URBAN TREE CANOPY

ASSESSMENT

NASHVILLE, TENNESSEE

DECEMBER | 2023

PlanIT Geo
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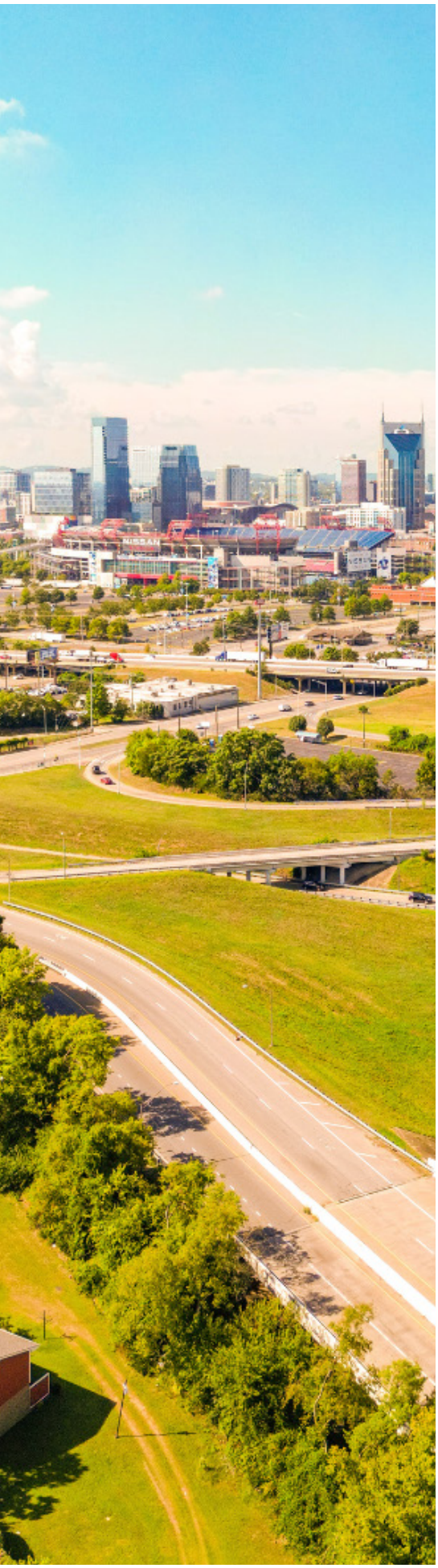
earth define



AN ASSESSMENT OF URBAN TREE CANOPY IN **NASHVILLE, TENNESSEE**

> **To be without trees would, in the most literal way, to be without our roots.**
>
> **-Richard Mabey**

PREPARED BY

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PREPARED FOR

The Metropolitan Government of Nashville and Davidson County

COMPLETED

December 2023

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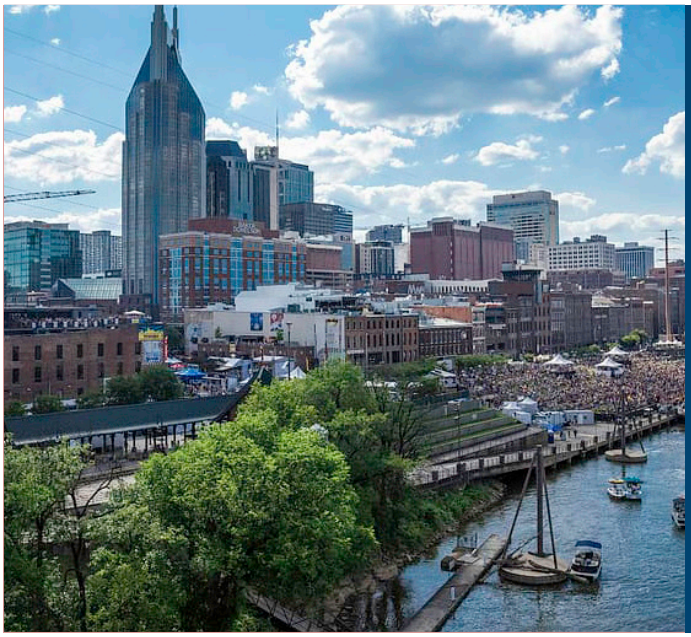


169,832
ACRES OF CANOPY

56%
OF METRO NASHVILLE'S LAND AREA WAS COVERED WITH CANOPY IN 2021

EXECUTIVE SUMMARY

BACKGROUND OF THIS ANALYSIS

Davidson County is located in middle Tennessee along the Cumberland River and covers approximately 525 square miles or 336,023 acres. The borders of Davidson County include both the Metropolitan Government of Nashville and Davidson County (Metro Nashville), and five satellite cities that are independently governed. Known for its vibrant music and arts scene, the Metro Nashville area is also home to many flourishing parks, natural areas, and green spaces. The City of Nashville has been a proud Tree City USA recipient for 28 years, has received the Arbor Day Foundation Growth Award for 11 years, and acknowledges that a healthy and thriving urban forest is integral in providing residents with meaningful environmental, social, and economic benefits.

This assessment mapped urban tree canopy (UTC) as well as possible planting area (PPA), and analyzed how they are distributed throughout Davidson County and its many geographic boundaries. Canopy size, extent, and distribution was quantified; however, this analysis does not attempt to define species composition or condition.

This study also used the same methodology to analyze UTC from 2010 and 2016. This was to provide a trend analysis of changes in the urban canopy. Previous Nashville UTC studies utilized different methodologies, such as different tree heights and inclusion of water bodies, and could not provide an accurate comparison to our current 2021 data.

For the purpose of this report, urban tree canopy refers to the percentage of tree canopy coverage compared to the overall land area, excluding water bodies.

PROJECT METHODOLOGY

The results, based on 2021 imagery from the USDA's National Agriculture Imagery Program (NAIP), provide a near-current look at land cover in Davidson County, which will allow Nashville to develop strategies to protect and expand the urban forest. This study utilized modern machine learning techniques to create land cover data that are reproducible and allow for a more uniform comparison in future tree canopy and land cover assessments.

LiDAR data was used to assist the classification model by applying a ten foot threshold to the LiDAR-derived canopy, chosen for its effectiveness in identifying young trees. The primary use of LiDAR was supplementary, assisting in capturing small trees. This was particularly crucial for correct assessment of the 2021 data due to the leaf-off condition of the NAIP imagery. Using this supplemental data, anything below ten feet was categorized as herbaceous or shrubs.

NAIP imagery and LiDAR were also utilized for the 2010 and 2016 assessments in combination with the machine learning techniques.

METRO NASHVILLE'S URBAN FOREST

In 2021, Metro Nashville contained 56% urban tree canopy cover, 24% possible planting area, and the other 20% of the municipality was classified as unsuitable for planting without significant land modification.

Of the eight transects within Metro Nashville, T2 Rural and T3 Suburban are the largest in acreage and together make up 87% of all canopy. By land use, Vacant or Farm and Residential - 1 Unit contributed to a total of 83% of all urban tree canopy and 77% of all possible planting area. Nine of the fourteen community Planning Areas do not meet their UTC goals, with Downtown, North Nashville, and South Nashville over 34% below.

Figure 1. | Davidson County occupies approximately 525 square miles along the Cumberland River in Tennessee. The Metro Nashville boundary encompasses 94% of the County.

From 2010 to 2021, Metro Nashville experienced a canopy increase of 1.7%. This demonstrates that the canopy gains from trees planting, natural revegetation, and canopy expansion were countered by tree loss. Most canopy decreases beyond natural tree death can be attributed to development and extreme weather events such as tornadoes. Since 2016, Metro's tree canopy has declined by 674 acres. With the Emerald Ash Borer infestation this trend will likely accelerate.

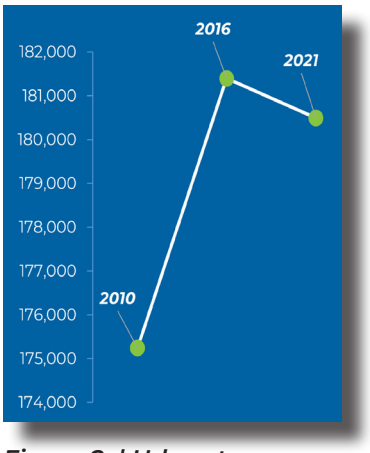


Figure 2. | Urban tree canopy acres in 2010, 2016, and 2021 in Davidson County.

RECOMMENDATIONS

The results of this analysis can be used to develop a continued strategy to protect and expand Metro Nashville's urban forest. This study revealed that Metro Nashville contains 169,832 acres of tree canopy, with more than 72,400 acres available for canopy expansion. Metro Nashville has the opportunity to continue to increase urban tree canopy coverage on both public and private property with partnerships such as the Root Nashville campaign. Through education and outreach programs to private landowners, Metro Nashville can aim to plant trees to control stormwater runoff, address tree inequity, and mitigate the urban heat island effect. It is important for Metro Nashville to use this assessment to inform future investments in the urban forest so that all those who live, work, and play in the city can benefit from the urban forest. Metro Nashville should proactively work to protect the existing urban forest and replenish the canopy with additional trees. Through management actions, strategic plantings, and protections for existing canopy informed by the UTC and PPA metrics included in this report, Metro Nashville has an opportunity to expand the quality and quantity of its current urban tree canopy for the benefit of future generations.

56%
URBAN TREE CANOPY

24%
POSSIBLE PLANTING AREA

17%
IMPERVIOUS SURFACE

Figure 3. | Based on an analysis of 2021 high-resolution imagery, Metro Nashville contains 56% tree canopy, 24% areas that could support canopy in the future, and 17% total impervious areas.

PROJECT

METHODOLOGY

Land cover, urban tree canopy, and possible planting areas were mapped using the sources and methods described below. These data sets provide the foundation for the metrics reported at the selected geographic assessment scales.

DATA SOURCES

This assessment utilized high-resolution (60-centimeter) multi-spectral imagery from the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP) collected in 2021 to derive the land cover data set. The NAIP imagery was used to classify all types of land cover. For canopy change analysis, 60 centimeter resolution NAIP imagery collected in 2016 and 1-meter resolution data was collected in 2010 to classify the historical tree canopy.

MAPPING LAND COVER

The land cover data set is the most fundamental component of an urban tree canopy assessment. Tree canopy and land cover data from the EarthDefine US Tree Map (https://www.earthdefine.com/treemap/) provided a six class land cover data set. The US Tree Map is produced using a modern machine learning technique to extract tree canopy cover and other land cover types from the latest available 2021 NAIP imagery. In addition, Metro Nashville provided LiDAR data for use in this assessment to further aid the classification model. This LiDAR data was primarily used to detect any potential trees and canopy missed by using NAIP imagery solely. The six classes that were categorized using NAIP imagery and aided by LiDAR data are shown in Figure 4 and described in the Glossary found in the Appendix.

Figure 4. | Six (6) distinct land cover classes were identified in the 2021 tree canopy assessment: urban tree canopy, shrubs, other vegetation, bare soil and dry vegetation, impervious surfaces, and water.

IDENTIFYING POSSIBLE PLANTING AREAS AND UNSUITABLE AREAS FOR PLANTING

In addition to quantifying Davidson County's existing tree canopy cover, another metric of interest in this assessment was the area where tree canopy could be expanded. To assess this, all land area in Davidson County that lacked existing tree canopy coverage was classified as either possible planting area (PPA) or unsuitable for planting.

Possible planting areas were derived from the vegetation and shrubs layer. Unsuitable areas, or areas where it was not feasible to plant trees due to biophysical or land use restraints (e.g. golf course playing areas, recreation fields, utility corridors, airports, etc.) were manually delineated and overlaid with the existing land cover data set (Figure 5). The final results were reported as PPA Vegetation, Unsuitable Impervious, Unsuitable Vegetation, Unsuitable Soil, and Water.

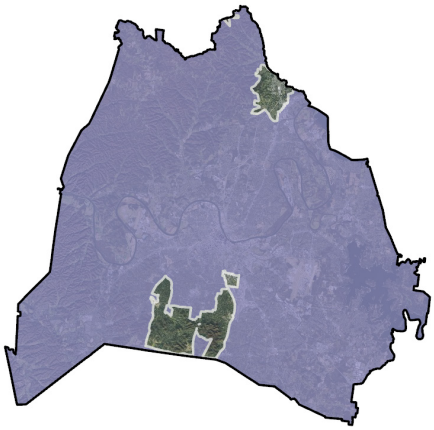
Figure 5. | Vegetative areas where it would be biophysically feasible for tree plantings but undesirable based on their current usage (left) were delineated in the data as "Unsuitable" (right). These areas included recreational sports fields, golf courses, and other open space.

DEFINING ASSESSMENT LEVELS

In order to best inform Metro Nashville and its various stakeholders, urban tree canopy and other associated metrics were tabulated across a variety of geographic boundaries. These boundaries include the full county boundary, the Metro Nashville boundary, services districts, transects, land use, community planning areas, and watersheds.

Davidson County Boundary

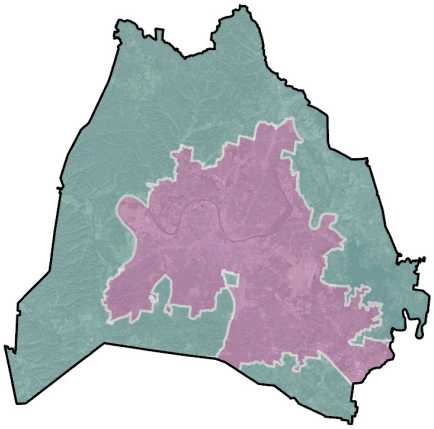
The **county boundary** is the one (1) main area of interest over which all metrics are summarized.



Metro Nashville Boundary

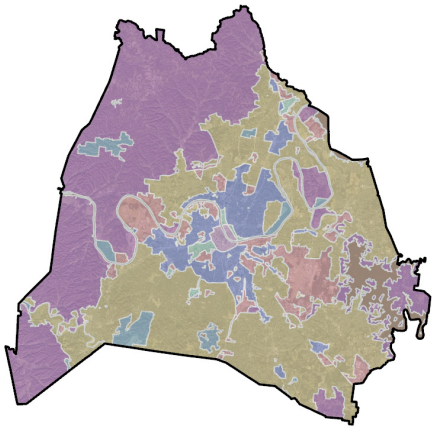
The **Metro Nashville boundary** was assessed to understand urban forest metrics within the county that are regulated by The Metropolitan Government of Nashville.

Figure 6. | Seven (7) distinct geographic boundaries were explored in this analysis: the full County boundary, the Metro Nashville boundary, services districts, transects, land use, community planning areas, and watersheds.



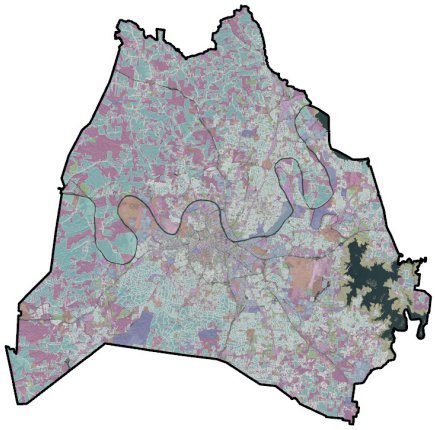
Services Districts

Two (2) **services districts** were assessed to understand how urban forest metrics differ between predominately urban areas and areas that are categorized as less urban.



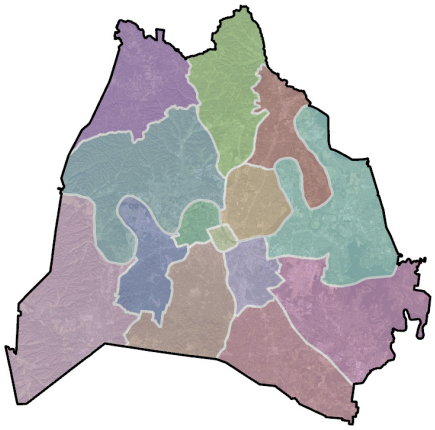
Transects

Seven (7) **transects** were assessed to help guide land use, zoning, and development regulations in a way that respects the natural characteristics of the County.



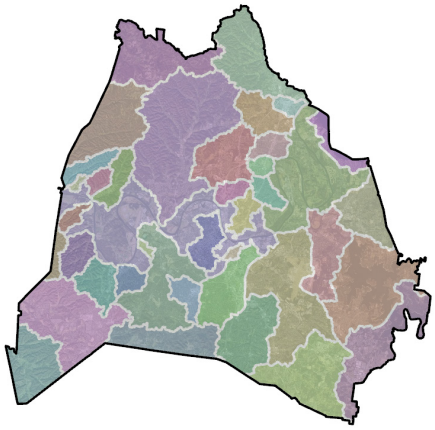
Land Use

Eleven (11) l**and use** classes were assessed to review the extent to which human interactions caused significant changes in the County's structure, pattern, and function of natural ecosystems.



Community Planning Areas

UTC was assessed for the **community planning areas** to provide additional insight about the local communities within Metro Nashville, totaling fourteen (14).



Watersheds

Because trees play an important role in stormwater management, forty (40) **watersheds** were assessed.

Figure 6. | Seven (7) distinct geographic boundaries were explored in this analysis: the full county boundary, the Metro Nashville boundary, services districts, transects, land use, community planning areas, and watersheds.

STATE OF THE CANOPY AND KEY FINDINGS

The results and key findings of this study, including the land cover map and canopy analysis results, are presented below. These results can be used to design a strategic approach to identifying existing canopy and future planting areas. Land cover percentages are based on the Metro Nashville boundary as of 2021. The boundary includes six land cover classes including tree canopy (over impervious surfaces and over pervious surfaces), shrub/scrub, soil and dry vegetation, other vegetation, impervious surfaces, and water (see Table 1 and Figure 7 for the breakdown of percentages). Note that metro-wide land cover data, presented below, represent the composition of the base land cover data and includes water, and is different from metro-wide urban tree canopy data presented on the following pages that is based exclusively on land area.

In 2021, Metro Nashville land cover consisted of 52% tree canopy, 23% other vegetation, 17% impervious surface, 5% water, and just 1% soil & dry vegetation and shrubs each.

Table 1. | Land cover classes in acres and percent in Metro Nashville.

Metro Nashville	Acres	% of Total
Metro Boundary	318,081	100%
Tree Canopy Over Pervious	165,624	52%
Other Vegetation	71,656	23%
Impervious Surfaces	55,039	17%
Water	14,506	5%
Tree Canopy Over Impervious	4,207	1%
Soil & Dry Vegetation	4,732	1%
Shrubs	2,316	1%

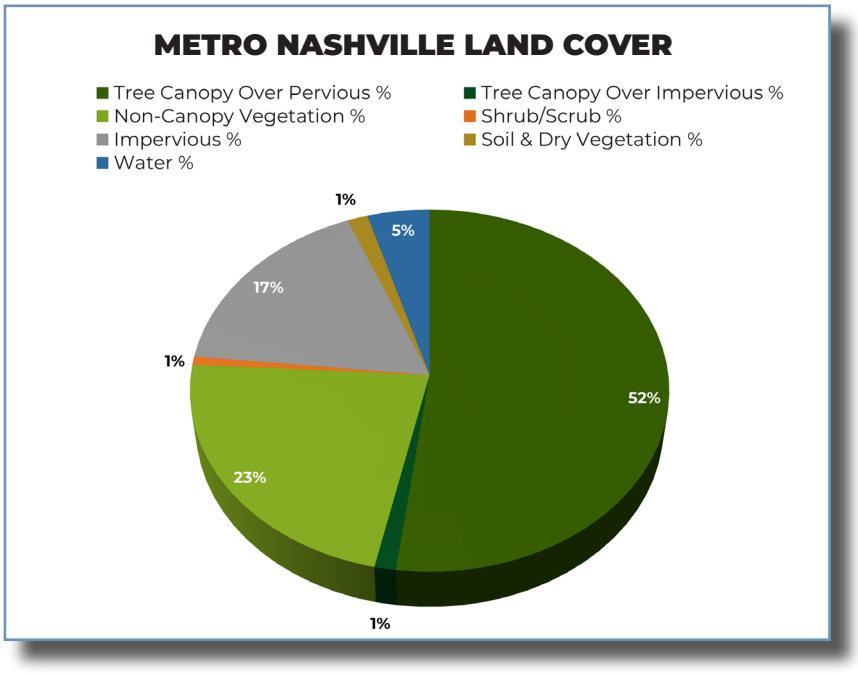


Figure 7. | Land cover classification results (percentages based on total area of Metro Nashville including water bodies).

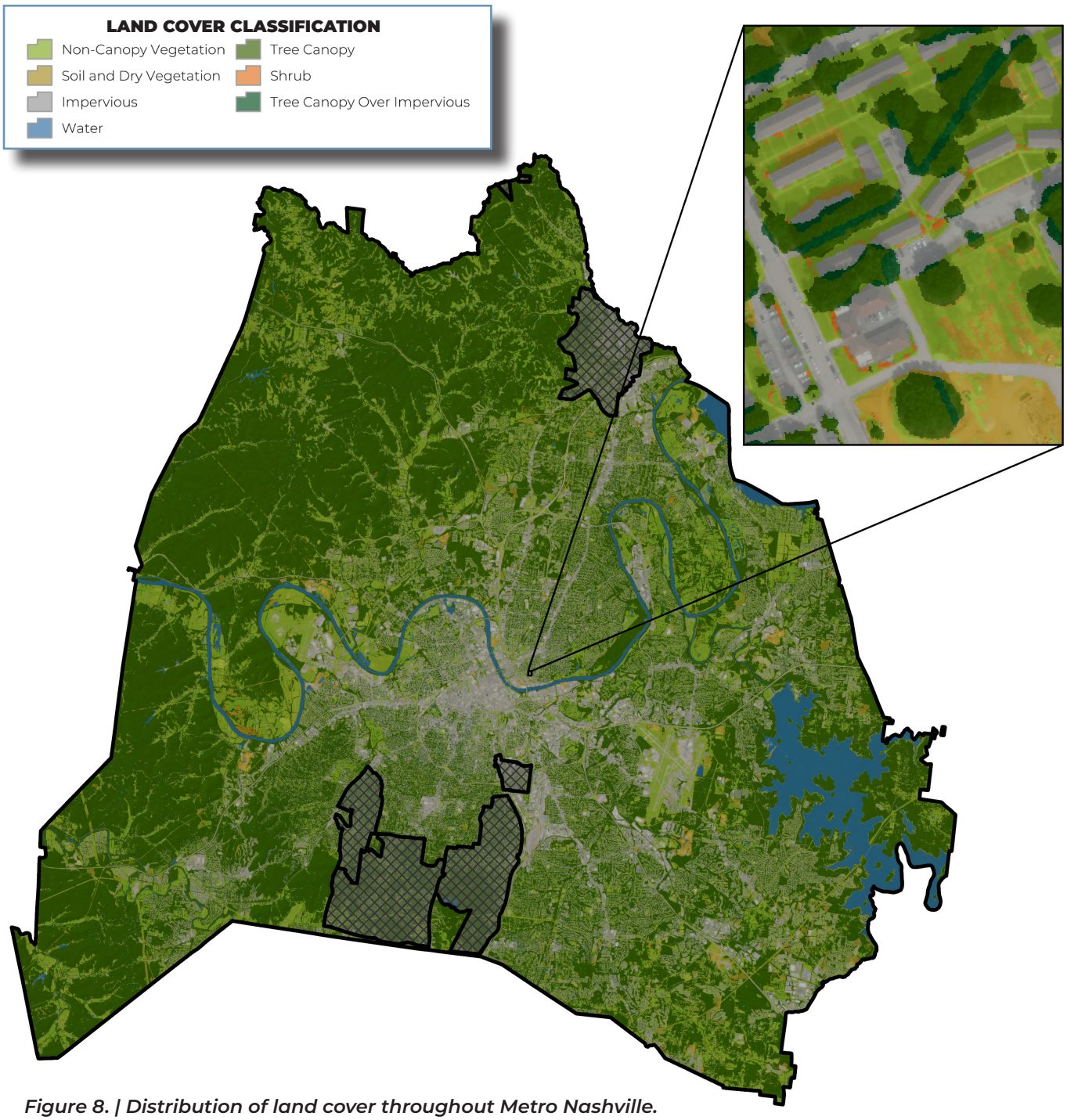


Figure 8. | Distribution of land cover throughout Metro Nashville.

METRO NASHVILLE URBAN TREE CANOPY

This tree canopy assessment utilized the land cover data as a foundation to determine tree canopy cover and possible planting areas (PPA) throughout Metro Nashville. After assessing the area's 303,575 land acres, over half (56%) of the study area was covered with canopy, with more than 72,400 acres still available to plant more trees. If Metro Nashville utilizes all of its plantable space, it could have the potential to reach 80% tree canopy cover. This theoretical limit can be used to help set realistic goals regarding canopy expansion.

A portion of the land area is not suitable for trees. About 17% of Metro Nashville is covered with impervious surfaces such as roads and parking lots. There was another 3% composed of recreational sports fields, areas of bare soil and dry vegetation, and other land types that are unsuitable for planting trees. Altogether, 20% of Metro Nashville was found to be unsuitable for tree planting.

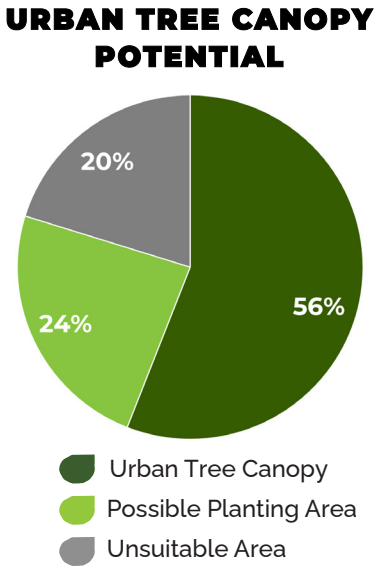


Figure 9. | Urban tree canopy, possible planting area, and areas unsuitable for UTC.

Figure 10. | Distribution of UTC, possible planting area, and areas unsuitable for UTC.

CANOPY AND IMPERVIOUS SURFACES

Metro Nashville's 169,832 acres of urban tree canopy were further divided into subcategories based on whether the canopy was overhanging pervious or impervious surfaces. Tree canopy overhanging an impervious surface offers many ecological advantages such as localized cooling through shading and increased storm-water control. Results indicated that Metro Nashville's UTC was predominantly overhanging pervious surfaces at 98%, while just 2% was overhanging impervious surfaces. Planting trees in rights of ways, along streets and sidewalks, and in other public areas, as well as strengthening ordinances for planting around parking lots in new developments can help to offset the negative effects of impervious surfaces.

METRO NASHVILLE URBAN TREE CANOPY CHANGE

In addition to assessing Metro Nashville's urban tree canopy using 2021 imagery, this study also quantified shifts in urban tree canopy by utilizing imagery from both 2016 and 2010. In this comprehensive study, maps of land cover and urban tree canopy in 2010, 2016, and 2021 were produced using identical classification methodologies. All assessments used machine learning techniques on high-resolution (60 cm when feasible and 1-meter for 2010) color-infrared aerial imagery. Changes were assessed at all of the geographic assessment scales (Metro Nashville boundary, Davidson County boundary, services districts, transects, land use, community planning areas, and watersheds). The most current boundaries were assessed in all years despite the fact that several of the geographic assessment scales may have changed due to annexation, population changes, and other land use reconfigurations since 2010.

Over the entire 11 year study period, Metro Nashville recorded a net gain in canopy of 5,095 acres, or a 1.7% increase. Metro Nashville accounted for 97% of the gain in canopy acres within Davidson County. This study found that from 2010 to 2016, there was a net increase in tree canopy (5,770 acres or a 1.9% increase); however from 2016 to 2021 there was a net loss of just over 670 acres of tree canopy.

It can be presumed that tree canopy likely fluctuated to some extent throughout the analysis time frame. This assessment serves as a snapshot of the canopy at the time of imagery collection. Additionally, the extent to which invasive species (both trees and shrubs) are adding to this observation was not assessed.

Generally, most losses of canopy can be traced back to commercial and residential developments, especially in the southeast portion of the metro area along I-24 and I-40. Canopy growth can be attributed to the growth of existing trees, natural regeneration, and tree plantings including those associated with the Root Nashville Campaign. Current levels of urban tree canopy in Metro Nashville can continue to be improved with careful, data-driven planning and planting efforts.

Table 2. | Urban tree canopy in 2010, 2016, and 2021.

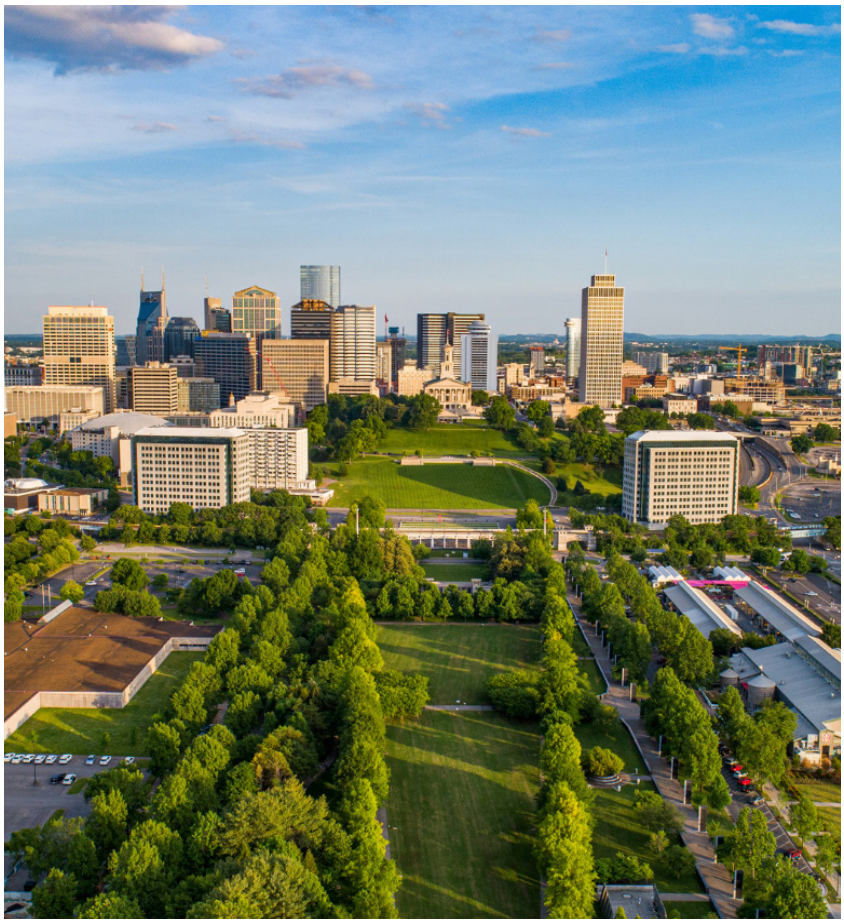
Metro Nashville	Land Area	UTC 2010		UTC 2016		UTC 2021		UTC Change (2010-2021)	
	Acres	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Urban Tree Canopy	303,575	164,736	54%	170,506	56%	169,832	56%	5,095	+1.7%

URBAN TREE CANOPY BY DAVIDSON COUNTY

Urban forestry metrics were assessed for the Davidson County boundary. In 2021, the bounty consisted of 56% UTC, 23% PPA, and 21% of the area within the boundary was classified as unsuitable for planting. Of the 21% unsuitable acres, 19% is unsuitable due to being impervious, and the other 2% is unsuitable due to being a recreational field, golf course, or another land-use type where it's preferred that trees aren't planted. Compared to the Metro Nashville boundary, Davidson County had an equal tree canopy percent of 56%, approximately 1% lower of available PPA , and approximately 1% more space unsuitable for trees. Davidson County also had 2% more impervious surface coverage.

Table 3. | Land cover classes in acres and percent in Davidson County.

Davidson County	Acres	% of Total
County Boundary	336,023	100%
Tree Canopy Over Pervious	175,848	52%
Other Vegetation	75,569	22%
Impervious Surfaces	58,049	17%
Water	14,615	4%
Tree Canopy Over Impervious	4,646	1%
Soil & Dry Vegetation	4,867	1%
Shrubs	2429	1%



URBAN TREE CANOPY CHANGE BY DAVIDSON COUNTY

In the first assessment period between 2010 and 2016, Davidson County experienced a gain in canopy of 6,150 acres (+2%). However, from 2016 to 2021, the County experienced a net loss in canopy cover. During this time, Davidson County lost just over 900 acres of canopy, equating to a slight decline of -0.3%. From 2010 to 2021, Davidson County experienced a net gain of 5,247 acres of canopy (+1.6%). Compared to canopy change throughout the assessment years within Metro-Nashville, Davidson County's change metrics are consistent with what the Metro area boundary experienced - a gain in canopy from 2010 to 2016, a loss in canopy from 2016 to 2021, but a net increase between 2010 and 2021 overall.

Table 4. | Urban tree canopy in 2010, 2016, and 2021.

Davidson County	Land Area	UTC 2010		UTC 2016		UTC 2021		UTC Change (2010-2021)	
	Acres	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Urban Tree Canopy	321,408	175,246	55%	181,396	56%	180,494	56%	5,247	+1.6%

URBAN TREE CANOPY BY SERVICES DISTRICTS

Urban tree canopy metrics were assessed for Metro Nashville's two services districts, Urban and General, in order to help understand the difference in UTC and PPA metrics along the urban and rural divide. The Urban Services District represents 36% of the land area of Davidson County while the General Services District accounts for 61% of the land area. As could be expected, the more rural General Services District had significantly higher canopy coverage with 67% UTC (131,623 acres) while the Urban Services District had a significantly lower canopy coverage of just 39% (48,803 acres). The potential for canopy growth is similar in either district, but, with 26% and 23% PPA for the Urban Services and General Services District, respectively. The Urban Services District should utilize the over 32,000 acres of possible plantable space to offset the expansive amount of impervious surfaces it contains, which amounts to 32% (40,814 acres) of the district's land area.

URBAN TREE CANOPY CHANGE BY SERVICES DISTRICTS

Overall, both districts experienced a net gain in canopy over the 11-year study period amounting to a 72 acre gain in the Urban Services District and a 5,179 acre gain in the General Services District, totaling an overall gain of 2%. Looking closer at the two subdivided study period years, the only loss in canopy was experienced within the Urban Services District between 2016 and 2021, where 1,841 acres of canopy was lost (equating to a -1.5% change). This loss of canopy in the Urban Services District since 2016 contributed to a slight net loss of canopy (-0.3%) in Davidson County between 2016 and 2021. The General Services District continued to gain canopy throughout the entire study period.

Table 5. | Urban tree canopy UTC, PPA, and UTC change by services district.

Services Districts	Land Acres	UTC Acres	UTC %	PPA Acres	PPA %	UTC Change Acres (2010-2016)	UTC Change Acres (2016-2021)	Overall UTC Change Acres (2010-2021)
Urban Services District	125,102	48,803	39%	32,073	26%	1,912.45	-1,841	72
General Services Districts	196,148	131,623	67%	44,261	23%	4,235.26	944	5,179
Totals	**321,250**	**180,426**	**56%**	**76,334**	**24%**	**6,148**	**-897**	**5,251**

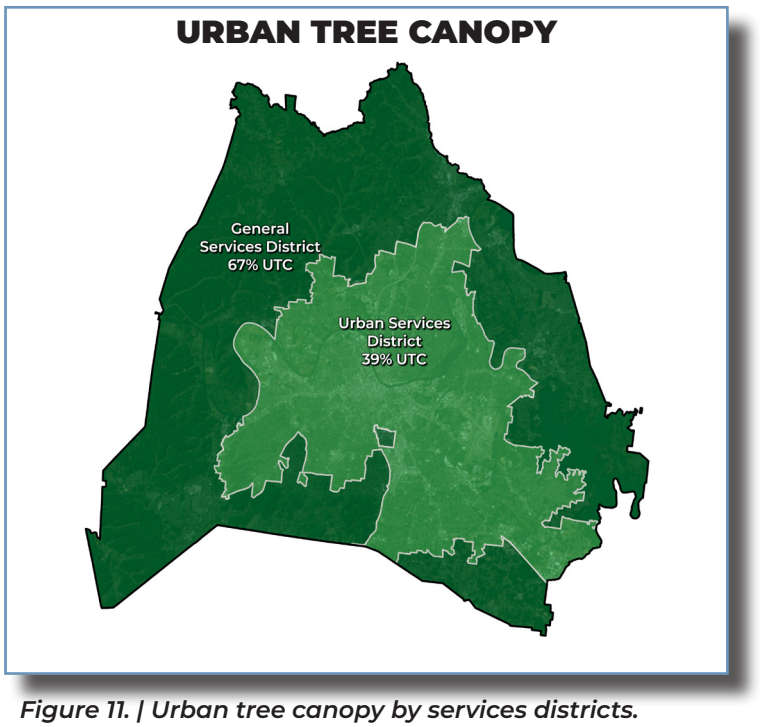


Figure 11. | Urban tree canopy by services districts.

URBAN TREE CANOPY BY TRANSECT

UTC and PPA were assessed for Metro Nashville's 7 transects. The two largest transects by acreage, T2 Rural and T3 Suburban, together make up 87% of all canopy. Although the T3 Suburban transect contributed to over 30% of the UTC distribution based on the overall transect land area, this transect falls in the middle UTC percent range compared to the other transects, with 48% of its 130,602 acres covered with canopy. The T2 Rural transect had the second highest canopy cover percent at 77% (93,871 acres). Unsurprisingly, the T1 Natural transect that encompasses most of the natural spaces in Davidson County had the highest canopy cover percentage of 81%. Only two transects, T5 Center and T6 Downtown had 10% or less UTC cover, although these two transects make up less than 1% of the land areas across all transects.

Because of their large land area compared to the other transects, T2 Rural and T3 Suburban together account for 80% of all PPA distribution. The T3 Suburban transect had the most PPA in terms of size (34,679 acres) and in proportion to its land area (27% PPA). Two additional transects also had over 20% PPA: the D District having 24% PPA (6,746 acres) and the T4 Urban type at 22% PPA (5,788 acres). It's worth noting that despite having relatively low UTC cover and relatively high unsuitable areas for planting trees (76% and 82% respectively), the T5 Center and T6 Downtown transects each had the potential to more than double their canopy cover by utilizing the possible plantable space in either transect. If all of the theoretical plantable space was used in these two areas, the T5 Center transect could grow its canopy cover to 23% and the T6 Downtown transect could grow its canopy cover to 18%. The 4 aforementioned transects (D District, T4 Urban, T5 Center, and T6 Downtown) had the highest impervious surface coverage of all transects. Canopy expansion in these areas can help mitigate the adverse effects of impervious surfaces, which include elevating local temperatures and exacerbating stormwater management issues.

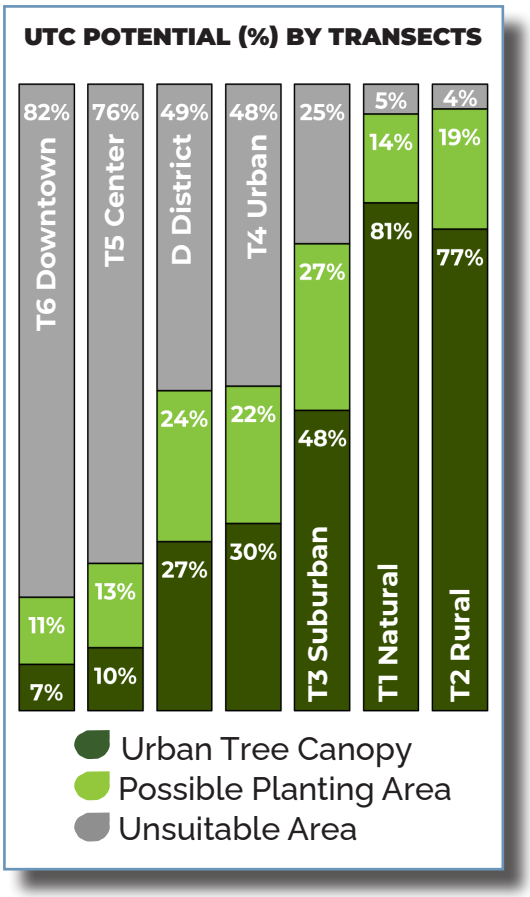
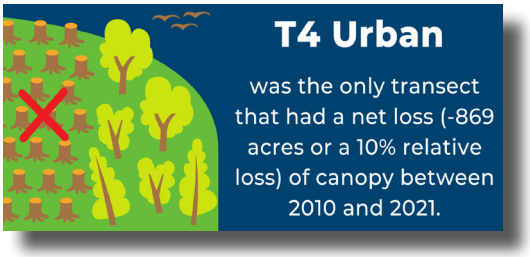


Figure 12. | Urban tree canopy potential by transect.



URBAN TREE CANOPY CHANGE BY TRANSECT

Dividing the urban tree canopy change results by Metro Nashville's transect types offered some additional insights as to how Metro Nashville's canopy has changed over time. The T4 Urban transect experienced a 10% relative loss of canopy throughout the 11-year study period (equivalent to a 3.3% net loss). The T3 Suburban transect is more than four times larger than T4 Urban; however, an analysis of building permits from 2016 to 2021 shows that both transects experienced similar increases in new building square footage despite the marked difference in size. This concentration of development in the T4 Urban transect may be a large factor in its canopy loss. Another four experienced a loss in canopy from 2016 to 2021: T3 Suburban, T4 Urban, T5 Center, and D District. The T2 Rural transect experienced the largest increase in canopy during the 2016 to 2021 period, with a gain of 1,626 acres. Three transect types (T2 rural, T1 Natural, and T6 Downtown) experienced a consistent trend upward and gained canopy throughout the entire study period. There was a net gain across all transects of 5,247 acres of canopy, with the T2 Urban and T3 Suburban contributing the most to that net increase from 2010 to 2021 (+3,834 acres and +1,592 acres, respectively). While the T3 Suburban transect initially gained canopy (3,054 acres or +2.3% between 2010 and 2016), it lost 1,462 acres between 2016 and 2021, which reduced the amount of canopy gained by nearly 50%.

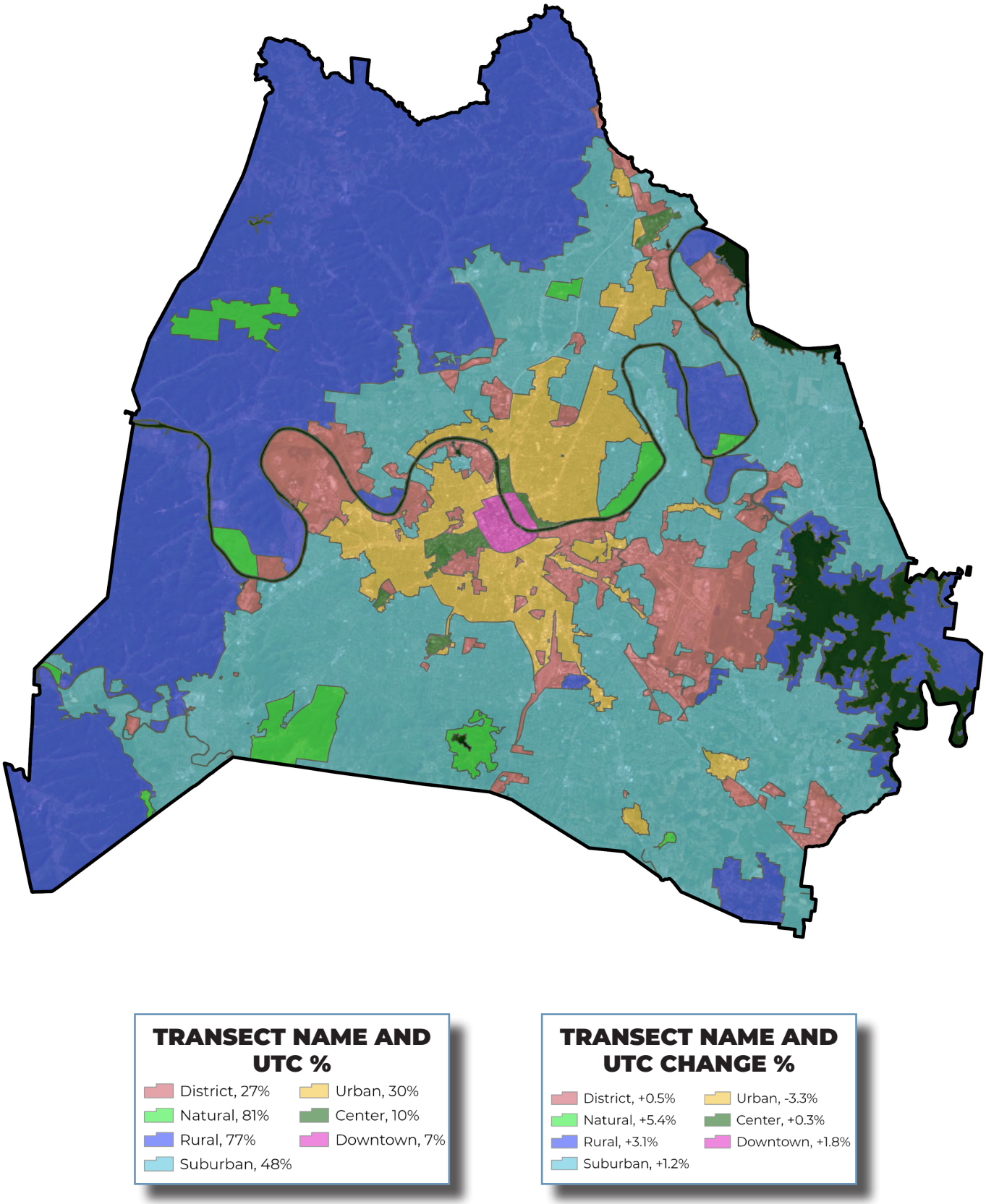


Figure 13. | Urban tree canopy percent and urban tree canopy change percent by transects (2010-2021). by transects.

URBAN TREE CANOPY BY LAND USE

To better understand how humans impact our natural surroundings based on how land is used, an assessment of tree canopy and plantable space was conducted across Metro Nashville's 11 land use types. Overall, 4 out of 11 land use types had higher than the countywide canopy cover of 56%, while no land use types fell below 10% canopy cover. Two land use types, Vacant or Farm (75% UTC) and Residential - 1 Unit (62% UTC) contributed to a total of 83% of the UTC distribution (totaling 143,940 acres). Land use types that are not assigned a category had the highest percentage of canopy cover at 84%. Three land use types fell below 25% canopy cover as followed: Industrial (24%), Commercial (22%), and Auto Parking (15%).

Despite having low UTC coverage and relatively high impervious surface cover, the Industrial, Commercial, and Auto Parking land use types (51%, 63%, and 63%, respectively) present the opportunity to increase canopy cover by planting trees in possible planting areas. The Industrial land use type had 1,874 acres (17%) of PPA, the Commercial land use type had 1,161 acres (14%) of PPA, and the Auto Parking land use type had 213 acres (18%) of PPA. Only 2% of the tree canopy in Metro Nashville as a whole covers impervious surfaces, so these areas with a lot of impervious surfaces should be considered for establishing more trees. In terms of additional opportunities within the land use types for possible planting area, the Community, Institutional, or Utility land use type offers the most PPA in proportion to its area (31%). Overall, the Vacant or Farm (15,220 acres) and Residential - 1 Unit (36,149) land use types had the most contribution of acreage to possible planting areas within land use types.

Table 6. | Urban tree canopy change and PPA by land use types.

Land Use Types	% of Total Land Area	2010 % UTC	2016 % UTC	2021 % UTC	PPA %
Residential - 1 Unit	46%	60%	62%	62%	27%
Vacant or Farm	28%	72%	75%	75%	19%
Community, Institutional or Utility	6%	28%	30%	30%	31%
Residential - 2 + Unit	5%	45%	46%	43%	22%
Industrial	4%	22%	26%	24%	17%
Commercial	3%	20%	22%	22%	14%
Park or Golf Course	3%	52%	54%	54%	22%
Not Assigned	2%	84%	85%	84%	8%
Office or Medical	2%	26%	27%	27%	22%
Auto Parking	0%	15%	16%	15%	18%
Residential - Nonhousehold	0%	58%	60%	63%	21%
Totals & Avgs	**100%**	**58%**	**60%**	**59%**	**23%**

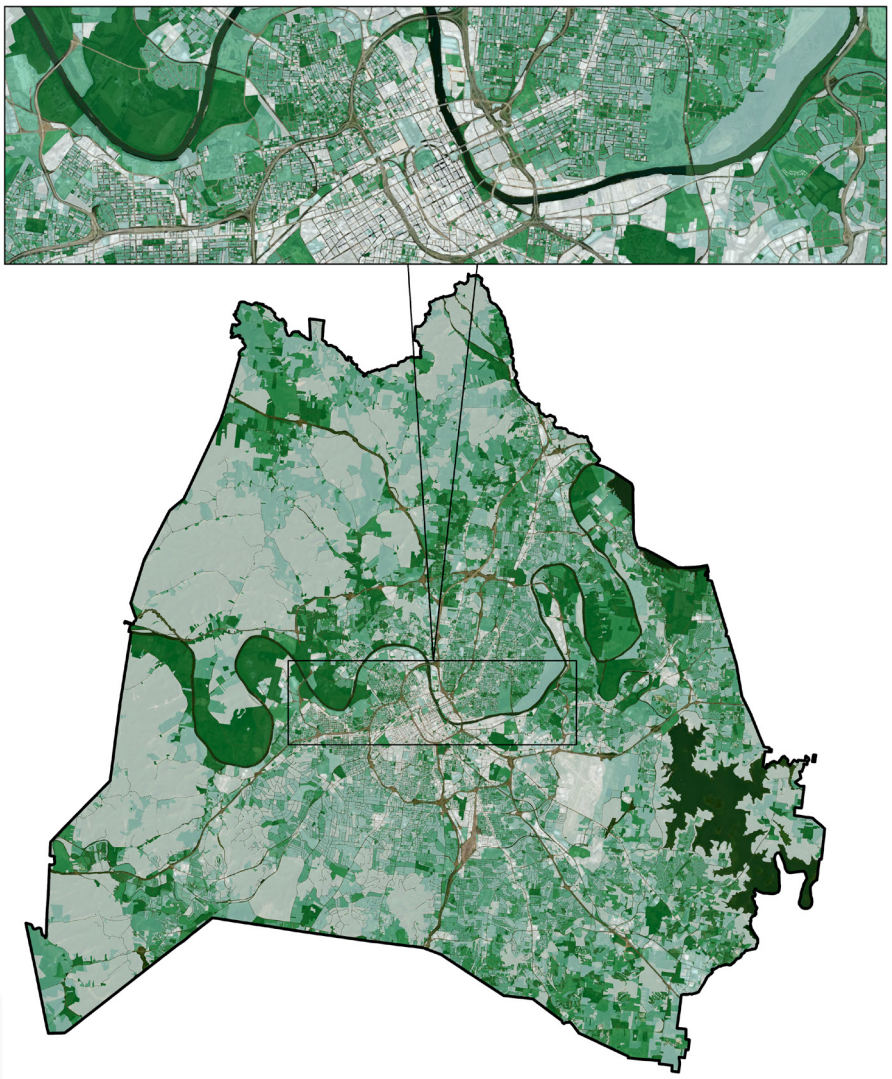


Figure 14. | Possible planting area by land use.

URBAN TREE CANOPY CHANGE BY LAND USE

Looking at the first assessment period from 2010 to 2016, every land use type experienced some degree of canopy cover increase, with the largest acreage gain in the Residential - 1 Unit type (+2,061 acres) and the largest percent gain in the Industrial land use type (+4.7% or +510 acres). Between 2016 and 2021, 7 of the 11 land use types experienced a loss in canopy cover, with the largest loss of 381 acres of canopy in the Residential 2 + unit type. Over the entire 11-year study period, only 2 land use types, Residential 2 + Unit and Auto Parking, experienced an overall loss in canopy cover (net loss of 209 acres and 1 acre, respectively). Overall, the Residential Non-Household land use type experienced the greatest percent increase of UTC in proportion to its land area (+4.9%), and Residential - 1 Unit type experienced the greatest acreage increase of 2,069 acres.

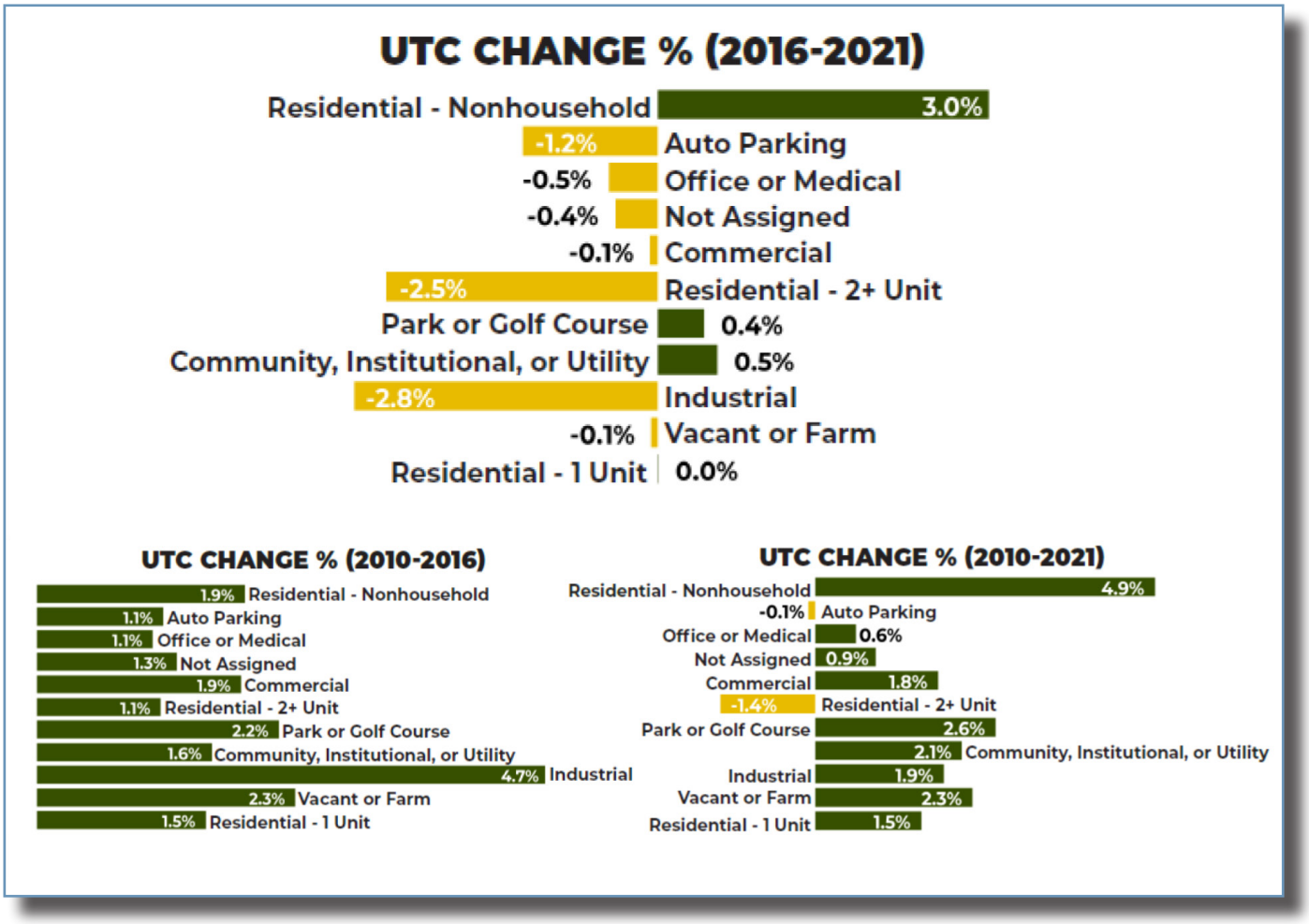
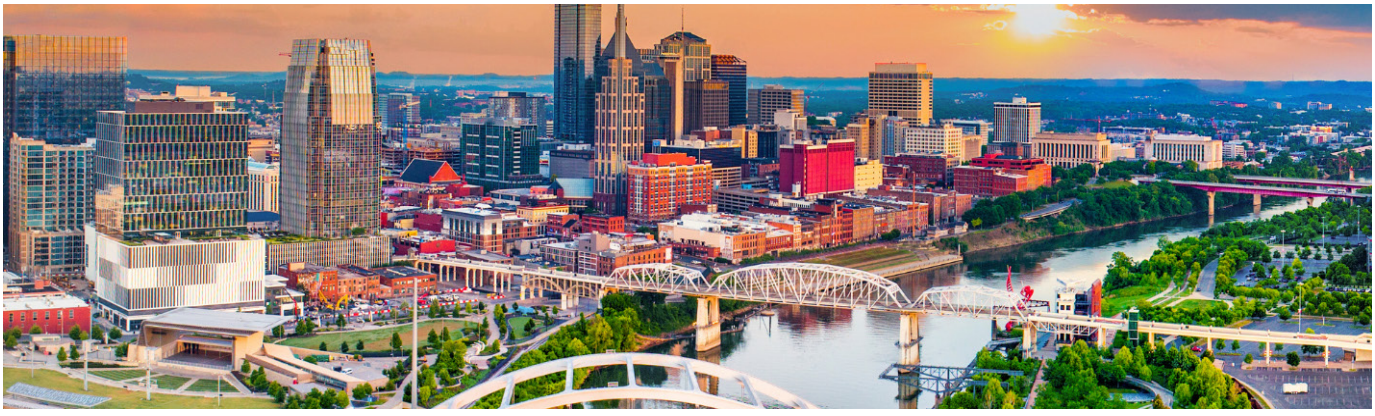


Figure 15. | Urban tree canopy change between 2010 and 2016, 2016 and 2021, and overall change between 2010 and 2021 by land use types.



URBAN TREE CANOPY BY COMMUNITY PLANNING AREAS

To help guide urban forestry planning efforts at the community-level scale, urban forest metrics were assessed for Davidson County's fourteen community planning areas. This assessment found that 10 out of 14 community planning areas had less than 56% UTC (the County's average), but the four areas that had higher than average canopy cover contributed to over 50% of all UTC across the county's land area. Bellevue and Bordeaux - Whites Creek - Haynes Trinity community planning areas contributed the most acreage of UTC, with 32,071 acres (72% UTC) and 31,264 acres (70% UTC), respectively. The Joelton community planning area had the highest UTC percent of 75%. Only one community planning area, Downtown, had less than 10% UTC. This planning area also had the highest coverage of impervious surfaces (75%).

In terms of PPA, the Madison and Donelson - Hermitage - Old Hickory community planning areas had the highest percent of PPA, with 30% and 29% PPA respectively. For the Donelson - Hermitage - Old Hickory planning area, this equates to 10,199 acres of PPA. If utilized, this planning area could theoretically raise its UTC coverage from 43% to 72%. It's worth noting that the Downtown planning area offers 183 acres (11%) of possible plantable space, which could more than double its canopy cover and offset the negative impacts of the large amount of impervious surfaces present in the area.

Table 7. | Urban tree canopy metrics by community planning areas.

Community Planning Area	Land Area (Acres)	Distribution of Land Area %	UTC (Acres)	UTC %	Distribution of UTC %	Total PPA (Acres)	Total PPA %	Distribution of PPA %
Joelton	25,153	8%	18,868	75%	10%	5,321	21%	7%
Bellevue	44,302	14%	32,071	72%	18%	7,707	17%	11%
Bordeaux - Whites Creek - Haynes Trinity	44,582	14%	31,264	70%	17%	9,523	21%	13%
Parkwood - Union Hill	26,785	8%	18,423	69%	10%	5,912	22%	8%
Green Hills - Midtown	24,839	8%	13,620	55%	8%	4,521	18%	6%
Southeast	27,225	8%	13,013	48%	7%	7,349	27%	10%
Antioch - Priest Lake	32,444	10%	15,302	47%	8%	6,609	20%	9%
Donelson - Hermitage - Old Hickory	34,694	11%	15,024	43%	8%	10,199	29%	14%
West Nashville	15,848	5%	6,871	43%	4%	3,973	25%	5%
Madison	16,575	5%	6,956	42%	4%	5,054	30%	7%
East Nashville	12,869	4%	5,270	41%	3%	3,091	24%	4%
South Nashville	9,796	3%	2,689	27%	1%	2,020	21%	3%
North Nashville	4,594	1%	972	21%	1%	1,152	25%	2%
Downtown	1,667	1%	136	8%	0%	183	11%	0%
Totals & Avgs	**321,372**	**100%**	**180,476**	**56%**	**100%**	**72,616**	**23%**	**100%**

URBAN TREE CANOPY CHANGE BY COMMUNITY PLANNING AREAS

Looking at the first change assessment period between 2010 and 2016, every community planning area gained canopy, with the largest percent gain in Madison (+2.5% or 634 acres). From 2016 to 2021, half of the community planning areas experienced canopy loss. During this time period, Joelton experienced the largest increase in canopy cover of 2.5% or 624 acres and Green Hills - Midtown experienced the largest loss in canopy cover of -2.9% or 712 acres lost. Over this 5-year period, there was a net loss of 903 acres. Over the entire 11-year study period, 7 community planning areas continued to gain canopy throughout the period (Joelton, Madison, Parkwood - Union Hill, Bordeaux - Whites Creek - Haynes Trinity, Bellevue, Downtown, and South Nashville), 3 initially gained canopy from 2010-2016 but had ultimately declined (West Nashville, North Nashville, and Green Hills - Midtown), and 4 community planning areas only lost canopy between 2016-2021 but otherwise had a net gain (Donelson - Hermitage - Old Hickory, Southeast, East Nashville, and Antioch - Priest Lake). Joelton had the largest net gain of 1,258 acres (+5.0%) and Green Hills - Midtown had the largest net loss of 395 acres (-1.6%).

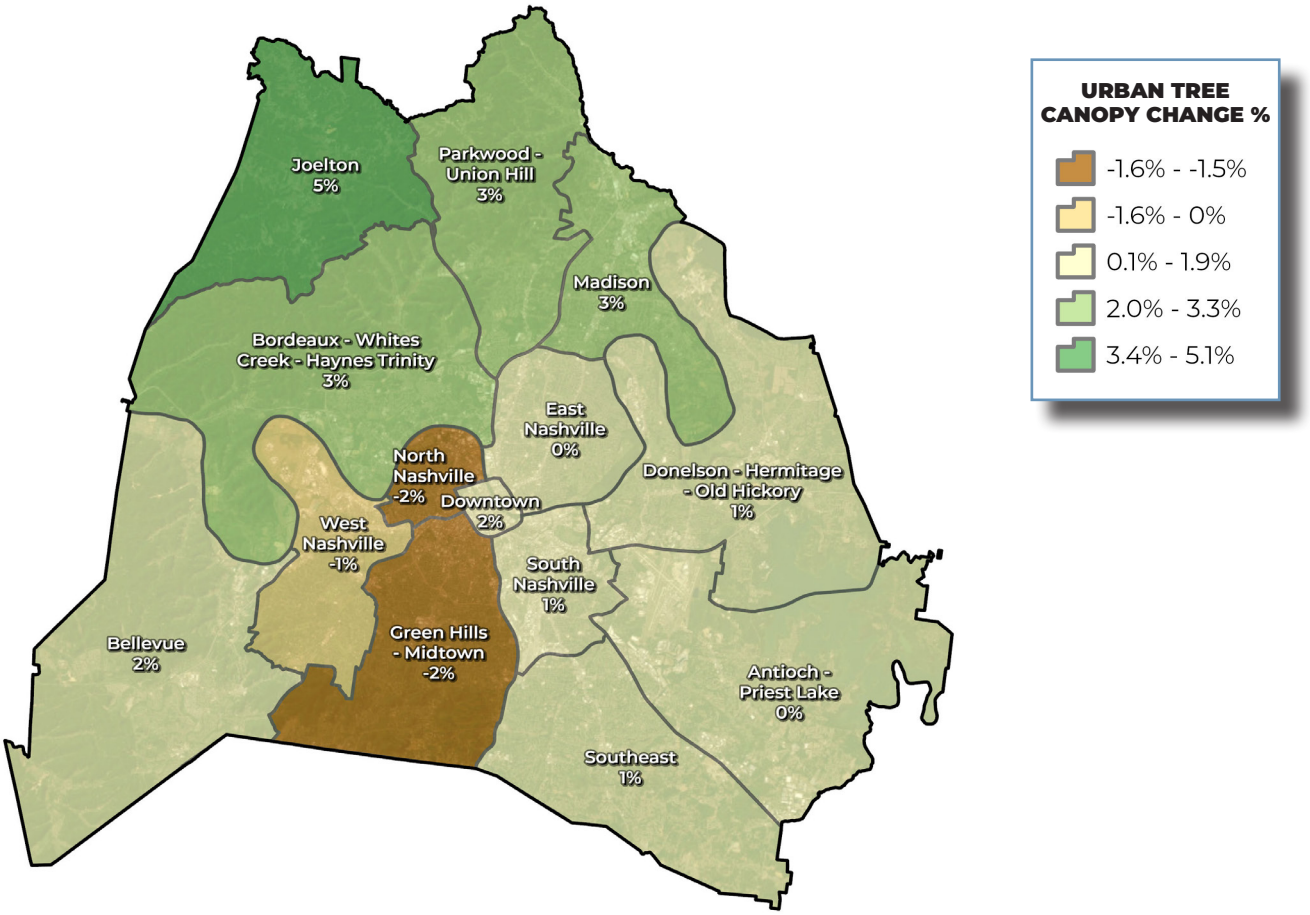


Figure 16. | Urban tree canopy change percent by community planning areas.

URBAN TREE CANOPY BY WATERSHEDS

Because of the benefits that trees provide for regulating stormwater runoff, reducing flooding, and improving soil infiltration, urban tree canopy metrics were also assessed across watersheds, including combined sewer areas. In general, our assessment found that watershed UTC was highest in watersheds on the edges of the County boundary as they got further away from the city center, with the exception of watersheds surrounding the Cumberland River (especially those located east of Downtown Nashville). Four watersheds - Whites Creek, Harpeth River, Cumberland River, and Marrowbone Creek - accounted for over 30% of the distribution of UTC acres across all of the watershed's total land area. Whites Creek watershed contributed the most canopy acres with 23,439 acres of UTC. Pond Creek, Island Creek, and Bull Run watersheds each had over 90% UTC, with 95%, 94%, and 91% UTC, respectively. Two combined sewer systems (CSS) fell under 20% canopy cover: the Kerrigan CSS with 17% UTC and the Driftwood CSS with 16% UTC.

Compared to the average PPA percent of the County (23%), 15 watersheds had higher than average PPA. The majority of the watersheds with higher-than-average PPA percentages are those that border the Cumberland River; so these watersheds should be prioritized for tree plantings to help with stormwater management in areas adjacent to the river. Out of all the watersheds, two combined sewer areas had the highest impervious surface percentages (CSS - Kerrigan and CSS - Driftwood). These areas surround downtown Nashville, and the utilization of the 790 acres of possible planting space, could help offset impervious surfaces impacts such as increased localized temperatures, increased likelihood of flooding, and combined sewer overflows. The Cumberland River and East Cumberland River watersheds had the most acreage of PPA available, with 8,287 acres (33%) and 6,811 acres (36%) of PPA, respectively.

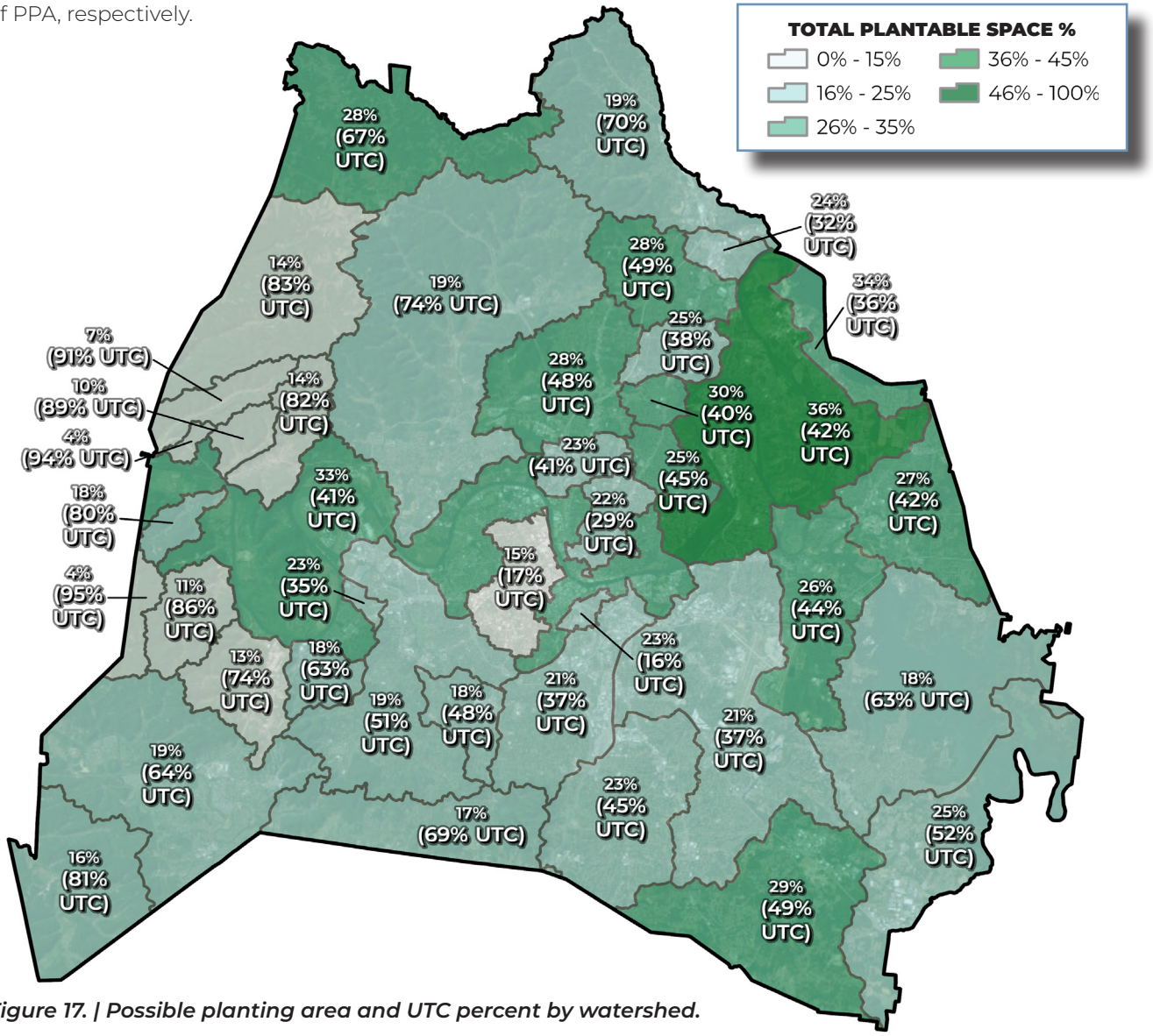


Figure 17. | Possible planting area and UTC percent by watershed.

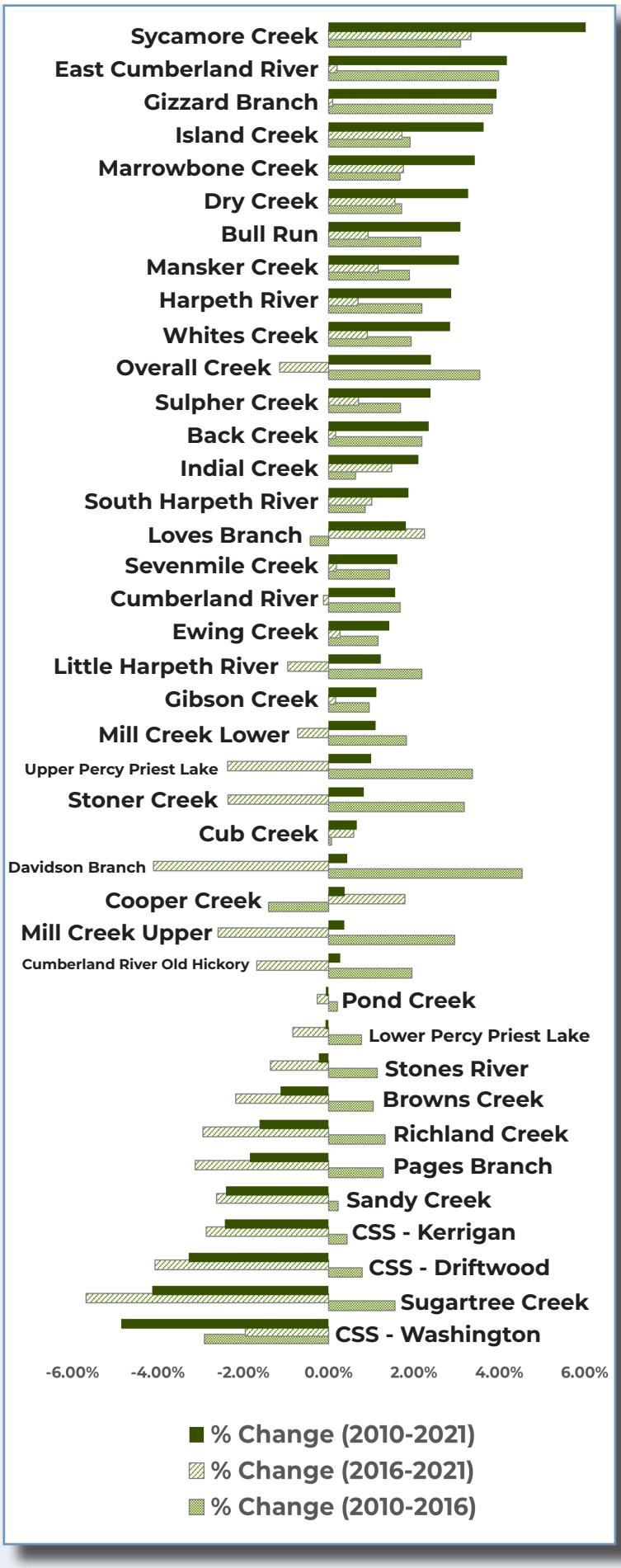


Figure 18. | Tree canopy change % by watersheds.

URBAN TREE CANOPY CHANGE BY WATERSHEDS

In the first assessment period from 2010 to 2016, all but three watersheds gained canopy, with the largest acreage gain in the East Cumberland River watershed (+748 acres). Loves Branch (-6 acres), Cooper Creek (-33 acres), and Washington CSS (-82 acres) watersheds saw slight decreases in canopy over this 6-year period. From 2016 to 2021, half of the watersheds lost canopy and half of the watersheds gained canopy. Sycamore Creek had the largest gain in canopy (+432 acres or +3.3%), and Richland Creek experienced the largest acreage loss in canopy (-431 acres). Sugartree Creek had the largest proportional loss with a 5.7% decline (-55 acres). Over the entire 11-year study period, total canopy gains offset the losses, with 29 watersheds gaining canopy. Overall, Sycamore Creek had the largest net gain in canopy of 833 acres (+6.4%) and Richland Creek watershed had the largest net loss in canopy of 237 acres.

CSS - Kerrigan Watershed

That encompasses downtown Nashville and is located along the Cumberland River:

Had a **net loss of canopy (-2.4% or -106 acres)** from 2010-2021

Had the **second lowest UTC percent (17%)** in 2021

Has **651 acres of possible planting area**, which could **nearly double** its canopy cover

Has the **highest coverage of impervious surfaces at 70%**

AN ANALYSIS OF POTENTIAL

AGENTS OF CHANGE

In addition to the analysis described previously, an attempt was made to survey Davidson County to help illustrate potential causes of canopy change (losses and gains). A qualitative survey was undertaken, and examples of some of the apparent largest causes of change were cataloged and described in detail below.

EXAMPLES OF CANOPY GAINS

Overall, the majority of canopy gains can be described by the following three categories: 1) new tree plantings and associated growth, 2) natural regeneration of areas previously classified as vegetation,and 3) growth/expansion of canopy previously existing at the time of the historical study. Some examples of canopy gains are documented below.

Figure 19. | Tree canopy gains attributed to growth and expansion of existing canopy in the northwest portion of the county north of I-24 and west of Bidwell Road.

Figure 20. | Tree canopy gains attributed to growth and expansion of existing canopy in Shelby Bottoms Park along the Cumberland River.

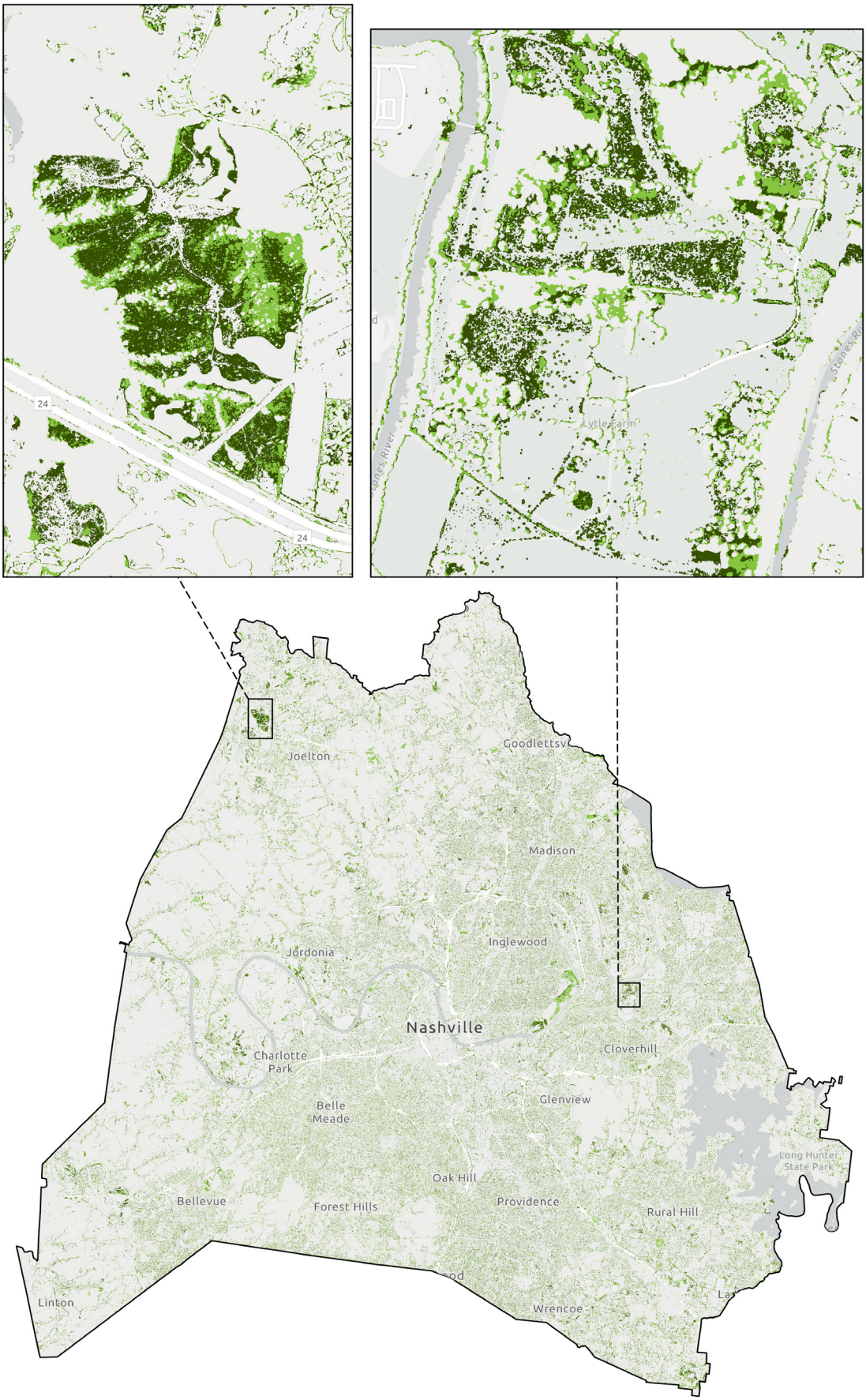


Figure 21. | Canopy gains from 2010-2021 over the study's entire AOI (Davidson County). Gains in dark green are more recent (2016-2021), while gains in light green are older (2010-2016).

EXAMPLES OF CANOPY LOSSES

Generally, large losses of canopy can be attributed to clearing for developments, residential and commercial development, as well as pruning or clear cutting for utility access. Other potential agents of losses may be attributed to tree mortality due to extreme weather events, hydrological shifts, or pressure from various pests and diseases. Figures 22 and 23 show the loss of canopy from 2016 NAIP imagery to 2021.

Figure 22. | Tree canopy losses from 2016 to 2021 due to clearing for development in the southeast portion of the county along Cane Ridge Road and Old Franklin Road.

Figure 23. | Tree canopy losses from 2016 to 2021 due to 2020 tornado damage in a Donelson neighborhood on Maplecrest Drive.

CONCLUSIONS

While canopy losses can be quite shocking and very apparent to the public eye, it's important to understand that most of the loss in canopy described in this report was in fact offset by the large number of gains described above. It's often difficult to notice the impact of growth of a tree or group of trees throughout the years, because these types of change happen so slowly. Gains are described by slow, incremental, and consistent changes from year to year, while losses are often defined by quick, sudden removal of large areas of woods and mature trees. Since 2010, Metro Parks has added 2,100 acres of land and is allowing certain areas to transition to forest.

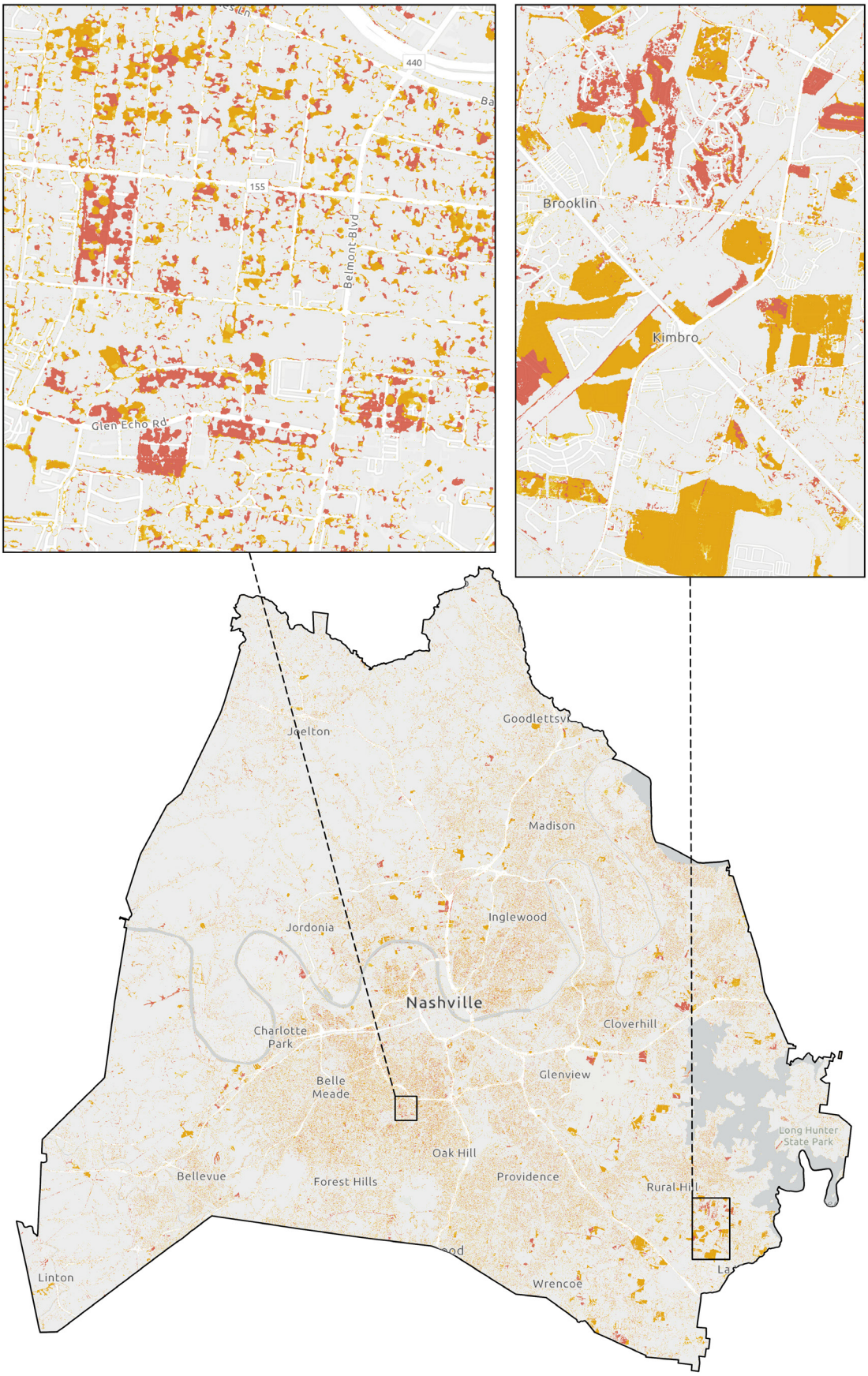


Figure 24. | Canopy losses from 2010-2021 over the project AOI (Davidson County). Areas in orange represent losses that occurred earlier in time (2010-2016), while losses in red occurred more recently (2016-2021).

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF KEY FINDINGS

Metro Nashville's urban tree canopy is a resource, and there is sufficient possible planting space available to increase the benefits it provides. The urban tree canopy serves as critical green infrastructure for the citizens of the city, and Metro Nashville has the responsibility of protecting and preserving it. Doing so is particularly crucial considering the current pace of urbanization, development, and population growth in the Metro Nashville area. Key findings of this study are represented in the figure below. For ease of reference, page numbers are included with each finding.

RECOMMENDATIONS

1. Leverage the results of this assessment to promote the urban forest and review canopy goals

The results of this assessment should be used to encourage investment in urban forest monitoring, maintenance, and management; to prepare supportive information for local budget requests/grant applications; and to develop targeted presentations for Metro Nashville leaders, planners, engineers, resource managers, and the public on the functional benefits of trees in addressing environmental issues. The land cover, tree canopy, and plantable space data should be disseminated to diverse partners for urban forestry and other applications while the data are current and most useful for decision-making and implementation planning. The information from this study can help establish new canopy cover goals for the short- and long-term planning which assists with the continued expansion of Nashville's urban forest to its known potential. Recurring assessments of the tree canopy represent important steps in ensuring the long-term health of its urban forest. Refining management strategies and revisiting strategic documentation can empower Metro Nashville and its stakeholders to not only evaluate its progress towards current objectives, but also formulate new ones as well.

In a 2016 study performed in-house by the Government of Metro Nashville, the below UTC goals were outlined for transects and community planning areas:

*Table 7. | Urban tree canopy cover of each **transect type (top)** and **community planning area (bottom)** compared to its respective goals.*

Transects	UTC Goal %	Current UTC %
D District	Site Specific	27%
T1 Natural	65%	81%
T2 Rural	65%	77%
T3 Suburban	50%	48%
T4 Urban	35%	30%
T5 Center	20%	10%
T6 Downtown	10%	7%

Community Planning Areas	UTC Goal %	Current UTC %
Antioch - Priest Lake	56%	47%
Bellevue	62%	72%
Bordeaux - Whites Creek - Haynes Trinity	63%	70%
Donelson - Hermitage - Old Hickory	52%	43%
Downtown	12%	8%
East Nashville	42%	41%
Green Hills - Midtown	52%	55%
Joelton	65%	75%
Madison	51%	42%
North Nashville	38%	21%
Parkwood - Union Hill	62%	69%
South Nashville	44%	27%
Southeast	51%	48%
West Nashville	48%	43%

2. Use the urban tree canopy data to identify areas to prioritize canopy expansion

Metro Nashville and its various stakeholders can utilize the results of the UTC and PPA analyses to identify the best locations to focus future tree planting and canopy expansion efforts. Trees can play a crucial role in promoting public health by improving air quality, reducing temperatures, and addressing climate change. Parcels may be acquired for public use as part of redeveloped neighborhoods to address community access to nature, climate, human health, and equity. This assessment should be used to identify areas with the greatest need for canopy expansion. Out of the seven transects the type furthest away from its canopy goal was the T5 Center transect. Fortunately, this area had 293 acres of plantable space. Targeting the T5 Center transect for tree planting could help offset the urban heat island effect, storm-water runoff, and air pollution. Looking at the community planning areas, North Nashville and South Nashville are equally distant from their respective goals and should be targeted for tree planting efforts by utilizing their total of 3,172 PPA acres.

3. Explore tree preservation and canopy expansion policies and legislation.

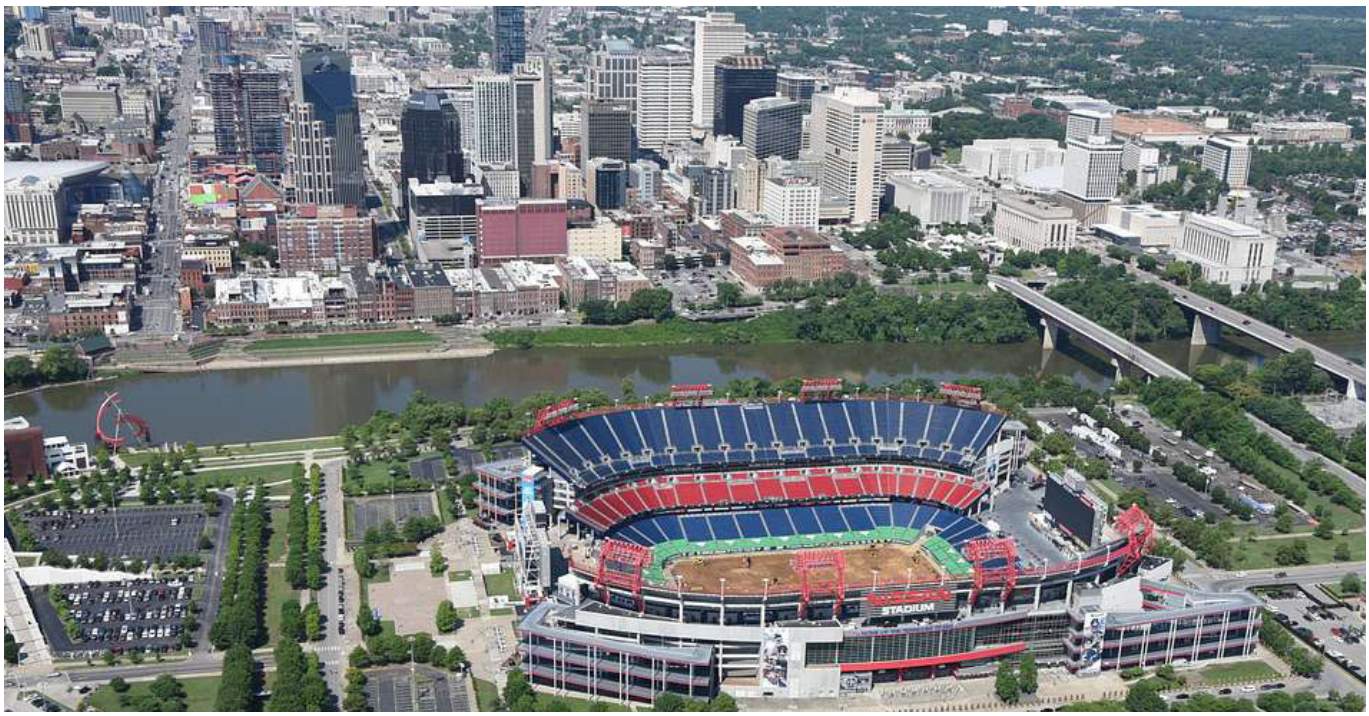
Metro Nashville should evaluate municipal codes to increase tree preservation, create space for existing trees during the development process, and set aside space for new larger stature trees to be planted adjacent to impervious surfaces, such as in the right-of-way, to maximize the benefits of trees. Adopting ordinances and policies that reflect a "complete green streets" design methodology can help harmonize gray and green infrastructure, simultaneously maximizing public functionality and environmental benefit.

4. Develop outreach programs towards private landowners

Metro Nashville's three residential land use types, Residential - 1 Unit, Residential - 2+ Unit, and Residential - Non-household accounted for over 50% of the UTC across all the land use types and for nearly 60% of all of the possible planting area. Nashville should focus on community outreach and education programs to better inform citizens and private landholders of the environmental, social, financial, and health benefits that trees provide and consider other strategies to help preserve existing trees and grow the tree canopy in the 39,610 acres of plantable space within these areas. The Root Nashville campaign should expand its efforts to increase canopy on private properties especially in under-served neighborhoods. Metro Nashville should also continue to develop partnerships with community based organizations and individual champions throughout neighborhoods to build stewardship at the community level. In addition, they should continue to conduct tree planting and tree maintenance events to increase awareness levels in the community.

5. Perform a canopy assessment at least every five years.

Performing a canopy assessment every five years is recommended. This assessment should be performed using the same methodology as this study to allow for data comparison.



REPORT

APPENDIX

ACCURACY ASSESSMENT

Classification accuracy serves two main purposes. Firstly, accuracy assessments provide information to technicians producing the classification about where processes need to be improved and where they are effective. Secondly, measures of accuracy provide information about how to use the classification and how well land cover classes are expected to estimate actual land cover on the ground. Even with high resolution imagery, very small differences in classification methodology and image quality can have a large impact on overall map area estimations.

The classification accuracy error matrix illustrated in Table A1 contain confidence intervals that report the high and low values that could be expected for any comparison between the classification data and what actual, on the ground land cover was in 2021. This accuracy assessment was completed using high resolution aerial imagery, with computer and manual verification. No field verification was completed.

THE INTERNAL ACCURACY ASSESSMENT WAS COMPLETED IN THESE STEPS:

1. Two hundred and fifty five, or approximately 0.5 points per square mile area in Davidson County (525 sq. miles), were randomly distributed across the study area and assigned a random numeric value.
2. Each sample point was then referenced using the NAIP aerial photo and assigned one of five generalized land cover classes ("Ref_ID") mentioned above by a technician.
3. In the event that the reference value could not be discerned from the imagery, the point was dropped from the accuracy analysis. In this case, no points were dropped.
4. An automated script was then used to assign values from the classification raster to each point ("Eval_ID"). The classification supervisor provides unbiased feedback to quality control technicians regarding the types of corrections required. Misclassified points (where reference ID does not equal evaluation ID) and corresponding land cover are inspected for necessary corrections to the land cover.[1]
5. Accuracy is re-evaluated (repeat steps 3 & 4) until an acceptable classification accuracy is achieved.

SAMPLE ERROR MATRIX INTERPRETATION

Statistical relationships between the reference pixels (representing the true conditions on the ground) and the intersecting classified pixels are used to understand how closely the entire classified map represents Davidson County's landscape. The error matrix shown in Table A1 represent the intersection of reference pixels manually identified by a human observer (columns) and classification category of pixels in the classified image (rows). The blue boxes along the diagonals of the matrix represent agreement between the two-pixel maps. Off-diagonal values represent the number of pixels manually referenced to the column class that were classified as another category in the classification image. Overall accuracy is computed by dividing the total number of correct pixels by the total number of pixels reported in the matrix (150 + 54 + 35 + 4 + 7 = 250/255 = 98.0%), and the matrix can be used to calculate per class accuracy percentages. For example, 54 points were manually identified in the reference map as non-canopy vegetation, and 55 of those pixels were classified as non-canopy vegetation in the classification map, meaning one point was misclassified. This relationship is called the "Producer's Accuracy" and is calculated by dividing the agreement pixel total (diagonal) by the reference pixel total (column total). Therefore, the Producer's Accuracy for non-canopy vegetation is calculated as: (54/55 = .982), meaning that we can expect that ~98% of all 2021 non-canopy vegetation in Davidson County, TN study area was classified as non-canopy vegetation in the 2021 classification map. This also applies to tree canopy classifications.

Conversely, the "User's Accuracy" is calculated by dividing the total number of agreement pixels by the total number of classified pixels in the row category. For example, classification pixels intersecting reference pixels were classified as Tree Canopy, and 2 pixels were identified as canopy in the reference map. Therefore, the User's Accuracy for Tree Canopy is calculated as: (150/152 =.987), meaning that ~99% of the pixels classified as Tree Canopy in the classification were actual tree canopy. It is important to recognize the Producer's and User's accuracy percent values are based on a sample of the true ground cover, represented by the reference pixels at each sample point. Interpretation of the sample error matrix results indicates this land cover, and more importantly, tree canopy, were accurately mapped in Davidson County in 2021.

[1] *Note that by correcting locations associated with accuracy points, bias is introduced to the error matrix results. This means that matrix results based on a new set of randomly collected accuracy points may result in significantly different accuracy values.*

Table A1. | Error matrix for land cover classifications in Davidson County, TN (2021).

Classification Data	Reference Data: Tree Canopy	Vegetation	Impervious	Soil / Dry Veg.	Water	Total Reference Pixels
Tree Canopy	150	2	1	0	0	153
Vegetation	1	54	0	0	0	55
Impervious	1	0	35	0	0	36
Soil / Dry Veg.	0	0	0	4	0	4
Water	0	0	0	0	7	7
Total	152	56	36	4	7	255

Overall Accuracy =	**98%**
Overall Margin of Error=	**1.4%**
Canopy Margin of Error =	**1.5%**

Producer's Accuracy	
Tree Canopy	99%
Veg. / Open Space	96%
Impervious	97%
Bare Ground / Soil	100%
Water	100%

User's Accuracy	
Tree Canopy	98%
Veg. / Open Space	98%
Impervious	97%
Bare Ground / Soil	100%
Water	100%

Margin of error values reported at 90% confidence interval

ACCURACY ASSESSMENT RESULTS

Interpretation of the sample error matrix offers some important insights when evaluating Davidson County's urban tree canopy coverage and how well aligned the derived land cover data are with interpretations by the human eye. The high accuracy of the 2021 data indicates that regardless of how and when it was achieved, Davidson County's current tree canopy can be safely assumed to match the figures stated in this report (approximately 56%).

GLOSSARY/KEY TERMS

Land Acres: Total land area, in acres, of the assessment boundary (excludes water).

Non-Canopy Vegetation: Areas of grass and open space where tree canopy does not exist.

Possible Planting Area - Vegetation: Areas of grass and open space where tree canopy does not exist, and it is biophysically possible to plant trees.

Shrub: Areas of shrub or other leafy and woody vegetation (smaller than 10 ft tall) that are not classified as tree canopy.

Soil/Dry Vegetation: Areas of bare soil and/or dried, dead vegetation.

Total Acres: Total area, in acres, of the assessment boundary (includes water).

Unsuitable Impervious: Areas of impervious surfaces that are not suitable for tree planting. These include buildings and roads and all other types of impervious surfaces.

Unsuitable Planting Area: Areas where it is not feasible to plant trees. Airports, ball fields, golf courses, etc. were manually defined as unsuitable planting areas.

Unsuitable Soil: Areas of soil/dry vegetation considered unsuitable for tree planting. Irrigation and other modifiers may be required to keep a tree alive in these areas.

Unsuitable Vegetation: Areas of non-canopy vegetation that are not suitable for tree planting due to their land use.

Urban Tree Canopy (UTC): The "layer of leaves, branches and stems that cover the ground" when viewed from above; the metric used to quantify the extent, function, and value of the urban forest.[2] Tree canopy is generally taller than 10 feet.

Water: Areas of open, surface water not including swimming pools.

[2] Raciti, S., M. F. Galvin, J. M. Grove, J. P. M. O'Neil-Dunne, A. Todd, and S. Clagett. 2006. *Urban tree canopy goal setting: A guide for Chesapeake Bay communities.* Annapolis, MD: USDA Forest Service, Northeastern State and Private Forestry, Chesapeake Bay Program Office.

DECEMBER | 2023

URBAN TREE CANOPY

ASSESSMENT

NASHVILLE, TENNESSEE

PlanIT Geo™
developers of TreePlotter

earth Define