A Report on Existing and Possible Tree Canopy in the City of Charlotte and Mecklenburg County, NC

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 (National Research Council, 2013). Establishing a tree canopy goal is crucial for communities seeking to improve their green infrastructure. A tree canopy assessment is the first step in urban forest planning, providing estimates for the amount of tree canopy currently present as well as the amount of tree canopy that could theoretically be established.

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 Exists?

An analysis of Mecklenburg County based on land cover data derived from high-resolution aerial imagery and LiDAR (Figure 1) found that 172,283 acres of the county were covered by tree canopy (termed Existing TC), representing 51% of all land in the county (47% within city limits). An additional 36% (121,294 acres) of the county's land area (37% within city limits) could theoretically be modified (termed Possible TC) to accommodate tree canopy. In the Possible TC category, 25% (83,851 acres) of total land area was classified as Vegetated Possible TC (23% within city limits) and another 11% (14% within city limits) as Impervious Possible TC (37,443 acres). Vegetated Possible TC, or grass/shrub, 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: Example of the land cover derived from high-resolution imagery and LiDAR for this project.

Project Background

The goal of the project was to apply the USDA Forest Service's Tree Canopy Assessment protocols to the City of Charlotte and Mecklenburg County (Figure 2). The analysis was conducted using year 2012 data. This project was made possible through funding from the City of Charlotte, North Carolina. 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 Mecklenburg County, the City of Charlotte, SavATree, and the USDA Forest Service's Northern Research Station.

Figure 2: Study area for the project. Land cover mapping and urban tree canopy assessments were carried out at both the county– and city-scales.

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).

Tree Canopy Results for the City and County

On a percentage basis, Mecklenburg County and the City of Charlotte have similar amounts of tree canopy as a percentage of land area, with 51% and 47% respectively . Possible Tree Canopy percentages are also similar between the County and the City. Possible TC in the County is 36% and Possible TC in the City is 37%. The difference between the two is the higher relative percentage of Possible TC within the City that is impervious. These Possible TC Impervious areas consist of non-building, non-road impervious surfaces such as driveways and parking lots. Establishing tree canopy on these surfaces, through either overhanging tree canopy or the removal of impervious surfaces, can offer substantial gains in ecosystem services. However, it is considerably more challenging than planting on Possible TC Vegetation, which consists of grass/shrub. Possible TC is only and indication of land where tree canopy could be established.

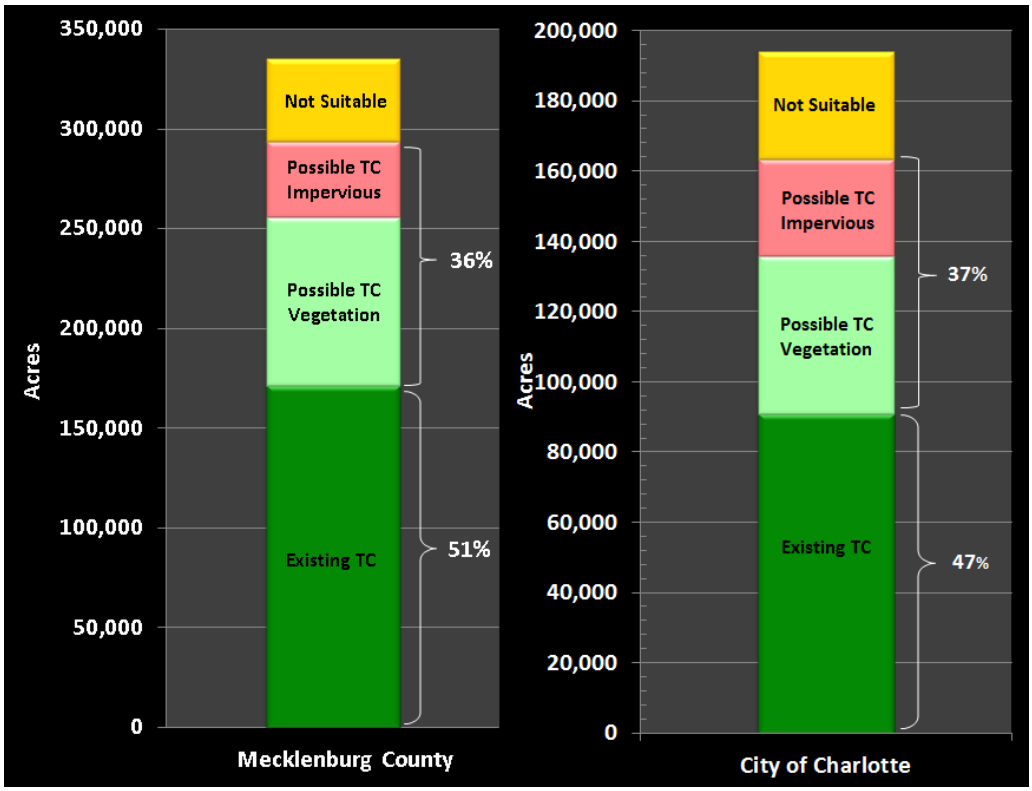


Figure 3: Tree canopy metrics for Mecklenburg County and the City of Charlotte.

Forest Patch Size

Tree canopy assessment has historically focused on measuring the amount of tree canopy. A new tree canopy patch analysis, developed to support the USDA Forest Service's Urban Tree Canopy (UTC) Assessment protocols, gives resource managers a better understanding of the type of tree canopy they have by dividing the tree canopy into large, medium, and small patches. Patches are delineated using a customized object-based approach that takes into account morphology, area, perimeter, and edge metrics. 57% of Mecklenburg County's tree canopy is in large patches, 38% in medium patches, and 6% in small patches (Figure 4).

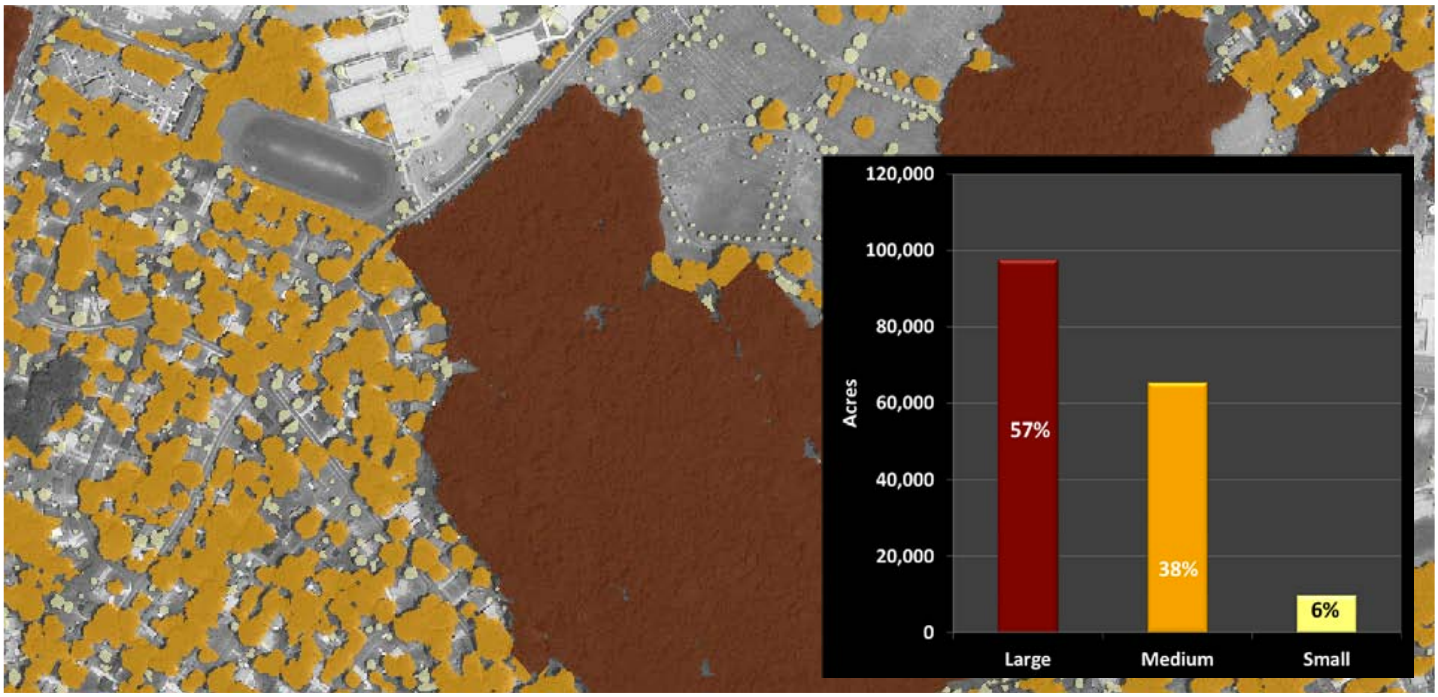


Figure 4: Tree Canopy Patch Analysis for Mecklenburg County.

Comparison to Previous Studies

This study is considered to be the most precise and accurate accounting of tree canopy for both the City and the County due to three factors: the availability of LiDAR, advanced object-based image analysis workflows, and a detailed QA/QC process. Differences in percent tree canopy from previous studies, such as the 2008 urban ecosystem assessment, likely result from the quality of the mapping as much as changes in the landscape. Figure 5 shows a comparison between the 2012 tree canopy layer developed in this study (Figure 5a) and the 2008 American Forests tree canopy layer (Figure 5c). The 2012 1-meter resolution imagery is provided for reference (Figure 5b). Although there were likely changes in the tree canopy over this 4-year period there are noticeable errors of both omission and commission in the 2008 layer. Individual trees along streets are sometimes missed in the 2008 layer, and in some cases, moderately-sized forest patches. Tree canopy also appears in the 2008 study in areas where it is unlikely to exist, such as in the middle of an industrial parking lot.

Figure 5: Comparison of NLCD 2001 (a) to high-resolution imagery (b) and tree canopy (c) derived for this study.

Parcel Summary

Tree Canopy (TC) metrics were summarized for each property in the County's parcel database (Figure 6). 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 divided by land area of the parcel). The resulting data can be used to assess the tree canopy and tree planting opportunities for every property in the Mecklenburg County.

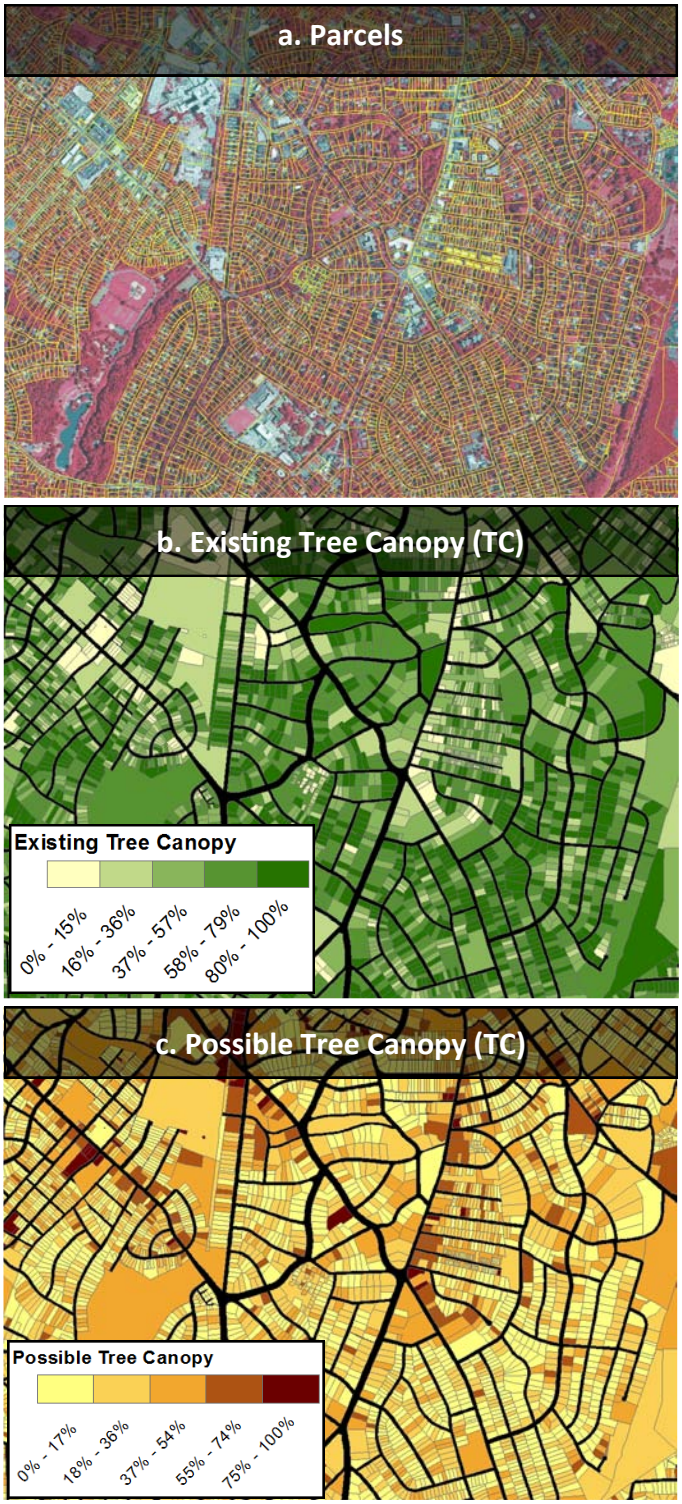


Figure 6: Tax Parcel-based TC metrics. TC metrics are generated at the parcel level (a), allowing each property to be evaluated according to its Existing TC (b) and Possible TC (c).

Rights-Of-Way

Land within Mecklenburg County can be broadly split into two categories (Figure 7), parcel land and rights-of-way (ROW). Parcel land refers to all land contained within the county's parcel database. Rights-of-Way (ROW) refers to "non-parcel" land, essentially street rights-of-way and water. The vast majority of the county's land base (88%) exists within parcels, with 5% of the land base for ROW Within City and 7% ROW Outside City (Figure 8). 50% of parcel land is covered by tree canopy. Within the ROW only 20-30% of the land is covered by tree canopy. Additional tree canopy (Possible TC) could theoretically be established on 37% of all the parcel land area, on 33% of the ROW Outside City, but on only 21% of the ROW Within City , largely due to the presence of roads and other transportation infrastructure. Establishing new tree canopy within the parcel land will likely be easier as much of the Possible TC falls into the Vegetation category whereas in the ROW much of the Possible TC is in the Impervious category (particularly on the ROW Within City). Nevertheless, the city could substantially improve its tree canopy through an "all lands" approach that includes both street tree plantings (within the ROW) and plantings on parcel land.

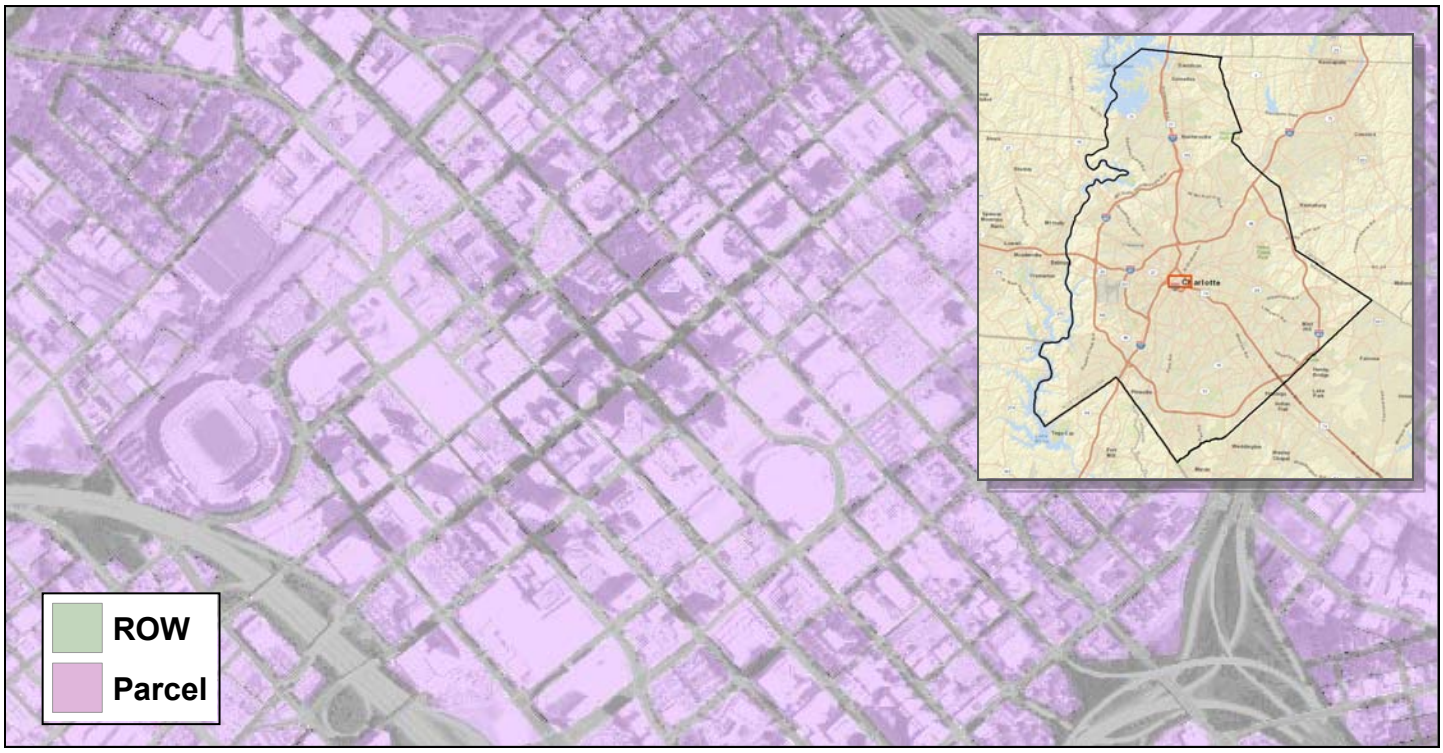


Figure 7: Parcels and ROW land division in Charlotte.

Figure 8: Tree Canopy (TC) metrics were summarized by parcels and ROW.

County Land Use Analysis

An analysis of Existing and Possible Tree Canopy by land use was conducted using the County's existing land use and right of way data (Figure 9 /10, Table A-1). For each land use category, tree canopy metrics were calculated as a percentage of all land in the Mecklenburg County study area (% Land), as a percentage of land area in the specified land use (% Category), and as a percentage of total area in the tree canopy type (% TC Type). Nearly 40% of Mecklenburg County is classified as Single Family -- Detached or Large Lot Residential, and thus it comes as no surprise that these two categories have a large fraction (almost one third) of the area's tree canopy, but also the most room to plant new trees. These two residential land use categories account for 41% of land in Mecklenburg County that is categorized as Vegetated Possible Tree Canopy. Lands categorized as Right-of-Way, Open Space/Recreation and Civic/Institutional also present opportunities for tree planting. Taken together Residential lands contain 45,305 acres (40%) of land classified as Possible Tree Canopy and might contain the most area where resources could efficiently be directed to increase tree canopy, although recreation and other open space would be competitive land uses.

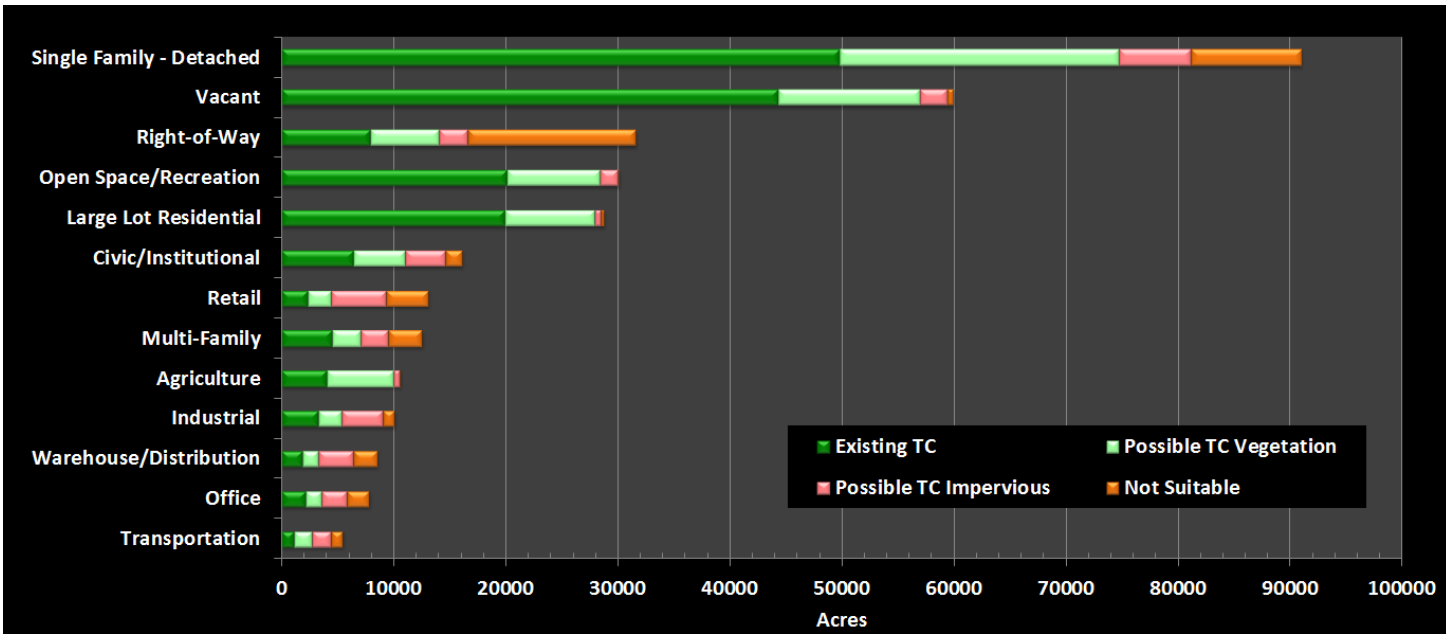


Figure 9: Tree Canopy (TC) metrics summarized for each land use class (classes smaller than 5,000 acres are not shown).

Figure 10: Land use data used for the UTC metrics. The graphic is centered on the intersection of I-77 and Tyvola Road.

Socio-Demographic Analysis

US Census block groups contain a wealth of socio-demographic information that, when combined with Tree Canopy metrics, provide new insights into the relationship between the citizens of Mecklenburg County and their tree canopy. This study computed tree canopy metrics using 2010 US Census block group data. Percent Existing and Percent Possible Tree Canopy maps indicate socio-demographic units where tree canopy is sparse and where planting opportunities exist (Figure 11a & 11b). These maps can be used to help direct resources for tree planting. Many of the block groups in the lowest median income bracket have a relatively low amount of tree canopy (Figure 11c). Population density is relatively high in some of these block groups with low amounts of Existing Tree Canopy and would thus be places to look at enhancing tree canopy for the benefit of these population centers (Figure 11d).

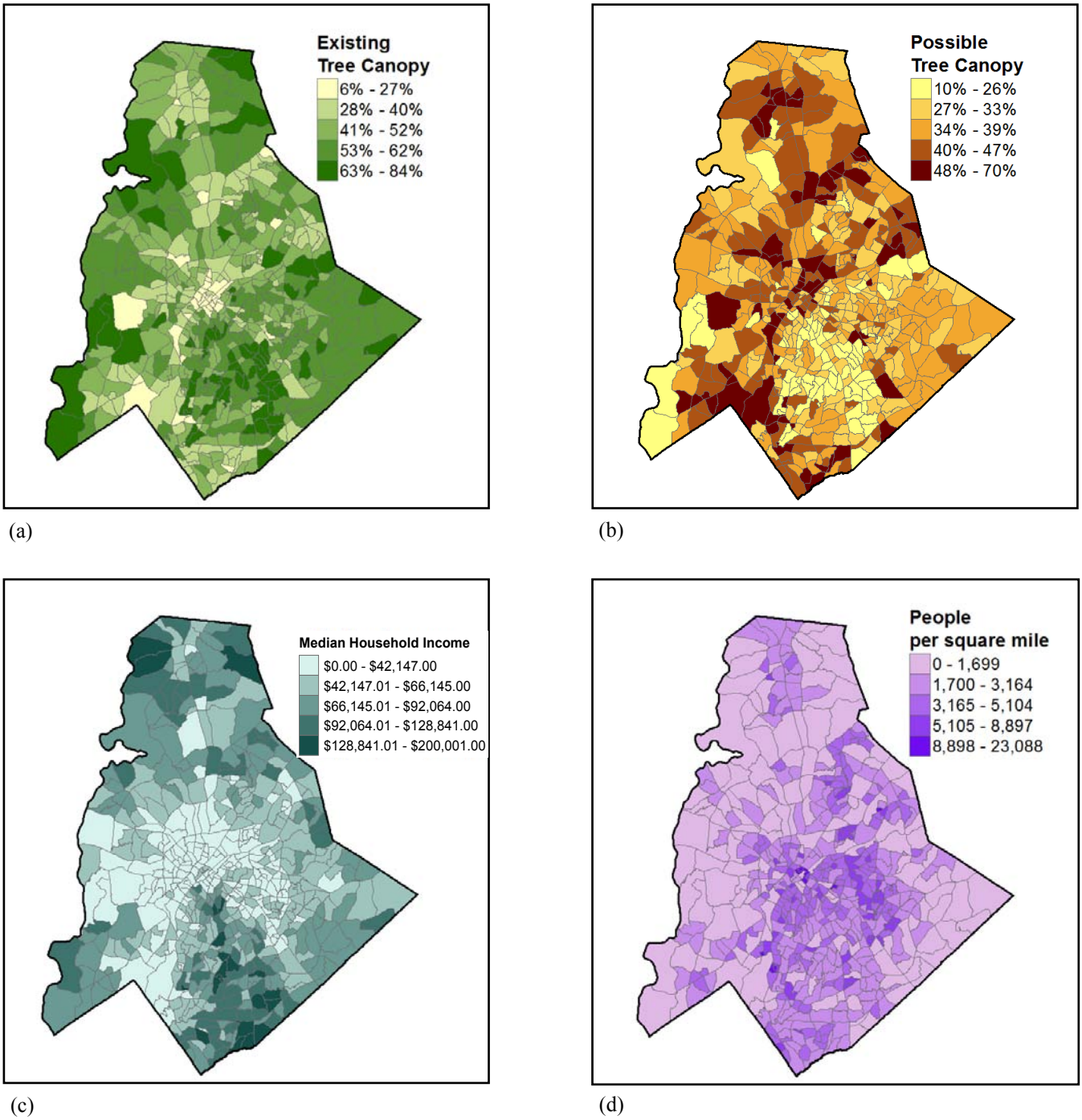


Figure 11: (a) Percent Existing TC; (b) Percent Possible TC; (c) 2011 median income per capita; and (d) people per square mile for census block groups in Mecklenburg County.

Priority Planting Index

The Priority Planting Index (PPI), developed by the US Forest Service, incorporates census data and Tree Canopy metrics to score block groups based on the need for tree plantings. It is a simplistic method to prioritizing areas for tree plantings. The Priority Planting Index, which factors in population density, Existing Tree Canopy, and per capita tree cover helps to identify areas where tree planting efforts can be targeted to address issues of environmental justice (Figures 12 & 13). A higher PPI score indicates a higher priority for planting. Interestingly, the areas with high PPI values also have relatively high amounts of Possible Tree Canopy.

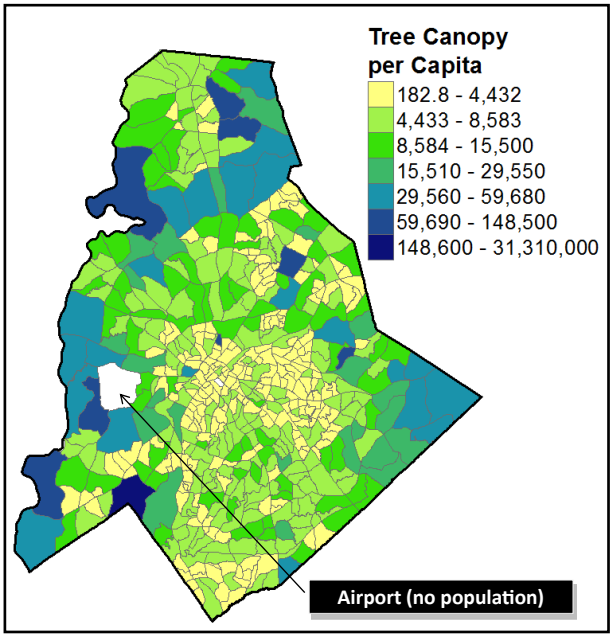


Figure 12: Tree canopy per capita by census block group in feet squared.

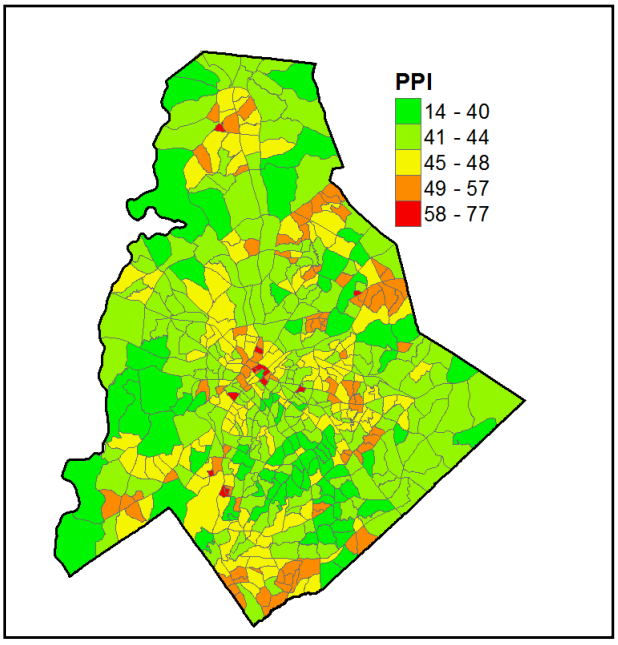


Figure 13: Priority Planting Index by census block group.

Surface Temperature

One of the chief benefits of tree canopy is the ability to reduce summer temperatures in urbanized areas, ameliorating the urban heat island effect. The urban heat island effect is largely a result of impervious surfaces, which unlike vegetation, retain and emit heat. Higher summer temperatures are associated with increased energy use, which in turn, drives up the cost of living along with operational costs for commercial and industrial operations. To examine the urban heat island effect in Mecklenburg County we used a Landsat satellite image acquired on June 1, 2011. Landsat has the ability to measure surface temperature at a relatively detailed scale. Landsat surface temperatures were summarized at the Census block group level and compared to both tree canopy and impervious surfaces (Figures 14 & 15). It was found that block groups with lower amounts of tree canopy and higher amounts of impervious surfaces tend to have higher temperatures.

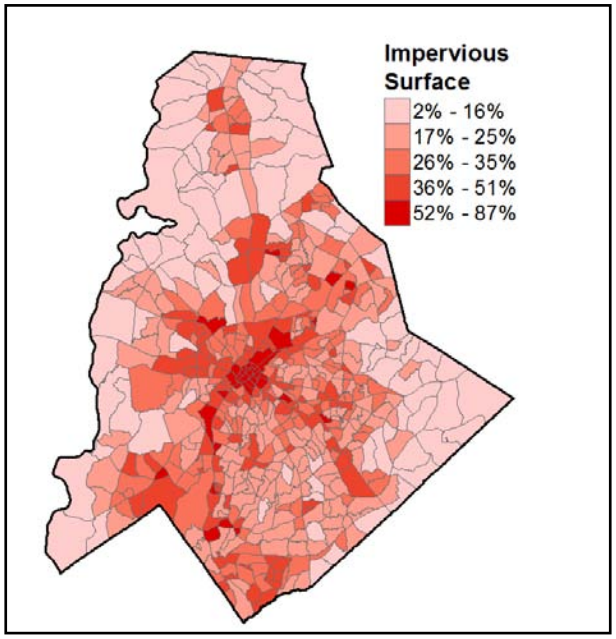


Figure 14: Amount of impervious surface by census block group.

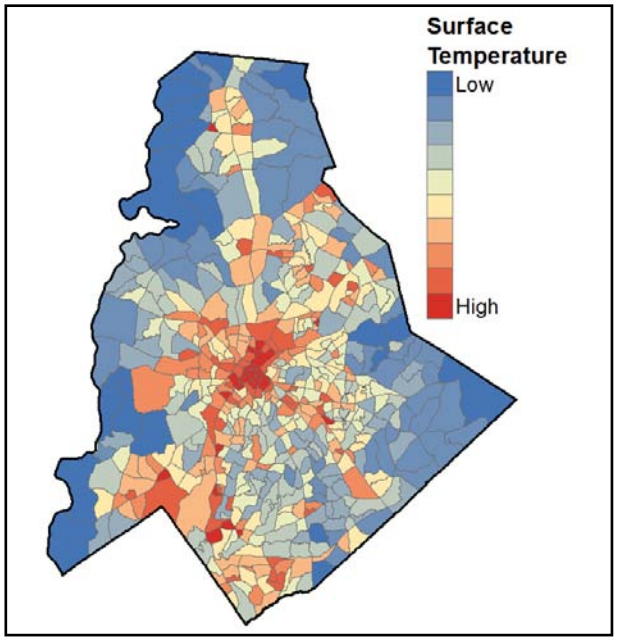


Figure 15: Surface temperature by census block group.

Plan Boundaries

Existing and Possible Tree Canopy were summarized by 32 Plan Boundaries delineated in a dataset acquired from the City of Charlotte that includes Plans adopted since 2005 (Figure 16). Of the 8 largest plan boundaries (those greater than 1,500 acres) 6 of the areas range from 45-59% forested (Figure 17). The Northlake Area and University City Area Plan areas are 34% and 35% forested, respectively; The Catawba Area Plan is 59% forested. The 8 largest plan boundaries account for 91% of all Tree Canopy within plan boundaries. Nearly all of the largest plan boundaries have at least one third of their area in Possible Tree Canopy. In terms of establishing new tree canopy, Steele Creek and Rocky River Road Areas have the largest fraction of the Vegetated Possible Tree Canopy category and together account for 62% of land in this category. Steele Creek also provides the greatest area of opportunity for establishing tree canopy on impervious surfaces, along with the Independence Boulevard and Northlake Areas. These 3 plan areas account for 60% of the Possible Tree Canopy Impervious type. New tree planting in impervious areas can provide many benefits but typically comes at greater expense compared to planting in areas of existing vegetative cover. A majority of the largest plan boundaries have a substantial fraction of land classified as vegetated possible tree canopy.

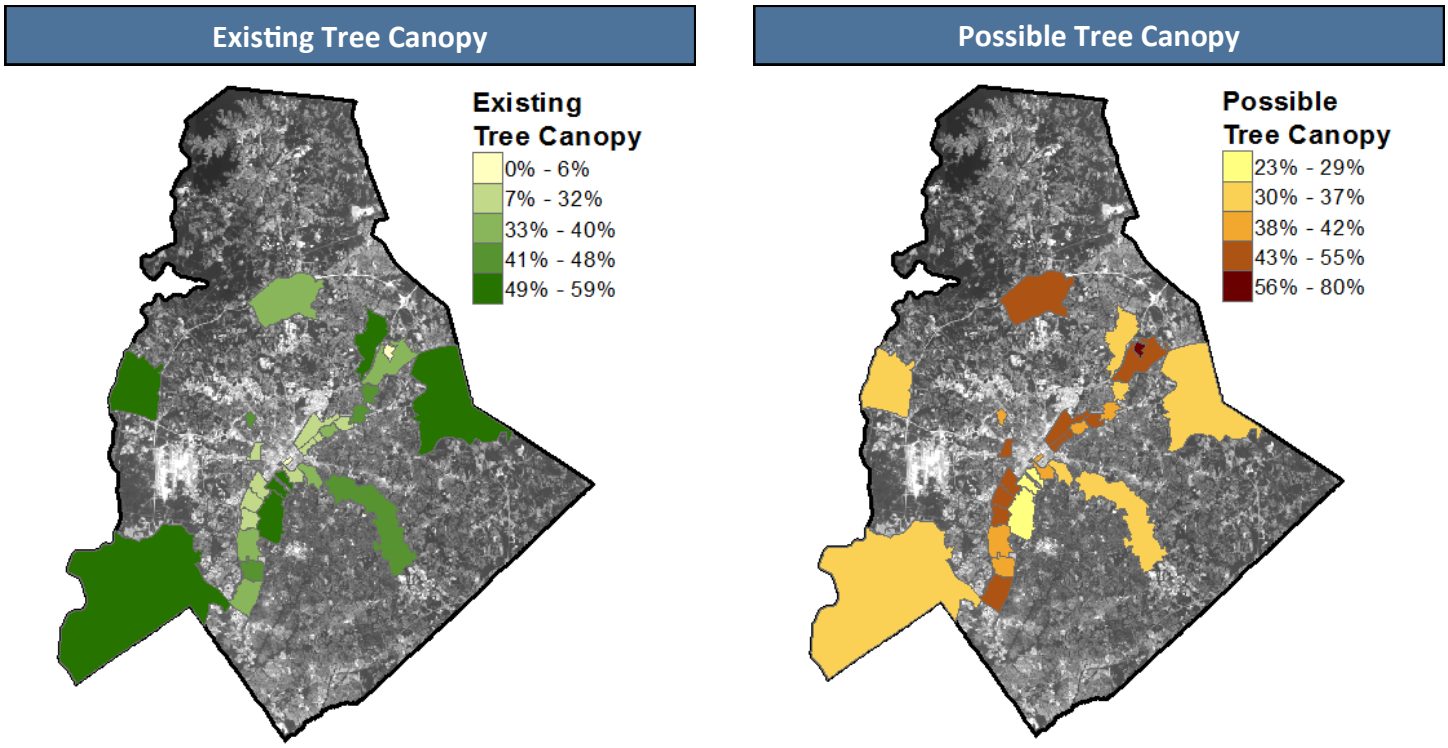


Figure 16: Existing and Possible Tree Canopy for Plan Boundaries adopted since 2005.

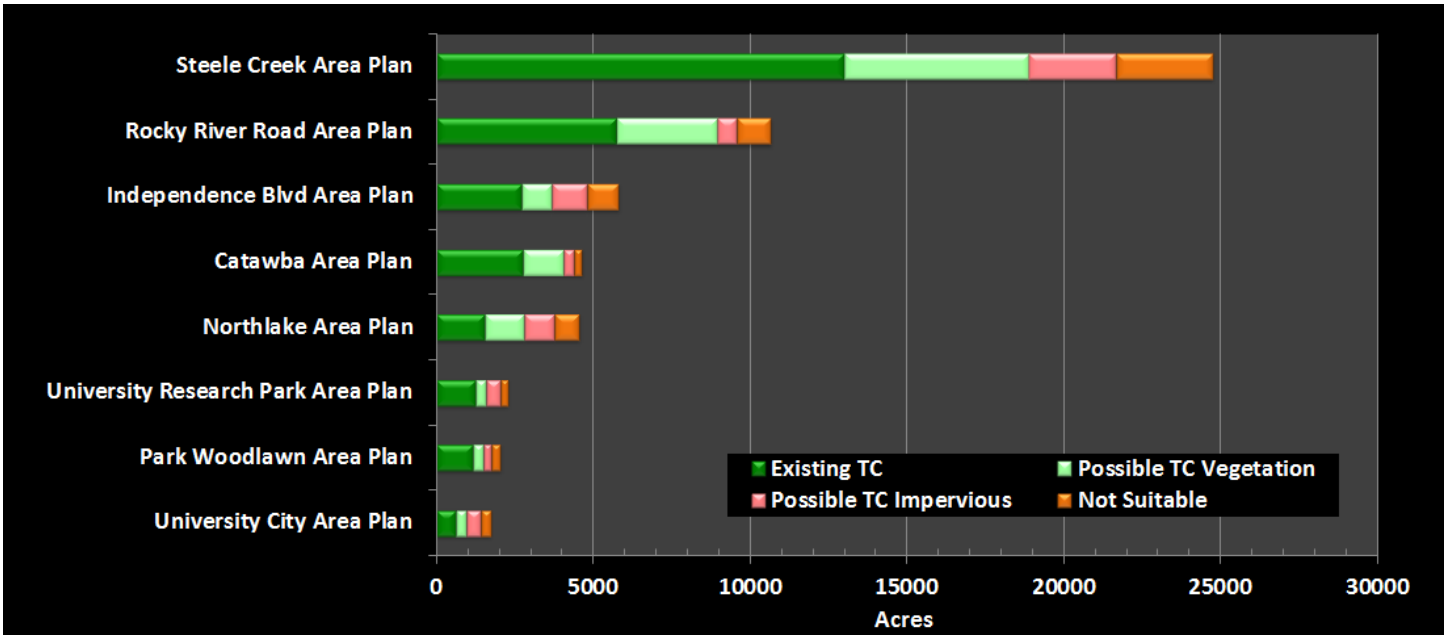


Figure 17: Tree Canopy metrics summarized by Plan Boundaries (only those boundaries larger than 2% of total plan boundary area are shown).

Centers/Corridors/Wedges

Existing and Possible Tree Canopy were also summarized by general use patterns in the city of Charlotte as represented by a dataset that divides the City into Centers, Corridors or Wedges (CCW; Figure 17). Not surprisingly, Existing Tree Canopy percentages are relatively high for Corridors and Wedges (Figure 18). The Wedge designation accounts for a full two-thirds of CCW area and contains 37% of the tree canopy; Corridors account for 16%. The Center City and Industrial Centers have the least tree canopy of these designated areas. Mixed Use Centers have the greatest amount of Existing Tree Canopy but still have a relatively high percentage of Possible Tree Canopy. Despite their relatively large proportions of tree canopy, Corridors and Wedges also present the greatest total area of Possible Tree Canopy (Figure 18). These areas also may be good places to focus tree canopy improvements efforts for developed land as they each have over 10,000 acres of Possible Tree Canopy classified as Impervious. On a percentage basis, Industrial Centers and the Center City have the largest fraction of Possible Tree Canopy (51% and 43%, respectively). The Center City would be another good focal point for tree canopy improvements on developed land as any gains here would have a positive influence on quality of life in the urban core. Mixed Use Activity Centers also have a substantial fraction of Possible Tree Canopy and may provide good planting opportunities, depending on the primary use.

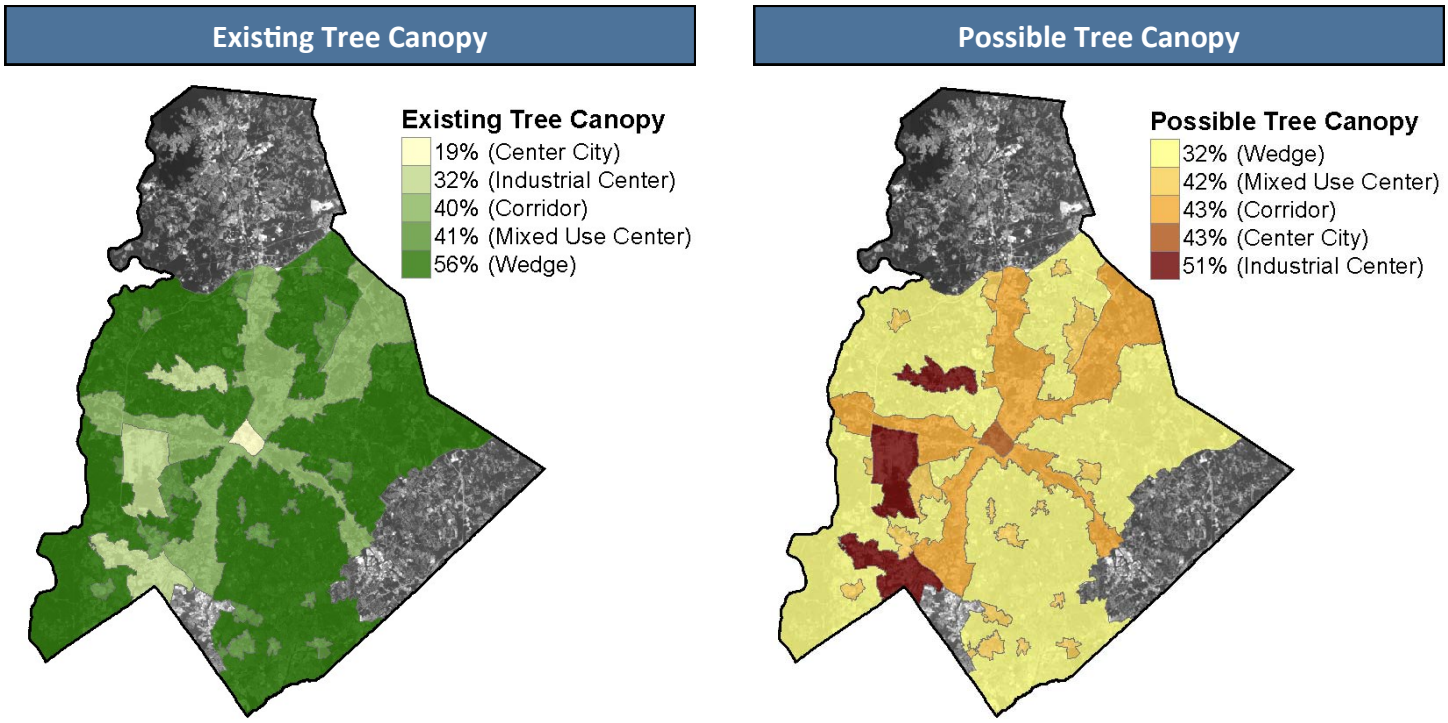


Figure 17: Percent Existing and Possible Tree Canopy by Center/Corridor/Wedge designation.

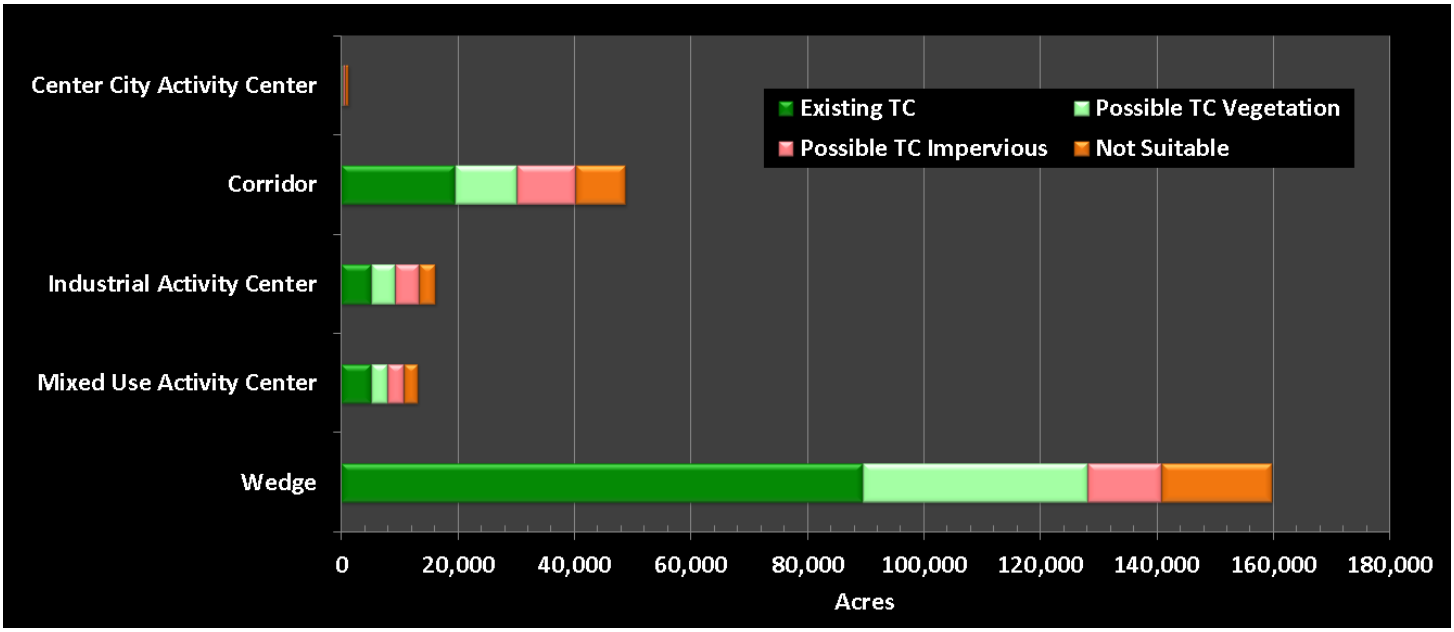


Figure 18: Tree Canopy metrics summarized by Center/Corridor/Wedge designation.

Riparian Areas

Riparian zones in Mecklenburg County have been modeled using variable width buffers around streams and other hydrologic features. These water quality buffers were provided by the County and range from 30 to 200 feet in width. Existing and Possible Tree Canopy were tabulated for these riparian areas (Figure 19). Within the riparian areas, which total 29,551 acres (land area), 73% of land is categorized as Existing Tree Canopy and 22% is categorized as Possible Tree Canopy. Of the 22% available land, only 4% is impervious surface, so ample opportunities exist to stabilize stream banks and protect water quality by increasing the amount of tree canopy in these environmentally important zones.

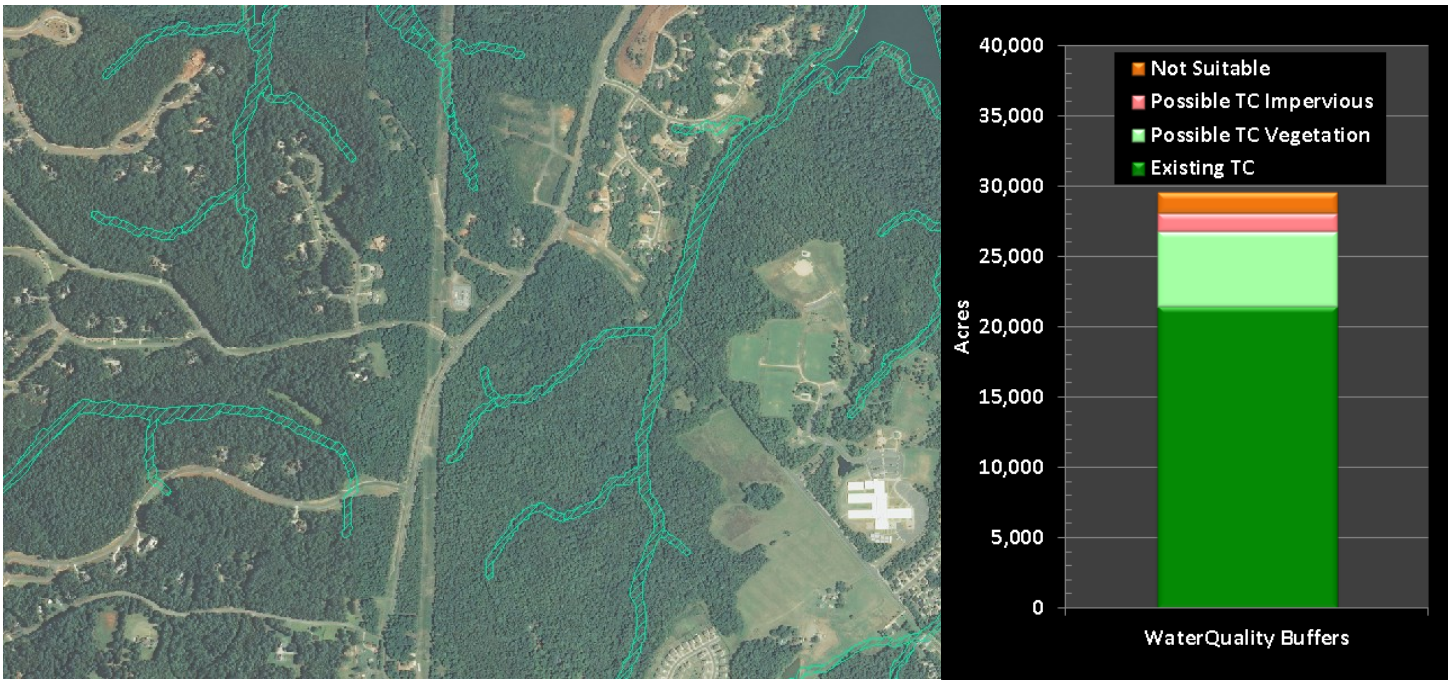
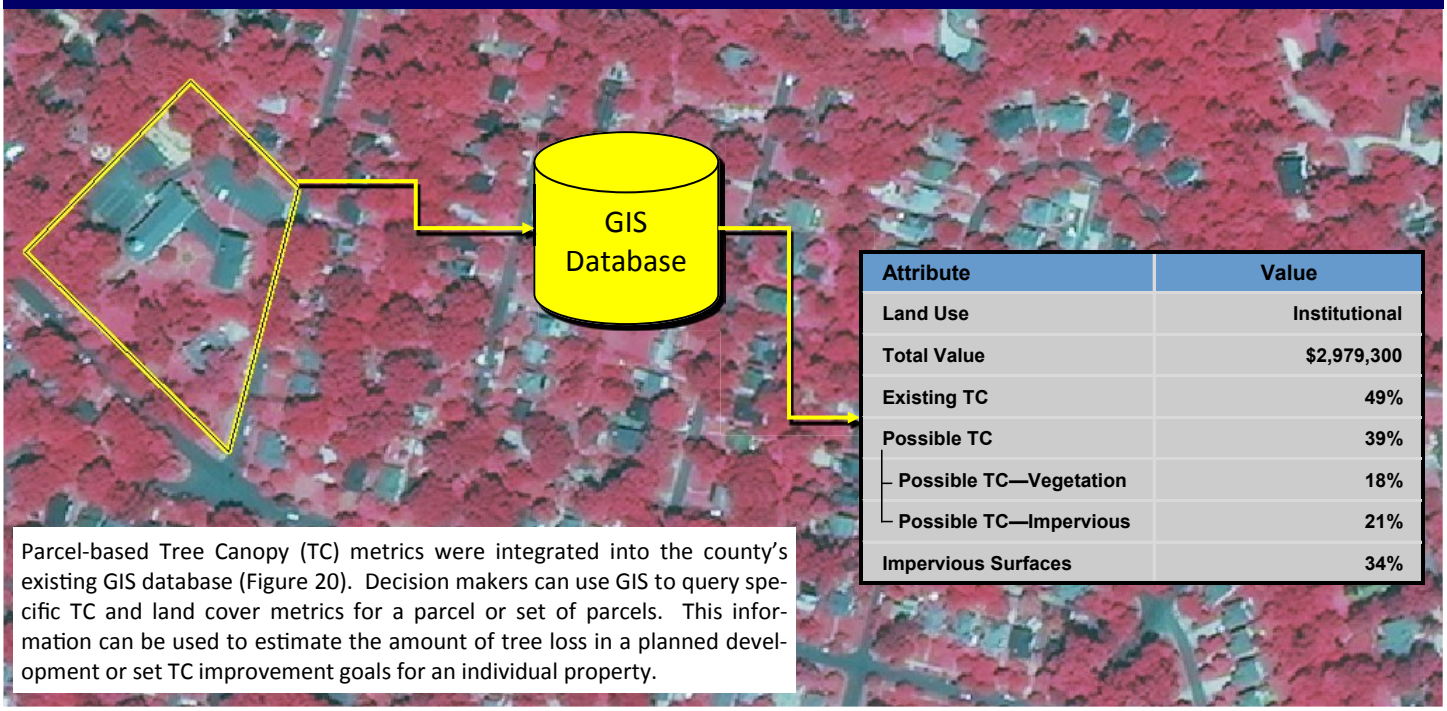


Figure 19. Tree Canopy metrics summarized by water quality buffers.

Decision Support



Attribute	Value
Land Use	Institutional
Total Value	$2,979,300
Existing TC	49%
Possible TC	39%
Possible TC—Vegetation	18%
Possible TC—Impervious	21%
Impervious Surfaces	34%

Parcel-based Tree Canopy (TC) metrics were integrated into the county's existing GIS database (Figure 20). 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 20: 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 1000-foot grid network is superimposed on the land-cover map (Figure 21a), it is possible to map regions of the study area where high values of Existing TC are tightly clustered (Figure 21b). A similar map was constructed for Possible TC (Figure 21c). 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 21d); these areas theoretically offer the best places to strategically expand Mecklenburg County's tree canopy and to increase its many attendant benefits. Unlike PPI (Figure 12), TCO does not take into account population information. As such, the areas with the highest TCO are rural and agricultural areas that have low Existing and high Possible TC. As with all such analyses, however, landscape context must be evaluated before setting priorities.

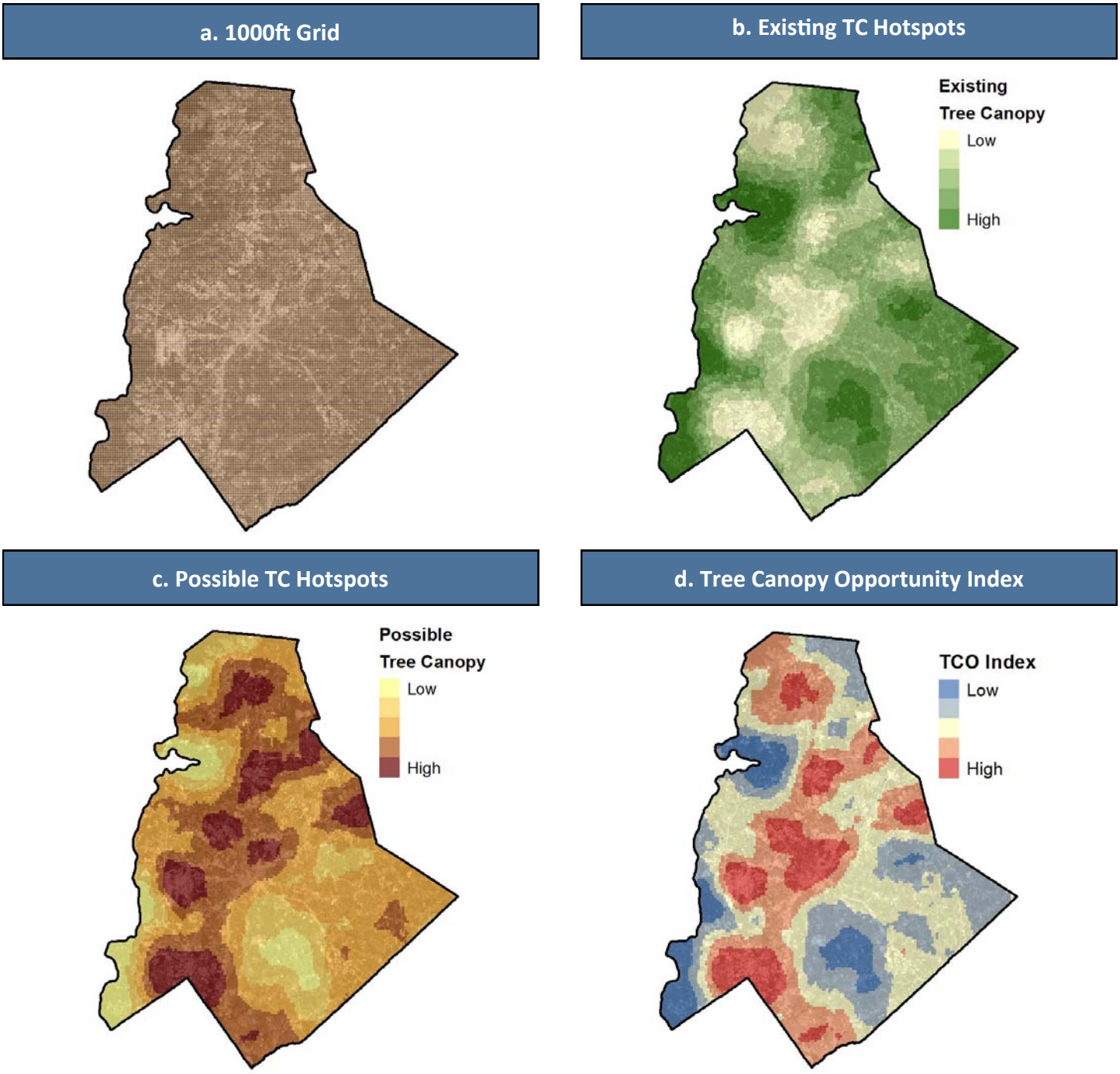


Figure 21: (a) Grid network (1000-foot cells) superimposed on land-cover map for Mecklenburg County and then used in spatial cluster analyses; (b) Spatial clustering of Existing TC in Mecklenburg County; dark green areas are highly clustered and have high Existing TC values; (c) Spatial clustering of Possible TC in Mecklenburg County; 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

- Tree canopy for Mecklenburg County is comparable to other urbanized counties in the Eastern United States (e.g. Baltimore County and Prince George's County, MD—Figure 21). Nevertheless, there exist areas ,both within the County and City that have well-below average tree canopy, indicating areas where improvements can be made to insure the benefits of trees are realized by the entire population.
- The City of Charlotte has substantially higher amounts of tree canopy compared to major cities such as New York and Washington DC (Figure 21), but is similar to less urbanized cities such as Pittsburgh (Figure 21).
- This study can assist Mecklenburg County and the City of Charlotte in meeting their tree canopy goals. These data can help the County and the City prioritize areas for increasing tree canopy based on biophysical and socio-demographic factors using tools such as the Priority Planting Index (PPI) or Tree Canopy Opportunity (TCO) Index.
- Residents are the largest single stakeholder group in terms of land use with respect to both Existing Tree Canopy and Possible Tree Canopy. Programs that educate the County's and City's residential land owners will be crucial for the long-term success of any tree canopy goals.
- Strategies for increasing tree canopy will likely differ by land use type. For example, tree planting initiatives on transportation corridors will likely target under-used lands and medians where possible while efforts in agricultural lands may focus on riparian buffers in order to insure a working agricultural landscape, yet at the same time reduce surface runoff.
- Tree canopy has a clear effect on surface temperature, helping to reduce the urban heat island effect. Increasing tree canopy, particularly in those areas with high amounts of impervious surfaces will reduce energy costs for residents and business in addition to making the area more livable.
- Despite the dominance of residential land use within the county all land use types have vegetated or impervious surfaces, that if improved, could yield additional tree canopy. For example, 26% of the land in industrial land use contains non-tree canopy vegetated land that is available for the establishment of new tree canopy.
- Efforts to preserve the county's current tree canopy and establish new tree canopy will likely take many forms. Tree canopy prioritization analyses can help managers make strategic decisions to match their objectives from the property parcel to the watershed scale.

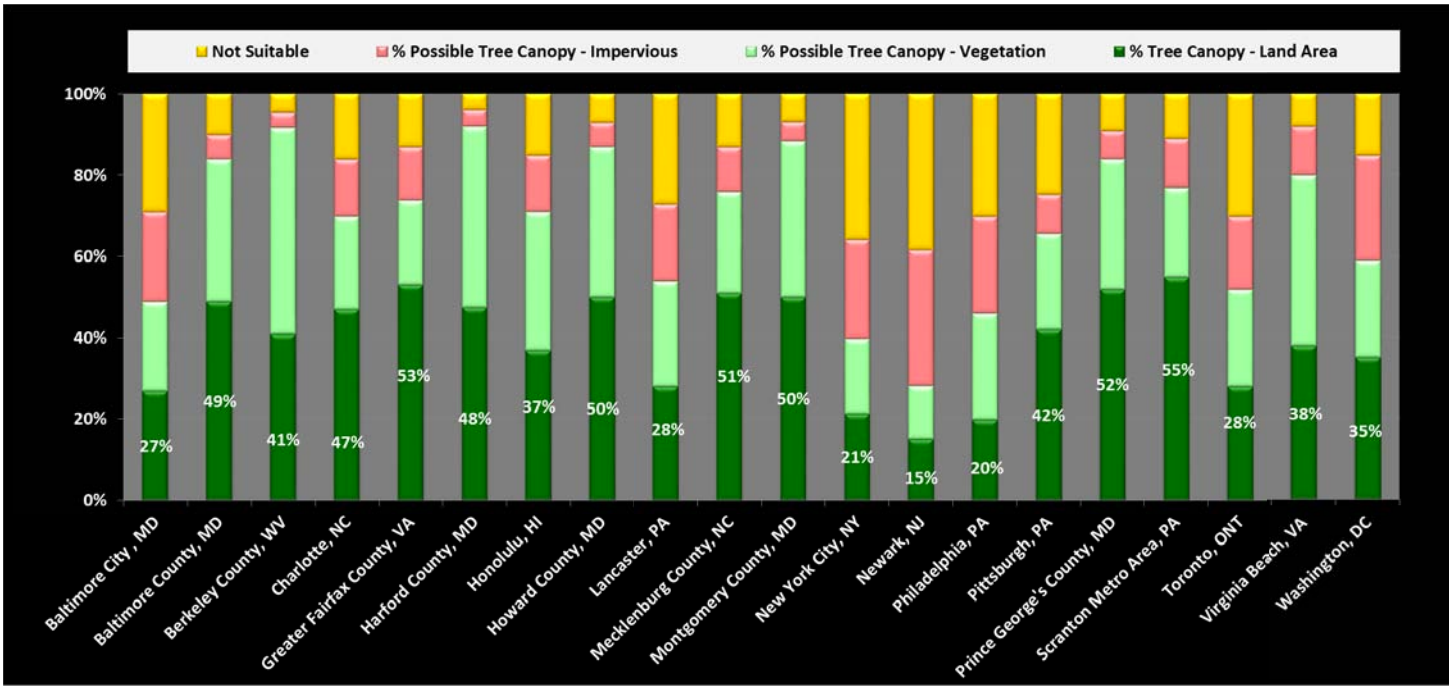


Figure 22: Results from other communities that have completed Tree Canopy Assessments.

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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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Appendix A: Additional UTC Metrics

Land Use	Existing TC			Possible TC Vegetation			Possible TC Impervious		
	% Land	% Category	% TC Type	% Land	% Category	% TC Type	% Land	% Category	% TC Type
Single Family - Detached	16%	55%	30%	8%	27%	31%	2%	7%	19%
Vacant	14%	74%	27%	4%	21%	16%	1%	4%	7%
Right-of-Way	2%	25%	5%	2%	19%	8%	1%	8%	8%
Open Space/Recreation	6%	67%	12%	3%	28%	10%	0%	5%	5%
Large Lot Residential	6%	69%	12%	3%	28%	10%	0%	2%	2%
Civic/Institutional	2%	40%	4%	1%	28%	6%	1%	22%	11%
Retail	1%	18%	1%	1%	16%	3%	2%	38%	14%
Multi-Family	1%	36%	3%	1%	20%	3%	1%	19%	7%
Agriculture	1%	38%	2%	2%	56%	7%	0%	5%	2%
Industrial	1%	33%	2%	1%	20%	3%	1%	36%	11%
Warehouse/Distribution	1%	22%	1%	0%	17%	2%	1%	36%	9%
Office	1%	28%	1%	0%	18%	2%	1%	29%	7%
Transportation	0%	21%	1%	1%	30%	2%	1%	30%	5%
Utility	1%	53%	2%	1%	33%	2%	0%	12%	2%
Horizontal Mixed Use Non-Residential	0%	21%	0%	0%	12%	0%	0%	43%	2%
Single Family - Attached	0%	56%	0%	0%	23%	0%	0%	8%	0%
Water	0%	79%	0%	0%	15%	0%	0%	5%	0%
Parking	0%	19%	0%	0%	14%	0%	0%	59%	0%
Vertical Mixed Use	0%	21%	0%	0%	9%	0%	0%	28%	0%
Horizontal Mixed Use - Residential/Non-Residential	0%	54%	0%	0%	21%	0%	0%	12%	0%

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

The % Land Area value of 2% indicates that 2% of Mecklenburg County's land area is covered by tree canopy in the Civic/Institutional land use class.

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

The % Land value of 40% indicates that 40% of land in the Civic/Institutional land use class is covered by tree canopy.

$$\text{\% TC Type} = \frac{\text{Area of TC type for land use category}}{\text{Area of all TC type}}$$

The % TC Type value of 4% indicates that 4% of all tree canopy is in land classified in the Civic/Institutional land use class.

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

Appendix B: Workflow