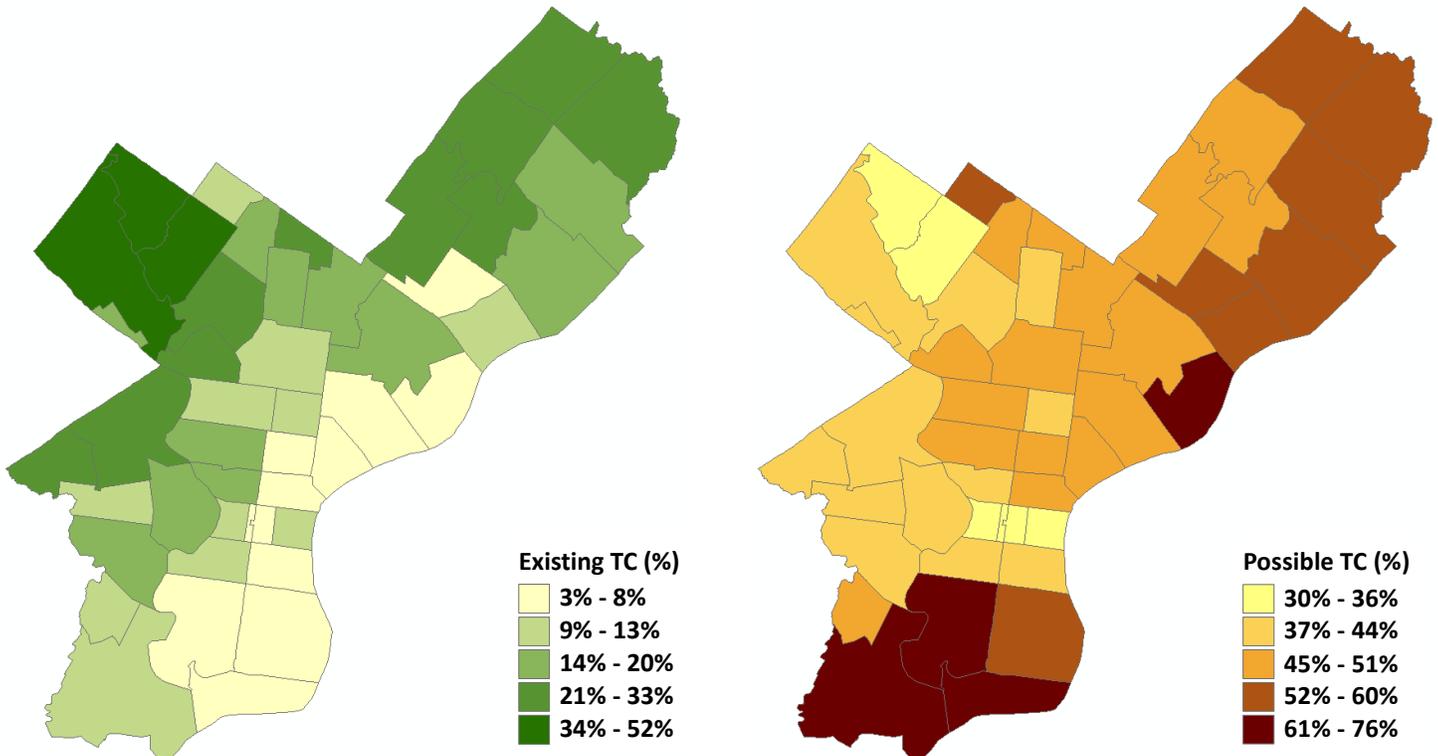


Figure 15. Existing TC (left) and Possible TC (right) as a percentage by zip code.

Water Features and Roads Analysis

Tree Canopy (TC) metrics were computed for a 50ft buffer surrounding all lakes, ponds, streams and rivers and for all roads including a 12ft buffer from the curb edge. Within the water buffer zone 56% of the land is tree canopy and 38% of the land is available for the establishment of tree canopy. Within the road buffer zone those values are 12% and 36% respectively.

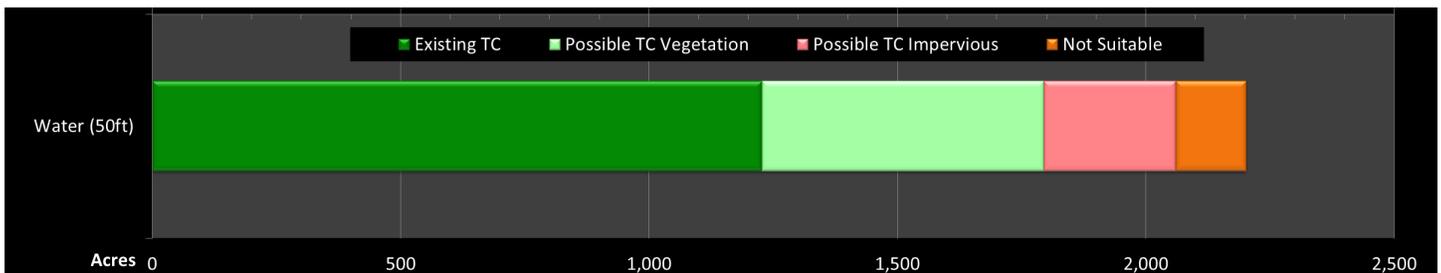


Figure 16: Tree Canopy metrics summarized for a 50ft buffer surrounding all water features.



Figure 17: Tree Canopy metrics summarized for all roads including a 12ft buffer from the road edge.

Socio-Demographic Analysis

Tree canopy metrics were computed for all US Census Block Groups within the city, allowing the tree canopy metrics to be integrated with socio-demographic data collected by the US Census. This type of information can help to inform tree planting initiatives by providing proxies for environmental justice (Existing TC %) and stewardship potential (% renter occupied and % vacant).

Existing Tree Canopy

Renter Occupied

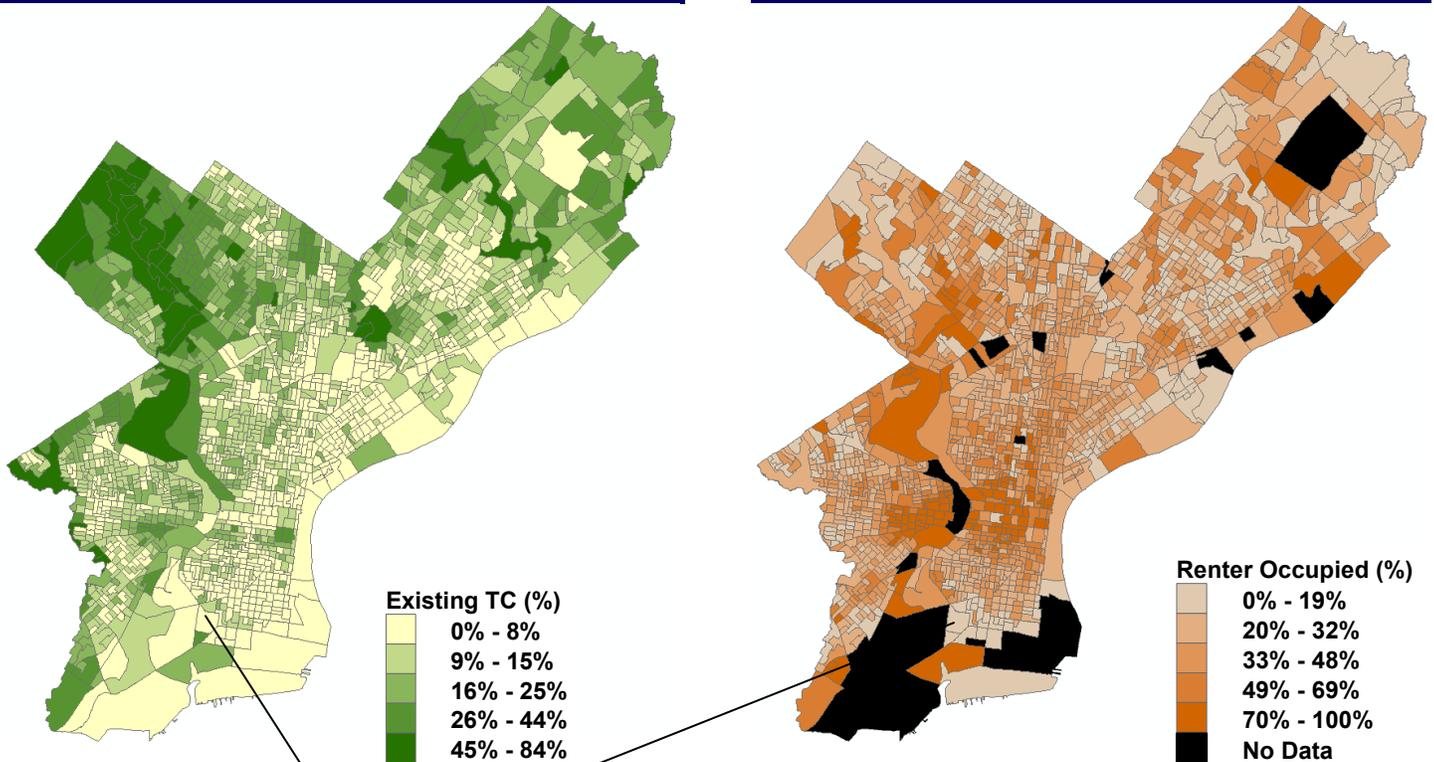


Figure 18. Existing TC (left) and Percent Renter Occupied (from 2000 Census) right, for US Census Block Groups.

Census block group 421010046001 is within the Girard Estates Neighborhood. Tree canopy is only 8% of the land area and Possible Tree Canopy is 59%. While most of the households are owner-occupied there are a relatively high percentage of vacant housing units.

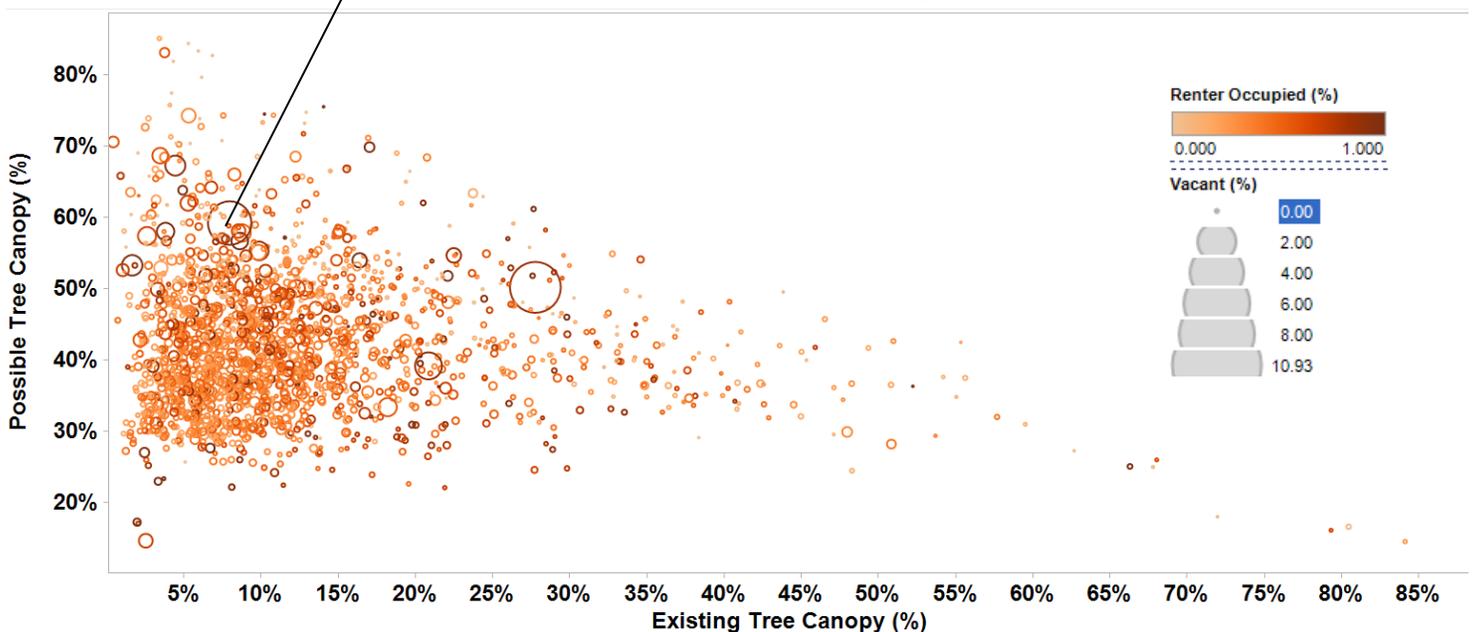


Figure 19: A combination of Census Block Group level Tree Canopy Metrics and socio-demographic information.

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 500-foot grid network is superimposed on the city's land-cover map (Figure 13a), it is possible to map regions of the city 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 city the best places to strategically expand the city's tree canopy and increasing its many attendant benefits.

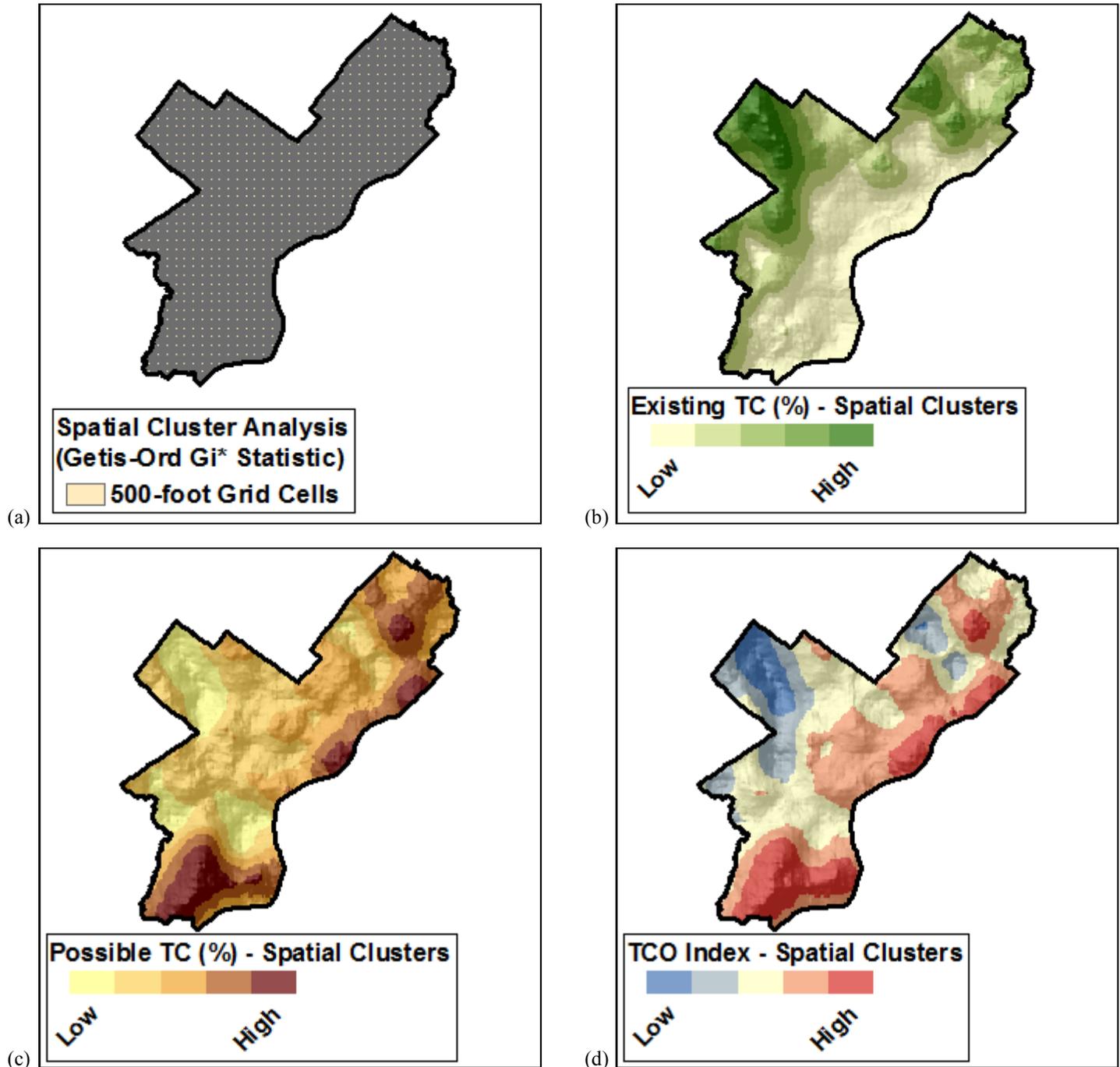


Figure 20: (a) Grid network (500-foot cells) superimposed on land-cover map for Philadelphia and then used in spatial cluster analyses; (b) Spatial clustering of Existing TC in Philadelphia; dark green areas are highly clustered and have high Existing TC values; (c) Spatial clustering of Possible TC in Philadelphia; 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

- Philadelphia'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 half of the land in Philadelphia could theoretically support tree canopy, planting new trees on much of this land may not be socially 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 and subdivisions 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.
- Philadelphia's residents control the majority of the City's tree canopy and have most of the land to plant trees. Programs that educate residents on tree stewardship and provide incentives for tree planting are crucial if Philadelphia 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.
- The city's rights-of-way (ROW) contain 16% Existing TC and 32% Possible TC, suggesting that opportunities exist for increasing the number of street trees.
- With TC metrics summarized at the subwatershed level, individual watersheds or basins can be examined and targeted for TC improvement. For example, research by Goetz et al. (2003) indicates that watersheds with 37% tree canopy can be categorized as "fair" in a stream health rating; watersheds with 45% tree canopy can be categorized as "good."

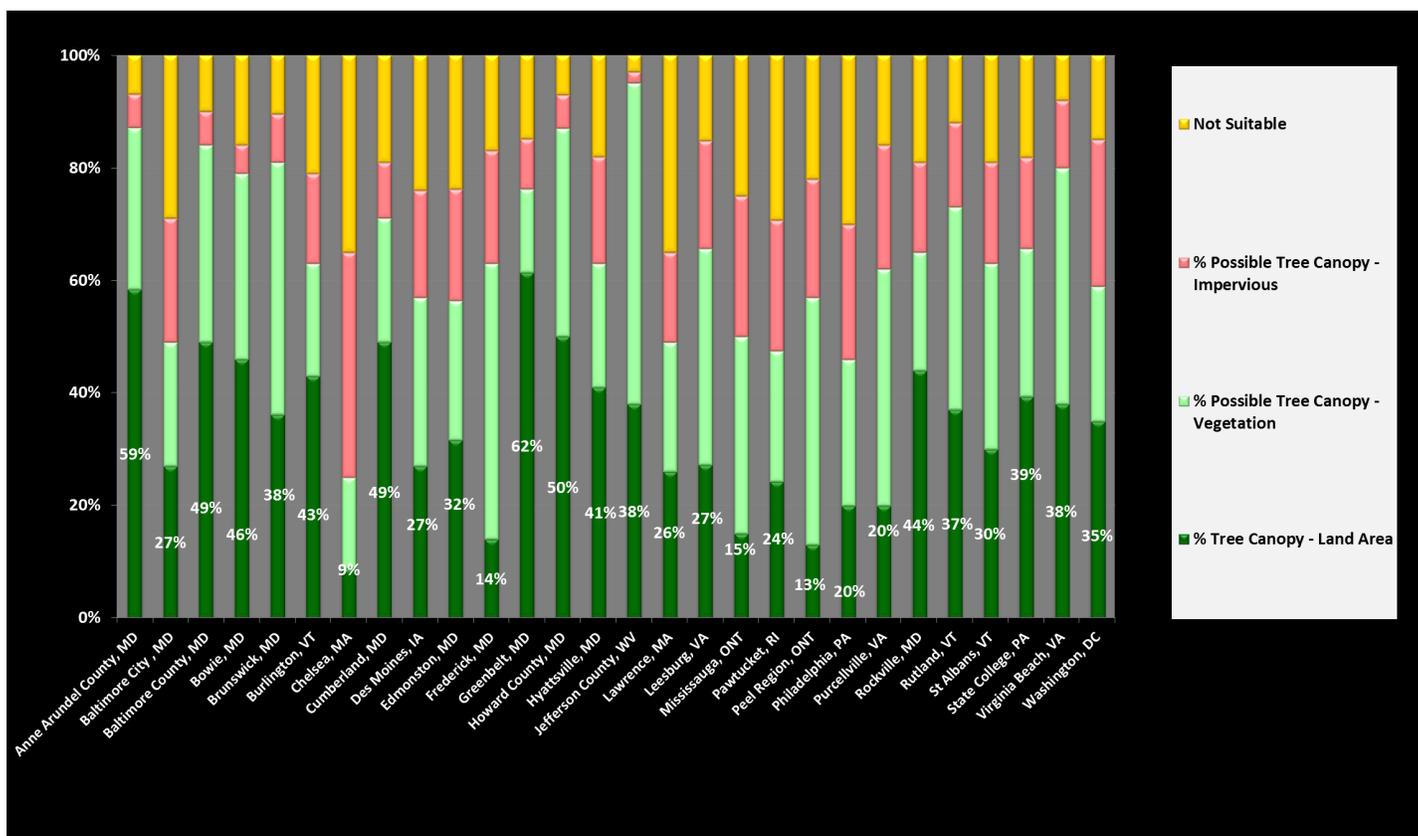


Figure 21: Comparison of Existing and Possible Tree Canopy with other selected cities that have completed Tree Canopy Assessments.

Prepared by:

Jarlath O'Neil-Dunne
University of Vermont
Spatial Analysis Laboratory
joneildu@uvm.edu
802.656.3324

Additional Information

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

Spatial Analysis Lab Tree Canopy Assessment Team: Brian Beck, Ray Gomez, Claire Greene, Dan Koopman, Sean MacFaden, Jarlath O'Neil-Dunne, Kelsea Peace, Keith Pelletier, Eleanor Regan, Anna Royar, Bobby Sudekum, and Emily West