Louisville Urban Tree Canopy Assessment

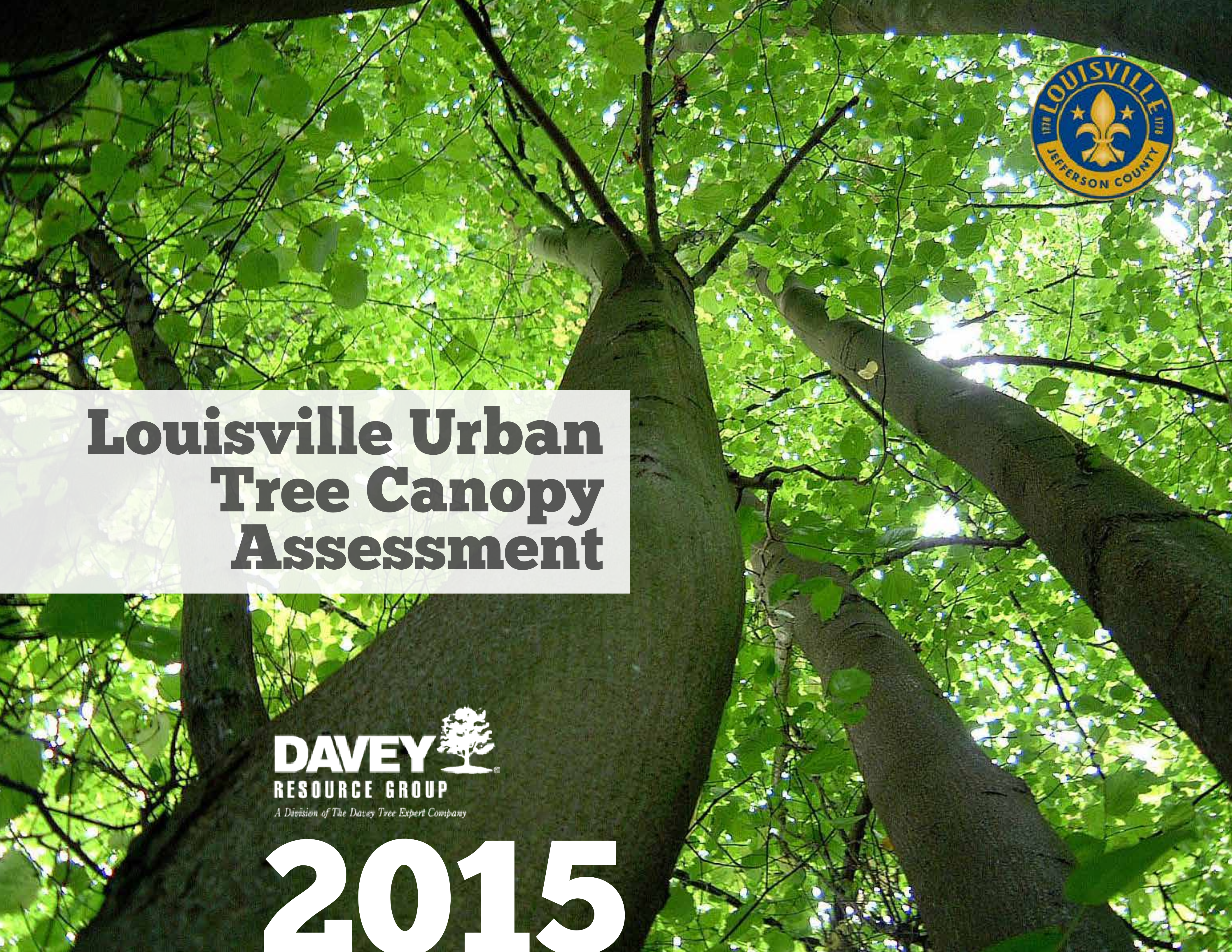

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Table of Contents

FINAL DRAFT

Executive Summary

2015 **Louisville Urban Tree Canopy Assessment**

Louisville UTC: 37%

Louisville UTC minus larger parks: ~30%

Residents, businesses and visitors of Louisville are privileged to be in an area rich in natural resources and beauty. Louisville supports a wide diversity of native woodlands, stately tree-canopied parks and streets, and expertly landscaped businesses and residences. Largely due to the high quality of life and opportunities for success, Louisville encompasses the most populated county in Kentucky.

Recently, however, tree canopy loss and urban heat island effects have become a concern.

The city's 2013 *Sustain Louisville* plan proposed a variety of actions to reverse the trend of these issues and challenges by achieving these important goals:

- decrease energy use,
- mitigate the risk of climate change impacts,
- achieve and exceed national air quality standards,
- improve waterway quality,
- mitigate urban heat island effects,
- increase opportunities for active living,
- provide nature-based recreation, and
- engage the community in sustainability practices.

The strategies for attaining these goals will be multi-faceted and long-term, but as a small or large part of the solutions for each one of these goals, **trees are indeed the answer.** The *Sustain Louisville* plan identified the Louisville Metro Tree Advisory's recommendation to conduct a countywide urban tree canopy (UTC) study to determine the historic and current amount and location of tree cover, quantify the benefits, set realistic goals to expand the tree canopy, and make recommendations for achieving these goals.

What do we have?

Currently, approximately 37% of the land, or just over 94,000 acres, in Louisville is covered by trees. **Canopy cover within the "old city boundary" (before the city-county merger in 2003) is 26%.**

In comparison to other cities and regions, the tree canopy is higher than Lexington (25%) and St. Louis (26%), but lower than Cincinnati (38%) and Nashville (47%). Louisville's canopy is also lower than American Forests recommendation of a 40% overall tree canopy cover.

Much of the tree canopy in Louisville grows in protected parks, and not directly where people live and work. Over 13,300 acres of tree canopy are located in just eight of the largest parks (such as Jefferson Memorial Forest, the Parklands of Floyd's Fork, Iroquois, and Cherokee Park). **Excluding large parks, the urban tree canopy in developed areas may be closer to 30%.**

Historically, a negative trend has also been established, as Louisville has lost 7%, or 6,500 acres, of its trees since 2004. That's a rate of 820 acres of canopy or 54,000 trees lost per year. The map at right (Figure 1) shows the rates of canopy decrease across Louisville between 2004 and 2012.

40% in 2004 → **38%** in 2008 → **37%** in 2012

To compound this trend, Louisville will experience a significant canopy loss due to the exotic pest emerald ash borer (EAB). Ash trees comprise 10%-17% of suburban and rural forests, meaning tens of thousands of ash trees will be lost in Louisville within the next five to ten years (UK 2014). Given the historic trend of tree loss and combined with the inevitable loss of ash trees from EAB, if no steps are taken to address canopy levels, Louisville's tree canopy will drop to 31% by 2022 and potentially to 21% by 2052. Future canopy projection is shown in Figure 2.

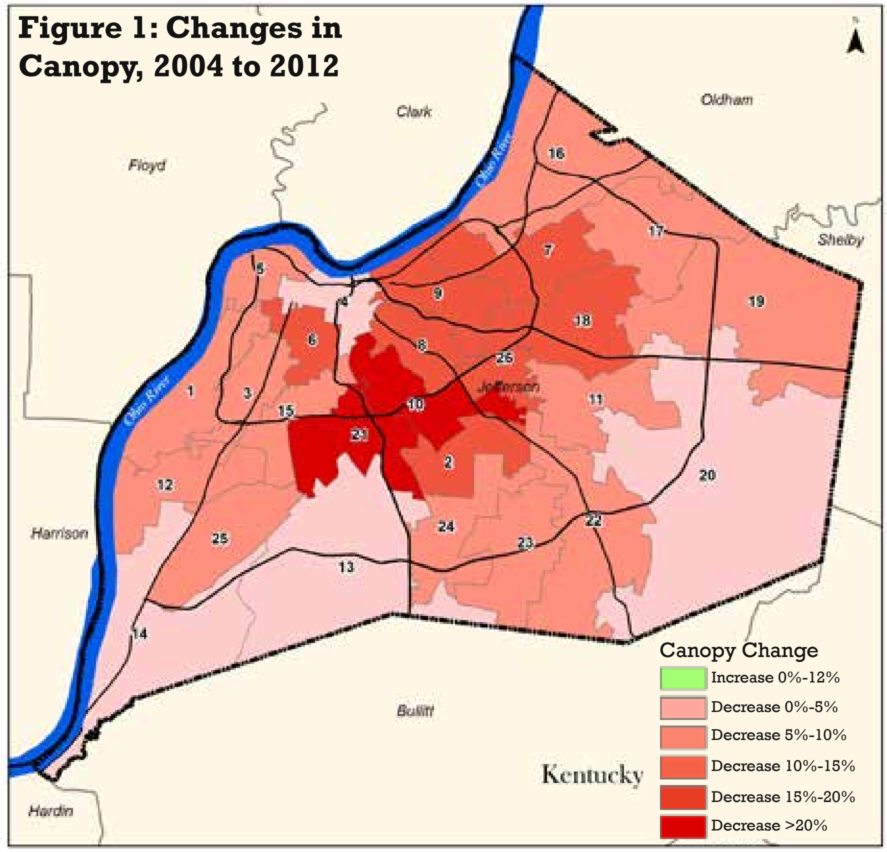

Figure 1: Changes in Canopy, 2004 to 2012

Louisville is losing an average of 820 acres (approximately 54,000 trees) of canopy each year.

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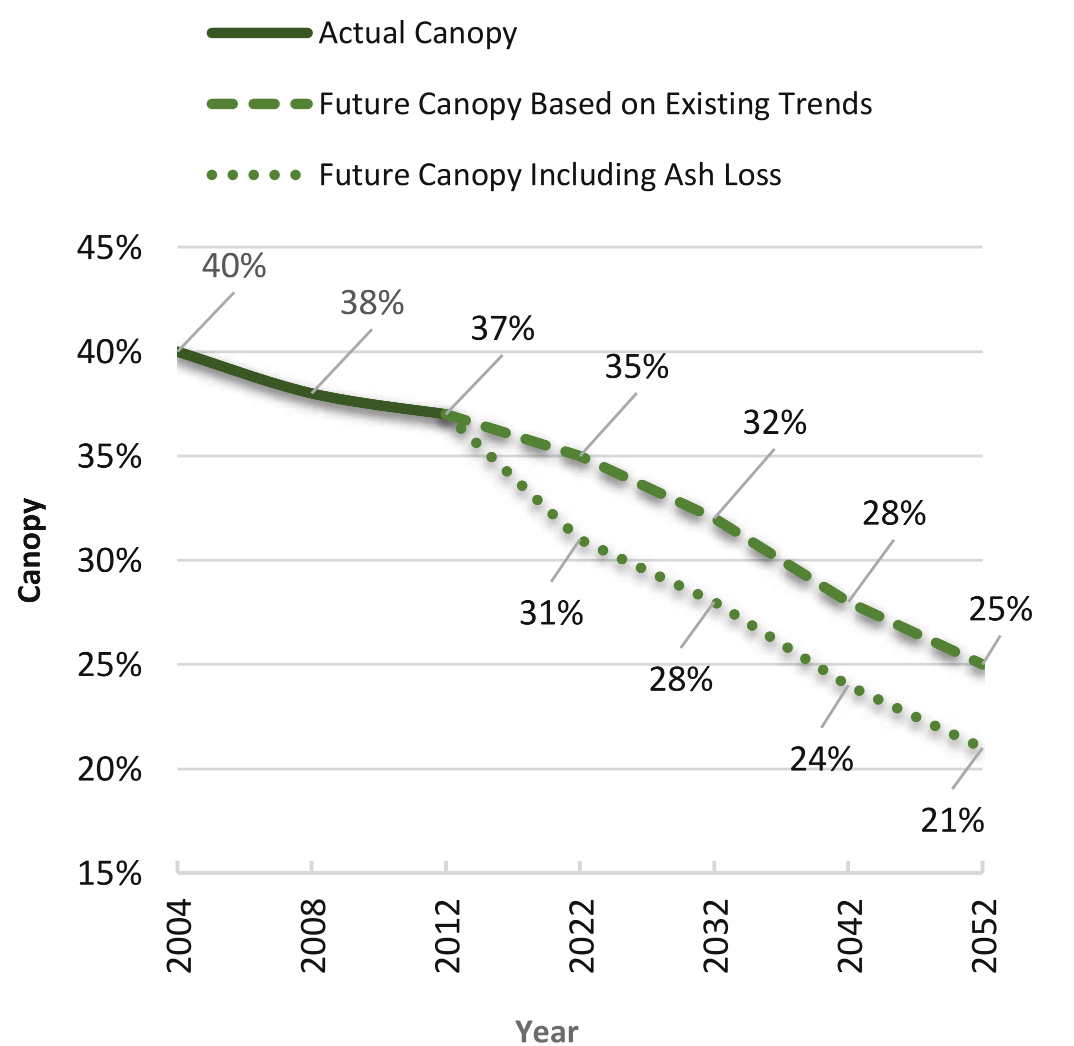
Given both the threats to and opportunities for managing and expanding the tree canopy in Louisville, and all of the ways trees can help achieve sustainability goals, this UTC assessment was undertaken to examine tree canopy in detail. Canopy was accurately mapped and then analyzed by a multitude of factors including land use, surface temperature, and demographics. Additionally canopy was segmented by council districts, neighborhoods, suburban cities and sewersheds.

For the first time, Louisville's citizens, allied organizations, and government agencies have accurate tree canopy data to rely upon and formulate next steps.

A prioritized planting plan was also created to maximize tree benefits in areas of greatest need. Plantable areas were evaluated based

If current trends hold, Louisville canopy is projected to decrease to 31-35% in the next ten years, dropping to as low as 21% over the next forty years.

Figure 2. Louisville's Estimated Future Canopy (No Action Taken)



on environmental features (proximity to local waterways, soil type, floodplains, slope, and forest fragmentation), stormwater issues, and urban heat island concerns.

Why trees?

Why does knowing how much tree canopy exists in Louisville matter, and why should more trees be planted? The answer is because trees are truly a community's "green asset" and an infrastructure component that provides a tremendous quantity of "ecosystem services" such as cleaning the air, intercepting stormwater before it reaches municipal sewer systems, increasing property values, absorbing carbon, saving money on energy costs, and moderating hot temperatures in urbanized areas.

Louisville's current canopy provides $330 million in benefits each year. This includes annually intercepting over 18 billion gallons of stormwater, removing 150,000 lbs. of carbon monoxide, 4.3 million lbs. of ozone, 500,000 lbs. of nitrogen dioxide, 600,000 lbs. of sulfur dioxide, and 1.2 million lbs. of soot, dust and other particulates that irritate human lungs.

Louisville trees provide approximately $330 million in benefits annually.

However, if the canopy continues to decrease, so too will these benefits. And if the trend is not reversed, the simultaneous decline in tree canopy and increase in population and development will cause more problems for aging, over-burdened infrastructure, and create real crises in public health and community livability.

What do we want?

Establishing tree canopy goals is an important action to ensure that trees, as a valuable green infrastructure asset, are maintained at minimum thresholds, even as Louisville continues to develop.

Louisville's preliminary goals are "no net loss" in five years, and increasing overall canopy to 40% or 45% in future years. The results from this UTC study will be used together with local expertise and open dialog to establish realistic and achievable city-wide goals, as well as goals for specific areas and land uses.

How do we get there?

Attaining canopy goals involves more than just planting trees. Maintaining and protecting the existing tree cover must go hand in hand with aggressive tree planting to achieve desired canopy cover. As a result of the UTC study, Louisville Metro Government and its citizens now have the statistical data, mapping analysis, and a prioritized planting plan that will help focus tree management and tree planting resources where they are needed most.

Recommendations for growing and protecting the tree canopy in Louisville based on the findings of the UTC study are provided to inform consensus and promote action. Thousands of young trees will need to be planted and thousands of mature trees will need to be cared for if trees are to be embraced as a way to reduce stormwater issues, improve air and water quality, and reduce the urban heat island effects in Louisville.

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Introduction

2015 **Louisville Urban Tree Canopy Assessment**

Trees in the city of Louisville are a major component of urban infrastructure, providing more than just aesthetics and shade. They provide numerous benefits that help address mounting issues in public health, stormwater, and energy and pollution management. Like many cities across the country, Louisville is facing a number of challenges brought on by aging infrastructure combined with continued growth and development. Add to this the ongoing loss of trees, and the challenges compound.

To understand and begin to address these issues, and at the recommendation of the Louisville Metro Tree Advisory Commission, Louisville tasked Davey Resource Group to perform an Urban Tree Canopy (UTC) assessment. The assessment determined the location and quantity of current canopy, calculated ecosystem services, documented historical change in land use and tree canopy, and analyzed canopy with socioeconomic and geographic variables, as well as surface temperatures and stormwater runoff.

This report provides an overview of the UTC process, assessment results, and recommendations for tree planting and management strategies.

Challenges in Louisville

Louisville is facing a number of major issues: urban heat island and its effects (both on human health and comfort and air quality), water pollution and stormwater flooding, and the steady loss of trees from extreme weather events (Ike Windstorm of 2008 and Ohio Valley Ice storm of 2009), insects and diseases, development, and lack of tree care.

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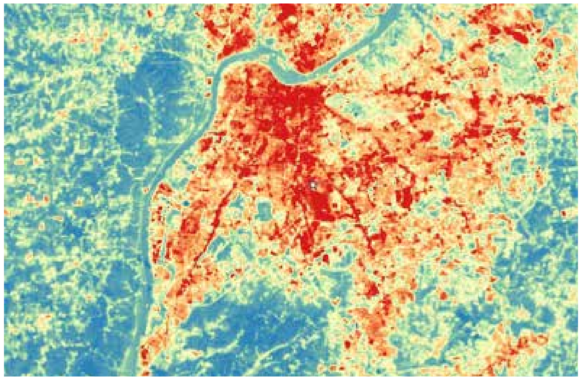


Urban heat measured by satellite in Louisville.
Image Source: Climate Central

Sewer manhole overflow in Louisville.
Image Source: MSD Project Win

Dead ash trees in naturalized area.
Image Source: USFS

Heat and Air Quality

Louisville was recently identified as one of the top ten fastest growing and most intense heat islands in the country. Heat islands have a number of negative effects, including an increase in summertime peak energy demand and costs, an increased severity of air pollution and emissions, and a rise in human health issues, especially when the temperature reaches over 90°F. Hotter temperatures help create dangerous ozone pollution levels that can trigger asthma attacks, heart attacks, and other serious health conditions (US EPA 2012).

Flooding and Water Pollution

Rainfall overwhelming Louisville's aging sewer system is a major factor for local water pollution and flooding issues. Combine the aging system with large increases in stormwater runoff from concrete and other impervious areas like roads, and buildings, and the problem compounds. Louisville's Metropolitan Sewer District (MSD) is under an EPA consent decree to reduce the amount and frequency of discharges from combined sewer overflows (CSOs) into local waterways. MSD has invested more than $1.4 billion in system expansion and upgrades, but problems persist during rainfalls. MSD's green infrastructure incentive program intends to reduce these overflows and improve water quality through natural means, including using trees to absorb and intercept rainwater (MSD 2014).

Tree Loss from Insects and Disease

Emerald ash borer (EAB) is present in Louisville. Ash (*Fraxinus spp.*) trees represent 10%-17% of all trees across the county, and unless every ash is treated (which is unrealistic) this species will disappear in the next 5 to 10 years (UK 2014). The loss of this significant portion of canopy will result in a substantial decline in ecosystem service benefits, further exacerbating heat island and stormwater issues. Additionally, land owners (both public and private) will be burdened with associated removal costs and liability issues. Beyond EAB, Louisville trees are also at risk from other serious pests and diseases, including Asian long-horned beetle, bacterial leaf scorch, and thousand canker disease.

FINAL DRAFT

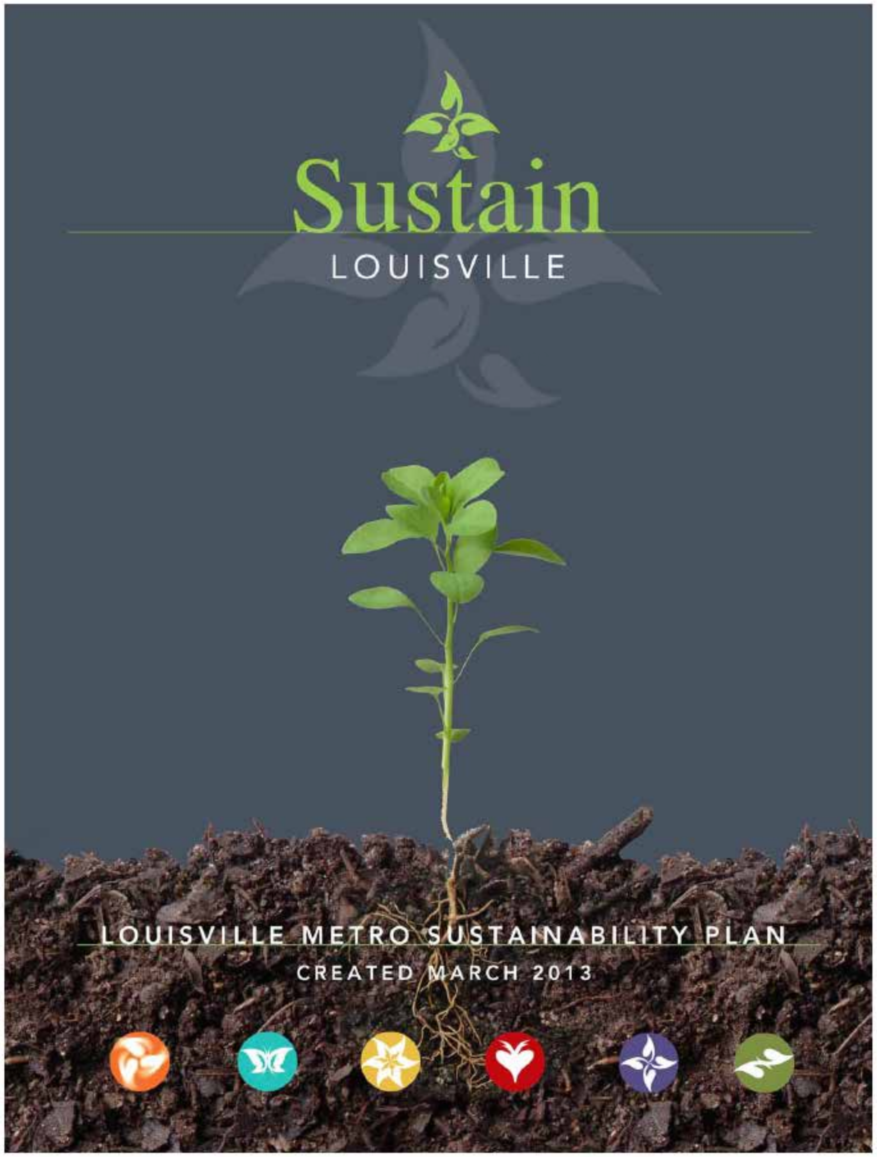
Solutions from *Sustain Louisville*

The *Sustain Louisville* plan was developed as part of a multifaceted response to these challenges and identified a significant need to reduce the city's carbon footprint, protect the environment, ensure the health and wellness of its citizens, and create a culture of sustainability.

Plan goals identified trees as an effective means of addressing many of the urban challenges facing the metropolitan area. A full list of goals from the plan can be found in Appendix C.

Tree canopy, and the benefits it provides, fits the "triple bottom line approach of people, prosperity and the planet" referenced in the plan. It does so by contributing to public health improvements, providing quantifiable economic benefits, and protecting the environment.

As the quantity and quality of tree canopy in the city increases, so too do the benefits that canopy provides. It is because trees are recognized to provide such substantial benefits that the Louisville Metropolitan Government has undertaken this UTC assessment.



FINAL DRAFT

Why Trees?

It is important for Louisville to look at trees as solutions to modern urban challenges. Trees provide a broad spectrum of environmental, economic, and social benefits (listed below), many of which are well documented by scientific research and are quantifiable at the community level. Specific and quantified benefits provided by Louisville's existing tree canopy are detailed in the Canopy Benefits section of this report.

Prevention of Water Pollution. Aging sewers, struggling to keep up with stormwater during a rainfall, overflow and pollute nearby waterways. Trees act as mini-reservoirs, helping to slow and reduce the amount of rainwater in storm drains. 100 mature trees can intercept 100,000 gallons of rainfall per year (USFS 2003).

Less Energy Consumption. Trees decrease energy consumption and moderate local climates by providing shade and acting as windbreaks.

Cleaner Air. Trees cleanse atmospheric pollutants (chemicals, particles, etc.), produce oxygen, and absorb carbon dioxide.

Temperature Moderation. Ever wonder why it always feels cooler in or near the woods? It's not just due to shade. Leaves emit water vapor making the ambient temperature lower. Temperature differences of 5-15 degrees can be felt when walking under tree-canopied streets (Miller 1997).

Reduced Asthma in Children. Trees improve air quality by trapping and holding a significant percentage (up to 60%) of pollen, dust and smoke from the air. (Coder 1996) Studies have shown that children who live on tree-lined streets have lower rates of asthma (Lovasi 2008).

Higher Property Values. Trees can increase residential property and commercial rental values by average of 7%. Conversely, values can decline by as much as 20% for properties with no trees (Wolf 2007).

Successful Business Districts. On average, consumers will pay about 11% more for goods in shaded and landscaped business districts (Wolf 1998b, 1999, and 2003). Consumers also feel that the quality of the products is better in business districts having trees (Wolf 1998a).

Less Crime. Apartment buildings with high levels of greenery had 52% fewer crimes than those without any trees; and apartment buildings with medium amounts of greenery had 42% fewer crimes than those without any trees (Kuo and Sullivan 2001a).

Lower Energy Costs. Trees moderate temperatures in the summer and winter, saving on heating and cooling expenses (North Carolina State Univ. 2012, Heisler 1986).

Better Health. Studies show individuals with views of or access to greenspace tend to be healthier. Employees experience 23% less sick time and greater job satisfaction, and hospital patients recover faster with fewer drugs (Ulrich 1984). Trees have also shown to have a calming and healing effect on ADHD adults and teens (Burden 2008).

Stronger, Positive Communities. Tree-lined streets can create stronger social ties. In one study, residents of apartment buildings with more trees reported they knew their neighbors better, socialized with them more often, had stronger feelings of community, and felt safer and better adjusted than did residents of more barren, but otherwise identical areas (Kuo 2001b).

Safer Streets. Traffic speeds and the amount of stress drivers feel are reduced on tree-lined streets, which also is likely to reduce road rage/aggressive driving (Wolf 1998a, Kuo and Sullivan 2001b).

Less Noise. Trees help reduce noise levels. A 100-foot wide densely planted tree buffer will reduce noise by 5-8 decibels (Bentrup 2008).

Wildlife Habitat. Connected urban greenways comprised of diverse shade and understory trees provide food, shelter, and water habitat that help connect wildlife with fragmented urban forests.

Erosion Prevention. Trees, especially tree roots, helps stabilize hillsides by reinforcing soil shear strength (Kazutoki and Ziemer 1991).

About the Study Area

Urban tree canopy was examined across all of Louisville. The City of Louisville encompasses all of Jefferson County, spanning approximately 398 square miles (254,720 acres) across north central Kentucky, and is bordered in the west by the Ohio River.

Junction of Waterson & I-71
Image Source: Dr. Keith Mountain

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Process & Methods

Louisville's UTC assessment followed these steps: existing and historic canopy coverage was determined using aerial imagery[1], and ecosystem services provided by current canopy was calculated. An assessment of realistic locations for potential canopy increases was then made by eliminating impervious areas, water bodies, etc., from possible planting areas. The potential planting areas were prioritized to provide a way for achieving canopy goals efficiently. Finally a summary report was written and all data files were delivered to Louisville Metropolitan Government for future use and analysis. Further details on each of these steps and methods are described throughout this report and detailed in the appendices.

This study used a combination of data sources, tools and analysis methods, including USDA aerial imagery (NAIP), third parties for accuracy assessments, remote sensing technology, census data, locally-supplied data, other scientific studies and more. These sources will be briefly referenced throughout this report and detailed in the appendix.

[1] NAIP imagery (National Agriculture Imagery Program) from the summer growing seasons of 2012, 2008 and 2004.

FINAL DRAFT

Country club north of Bowman Field
Image Source: Dr. Keith Mountain

UTC RESULTS

Louisville Urban Tree Canopy Assessment

UTC Results

2015 Louisville Urban Tree Canopy Assessment

Based on the most recent aerial imagery (2012), Louisville's tree canopy covers **37%** (just over 94,000 acres) of the entire county. **Excluding large parks, the urban tree canopy in developed areas is closer to 30%.** Canopy cover within the old city boundary (before the city-county merger in 2003) is **26%.**

In comparison to other cities and regions, the tree canopy is higher than Lexington (25%) and St. Louis (26%), but lower than Cincinnati (38%) and Nashville (47%), as shown in Table 1. Louisville's canopy is also lower than American Forests recommendation of 40% overall UTC.

Tree canopy is considered one of five land cover classifications, along with grass/low vegetation, impervious surfaces (concrete, buildings, and roads), bare soil and bodies of water. Figure 3 illustrates land cover as of 2012 in Louisville along with an explanation of each classification.

Once overall canopy is determined, this data can be broken down into useful segments and examined further to identify trends, including canopy by multiple political boundaries (council districts, neighborhoods, and suburban cities), as well as by categories of land use, the type of problems occurring (flooding, excessive heat) and exploring correlations with the people who reside/work throughout the metropolitan area (socioeconomics and demographics).

Louisville's urban tree canopy assessment produced a significant amount of data. The findings of the UTC assessment are highlighted in the following sections, while data and GIS files have been provided electronically to the Louisville Metropolitan Government for future use and analysis.

Table 1. City Comparisons

CITY COMPARISONS: How does Louisville's overall urban tree canopy coverage compare regionally?

	Canopy Cover	Study Area	Date Reported
Charlotte, NC *	49%	298 mi^2	2012
Nashville, TN *	47%	475 mi^2	2010
Pittsburgh, PA	42%	58 mi^2	2011
Knoxville, TN	40%	103 mi^2	2014
*Recommended***	*40%*	-	-
Cincinnati, OH	38%	78 mi^2	2011
Louisville, KY*	**37%**	**398 mi^2**	**2014**
Evansville, IN	26%	44 mi^2	2011
St. Louis, MO	26%	96 mi^2	2010
Lexington , KY	25%	85 mi^2	2014

** Study area spans city & surrounding county.*

*** Recommended canopy by American Forests*

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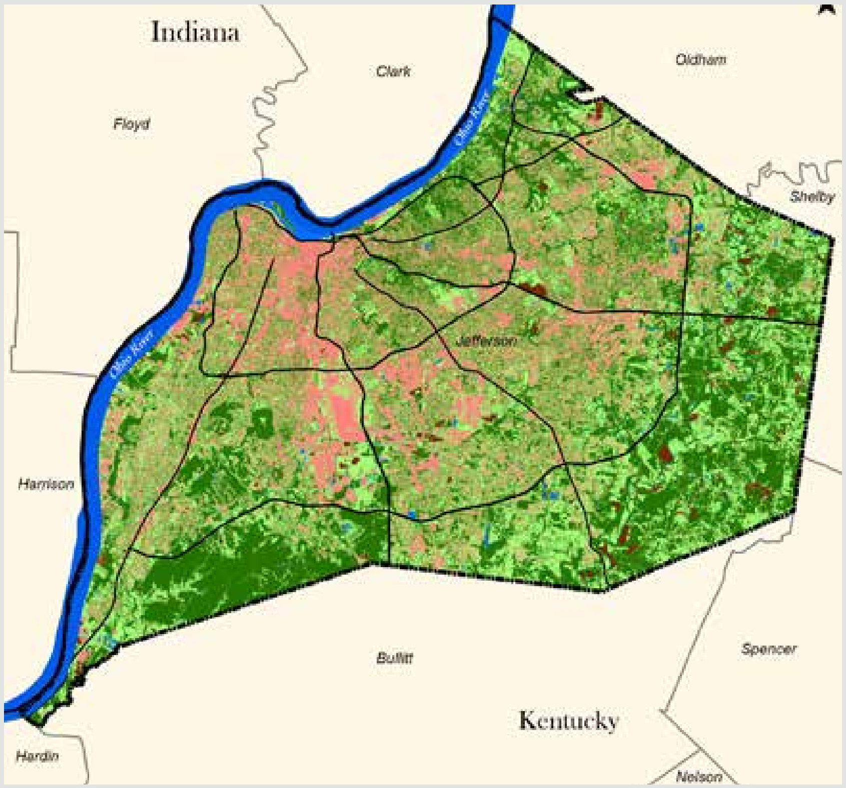
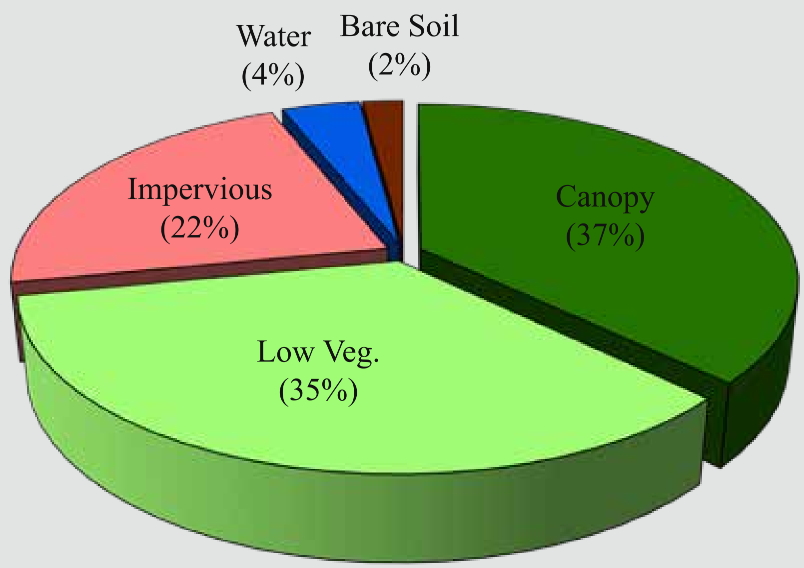
Figure 3. Louisville 2012 Land Cover





Tree Canopy – 37%
Trees' leaf-covered branches, as seen from above.

Grass/Low Vegetation– 35%
Parks, golf courses, fields, lawns.

Water – 4%
All bodies of water including lakes, ponds, rivers and streams.

Impervious Surfaces –22%
Roads, sidewalks, buildings, parking lots - all areas where water cannot soak into the ground.

Bare Soil – 2%
All open areas like sports fields, vacant lots, and construction sites.

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Changes Over Time

Louisville is fortunate to have access to multiple years (2004, 2008 and 2012) of canopy and land cover data, allowing unique and valuable insights into where canopies are changing and why.

The UTC analysis revealed that tree canopy in Louisville has decreased from 40% in 2004 to 37% in 2012 as shown in the Table 2, constituting a 7%* change between 2004 and 2012. This equates to a loss of approximately 6,500 acres of tree canopy, averaging 820 acres of tree canopy loss per year, or 54,000 trees per year (assuming a 29-ft crown diameter).

40% in 2004 → **38%** in 2008 → **37%** in 2012

Decreases in canopy cover can often be attributed to increases in roads and buildings (impervious land cover) from development. Such appears to be the case in Louisville. Between 2004 and 2012, while canopy decreased, impervious land cover increased by 15%.

The rate of tree canopy loss between the first four years (2004 to 2008) was higher than the rate between the latter four years (2008 to 2012). Decreases in canopy cover can often be attributed to increases in roads and buildings (impervious land cover). Between 2004 and 2012, while canopy decreased, impervious land cover increased by 15%. The same period shows a 9% increase in the grass/low-lying vegetation land cover (all pervious areas excluding canopy) which may be attributed to certain types of development such as new recreational and other open spaces like sports fields, etc., but further research would be required to pinpoint specific drivers of these changes.

Table 2. Canopy and Other Land Cover Changes, 2004-2012

	Year 2004	Year 2008	Year 2012	Rate of Change*
Tree Canopy	40%	38%	37%	-7%
Buildings, Sidewalks, Roads, etc. *("Impervious")*	30%	31%	35%	15%
Grass/Low-Lying Vegetation *("Other Pervious")*	20%	21%	22%	9%
Bare Soil	4%	4%	4%	0%
Water	6%	6%	2%	-65%

Note: Rates of change were calculated on the canopy to the nearest hundredth of a percent, then rounded to the nearest whole percentage number.

Louisville has lost approximately 6,500 acres of canopy since 2004, averaging 820 acres or 54,000 trees per year.

* Rate of Change in this report is determined as a percentage, comparing old values to current values using the following equation: $\frac{\text{current value - older value}}{\text{older value}} \times 100$
For example, if a park had 46 trees in 2004, and only 42 trees in 2012, that constitutes a -10% change.

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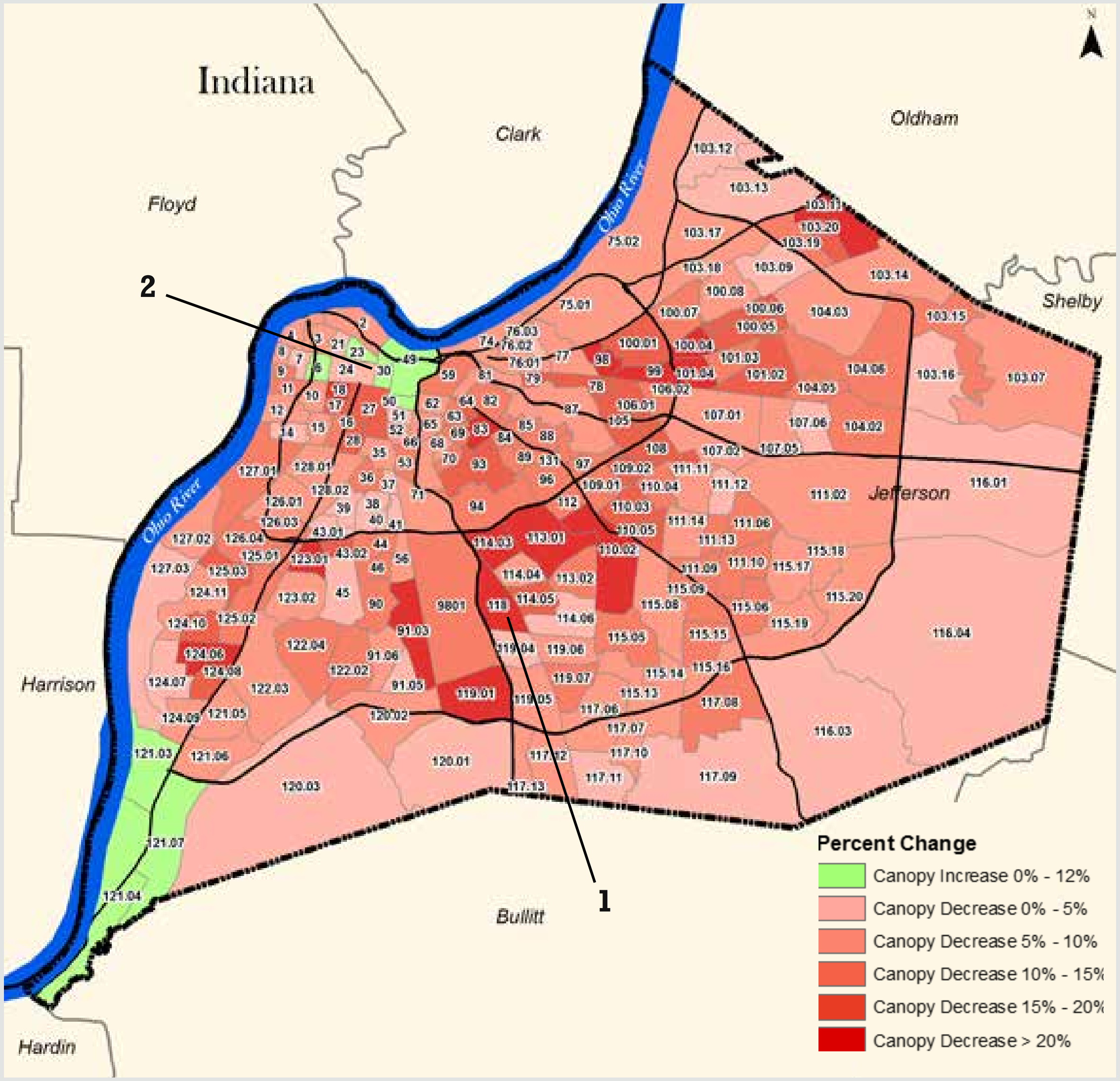
Figure 4. Rates of Canopy Change, 2004-2012 (shown by census tract)



Changes in canopy were examined within each census tract. Of the 191 tracts in the study area, 179 tracts (94% of all tracts) experienced a loss of canopy since 2004, as shown in Figure 4.

Tract 118 (point 1 on map) experienced the greatest canopy loss with a 31% drop, and 15 tracts experienced a 20% or greater drop in canopy (shown in darkest red on map).

Eight census tracts located in the downtown area and the southwest corner of the county experienced a gain in UTC (shown in green on map).

Tract 30 (point 2 on map) experienced the largest percent canopy gain (12% growth) with UTC cover increasing from 13% in 2004 and 2008 to 15% in 2012.

A full list of canopy by census tract has been provided to Louisville Metro Government electronically.

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By Council District

Current and past canopy cover segmented by the 26 council districts can been seen in Table 3 and Figure 5.

Council District 20 has the highest UTC percentage, followed by Districts 13, 14, and 25.

Districts with the greatest amount of canopy hold some of the larger parks and naturalized areas in Louisville.

Districts 4, 6 and 21 had the lowest UTC.

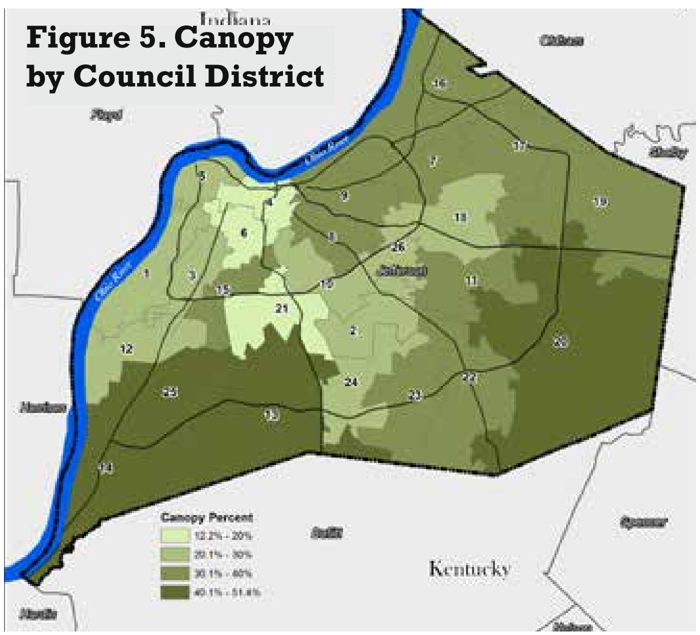


Figure 5. Canopy by Council District

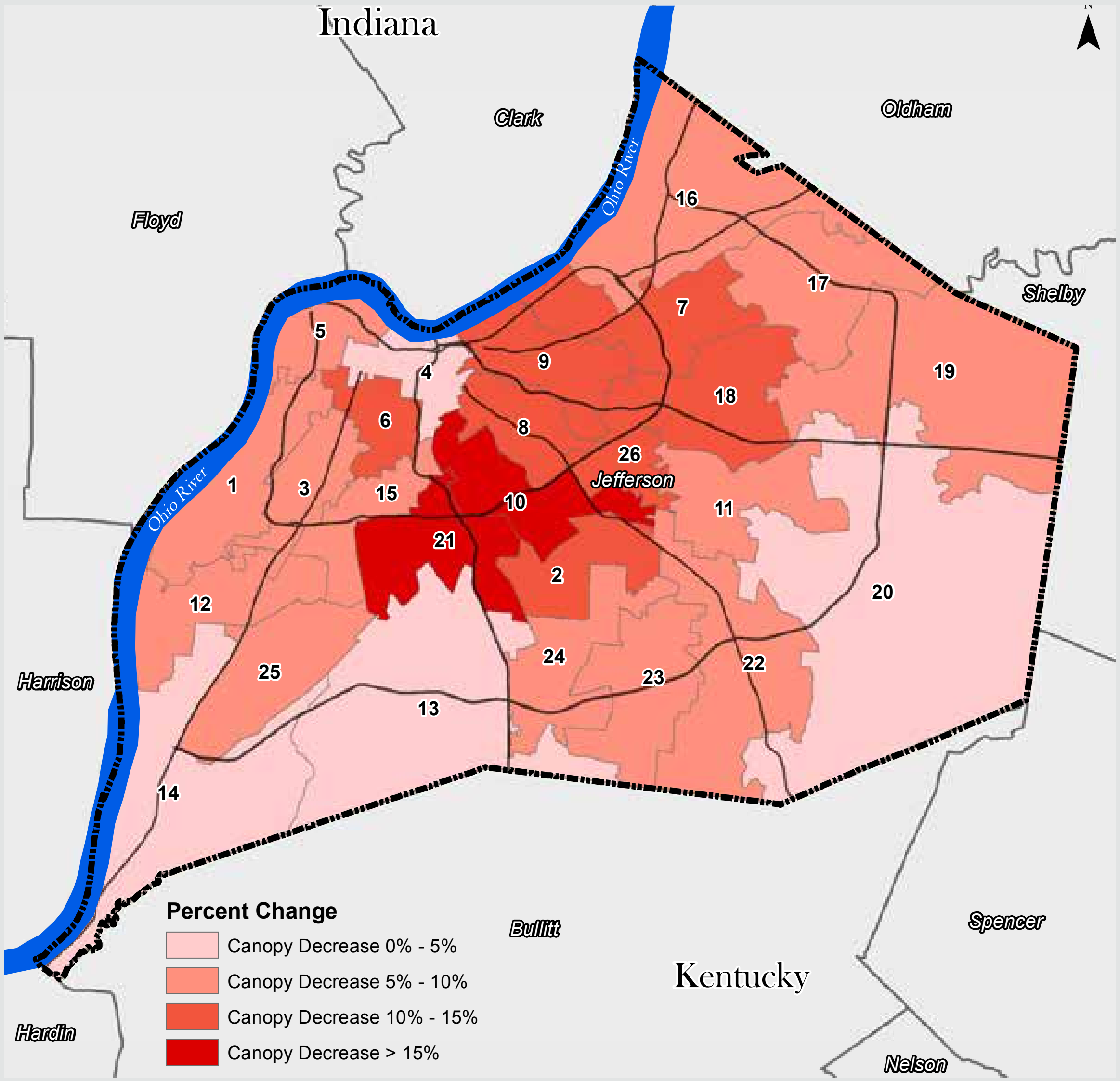
Table 3. Historic and Current UTC by Council District

	Size (Acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change
District 1	9,389	4%	30%	28%	27%	-9%
District 2	4,986	2%	26%	23%	22%	-14%
District 3	4,537	2%	23%	23%	21%	-9%
District 4	4,153	2%	13%	12%	12%	-4%
District 5	5,371	2%	25%	23%	23%	-6%
District 6	3,291	1%	20%	19%	18%	-12%
District 7	7,956	3%	45%	42%	40%	-11%
District 8	4,322	2%	45%	43%	40%	-12%
District 9	6,515	3%	37%	35%	33%	-11%
District 10	6,410	3%	30%	28%	25%	-16%
District 11	7,032	3%	34%	33%	32%	-6%
District 12	8,402	3%	31%	29%	29%	-5%
District 13	20,928	8%	50%	48%	48%	-4%
District 14	18,013	7%	47%	46%	46%	-1%
District 15	4,316	2%	33%	32%	31%	-6%
District 16	16,158	6%	43%	42%	40%	-7%
District 17	8,916	4%	39%	38%	36%	-9%
District 18	7,406	3%	31%	29%	27%	-10%
District 19	19,935	8%	43%	41%	39%	-8%
District 20	39,330	15%	53%	52%	51%	-3%
District 21	7,143	3%	19%	17%	16%	-17%
District 22	12,991	5%	38%	37%	35%	-8%
District 23	7,988	3%	37%	36%	34%	-8%
District 24	6,972	3%	31%	30%	29%	-7%
District 25	7,702	3%	48%	46%	45%	-8%
District 26	4,160	2%	28%	27%	24%	-14%

Note: Rates of change were calculated on the canopy to the nearest hundredth of a percent, then rounded to the nearest whole percentage number.

FINAL DRAFT

Figure 6. Rates of Canopy Change between 2004-2012 (shown by council district)



Every council district experienced a loss of tree canopy over the eight-year period, as shown in Figure 6. Over one-third of council districts experienced double-digit losses.

District 21 had the greatest canopy loss (a decrease of 17%) with District 14 experiencing the smallest drop of 1%.

By Suburban City

Canopy was also segmented by the 83 suburban cities (outside the old city boundary) within the study area. The canopy cover within all suburban cities combined is 31%. The ten cities with the greatest and least amount of UTC cover are listed in Table 4.

All but two of the 83 cities experienced a loss of tree canopy in the eight-year time frame. The highest loss occurred in South Park View (-55%), Cold Stream (-41%) and Watterson Park (-37%). The two cities reporting a gain in canopy were Heritage Creek (+24%) and West Beuchel (+9%). These and other data on canopy change can be see in Table 5.

A full list with detailed data for all suburban cities is available in Appendix B.

City of Shively
Image Source: Erin Thompson

Table 4. Ten Highest / Ten Lowest UTC by Suburban City

	Suburban City	Canopy %
Highest Canopy	Mockingbird Valley	70%
	Ten Broeck	69%
	Indian Hills	64%
	Glenview	60%
	Hollyvilla	57%
	Brownsboro Farm	57%
	Anchorage	57%
	Riverwood	56%
	Druid Hills	56%
	Hills and Dales	55%
Lowest Canopy	Langdon Place	23%
	Hickory Hill	22%
	Shively	22%
	Parkway Village	21%
	Lynnview	19%
	Coldstream	19%
	Sycamore	17%
	Watterson Park	15%
	Poplar Hills	13%
	West Buechel	11%

Table 5. Rates of Change in Canopy by Suburban City

LEAST Canopy Decrease	Size (Acres)	2004 Canopy	2008 Canopy	2012 Canopy	*Rate of Change*
Heritage Creek	292	19%	23%	24%	*24%*
West Buechel	412	10%	11%	11%	*9%*
Green Spring	168	50%	49%	49%	*-2%*
Murray Hill	85	47%	47%	46%	*-3%*
Prospect	2,514	41%	41%	40%	*-3%*
Hills and Dales	64	57%	56%	55%	*-3%*
Riverwood	132	58%	57%	56%	*-4%*
Hollyvilla	219	60%	59%	57%	*-5%*
Indian Hills	1,252	67%	67%	64%	*-5%*
Cambridge	35	51%	51%	48%	*-6%*

HIGHEST Canopy Decrease	Size (Acres)	2004 Canopy	2008 Canopy	2012 Canopy	*Rate of Change*
Bellemeade	180	50%	40%	36%	*-28%*
Meadow Vale	117	33%	27%	23%	*-29%*
Woodlawn Park	161	40%	35%	28%	*-30%*
Worthington Hills	158	39%	38%	28%	*-30%*
Beechwood Village	177	48%	41%	33%	*-31%*
Rolling Hills	121	33%	25%	23%	*-31%*
Richlawn	65	53%	48%	34%	*-36%*
Watterson Park	919	24%	21%	15%	*-37%*
Coldstream	141	32%	23%	19%	*-41%*
South Park View*	77	64%*	7%*	28%*	*-55%*

Note: Rates of change were calculated on the canopy to the nearest hundredth of a percent, then rounded to the nearest whole percentage number.

Using Both Percentage and Acreage

* South Park View's canopy experienced some interesting changes between 2004 and 2012, varying from 64% in 2004 to 7% in 2008 and back up to 28% in 2012 (see Table 5). This was significant change over a short period of time and warranted further examination. Land (shown in images at right) appears to have been cleared between 2004 and 2008, then left to regenerate between 2008 and 2012. The most recent images show regenerated of trees (darker green color in 2012 image) that were tall enough to be considered tree canopy (as opposed to low-lying vegetation) during classification of the 2012 imagery.

Aerial view of South Park View, 2004-2012

Large variations in canopy coverage are not uncommon when dealing with smaller areas like South Park View (77 acres), so it is important to consider acreage of canopy as well as canopy cover percent.

By Neighborhood

The 78 neighborhoods within **the old city boundaries of Louisville have a combined canopy cover of 26%.**

Generally, neighborhoods with the greatest amount of UTC are home to some of the larger parks and naturalized areas in Louisville, while neighborhoods with the least amount of UTC contain industrial and airport-related areas. Table 6 lists the five neighborhoods with the highest and lowest UTC cover, the map in Figure 7 shows neighborhood canopy rates graphically.

Table 6: Five Highest / Five Lowest UTC by Neighborhood

	Neighborhood	Canopy %
Highest	Iroquois Park	68%
	Cherokee Seneca	55%
	Cherokee Gardens	53%
	Brownsboro Zorn	51%
	Audubon Park	48%

	Neighborhood	Canopy %
Lowest	University	11%
	Phoenix Hill	11%
	Central Bus. District	8%
	Fairgrounds	6%
	Standiford	3%

Figure 7. Neighborhood Canopy

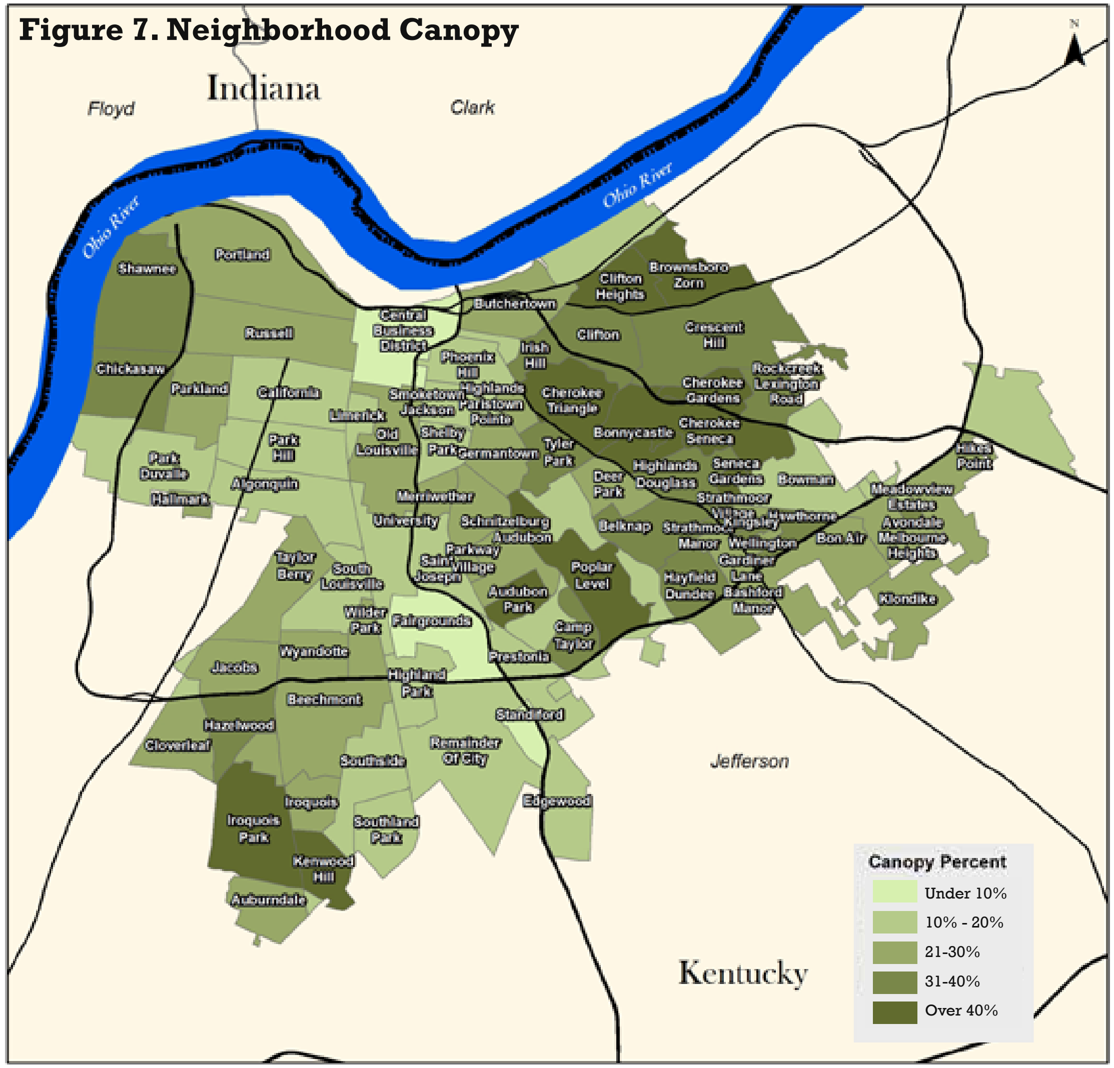
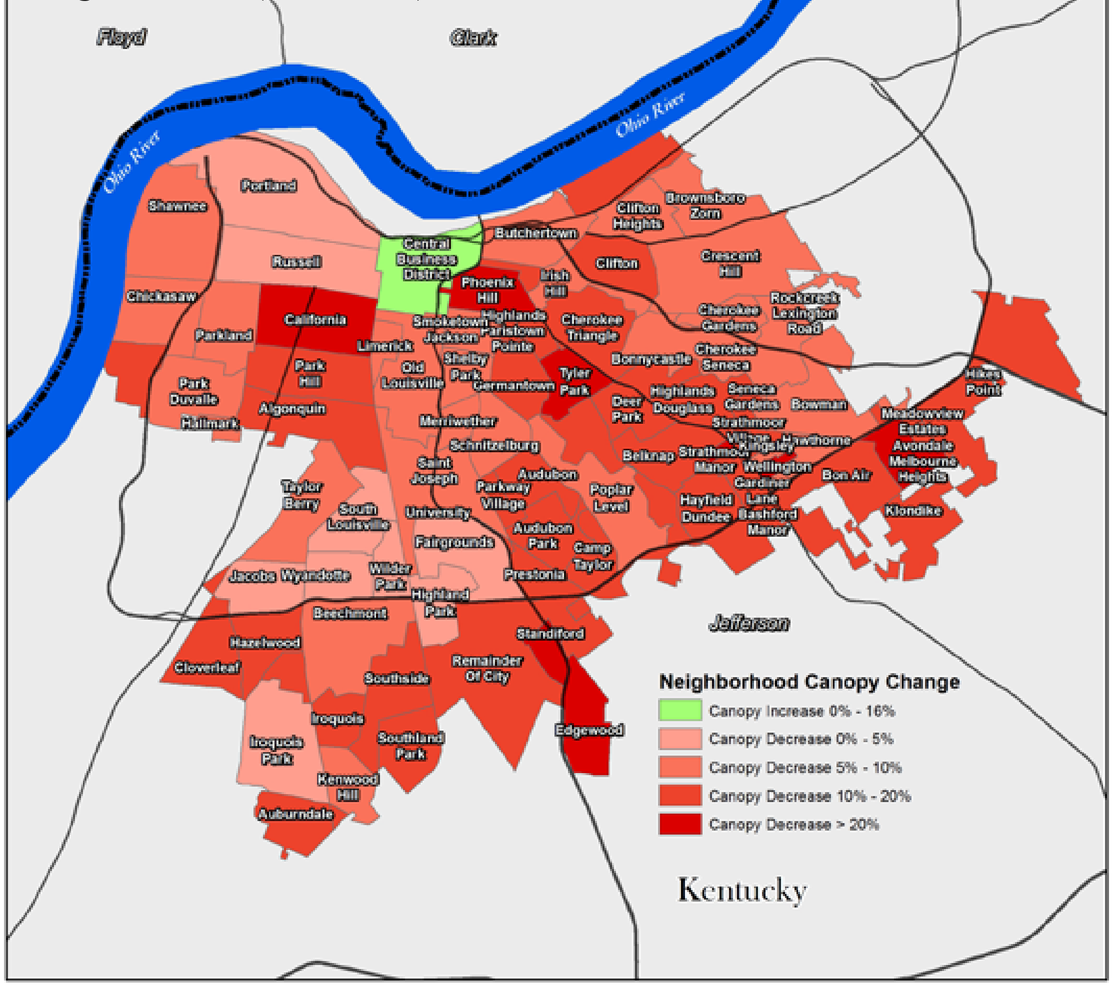


Figure 8. Rates of Change in Canopy by Neighborhood (2004-2012)



Every neighborhood experienced a decrease in tree canopy between 2004 and 2012 except for three urban core areas: the Central Business District (+16%), Russell (no change), and Fairgrounds (no change). Edgewood experienced the largest decline in UTC in the eight-year period (-51%), followed by Tyler Park (-24%). Table 7 lists the five neighborhoods with the highest and lowest change rates of UTC, while canopy change rates are shown graphically in Figure 8. A full table of canopy data for each neighborhood can be found in Appendix B.

Table 7. Rates of Change in Canopy by Neighborhood

Least Canopy Decrease	Size (Acres)	2004 Canopy	2008 Canopy	2012 Canopy
Central Bus. Dist.	758	7%	7%	8%
Russell	898	21%	20%	21%
Fairgrounds	693	6%	6%	6%
Wyandotte	348	26%	27%	25%
Wilder Park	237	30%	31%	29%

Highest Canopy Decrease	Size (Acres)	2004 Canopy	2008 Canopy	2012 Canopy
Phoenix Hill	373	14%	11%	11%
Standiford	175	4%	4%	3%
Wellington	57	32%	28%	25%
Tyler Park	329	48%	48%	37%
Edgewood	476	33%	21%	16%

Note: Rates of change were calculated on the canopy to the nearest hundredth of a percent, then rounded to the nearest whole percentage number.

FINAL DRAFT

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By Land Use

Canopy coverage was analyzed by nine basic classes of land use (as defined by the county property valuator at the parcel level): commercial, single-family residential, multi-family residential, industrial, public/ semi-public, parks, rights-of-way, farmland, and vacant land. Additionally, the net gain or loss of actual acres of canopy over the eight -year period was calculated for each land class. Resulting canopy data by each land class is shown in Table 8.

All nine land use categories experienced a drop in canopy, with a total canopy loss of over 6,500 acres from 2004 to 2012. As of 2012, the highest percentages of tree canopy

Over half of all canopy acreage lost occurred on single-family residential land.

Table 8. Change in Canopy by Land Use

Canopy %	Acreage in Study Area (as of 2012)	Percent of Study Area (as of 2012)	Canopy Cover % 2004	2008	2012	Rate of Change
Rights-of-Way	31,335	13%	22%	21%	19%	*-15%*
Industrial	17,556	7%	17%	16%	15%	*-12%*
Commercial	15,011	6%	16%	15%	15%	*-9%*
Residential – Single-Family	82,721	34%	46%	44%	42%	*-8%*
Residential – Multi-Family	7,971	3%	24%	23%	22%	*-8%*
Public / Semi-Public	17,114	7%	34%	33%	32%	*-7%*
Vacant Land	18,742	8%	63%	61%	61%	*-4%*
Parks / Open Space	25,887	11%	59%	58%	58%	*-1%*
Farmland	30,082	12%	52%	51%	51%	*-1%*
	246,418	*100%*				

Canopy Acres	Acreage in Study Area (as of 2012)	Percent of Study Area (as of 2012)	Acres of Canopy 2004	2008	2012	Change in Acres
Residential - Single Family	82,721	34%	37,795	36,402	34,500	*-3,295*
Rights-of-Way	31,335	13%	6,988	6,603	6,093	*-896*
Vacant Land	18,742	8%	11,889	11,506	11,364	*-525*
Public / Semi-Public	17,114	7%	5,896	5,617	5,418	*-478*
Industrial	17,556	7%	2,996	2,770	2,677	*-320*
Farmland	30,082	12%	15,514	15,428	15,217	*-297*
Parks & Open Space	25,887	11%	15,193	15,070	14,912	*-281*
Commercial	15,011	6%	2,466	2,311	2,195	*-271*
Residential – Multi-Family	7,971	3%	1,907	1,819	1,732	*-175*
	246,418	*100%*	*100,644*	*97,526*	*94,106*	***-6,538***

Note: Rates of change were calculated on the canopy to the nearest hundredth of a percent, then rounded to the nearest whole percentage number.

FINAL DRAFT

occurred on vacant land (61%), parks and open space (58%), and farmland (51%). Rights-of-way (19%), industrial (15%), and commercial (15%) contain the lowest tree canopy coverage percentages.

The largest and most predominant land use category in the 2012 study area, as is evident in the land use map (Figure 9), is single family residential (encompassing 34% of the entire area) with a 42% UTC (down from 46% in 2004).

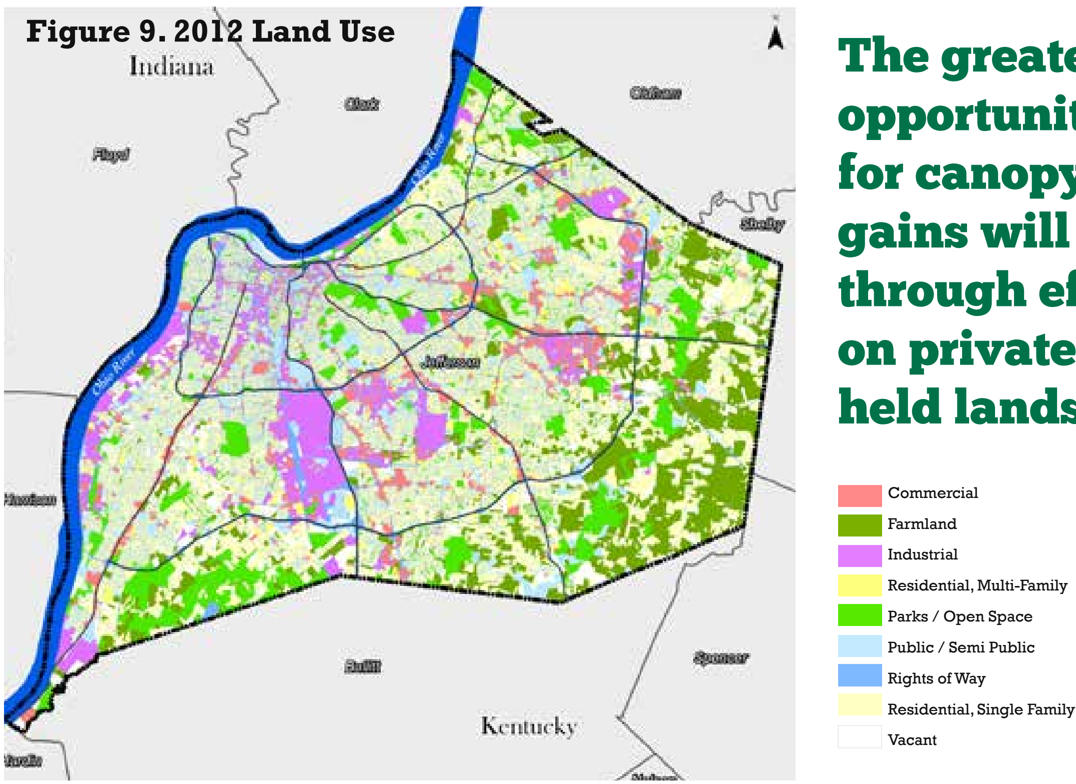
Though this category did not experience the highest percentage change compared to other categories, it accounts for over half of all acres of canopy loss (3,295 acres lost). Because trees in residential areas provide the greatest direct benefits to people in terms of energy conservation, human health, and property value, the reason for canopy loss - whether from land development and/or the decline of mature trees due to pests or lack of proper maintenance - is significant and warrants further investigation.

The land use category that experienced the most significant change *rate* was rights-of-way with a drop of 15% over time, from 22% in 2004 to 19% in 2012, equaling a loss of 896 acres of canopy. This tree loss occurred primarily on both residential streets and state routes, as interstate rights-of-way comprise a lower proportion of the total rights-of-way acreage.

Commercial and industrial categories reported the lowest 2012 tree canopy coverage (15%). Current research has demonstrated that business districts are more successful with tree canopies (detailed in the Why Trees section).

Based on canopy acres, publicly controlled land (public/semi public, rights-of-way and parks/open space land uses) comprises 31% of all land and makes up 28% of Louisville's total canopy, while privately owned land comprises 69% of all land use and carries the remaining 72% of canopy cover. So while significant improvement to Louisville's tree cover can be made by planting on public property, the greatest opportunities for substantial and long-term canopy gains will come through efforts on privately-held lands.

Figure 9. 2012 Land Use



The greatest opportunities for canopy gains will come through efforts on privately-held lands.

Special Project Area: SoBro

For the UTC assessment, the South Broadway (or SoBro) District was designated as an "area of interest" due to ongoing revitalization efforts, separate from any existing neighborhood boundary, and thus received a separate, basic canopy analysis.

Tree canopy and related data were examined to aid in the community's ongoing efforts to revitalize this 225-acre area between downtown Louisville and the University of Louisville and Churchill Downs. A land cover aerial map of the area can be seen in Figure 10.

SoBro has a UTC of 9% overall (21 acres of canopy), as seen in Table 9. Canopy and other land covers have not changed since 2004, except for a slight change in 2008 between low-lying vegetation and bare soil for a few years, likely from a construction-related project.

Table 9. SoBro Land Cover Changes

	Year 2004	Year 2008	Year 2012	Rate of Change
Tree Canopy	9%	9%	9%	0%
Buildings, Sidewalks, Roads, etc. *("Impervious")*	80%	80%	80%	0%
Grass/Low-Lying Vegetation *("Other Pervious")*	10%	8%	10%	0%
Bare Soil	0%	2%	0%	0%
Water	0%	0%	0%	0%

Figure 10. SoBro Land Cover Map

(as seen from UTC Webviewer)

FINAL DRAFT

Canopy & Socioeconomics

Are there correlations between Louisville residents and their canopy cover? Analysis of multiple socioeconomic factors and tree canopy can provide answers, identify trends and priority areas, and provide direction for establishing planting goals.

Canopy coverage at the census tract and council district levels (191 tracts, 26 districts) was analyzed by socioeconomic and demographic data collected from the U.S. Census (2006-2010 American Community Survey 5-Year Estimates). Highlights of findings are listed below with data charts available in Appendix B.

Socioeconomic Trends:

Canopy is higher in wealthier areas. Higher income areas have as much as twice the canopy coverage as lower income tracts.

Canopy decreases as population density increases. The percentage of canopy coverage decreases as population density (number of people per square mile) increases. Dense urban areas are made up of primarily impervious surfaces, which leave little room for large amounts of canopy.

Canopy is higher in areas with higher percentages of older residents (ages 45 and older). Canopy was found to increase as the percentage of the population over 45 increased, especially within the age group 45-64. When mapping the census tracts with higher densities of this age group, these groups tended to live in the outer areas of Louisville, along with a smaller concentration along the inner loop closer to the downtown area.

Canopy tends to be lower in areas dominated by rental properties, and higher in areas with majority owner-occupied houses. Higher tree canopy is strongly correlated with home ownership. This relationship is likely attributed to a number of factors: owner-occupied properties often include greater amount of green space than would typically be found in higher density rental housing such as apartments and townhomes. Homeowners also have more of a financial investment in their properties and neighborhoods, are less transient than renters, and therefore are more likely to plant and care for trees on their property and would desire tree-lined streets.

Canopy is higher in areas with higher educated residents. Canopy was found to increase as the population with college education increased, and canopy decreased as the population with high school diplomas or less increased.

Canopy is higher in areas dominated by high-value homes. Canopy was found to increase overall as the percentage of homes valued over $100,000 increased, though the increases are less pronounced with homes valued at $100,000-$500,000 and more pronounced with homes valued over $500,000. As the percentage of homes valued under $100,000 increases in an area, the canopy decreases by almost half.

Canopy potential increases as the concentration of newer homes increase. Canopy was found to decrease in only those structures built before 1950. Older structures concentrated around the older city center of Louisville are, in general, more urban with less space for tree canopy. Newer homes built after 1950 tended to be located in the outer suburbs with more space for canopy.

FINAL DRAFT

CANOPY & THE URBAN HEAT ISLAND

2015 Louisville Urban Tree Canopy Assessment

As discussed in the Challenges section, Louisville has directed efforts toward reducing its growing urban heat island through tree canopy. Trees are considered one of the most cost-effective, long-term solutions to mitigating heat islands.

Heat reductions can be achieved by strategically locating tree planting sites, but the first step is to identify hot spots within Louisville.

Based on surface temperature data, it was determined that 12% (approximately 31,000 acres) of Louisville is heat-stressed, or classified as "hot spots" (over 94.5°F, as explained further in the Two Methods to Identify Hot Spots section on opposite page).

As expected, the vast majority of hot spots were areas with large amounts of impervious surface and low amounts of tree canopy. Tree canopy made up only 8% of the land cover in designated hot spots, while impervious and bare soil covered a combined 66%. The hot spots maps (opposite page) clearly show a concentration within the urban core of Louisville, from the downtown area to the airport.

Data (size, land cover, canopy) on hot spots have been made available electronically at the census tract, council district, neighborhood, suburban city, sewershed and parcel levels. This data was also used in the prioritization of planting areas, discussed in the Planting Plan Development section of this report.

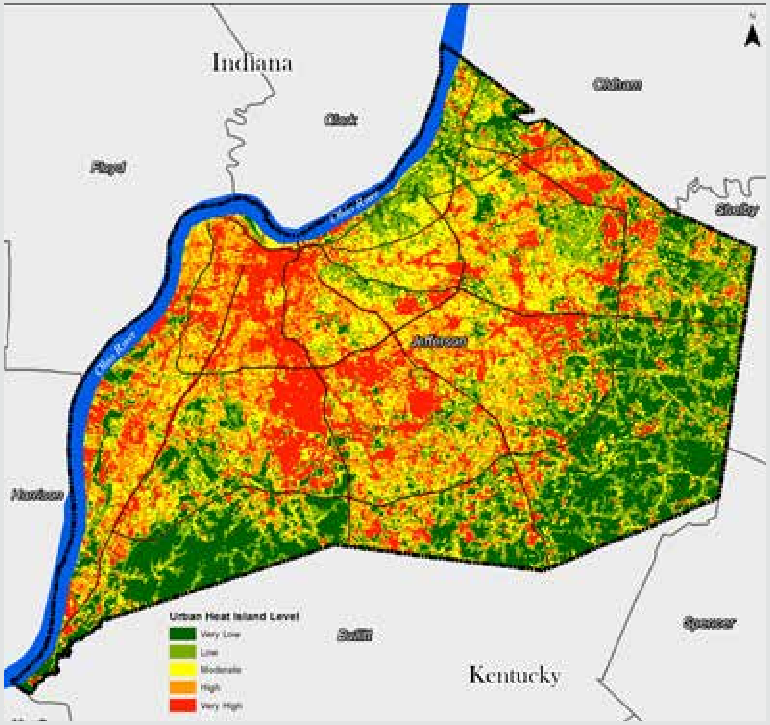
Louisville has 31,000 acres (12% of study area) classified as heat stressed, or "hot spots." Combined, hot spots have 8% tree canopy and 66% impervious and bare soil cover.

FINAL DRAFT

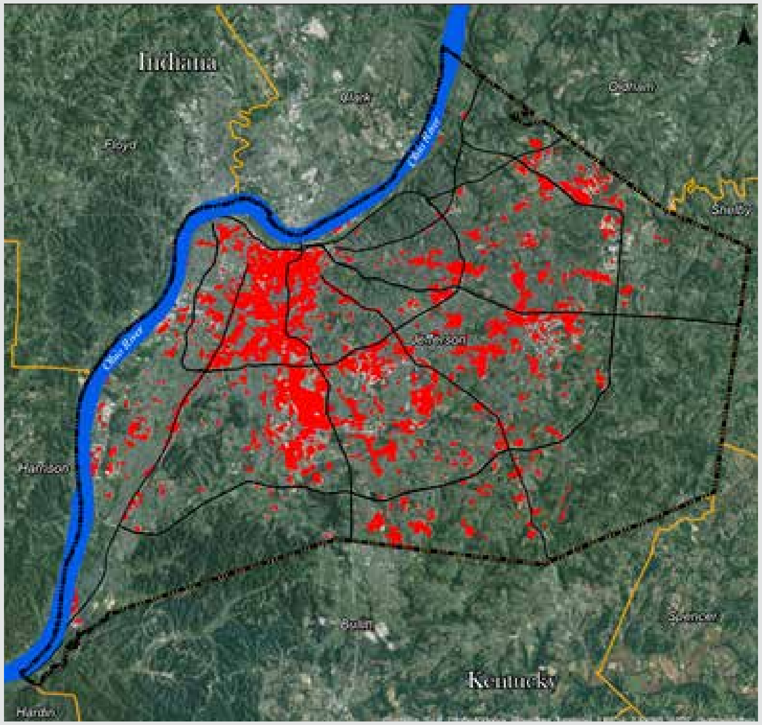
Two Methods to Identify Hot Spots

UTC assessments can *predict* hot spots based on a ratio of impervious surfaces to tree canopy. Hot spot ratios in 100x100 meter grids are graphically depicted in the Impervious to Canopy Ratio map (below left). However, Louisville has partnered with Georgia Institute of Technology in a comprehensive study of Louisville's heat island and potential mitigation efforts, (expected completion in summer 2015). This study acquired actual surface temperature readings from Landsat 5 satellite imagery to identify *actual* hot spots - simultaneous temperature readings allowing identification and segmentation of *relatively* hot areas. Readings were taking at one point in time on one cloudless summer day in July 2010. Temperature findings ranged from 58°F - 125°F. For the purposes of this study, areas with the highest temperature range (above 94.5°F) were designated as *hot spots*. These areas are shown in red in the Surface Temperature map (below right). Although both methods were used in this assessment, this report utilizes results from the surface temperature data method.

Method 1: Impervious to Canopy Ratio



Method 2: Surface Temperature



FINAL DRAFT

By Land Use

The hottest land use categories were found to be commercial, multi-family residential, and industrial. Half of all commercial land was located in hot spot areas, along with 40% of multi-family residential land and 39% of industrial land. Together, these three categories accounted for almost 20,000 acres of heat stressed areas, or 63% of all hot spots in Louisville, as shown in the Table 10.

Despite the fact that single-family residential land use is the largest use of land in Louisville, covering 34% (approximately 83,000 acres) of the study area, it makes up only 13% (4,000 acres) of hot spot areas.

These numbers suggest that localized urban heat island effect (defined as surface temperature differential only, not as human vulnerability) may not be significantly abated by residential plantings alone. The data do show that commercial districts perform better when surrounded by trees and landscaping (as mentioned in the Why Trees section). Further analysis is required to assess actual population vulnerability to heat, especially at the neighborhood level, but reducing temperature differentials county-wide may be achieved in a shorter time by accelerating tree planting in commercial and multi-family areas.

Commercial, multi-family residential and industrial land make up 63% of all hot spots.

Table 10. Hot Spots by Land Use

	Size *(acres)*	Hot Spot Acres	% Hot Spot in Land Use	Avg. Temp *(F) in* Hot Spots	Hot Spot Land Cover: Canopy	Veg.	Impervious / Bare Soil
Commercial	15,011	**7,448**	50%	94°	5%	17%	77%
Industrial	17,556	**6,838**	39%	92°	2%	20%	77%
Rights-of-way	31,335	**5,359**	17%	90°	7%	25%	68%
Residential: Single Family	82,721	**4,074**	5%	88°	18%	48%	34%
Public/Semi-Public	17,114	**3,238**	19%	89°	7%	26%	67%
Residential: Multi-Family	7,971	**3,171**	40%	93°	12%	33%	54%
Vacant	18,742	**422**	2%	84°	15%	44%	38%
Parks/Open Space	25,887	**292**	1%	83°	13%	55%	31%
Farmland	30,082	**123**	0%	83°	7%	57%	35%
Totals	***246,418***	***30,966***	***12%***				

FINAL DRAFT

By Suburban City

Hot spots were identified in just over half of the 83 suburban cities within Louisville, totaling a combined area of approximately 5,800 acres.

More than 40% of Watterson Park, West Buechel, Forest Hills, Parkway Village, and Hurstbourne Acres are classified as hot spots.

Jeffersontown and St. Matthews topped the list of large hot spot acreage with 1,836 acres and 873 acres, respectively.

Table 11 lists the twenty suburban cities with the largest hot spot areas. Comprehensive hot spot data has been made available electronically.

Table 11. Top 20 Suburban Cities with the Largest Amount of Hot Spots

	Size *(acres)*	Hot Spot Acres	% Hot Spots	Avg. Temp *(F)* of Hot Spots	Hot Spot Land Cover		
					Canopy	Veg.	Impervious / Bare Soil
Jeffersontown	6,372	**1,836**	29%	92°	10%	28%	61%
St. Matthews	2,771	**873**	31%	93°	10%	19%	71%
Shively	2,953	**776**	26%	92°	9%	24%	67%
Middletown	3,264	**479**	15%	89°	8%	26%	65%
Watterson Park	919	**432**	47%	93°	7%	21%	72%
Lyndon	2,317	**344**	15%	90°	9%	26%	65%
West Buechel	412	**174**	42%	94°	6%	19%	75%
Hurstbourne	1,146	**152**	13%	91°	11%	23%	66%
Heritage Creek	292	**114**	39%	91°	2%	64%	34%
Douglass Hills	845	**96**	11%	91°	16%	28%	55%
Forest Hills	175	**89**	51%	95°	11%	17%	72%
Hurstbourne Acres	211	**83**	40%	94°	15%	26%	60%
Graymoor/Devondale	472	**78**	17%	89°	10%	33%	57%
Blue Ridge Manor	117	**35**	30%	93°	13%	21%	66%
Windy Hills	567	**30**	5%	89°	15%	22%	63%
Meadow Vale	117	**25**	22%	91°	0%	6%	93%
Prospect	2,514	**25**	1%	85°	4%	14%	82%
Parkway Village	56	**24**	43%	94°	12%	32%	55%
Rolling Hills	121	**24**	20%	92°	6%	17%	77%
Coldstream	141	**14**	10%	91°	6%	56%	38%

FINAL DRAFT

By Council Districts

Comparing acreage of council district hot spots (shown in Table 12), Districts 13, 21, and 4 produce the largest hot spots, with a combined total of 8,100 acres or 26% of all Louisville hot spots. These three districts have impervious and bare soil land cover percentages in the 70's.

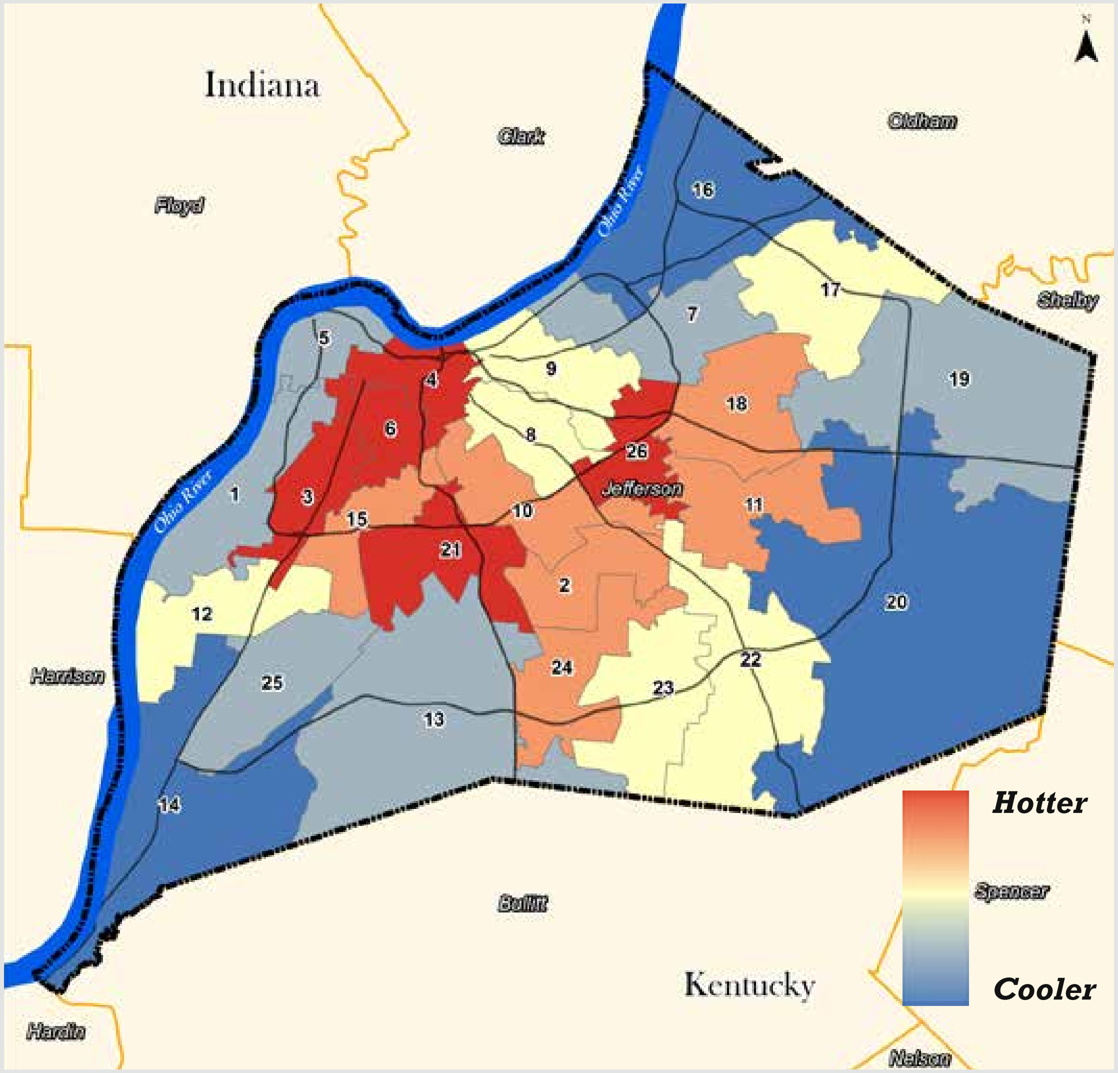
Districts 4 and 6 in the old city boundary report the largest percentage of the district as hot spots.

Table 12. Council District Hot Spots

	Size *(acres)*	Hot Spot Acres	Hot Spots as % of District	Avg. Temp *(F)* of Hot Spots	Hot Spot Land Cover Canopy	Veg.	Impervious / Bare Soil
District 13	20,928	**2,880**	14%	86°	3%	26%	70%
District 21	7,143	**2,871**	40%	94°	4%	24%	73%
District 4	4,153	**2,348**	57%	92°	11%	17%	72%
District 6	3,291	**1,891**	57%	95°	10%	20%	70%
District 10	6,410	**1,758**	27%	91.6°	9%	23%	69%
District 11	7,032	**1,570**	22%	91°	12%	31%	57%
District 15	4,316	**1,562**	36%	91.6°	12%	25%	62%
District 3	4,537	**1,519**	33%	93°	9%	24%	67%
District 18	7,406	**1,416**	19%	91°	10%	25%	65%
District 24	6,972	**1,251**	18%	91°	6%	27%	66%
District 22	12,991	**1,194**	9%	88°	7%	47%	46%
District 2	4,986	**1,176**	24%	91.8°	7%	30%	63%
District 20	39,330	**1,163**	3%	84°	7%	42%	52%
District 17	8,916	**1,159**	13%	89°	5%	23%	72%
District 26	4,160	**1,026**	25%	92°	11%	22%	68%
District 12	8,402	**934**	11%	88°	5%	33%	61%
District 19	19,935	**805**	4%	86°	8%	27%	65%
District 23	7,988	**674**	8%	88°	8%	47%	45%
District 1	9,389	**674**	7%	87°	4%	29%	66%
District 9	6,515	**616**	9%	89°	10%	18%	72%
District 5	5,371	**503**	9%	86°	13%	22%	66%
District 16	16,158	**472**	3%	84°	6%	36%	58%
District 8	4,322	**451**	10%	90°	16%	22%	62%
District 7	7,956	**413**	5%	87°	9%	27%	64%
District 25	7,702	**327**	4%	86°	4%	28%	68%
District 14	18,013	**312**	2%	83°	3%	23%	71%
Totals	*254,322*	*30,965*	*12%*				

FINAL DRAFT

Figure 11. Average Surface Temperature by Council District



When looking at the average temperatures (shown in Figure 11), Districts 3, 4, 6, 21, and 26 reported the highest temperatures (above 92°F, highlighted in dark red in the map). As a point of comparison, at the exact same day and time, Districts 14, 16, and 20 reported temperatures of 83-84°F.

The hottest districts are located in the old city boundary as well as around the industrial corridors and highways, specifically along I-264, I-65 and Dixie Highway / U.S. Highway 31W.

FINAL DRAFT

By Neighborhoods

Comparing acreage of neighborhood hot spots, Central Business District, Algonquin, and Fairgrounds each show more than 70% of their areas as heat stressed. These neighborhoods have impervious land cover around 80% and tree canopy of 7% or less.

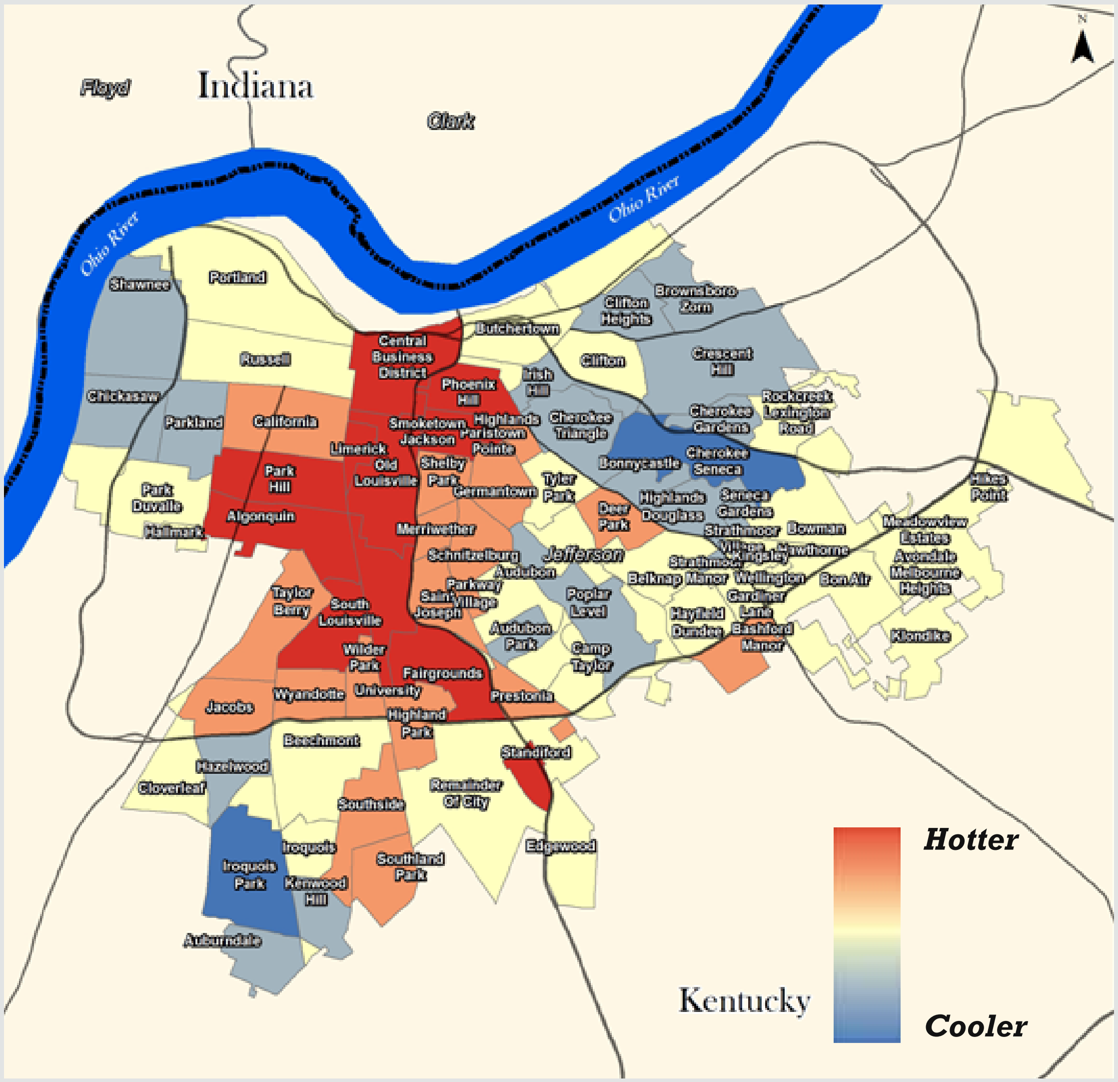
Table 13 shows the twenty neighborhoods with the largest hot spots. A full table of neighborhood hot spot data has been delivered electronically.

Table 13. Top 20 Neighborhoods with Largest Hot Spots

	Size *(acres)*	Hot Spot Acres	% Hot Spots	Avg. Temp *(F)* of Hot Spots	Hot Spot Land Cover		
					Canopy	Veg.	Impervious / Bare Soil
Central Bus.Dist.	758	**587**	77%	97°	7%	9%	84%
Algonquin	763	**539**	71%	96°	7%	22%	71%
Fairgrounds	693	**496**	72%	97°	4%	17%	79%
Old Louisville	767	**452**	59%	95°	13%	16%	71%
University	522	**446**	85%	97°	8%	21%	71%
Park Hill	643	**430**	67%	96°	8%	23%	69%
South Louisville	496	**383**	77%	96°	12%	23%	65%
California	787	**357**	45%	94°	6%	19%	76%
Phoenix Hill	373	**352**	94%	98°	10%	17%	73%
Southside	589	**275**	47%	94°	6%	21%	73%
Schnitzelburg	371	**211**	57%	94°	17%	32%	52%
Saint Joseph	387	**209**	54%	94°	16%	28%	56%
Wyandotte	348	**208**	60%	94°	22%	32%	47%
Smoketown Jackson	253	**203**	80%	96°	13%	21%	66%
Highland Park	375	**181**	48%	94°	4%	41%	55%
Shelby Park	260	**156**	60%	95°	13%	19%	68%
Standiford	175	**135**	77%	97°	2%	33%	65%
Limerick	145	**108**	74%	96°	12%	23%	65%
Highlands	117	**53**	45%	94°	17%	19%	64%
Paristown Pointe	43	**35**	81%	96°	12%	19%	69%

FINAL DRAFT

Figure 12. Average Surface Temperature by Neighborhood



Average temperature by neighborhood is shown in Figure 12.

The hottest neighborhoods are clustered along an interstate corridor from the urban center to the airport.

Central Business District, Fairgrounds, University, Phoenix Hill, and Standiford reported the highest average temperatures of 97-98°F (highlighted in dark red in the map). At the exact same day and time, Cherokee Gardens, Cherokee Seneca, and Iroquois Park reported temperatures of 83-85°F.

CANOPY & STORMWATER

2015 **Louisville Urban Tree Canopy Assessment**

Louisville trees intercept an impressive 18.8 billion gallons of the 72.4 billion gallons of stormwater runoff generated each year.

Tree canopy is a proven and viable solution to stormwater issues plaguing many cities across the country, including Louisville. Identifying priority locations for stormwater management and identifying canopy trends in those locations are critical to mitigation efforts.

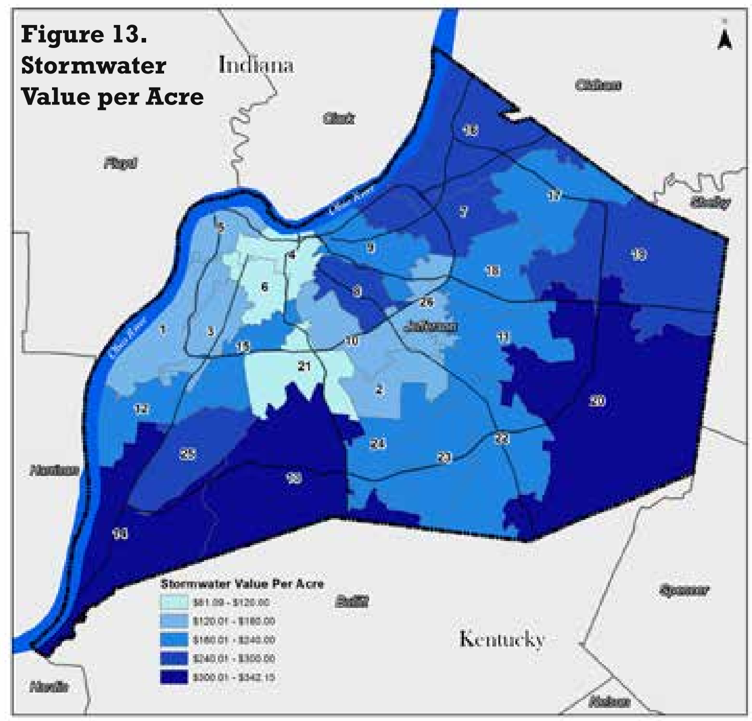
Metropolitan Sewer District's (MSD) stormwater system is located primarily in the old city boundary of Louisville. However, Louisville's trees manage stormwater across the study area. For this reason, canopy was segmented by both the urban sewersheds and across the study area by council district to quantity benefits and identify problem areas and places for potential tree plantings as green infrastructure solutions. This data was also used in the prioritization of planting areas, discussed in the Planting Plan Development section of this report.

By Council District

The amount of stormwater runoff per council district is directly related to the size of the district. Similarly, the amount of runoff intercepted by tree canopy is directly related to the acres of existing tree canopy per district.

It can then be expected that the larger outer districts (13, 14, 20) top the list of highest value per acre of stormwater management because of high UTCs (as seen in Figure 13 and Table 14). However one district close to the urban core, District 8, makes the top five list of highest benefits per acre despite its smaller size, thanks to its 40% canopy coverage. Note the effects of higher canopy cover percentages on stormwater in Table 14.

Figure 13. Stormwater Value per Acre



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DAVEY RESOURCE GROUP
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Table 14. Stormwater by Council District

	Size (acres)	Canopy (2012)	Canopy Acres	Impervious (2012)	Impervious Acres	Stormwater Runoff Volume Annually (gal)	Reduction by Existing Canopy (gal)	Value of Canopy Reduction	Value per Acre
District 20	39,330	51%	20,206	7%	2,568	11,197,418,696	4,028,965,127	$13,456,744	**$342**
District 13	20,928	48%	9,979	19%	3,990	5,958,397,841	1,989,815,876	$6,645,985	**$318**
District 14	18,013	46%	8,315	11%	1,970	5,128,512,247	1,657,891,089	$5,537,356	**$307**
District 25	7,702	45%	3,448	20%	1,559	2,192,723,572	687,575,820	$2,296,503	**$298**
District 8	4,322	40%	1,723	30%	1,283	1,230,585,045	343,591,415	$1,147,595	**$266**
District 16	16,158	40%	6,428	14%	2,203	4,600,265,859	1,281,678,562	$4,280,806	**$265**
District 7	7,956	40%	3,147	22%	1,782	2,265,023,946	627,496,537	$2,095,838	**$263**
District 19	19,935	39%	7,852	15%	2,948	5,675,679,060	1,565,567,728	$5,228,996	**$262**
District 17	8,916	36%	3,198	27%	2,404	2,538,383,141	637,595,194	$2,129,568	**$239**
District 22	12,991	35%	4,587	14%	1,819	3,698,664,701	914,587,930	$3,054,724	**$235**
District 23	7,988	34%	2,750	19%	1,491	2,274,254,121	548,372,021	$1,831,563	**$229**
District 9	6,515	33%	2,126	30%	1,952	1,854,782,621	423,924,892	$1,415,909	**$217**
District 11	7,032	32%	2,221	33%	2,328	2,002,151,351	442,786,238	$1,478,906	**$210**
District 15	4,316	31%	1,317	38%	1,656	1,228,764,872	262,545,484	$876,902	**$203**
District 12	8,402	29%	2,442	24%	2,035	2,392,204,192	486,976,715	$1,626,502	**$194**
District 24	6,972	29%	1,995	30%	2,072	1,984,912,216	397,738,078	$1,328,445	**$191**
District 18	7,406	27%	2,034	33%	2,443	2,108,415,234	405,529,520	$1,354,469	**$183**
District 1	9,389	27%	2,526	26%	2,462	2,673,004,083	503,665,733	$1,682,244	**$179**
District 10	6,410	25%	1,603	41%	2,659	1,825,069,630	319,642,574	$1,067,606	**$167**
District 26	4,160	24%	1,013	41%	1,708	1,184,351,961	202,009,584	$674,712	**$162**
District 5	5,371	23%	1,254	25%	1,350	1,529,076,719	249,976,802	$834,923	**$155**
District 2	4,986	22%	1,097	36%	1,777	1,419,618,463	218,645,662	$730,277	**$146**
District 3	4,537	21%	940	43%	1,959	1,291,615,984	187,362,341	$625,790	**$138**
District 6	3,291	18%	583	58%	1,903	936,920,358	116,207,196	$388,132	**$118**
District 21	7,143	16%	1,108	49%	3,497	2,033,646,152	220,879,597	$737,738	**$103**
District 4	4,153	12%	506	53%	2,210	1,182,243,632	100,820,560	$336,741	**$81**
Totals	*254,322*					*72,406,685,697*	*18,821,848,275*	*$62,864,974*	*$247*

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By Sewershed

MSD divides its stormwater system into 101 sewersheds, which are located in the urban core of Louisville (see Figure 14).

Based on stormwater data provided by MSD, along with a list sewersheds with flooding and drainage problems, canopy and other relevant data was analyzed to identify trends and areas of opportunity for green infrastructure efforts.

MSD's priority sewersheds span across parts of the Limerick, Smoketown Jackson, Shelby Park, Germantown, Irish Hill, Phoenix Hill, Highlands, Deer Park, Clifton Heights, and Clifton neighborhoods. Canopy data on these sewersheds can be seen in Table 15. A full-page map showing the overlay of priority sewersheds and neighborhood boundaries can be found in Appendix B.

Overall, UTC has decreased in all ten priority sewersheds since 2004, with losses ranging from 3% to 35%. Based on this trend, flooding and drainage problems are not likely to improve without additional canopy.

The data suggests that even modest increases in canopy cover in these priority sewersheds should result in significant reductions in runoff volume and treatment costs. CSO #154 has 35 acres of UTC that intercept over 1 million gallons of runoff for an annual benefit of $3,700. CSO #153 has just 6 acres more UTC, but those extra 6 acres result in the area being able to intercept double the amount of runoff and more than double the annual value to MSD. These sewersheds have equal impervious surface percentages, so tree canopy is a significant factor in stormwater management in these sewersheds.

This stormwater issue is one of the three factors used to prioritize the planting plan, discussed later in this report.

Table 15. MSD Priority Sewersheds

	Sewershed Data				Reduced by Canopy				Canopy Change Over Time			
	MSD Priority	Acres	Impervious Surface % (2012)	Annuals Stormwater Runoff (gal)	Gallons Reduced	% of CSO Runoff	Value of Reduction*	Value / Acre	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change
CSO #141	**1**	9	75%	2,498,591	183,740	7%	$614	$70	11%	11%	10%	-3%
CSO #82	**2**	13	37%	3,676,084	913,135	25%	$3,050	$236	37%	39%	35%	-5%
CSO #120	**3**	15	68%	4,391,465	367,923	8%	$1,229	$80	16%	16%	12%	-24%
CSO #154	**4**	35	47%	9,890,546	1,117,214	11%	$3,731	$107	18%	20%	16%	-8%
CSO #153	**5**	41	47%	11,723,744	2,337,354	20%	$7,807	$190	31%	30%	28%	-8%
CSO #106	**6**	10	29%	2,809,023	842,860	30%	$2,815	$285	66%	66%	43%	-35%
CSO #137	**7**	72	25%	20,545,401	3,239,408	16%	$10,820	$150	27%	26%	23%	-16%
CSO #83	**8**	30	58%	8,680,070	1,346,655	16%	$4,498	$148	25%	25%	22%	-11%
CSO #119	**9**	4	74%	1,271,412	95,145	7%	$318	$71	12%	12%	11%	-13%
CSO #179	**10**	223	64%	63,562,886	7,328,571	12%	$24,477	$110	17%	18%	16%	-4%
	Totals:	*453*		*129,049,222*	*17,772,005*	*14%*	*$59,359*	*$131*				

** Based on the $3.34 determined by MSD as the cost to treat 1 gallon of runoff.*

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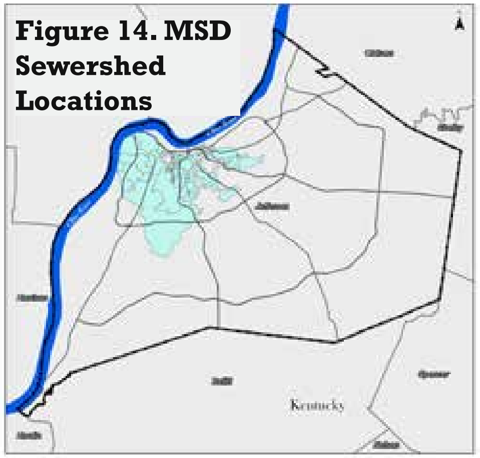

Figure 14. MSD Sewershed Locations

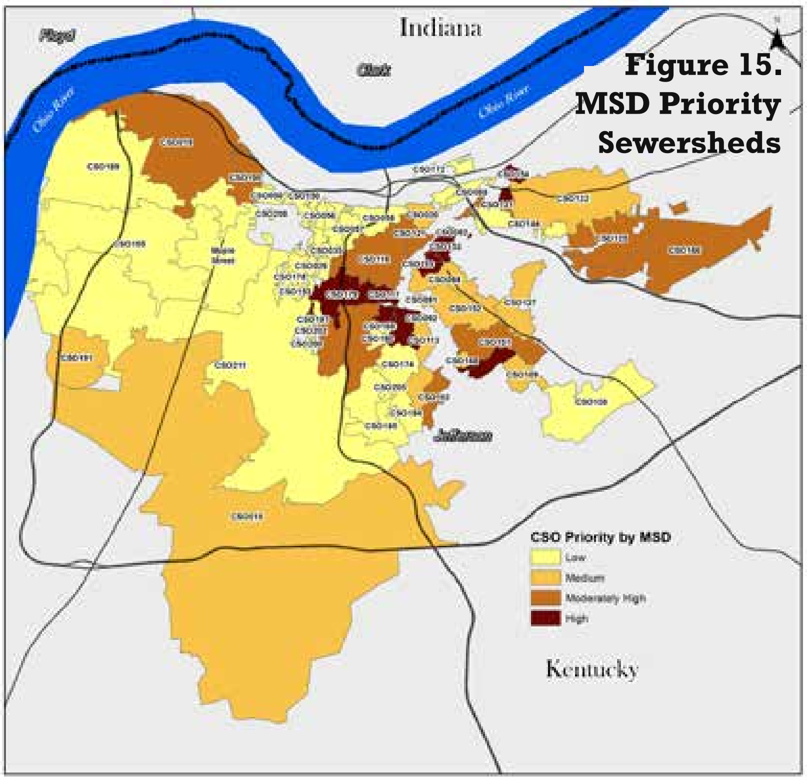

Figure 15. MSD Priority Sewersheds

Table 16. Rates of Change in Canopy by Sewershed

HIGHEST Increase in Canopy	Size (acres)	Canopy Cover % 2004	Canopy Cover % 2008	Canopy Cover % 2012	Rate of Change
CSO #172	10	2%	9%	8%	247%
CSO #54	4	5%	11%	13%	171%
CSO #55	16	2%	3%	5%	161%
CSO #56	36	2%	3%	4%	155%
CSO #38	9	2%	4%	4%	136%
CSO #35	16	1%	3%	3%	110%
CSO #181	42	2%	3%	4%	77%
CSO #51	6	5%	6%	8%	70%
CSO #22	63	3%	3%	4%	57%
CSO #150	2	13%	15%	19%	42%

HIGHEST Decrease in Canopy	Size (acres)	Canopy Cover % 2004	Canopy Cover % 2008	Canopy Cover % 2012	Rate of Change
CSO #27	9	2%	1%	1%	-44%
CSO #106	10	66%	66%	43%	-35%
CSO #58	121	10%	8%	7%	-31%
CSO #16	4	33%	35%	24%	-27%
CSO #126	37	59%	51%	44%	-26%
CSO #120	15	16%	16%	12%	-24%
CSO #187	6	19%	19%	15%	-23%
CSO #104	69	36%	32%	28%	-23%
CSO #148	26	54%	54%	42%	-22%
CSO #121	102	13%	10%	10%	-21%

Note: Canopy percentages have been rounded to nearest whole number. Rates of change were calculated on the exact canopy number xx.xx%, then rounded to the nearest whole number.

CANOPY & ECOSYSTEM HEALTH

2015 Louisville Urban Tree Canopy Assessment

The urban ecosystem is extremely complex and diverse; existing in a multitude of layers formed by small, functional ecosystems that together form a larger system. The overall health of the ecosystem depends on the ability of the trees, plants, wildlife, insects, and humans to interact. This crucial interaction of species requires connected forests, or greenspace corridors.

Urban development and sprawl not only decrease canopy, but often carve up connected forests into fragmented sections (shown in Figure 16), prohibiting wildlife interaction, and leading to further ecosystem degradation. This, in turn, leads to a decline in habitat quality and results in imbalance to microclimates, an increased risk and susceptibility to invasive species, and a loss of regional air quality.

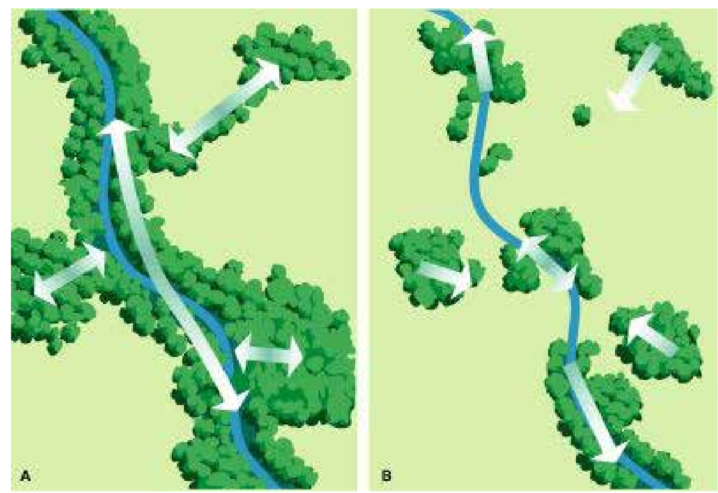

Figure 16. Wildlife corridors in area (A) link habitats while fragmented forests in area (B) lead to a decline in habitat quality. *Image Source: Federal Interagency Stream Restoration Group*

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Louisville's existing canopy was analyzed for this fragmentation, focusing on how and to what degree tree canopy is spatially distributed and/or fragmented. The findings are detailed at right.

In terms of forest health and ecosystem integrity, a significant portion of Louisville's canopy is serving as a functioning forested ecosystem (core canopy). However, one fourth of the canopy is severely fragmented.

Improvements can be made by creating linkages between patches of forest. Linking patch canopy areas through tree planting to create more edge and core areas will increase the recreational and ecosystem benefits of natural woodlands and greenways.

Forest Fragmentation Findings

Core Canopy (35,139 acres)
Tree canopy that exists within and relatively far from the forest/non-forest boundary (i.e., forested areas surrounded by more forested areas). These are the largest areas of contiguous canopy and function as native habitat. This category makes up 37% of Louisville's total canopy.

Edge Canopy (28,396 acres)
Tree canopy that defines the boundary between core forests and large non-forested land cover features. When large enough, edge canopy may appear to be unassociated with core forests. This category makes up 30% of Louisville's total canopy.

Patch Canopy (23,606 acres)
Tree canopy that comprises a small forested area that is surrounded by non-forested land cover. This category makes up 25% of Louisville's total canopy.

Perforated Canopy (7,146 acres)
Tree canopy that defines the boundary between core forests and relatively small clearings (perforations) within the forest landscape. This category makes up 8% of Louisville's total canopy.

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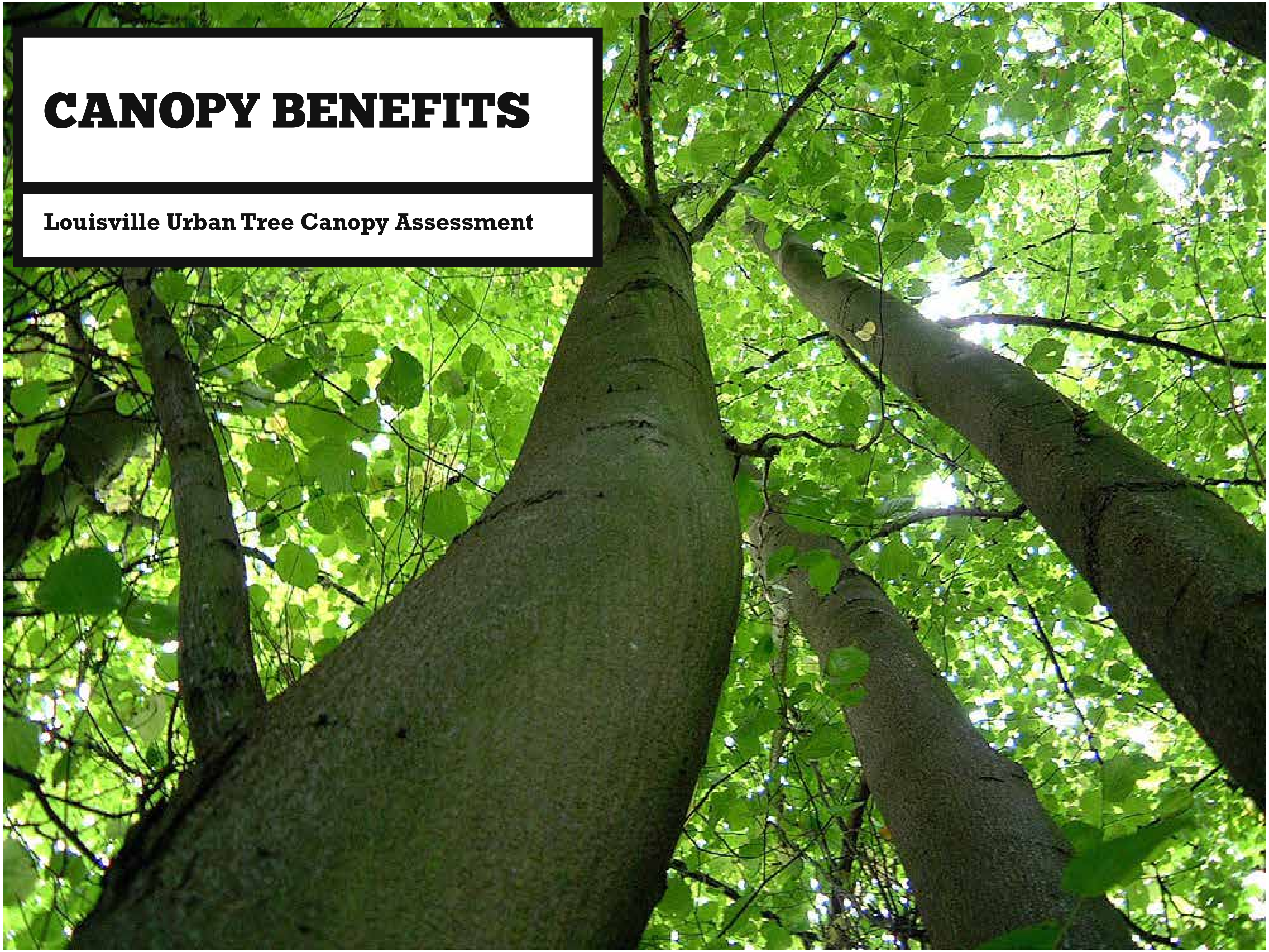
Intersection of Breckinridge and Shelbyville Road. Trinity High School to lower left.
Image Source: Dr. Keith Mountain

CANOPY BENEFITS

Louisville Urban Tree Canopy Assessment



CANOPY BENEFITS

2015 **Louisville Urban Tree Canopy Assessment**

This study used a variety of tree canopy assessment and analytical tools to quantify and value the benefits of trees' ability to store carbon, clean the air, provide energy savings, intercept and absorb stormwater and boost property values. Detailed descriptions of models used to calculate benefits listed in Table 17 can be found in Appendix A.

The various ecosystem services derived from Louisville's canopy provide compelling data in support of additional tree planting.

Benefits of Louisville trees have been segmented by council district, census tract and sewershed. Because these segmentations vary so greatly in size, benefits were compared using two metrics; first by the total value of benefits, then by value of benefits per acre.

Council district and census tract highlights can be found on the following pages. Full tables of benefits have been provided electronically.

Louisville trees provide approximately $330 million in benefits annually.

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Overall Benefits

Overall, Louisville's existing canopy provides its residents with almost $330 million in benefits annually.

On top of the annual benefits, carbon stored over the lifetime of Louisville trees contributes an additional $230 million in benefits, bringing the collective benefit amount to $560 million.

Table 17 lists a summary of the benefits provided by Louisville trees. Specifics on each of these benefits are detailed in the following pages.

Table 17. Louisville Tree Canopy Benefits

Benefit	*Quantity*	*Unit*	*Value*
STORMWATER: Reduction of Runoff	18,835,266,390	*gallons*	$62,909,790
ENERGY: Savings from Avoided Cooling	67,649,325	*kWhs*	$5,463,356
PROPERTY: Increases in Property Values	-	*$*	$239,969,791
AIR: Carbon Monoxide (CO) Removed	149,120	*lbs.*	$99,078
AIR: Nitrogen Dioxide (NO_2) Removed	517,780	*lbs.*	$219,678
AIR: Ozone (O_3) Removed	4,366,940	*lbs.*	$7,932,540
AIR: Sulfur Dioxide (SO_2) Removed	622,280	*lbs.*	$78,727
AIR: Dust, Soot, Other Particles Removed (Particulate Matter, PM10)	1,242,280	*lbs.*	$3,879,821
Carbon Sequestered	444,112	*tons*	$8,599,490
		Total Annual Benefits	**$329,152,271**
Carbon Storage Over Canopy's Lifetime *(not an annual benefit)*	11,941,333	*tons*	$231,224,066
		Total Benefits Overall	**$560,376,337**

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18.8 billion gallons of stormwater intercepted annually

$5 million in energy savings for consumers annually

$240 million increase in Louisville property values

Stormwater Runoff Reduction

Trees in Louisville are able to intercept an impressive 18.8 billion gallons of stormwater annually – that's enough to fill over 28,000 olympic-sized swimming pools. This important infrastructure service provided by trees is valued at approximately $63 million. Trees intercept rainfall by temporarily holding rainwater on leaves and bark, delaying that water from reaching the ground and moderating peak runoff quantities. Tree roots also directly absorb stormwater by consuming water stored in soil pores, and thereby increasing the capacity of local soils to store rainwater. Stormwater reduction rates are based on an average annual rainfall of 45.2 inches and equates to almost 200,000 gallons of stormwater reduction per acre of tree canopy.

Energy Savings

The cooling benefit of shade trees is perhaps the most widely recognized benefit of trees. The urban forest in Louisville is estimated to save 67 million kilowatt hours of energy - a savings of over $5 million for consumers. Natural cooling provided by urban trees reduces consumer demand for electricity which, in turn, also reduces harmful emissions released from the burning of fossil fuels because of the decreased demand on power plants. The cooling benefit of shade trees can also be felt at the street level where lower ambient temperatures of 5 to 15 degrees have been recorded around street trees (Miller, 1997). Adding trees for their cooling benefits alone in areas with large amounts of concrete (impervious surfaces) would quickly help reduce ambient temperatures in Louisville's urban heat islands.

Increases in Property Values

How many times have realtors enticed prospective buyers to a community touting the "highly sought-after neighborhood with tree-lined streets?" In one survey by Arbor National Mortgage and American Forests, 83% of realtors indicated that large, mature trees had a "strong or moderate impact" on home sales under $150,000. For homes over $250,000, the response increases to 98%. Homes with trees were also reported to sell more quickly that those without. Louisville trees can be attributed almost $240 million in property value increases, representing the largest single benefit value reported.

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6.9 million lbs. of pollutants removed from the air annually

400,000 tons of carbon dioxide removed from the atmosphere annually

Air Quality Improvements

Every year Louisville trees remove huge amounts of pollution from the air: over 150,000 lbs. of carbon monoxide (CO), 500,000 lbs. of nitrogen dioxide (NO2), 4.3 million lbs. of ozone (O3), 600,000 lbs. of sulfur dioxide (SO2) and 1.2 million lbs. of dust , soot and other "particulate matter" (PM10). This equates to an impressive value of $12.2 million worth of air quality improvements annually. Ozone pollution represents the greatest benefit value to Louisville residents at $7.9 million. Reforestation efforts in and around urban areas have been shown as one of the more cost effective and feasible methods to controlling dangerous ground-level ozone, which is known to cause increases in respiratory and cardiovascular diseases and human deaths world-wide (Kroeger et al, 2014).

Carbon Reduction

The total carbon reduction benefit provided by trees can be measured in two categories. The first is the amount of carbon dioxide absorbed by tree leaves annually, which has been calculated at over 400,000 tons. The second is the amount of carbon stored in woody tissue of living trees over its lifetime, calculated at almost 12 million tons. These two carbon sequestration avenues represent a total benefit value of $240 million. This is an important benefit to Louisville residents as it mitigates atypical climatic patterns believed to be influenced by excess atmospheric carbon.

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By Council District

Tree benefits by council district were examined in two ways: total benefits value and benefits per acre. Benefits per acre allow a more equal comparison of benefits contributions.

Table 18 lists this information for each council district, and maps of both metrics can be seen in Figures 17 and 18.

The five council districts with the highest dollar value of benefits (Districts 20, 13, 19, 14 and 16) are all situated on the outer perimeter of the study area, cover 45% of the study area, and represent 53% ($296 million) of Louisville's total canopy benefits. This can be attributed to their large size and less dense population.

Figure 17. Total Benefits, by Council District

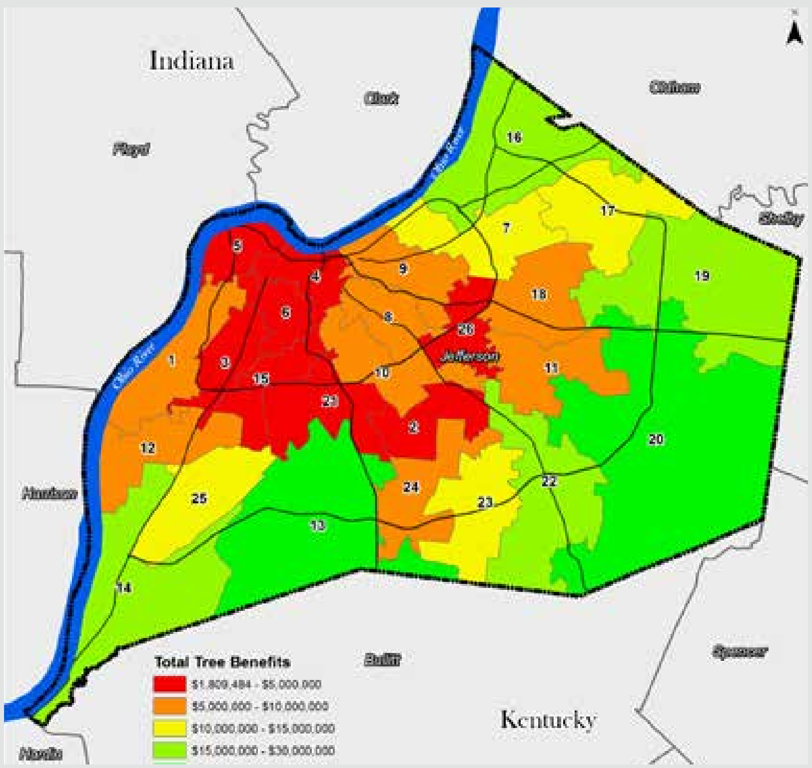
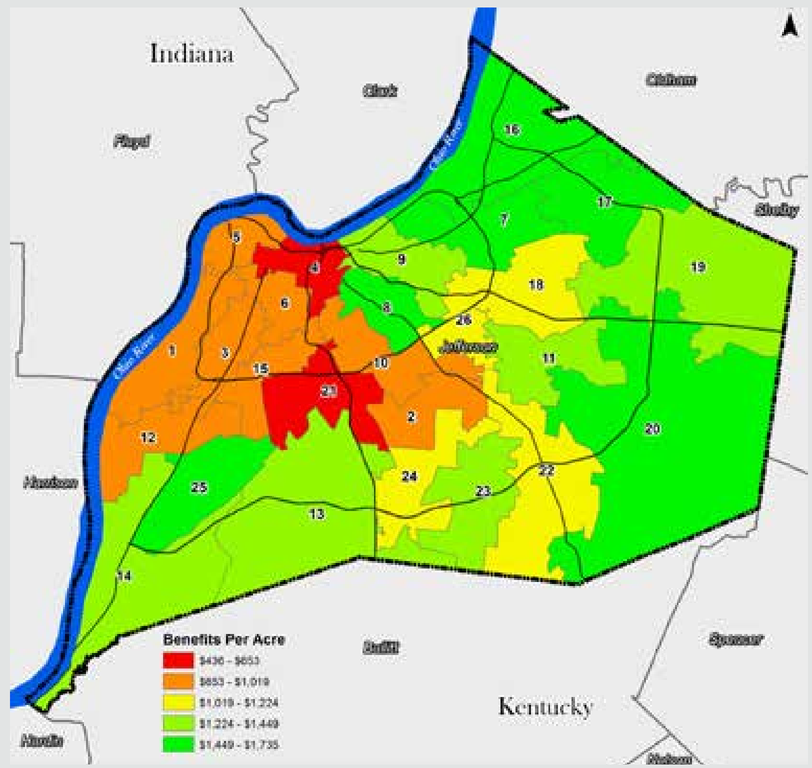


Figure 18. Benefits per Acre, by Council District



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The five council districts with the smallest dollar value of benefits (Districts 2, 3, 4, 6 and 26) make up 8% of the entire study area, are located in and around the old city boundary and contribute 5% ($28 million) of Louisville's total benefits. Districts 25 ($1,735) and 7 ($1,692 per acre), located closer to the urban center, emerged as having the highest benefits per acre. Districts 4 ($436 per acre) and 21 ($653 per acre), situated along the urban corridor between downtown and the airport, showed the lowest benefits per acre.

Table 18. Canopy Benefits by Council District, by Value per Acre

	Acres	Canopy	Air Quality	Total Carbon*	Stormwater	Energy Saved	Property Value	TOTAL	Value / Acre
District 25	7,702	45%	$444,206	$8,760,968	$2,296,503	$210,728	$10,096,286	$21,808,692	**$1,735**
District 7	7,956	40%	$403,309	$7,998,980	$2,095,838	$250,340	$10,427,460	$21,175,927	**$1,692**
District 8	4,322	40%	$221,737	$4,387,246	$1,147,595	$329,573	$5,043,212	$11,129,363	**$1,596**
District 20	39,330	51%	$2,591,117	$51,512,548	$13,456,744	$253,934	$43,342,162	$111,156,504	**$1,563**
District 17	8,916	36%	$403,954	$8,110,591	$2,129,568	$182,557	$10,847,858	$21,674,528	**$1,554**
District 16	16,158	40%	$820,560	$16,259,169	$4,280,806	$221,731	$18,441,492	$40,023,759	**$1,507**
District 13	20,928	48%	$1,293,914	$25,203,540	$6,645,985	$240,113	$21,243,585	$54,627,137	**$1,449**
District 19	19,935	39%	$1,024,610	$19,873,390	$5,228,996	$243,783	$20,208,063	$46,578,842	**$1,375**
District 23	7,988	34%	$359,841	$7,016,668	$1,831,563	$176,974	$7,948,402	$17,333,448	**$1,323**
District 14	18,013	46%	$1,078,055	$21,097,071	$5,537,356	$212,001	$15,959,913	$43,884,397	**$1,307**
District 11	7,032	32%	$292,429	$5,617,890	$1,478,906	$177,075	$7,040,259	$14,606,559	**$1,307**
District 9	6,515	33%	$270,698	$5,398,043	$1,415,909	$321,471	$6,255,606	$13,661,728	**$1,298**
District 22	12,991	35%	$590,877	$11,567,060	$3,054,724	$148,793	$11,694,229	$27,055,683	**$1,224**
District 18	7,406	27%	$258,333	$5,158,625	$1,354,469	$200,204	$6,866,253	$13,837,883	**$1,197**
District 24	6,972	29%	$257,499	$5,054,704	$1,328,445	$182,321	$5,873,061	$12,696,030	**$1,122**
District 26	4,160	24%	$132,494	$2,580,368	$674,712	$179,111	$3,491,620	$7,058,304	**$1,099**
District 15	4,316	31%	$175,562	$3,333,192	$876,902	$215,647	$3,008,409	$7,609,712	**$1,019**
District 12	8,402	29%	$319,516	$6,202,656	$1,626,502	$169,222	$6,090,942	$14,408,839	**$1,003**
District 10	6,410	25%	$210,671	$4,066,686	$1,067,606	$227,676	$4,500,380	$10,073,019	**$960**
District 3	4,537	21%	$122,539	$2,398,355	$625,790	$186,699	$3,198,419	$6,531,802	**$930**
District 2	4,986	22%	$141,793	$2,783,658	$730,277	$154,054	$3,419,855	$7,229,637	**$912**
District 1	9,389	27%	$326,764	$6,414,243	$1,682,244	$179,951	$5,469,811	$14,073,012	**$840**
District 5	5,371	23%	$164,108	$3,189,652	$834,923	$258,433	$2,983,410	$7,430,525	**$811**
District 6	3,291	18%	$74,639	$1,484,569	$388,132	$211,952	$1,732,600	$3,891,892	**$748**
District 21	7,143	16%	$144,293	$2,788,586	$737,738	$189,599	$3,491,474	$7,351,690	**$653**
District 4	4,153	12%	$65,144	$1,290,270	$336,741	$139,414	$1,221,920	$3,053,488	**$436**

** Total carbon includes annual benefits plus lifetime storage benefits. All other values are annual.*

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By Census Tract

Tree benefits segmented by the 191 census tracts were examined by both the total benefits value and benefits value per acre (as described in the previous Benefits by Council Districts section). Table 19 lists the highest and lowest five tracts for both metrics, and maps of both metrics can be seen in Figures 19 and 20.

The five census tracts with the highest dollar value of benefits are all situated on the outer perimeter of the study area, cover 22% of the entire county and provide 31% ($176 million) of the total tree benefits value. The lowest five census tracts on that list make up less than 1% of the entire study area and provide less than 1% (approximately $1.1 million) of the total tree benefits.

Figure 19. Total Benefits, by Census Tract

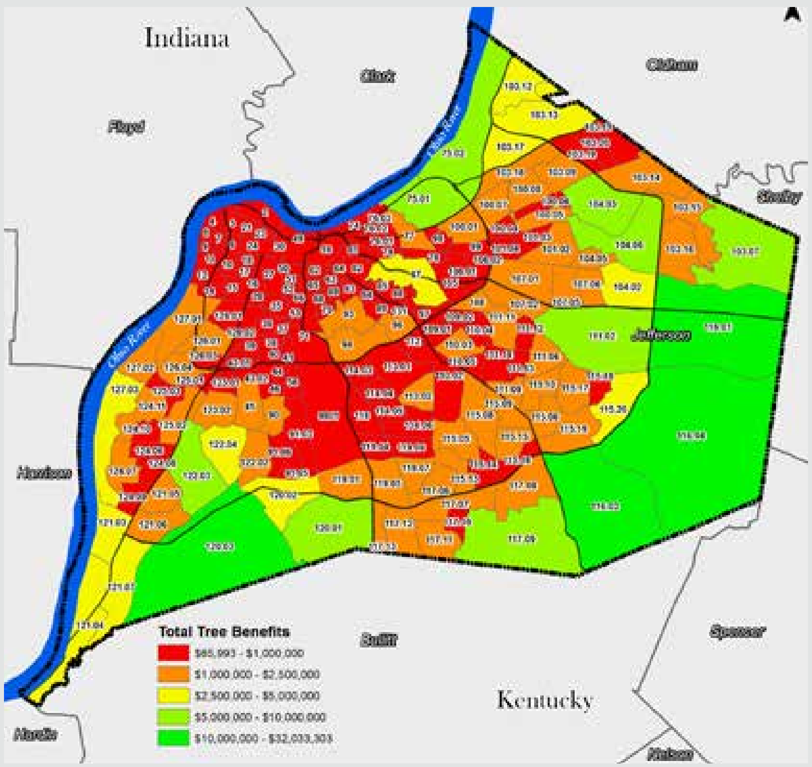

Figure 20. Benefits per Acre, by Census Tract

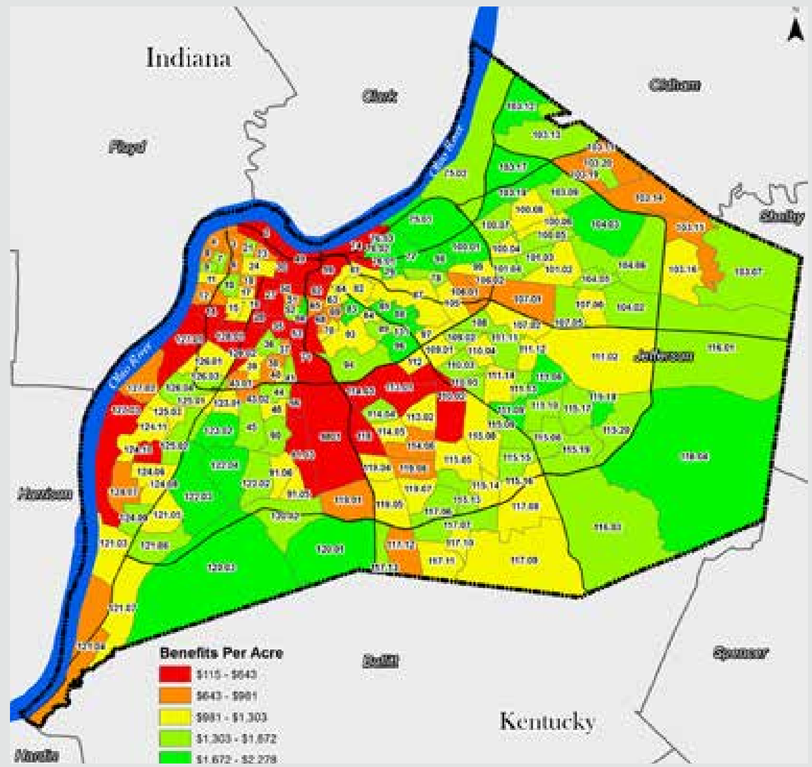

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Table 19. Five Highest and Lowest Tracts for Benefits (Total and Per Acre)

Highest Total Benefits

Tract	Acres	Canopy	Air Quality	Total Carbon	Stormwater	Energy Saved	Property Value	TOTAL BENEFITS	Value / Acre
116.04	18,778	57%	$1,402,267	$28,123,360	$7,139,228	$53,953	$22,429,415	**$59,148,224**	$3,150
120.03	11,749	76%	$1,161,598	$23,548,740	$5,981,554	$62,925	$16,744,194	**$47,499,012**	$4,043
116.01	10,687	49%	$671,068	$13,604,480	$3,452,253	$54,057	$11,361,923	**$29,143,781**	$2,727
116.03	8,811	51%	$584,985	$11,859,060	$3,005,324	$43,878	$7,965,310	**$23,458,558**	$2,662
103.07	5,863	44%	$340,559	$6,829,560	$1,736,555	$28,734	$7,456,881	**$16,392,289**	$2,796
	Totals		*$4,160,477*	*$83,965,200*	*$21,314,914*	*$243,547*	*$65,957,723*	***$175,641,864***	

Lowest Total Benefits

Tract	Acres	Canopy	Air Quality	Total Carbon	Stormwater	Energy Saved	Property Value	TOTAL BENEFITS	Value / Acre
50	189	11%	$2,555	$51,800	$13,201	$7,303	$41,073	**$115,932**	$613
35	165	8%	$4,679	$94,860	$23,988	$5,273	$76,962	**$205,762**	$1,244
53	169	13%	$6,823	$138,160	$34,647	$11,539	$80,966	**$272,135**	$1,613
37	434	18%	$4,011	$80,400	$20,499	$12,154	$105,722	**$222,786**	$513
49	178	5%	$8,675	$175,840	$45,295	$6,084	$85,817	**$321,711**	$1,809
			$26,743	*$541,060*	*$137,630*	*$42,353*	*$390,540*	***$1,138,327***	

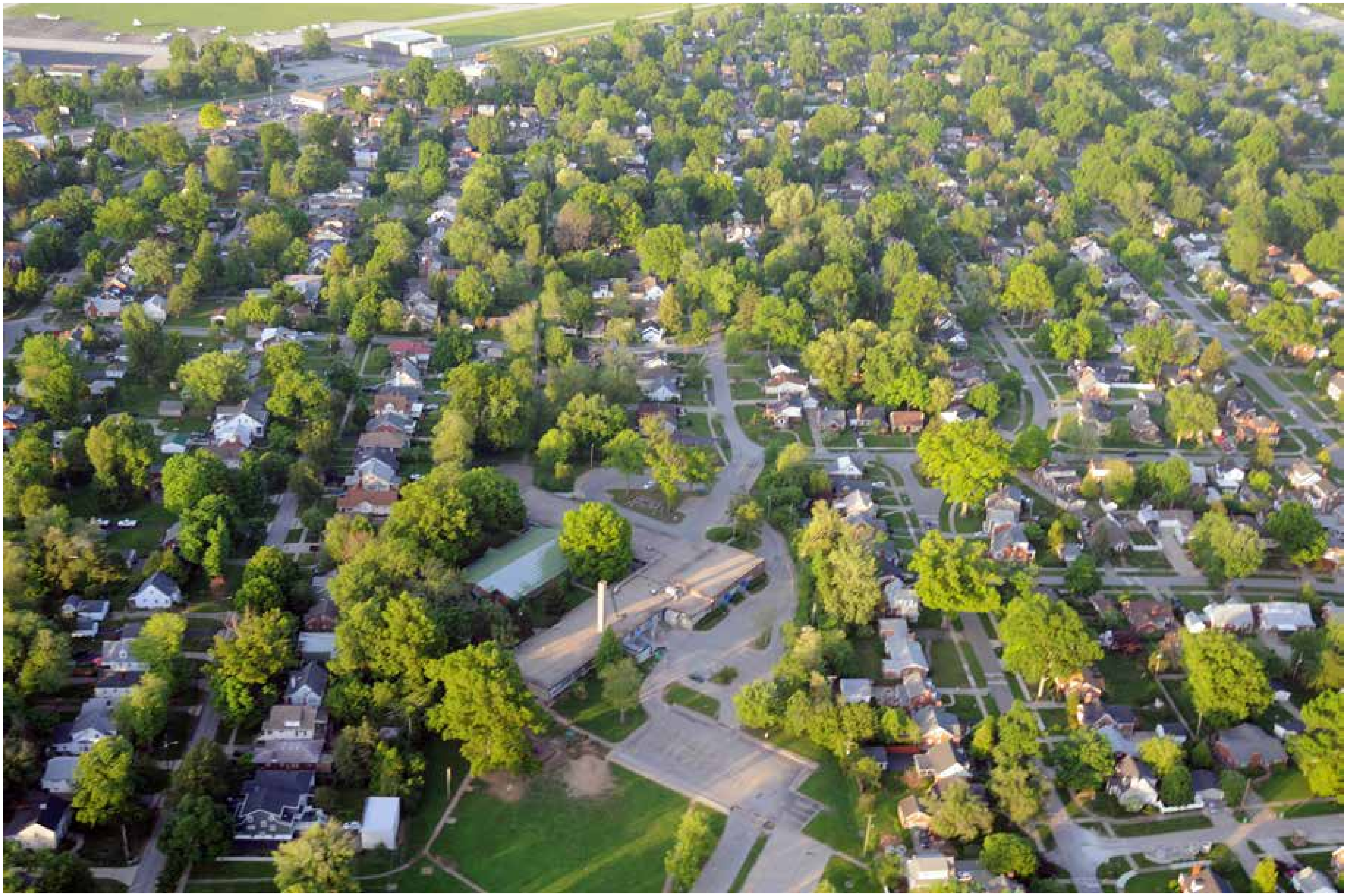
Highest Benefits per Acre

Tract	Acres	Canopy	Air Quality	Total Carbon	Stormwater	Energy Saved	Property Value	Total Benefits	VALUE / ACRE
84	205	23%	$6,109	$1,204,000	$31,538	$22,505	$183,312	$1,447,463	**$7,060**
114.05	611	2150%	$17,181	$3,370,460	$87,497	$34,554	$526,453	$4,036,145	**$6,603**
120.03	11,749	7645%	$1,161,598	$23,548,740	$5,981,554	$62,925	$16,744,194	$47,499,011	**$4,043**
120.01	4,444	6725%	$389,174	$7,889,780	$1,990,061	$38,058	$5,977,214	$16,284,287	**$3,665**
122.04	1,779	5628%	$129,398	$2,622,960	$666,798	$49,753	$2,918,738	$6,387,647	**$3,590**

Lowest Benefits per Acre

Tract	Acres	Canopy	Air Quality	Total Carbon	Stormwater	Energy Saved	Property Value	Total Benefits	VALUE / ACRE
50	178	11%	$2,555	$51,800	$13,201	$7,303	$41,073	$115,933	**$652**
91.03	1,324	10%	$17,127	$347,100	$86,109	$3,175	$290,909	$744,421	**$562**
35	434	8%	$4,679	$94,860	$23,988	$5,273	$76,962	$205,763	**$474**
9801	4,396	6%	$33,420	$677,720	$177,731	$1,975	$268,913	$1,159,760	**$264**
49	1,275	5%	$8,675	$175,840	$45,295	$6,084	$85,817	$321,711	**$252**

** Total carbon includes annual benefits plus lifetime storage benefits. All other values are annual.*



Louisville suburb south of Bowman Field
Image Source: Dr. Keith Mountain

ACTION PLAN DEVELOPMENT

Louisville Urban Tree Canopy Assessment

Action Plan Development

2015 **Louisville Urban Tree Canopy Assessment**

Clearly trees provide many benefits in Louisville, and this UTC assessment revealed that there are many opportunities for canopy expansion to increase these benefits. Tree planting, however, should be guided by realistic goals and a prioritized plan based on local issues and values.

Setting Goals

Setting tree canopy and planting goals is an important step in the planning process as it provides metrics to measure performance throughout the coming years and ensures the goals set are realistic.

What canopy percent to aim for?
American Forests, a recognized leader in conservation and community forestry, has established standards and goals for canopy cover in metropolitan areas. They recommend that cities set an overall canopy goal of 40% with 15% canopy in central business districts, 25% canopy in urban neighborhoods, and 50% canopy in suburban neighborhoods. When compared to American Forest's canopy standards, the data indicates that Louisville's overall and urban residential canopy meets or exceeds the targets. However, the UTC in both the central business district and suburban residential areas fall significantly short of the recommended goals (see Table 20).

Table 20. Canopy Standards

	American Forest Rec.*	Louisville Canopy 2004	2008	2012
Average of All Zones	40%	40%	38%	37%
Central Bus. Districts	15%	7%	7%	8%
Urban Residential**	25%	29%	28%	26%
Suburban Residential**	50%	37%	36%	35%

**American Forests recommendations for metropolitan areas east of the Mississippi.*

*** For purposes of this snapshot analysis, council districts 4,5,6,8 and 9 were considered urban residential areas, and council districts 12,16,17, 23 and 24 were considered suburban residential.*

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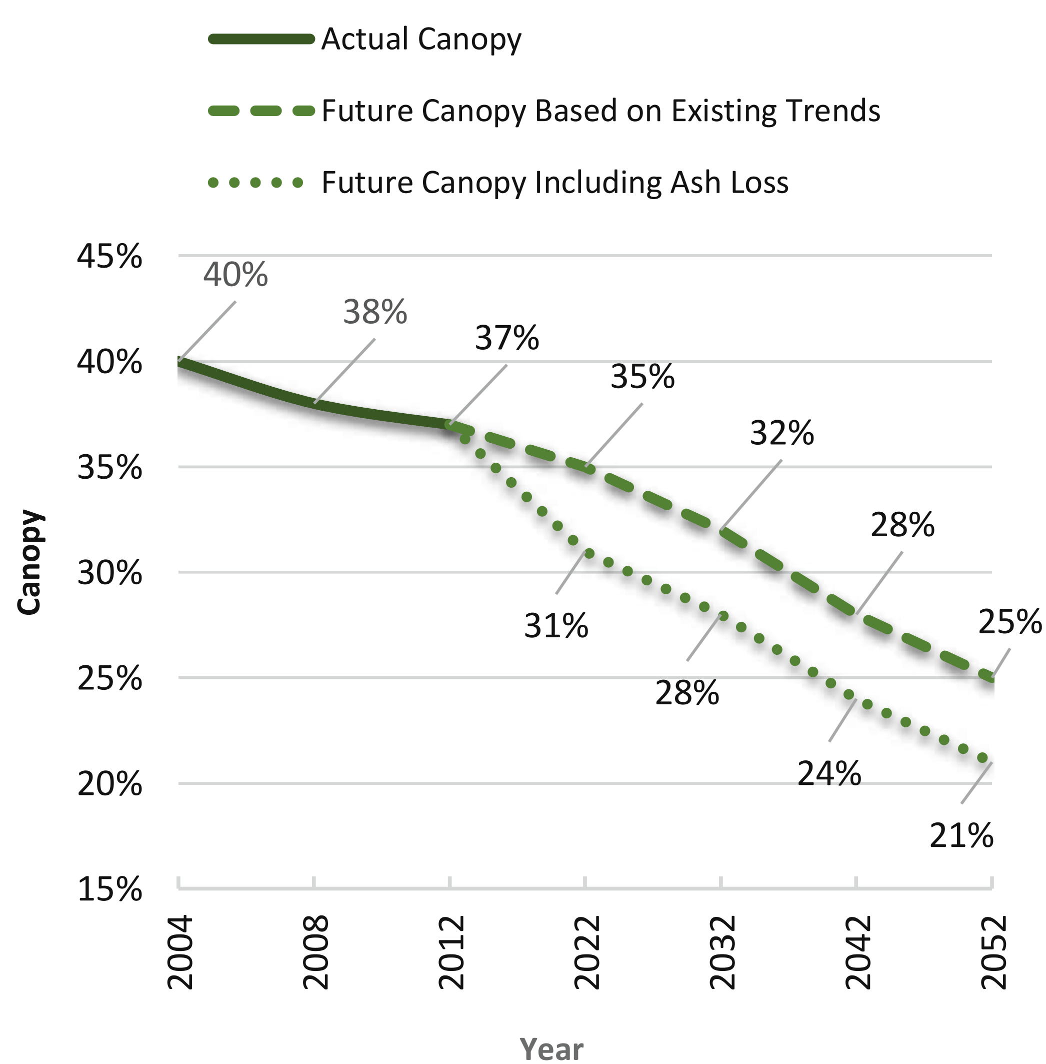
However, every community is unique, and the American Forest goals should only be considered general guidelines. Determining tree canopy goals for Louisville will involve a multi-step process of using these "ideal" canopy rates in combination with what is realistic and acceptable in Louisville, when balanced with other community, economic and social goals.

What does the future look like? Louisville lost over 6,500 acres of tree canopy between 2004 and 2012. This effectively represents an average annual loss of 820 acres, equivalent to more than 54,000 trees per year.[1] If this current trend holds, and compounds with the losses projected from EAB, Louisville tree canopy is projected to fall to 31%-34% in the next ten years, dropping to as low as 21% over the next forty years (see Figure 21).

If current trends hold, Louisville canopy is projected to decrease to 31-35% in the next ten years, dropping to as low as 21% over the next forty years.

Figure 21. Louisville's Estimated Future Canopy



[1] This esimation of trees is based on a 29' average canopy diameter of a mature tree.

FINAL DRAFT

How much canopy is possible in Louisville?
The level of possible canopy is determined by adding the existing canopy to the amount of available planting space in Louisville. This data is important to have when setting realistic canopy goals.

Analysis of available planting space involves more than simply assuming all pervious surfaces currently without trees (grass/low-lying vegetation or bare soil) are potential planting locations. Some pervious surfaces are not suitable for planting (golf courses, agricultural fields, cemeteries, airports, recreational fields, some parts of rights-of-way, etc.). Likewise, not all impervious areas should be ruled out for planting, as trees can still be added in certain locations (trees in sidewalk areas, parking lot islands, etc.).

Potential realistic plantable areas are therefore determined by excluding those pervious areas unsuitable for planting and including impervious areas where trees could realistically be added. The resulting area is termed **Realistic Plantable Areas (RPAs)**.

The **maximum canopy possible** is, therefore, determined by calculating the resulting canopy if 100% of RPAs were indeed planted with the largest canopy-producing tree possible for that location. That canopy can then be added to the existing canopy to reach a maximum canopy percentage. UTC analysis has indentified over 66,000 acres of RPAs (land that could be planted with trees). Planting 100% of the

Table 21. Potential Canopy by Council District

	2012 Canopy	**Realistic Plantable Areas (RPAs)** (acres)	**Potential Canopy of RPAs**	**Maximum Canopy Possible** (current canopy + potential canopy)
District 1	27%	2,343	25%	52%
District 2	22%	1,587	32%	54%
District 3	21%	1,498	33%	54%
District 4	12%	678	16%	29%
District 5	23%	1,047	19%	43%
District 6	18%	729	22%	40%
District 7	40%	1,946	24%	64%
District 8	40%	961	22%	62%
District 9	33%	1,313	20%	53%
District 10	25%	1,730	27%	52%
District 11	32%	2,019	29%	60%
District 12	29%	2,694	32%	61%
District 13	48%	5,417	26%	74%
District 14	46%	4,016	22%	68%
District 15	31%	1,088	25%	56%
District 16	40%	3,787	23%	63%
District 17	36%	2,759	31%	67%
District 18	27%	2,095	28%	56%
District 19	39%	5,126	26%	65%
District 20	51%	7,962	20%	72%
District 21	16%	1,757	25%	40%
District 22	35%	4,367	34%	69%
District 23	34%	3,047	38%	73%
District 24	29%	2,514	36%	65%
District 25	45%	2,340	30%	75%
District 26	24%	1,216	29%	54%
Totals	37%	66,037 acres total	27%	63%

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RPA sites would add 26% canopy cover to the existing 37% canopy, setting the maximum UTC possible in Louisville to be 63%. Table 21 shows the maximum canopy levels for each of Louisville's council districts.

What should be the canopy goals for Louisville? Now that past loss trends and maximum possible canopy have been identified, realistic canopy goals can be developed. A good starting point is the combination of American Forests recommended canopy, Louisville's preliminary goals (no net loss, 40% and 45% canopy), and maximum canopy possible.

A determination of goals must be made locally, based on what is economically, ecologically, and politically feasible for canopy across various land uses and jurisdictions. This will require input and support from the public, local leaders, and subject matter experts to set local goals that are based on local values, local environmental and quality of life goals, compliance with federal and local clean air and water regulations, and economic development plans.

Once realistic goals are determined, the Louisville Metro Government and stakeholders can pursue those goals using policies, procedures, education, incentives, and various funding avenues.

Factoring in Ash Loss

EAB is a significant urban threat in Louisville and tree loss due to this exotic insect should be factored into the discussion future canopy loss. However, this UTC assessment does not reflect tree losses attributable to EAB infestations because it was only during the last few years that the EAB populations reached a critical mass and had infested trees long enough for symptoms to occur. However, it is likely that 2015 aerial photography will show measurable losses in canopy due to EAB.

It is estimated that between 10% and 17% of Louisville's tree canopy is comprised of ash species (UK 2014), equating to an estimated 625,000 - 1,000,000 trees that will be lost to EAB in the next five to ten years. Further analysis may be required to fine-tune the actual number of trees that will be lost to EAB in the coming years. Using more recent aerial photography in combination with an i-Tree Eco or hyperspectral imagery project will identify the location of the ash tree populations and concentrations in Louisville.

If analysis reveals that ash are primarily in naturalized woodland areas, annual tree replacement numbers can be reduced. Existing younger understory trees will grow and other mature trees' crowns will spread to fill the gaps left by ash trees. Targeted reforestation may be the only tree planting response required in these areas to offset the impact of EAB.

However, if a significant number of ash trees are in urban and suburban areas growing as landscape trees, then tree replacement planting on at least a one-to-one ratio or greater should be considered, as ash in these locations would be contributing significant stormwater, urban heat island, and energy conservation benefits.

FINAL DRAFT

Action Scenarios

Given the serious loss of regional tree canopy, an aggressive plan must be devised and implemented to achieve Louisville's preliminary goals of no net loss in five years and 40% or 45% overall canopy in future years.

The following scenarios are offered for perspective and as a reference for the recommendations presented later in this report.

Each scenario involves a defined intensive set of actions (or lack thereof) over the first ten years, then less intense but ongoing action in the following thirty years to reach pre-determined goals in a forty-year time span.

Note that increases in tree canopy can come not only from planting new trees, but also from preserving existing trees. For this reason, each scenario includes an option for planting efforts alone, as well as a combination of planting and loss reduction. The scenarios show that reducing the rate of annual canopy loss can reduce planting costs by as much as 50%. Specific loss reduction efforts

Table 22. Scenarios for Future Canopy

	Scenario 0: No Action	Scenario 1: No Net Loss		Scenario 2: 40% Canopy Goal		Scenario 3: 45% Canopy Goal	
		1a	1b	2a	2b	3a	3b
Method	No Action	Planting Only	Planting + Loss Reduction	Planting Only	Planting + Loss Reduction	Planting Only	Planting + Loss Reduction
Trees Planted Annually, Years 1-10	0	54,120	27,060	102,432	75,372	186,384	159,324
Trees Planted Annually, Years 11-40	0	54,120	27,060	54,120	27,060	54,120	27,060
Acres Lost Over 40 years	32,800	32,800	16,400	32,800	16,400	32,800	16,400
Acres Planted Over 40 years	0	32,800	16,400	40,120	23,720	52,840	36,440
Trees Planted Over 40 years	0	2,164,800	1,082,400	2,647,920	1,565,520	3,487,440	2,405,040
Resulting Canopy at Year 40	24%	37%	37%	40%	40%	45%	45%
Total Planting Costs	$0	$1,039,104,000	$519,552,000	$1,271,001,600	$751,449,600	$1,673,971,200	$1,154,419,200

Assumptions and Notes on Scenarios:
All tree plantings are landscape trees (2'' caliper or higher) valued at $480 per tree retail value (tree plus labor)
Tree counts are based on a 29' average crown diameter of a mature tree, one acre of land can hold 66 trees.
Scenarios extend 40 years to allow for trees planted in first ten years to mature.
Scenarios do not factor in ash loss from EAB (see Factoring in Ash Loss inset).
To demonstrate the impact of loss reduction efforts, annual loss was reduced in 1b, 2b and 3b by 50% as an example only.
Full tables on calculations to reach these numbers can be found in Appendix B.

(policies, ordinances) are presented in the recommendations section. Each scenario is summarized in Table 22, with a detailed table in Appendix B.

Scenario 0: No Action
A "no action" scenario is provided as a baseline. If no changes are made and zero trees are planted, overall canopy will drop to 24% by year 40 (closer to 20% with the impact of EAB).

Scenario 1: No Net Loss
Assuming no change in rate of annual canopy loss, Louisville will need to add just over 820 acres (or approximately 54,000 trees) every year to counter the annual historic decline.

As shown in scenario 1a, forty years of working to counter losses by tree planting alone will require planting of just over 2.1 million trees, equivalent to over $1 billion dollars.

Scenario 1b assumes loss reduction efforts are in place that cut the current annual loss rate in half (to only 410 acres lost per year). With this in place, no net loss could be achieved by planting just over 27,000 trees every year. After forty years, this equates to 1 million trees planted, equivalent to $520 million – approximately half the cost of scenario 1a.

Defining "No Net Loss"

It is important to consider that there are two ways to define "no net loss" in urban tree canopy, and the differences are worth noting from the outset.

Method #1: Replant One Tree for Every Tree Lost
A one-to-one ratio of the trees lost to trees planted is a valid way to define "no net loss." This is based on a long-term perspective that accepts the premise that a new young tree will replace a lost mature tree over time.

Method #2: Replace Actual Square Footage of Canopy Lost
Another valid way to define"no net loss" is to calculate crown acreage of mature trees lost and balance that immediately with the acreage of new tree crowns planted. This view is based on a more short-term perspective of planting multiple new trees for every mature tree lost in an effort to immediately restore actual canopy area lost.

For example, when a mature oak with a canopy of 3,000 square feet is lost, achieving no net loss from planting a two-inch tree with a 300 square foot canopy could be achieved in two ways, depending on your viewpoint. Under Method #1, planting one new tree to replace the mature oak achieves no net loss. Under Method #2, ten trees must be planted to achieve no net loss.

In practice, both definitions can be used in a large region like Louisville. For rural and woodland areas, the one-to-one ratio is typically used by traditional forest managers given trees' life spans and other characteristics of the ecosystem. In urban areas, urban forest managers tend to want equal square footage of canopy replaced due to the lack of natural environment and the immediate benefits even small crowns can provide the community, especially for stormwater management.

The choice of definition (often the basis of future tree planting projects, land use policies, regulations, and educational efforts) is a local decision, based on local community values.

FINAL DRAFT

Scenario 2: 40% Canopy Goal
This study has determined Louisville will need to add approximately 7,300 acres of canopy to the existing canopy to reach the 40% UTC goal. At the current rate of annual loss, this will be a challenging task.

Scenario 2a assumes the ongoing rate of canopy loss (820 acres or 54,000 trees a year) throughout the 40-year period, but with heavy planting levels (100,000 trees per year) over the first ten years to both counter the annual loss and add the 7,300 acres needed to reach the 40% UTC goal. After the first ten years of heavy planting, work in the remaining 30 years would just involve planting to offset standard annual losses (820 acres per year). Forty years of working to achieve 40% canopy by tree planting alone will require just over 2.6 million trees planted, equivalent to over $1.3 billion dollars.

Scenario 2b assumes losses are reduced by half and active tree planting over the first ten years. In the first ten years, only 75,000 new tree plantings would need to be planted, with 27,000 needed for the next 30 years to reach the 40% canopy cover goal. This equates to a total of 1.5 million trees planted for approximately $750 million – again, just over half the cost of scenario 2a that is dependent on tree planting alone to reach goals.

Scenario 3: 45% Canopy Goal
According to the 2012 findings in this report, Louisville will need to add approximately 20,000 acres to reach the 45% UTC goal. This will be a challenging goal to reach by planting alone. For this reason, tree preservation efforts become even more critical for overall success.

Scenario 3a assumes the continued loss of canopy of over 820 acres (54,000 trees) a year throughout the 40-year period, but with heavy planting levels (186,000 trees per year) over the first ten years to both counter the annual loss and add the 20,00 acres needed to reach the 45% UTC goal. After the first ten years of heavy planting, work in the remaining 30 years would again involve planting only to offset annual losses (820 acres per year). Forty years of working to achieve the 45% canopy goal through tree planting alone will add up to almost 3.5 million trees planted, equivalent to over $1.6 billion dollars.

Scenario 3b assumes substantial tree planting over the first ten years, but with canopy loss slowed to half the current rate. In the first ten years, only 160,000 new tree plantings would need to be planted, with 27,000 needed for the next 30 years to reach the 45% canopy cover goal. This equates to a total of 2.4 million trees planted for approximately $1.1 billion – 30% less than the cost of depending on tree planting alone in scenario 3a.

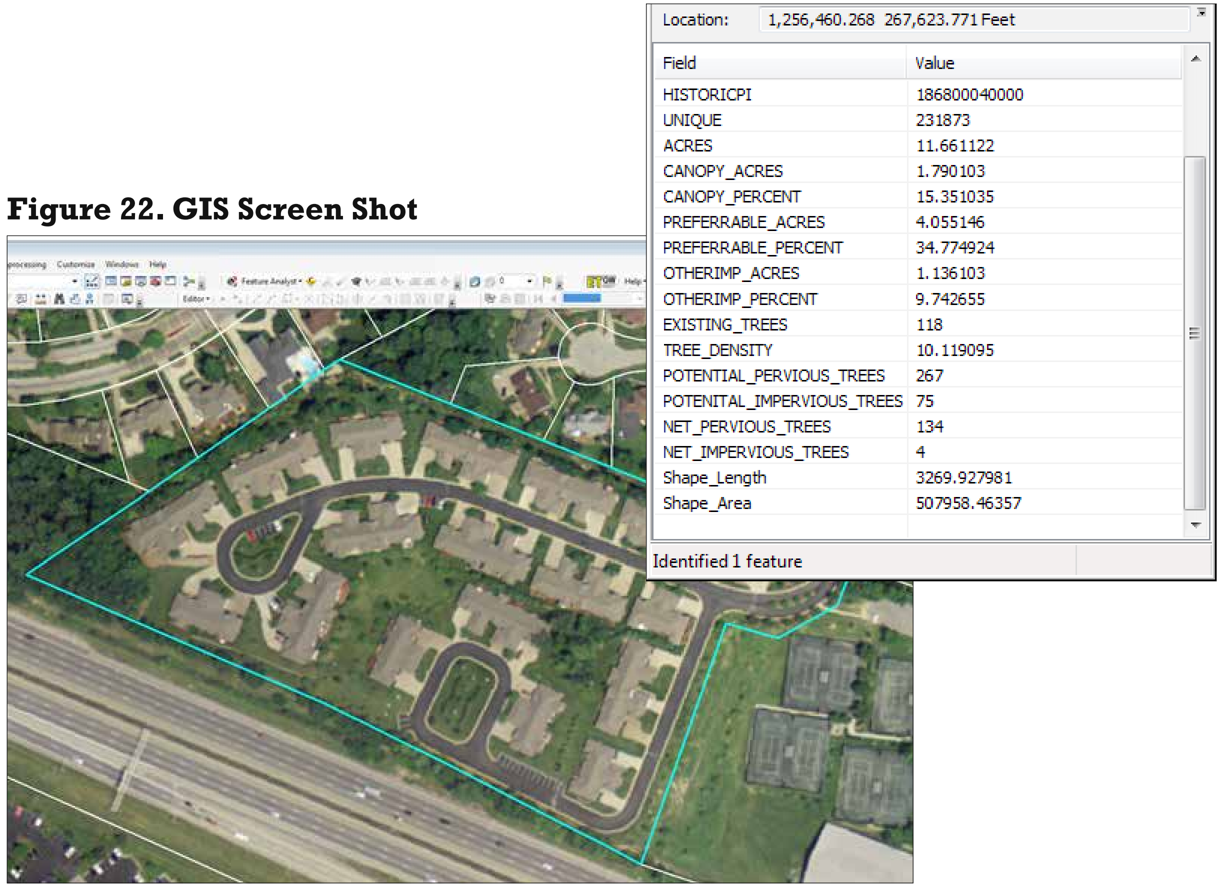
Clearly, tree preservation efforts to arrest the current annual loss rate are just as important to incorporate into urban forest management as tree planting. Recommendations for tree preservation initiatives are included in the recommendations section of this report.

Planting Plan Format

The UTC-based and prioritized planting plan provided within this project is a tool that can be used for planning, budgeting, applying for grants, inter-agency project development, public education, and many other uses.

The plan should not, however, be considered as a traditional landscape design and installation plan. It exists as an electronic GIS data layer with embedded information (Figure 22), and as such can be easily queried, updated, and used for additional project-based analyses. Tree planting areas have not been field-verified and the tree quantities suggested for a given area are estimates based on the accuracy of the data provided by LOJIC and other project partners.

Figure 22. GIS Screen Shot



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Prioritization of Planting Areas

At this point, the *potential realistic plantable areas* have been identified, but not yet prioritized. While all available planting sites in Louisville may ultimately be planted over the next several decades, the trees that are planted in the next several years, should be planned for areas in most need, and where they will provide the most benefits and return on investment.

To identify planting areas that will return the greatest and most diverse amount of benefits to Louisville, each plantable area was evaluated based on three factors:

- environmental features/sensitivity (a combination of canopy location related to surface waters and impaired waterways, soil type, floodplains, slope, and forest fragmentation),
- stormwater issues, and
- urban heat island concentrations.

Each factor was used to create individual grids that were assigned a value between 0 and 4 identifying priority planting importance from Very Low to Very High. The resulting information was then mapped for individual categories of information, such as urban

Table 23. Prioritization Factors & Results

Environmental Sensitivities Priority

Priority	Number of Areas	Acres
Very Low	363,529	38,752
Low	42,453	5,633
Moderate	57,813	7,983
High	69,017	8,805
Very High	41,412	4,563

Urban Heat Island Priority

Priority	Number of Areas	Acres
Very Low	277,044	3,534
Low	120,293	25,479
Moderate	12,178	11,411
High	107,161	16,634
Very High	57,548	8,678

Stormwater Management Priority

Priority	Number of Areas	Acres
Very Low	272,215	2,238
Low	73,140	3,606
Moderate	67,148	26,493
High	107,384	25,939
Very High	54,337	7,461

Priority Level
Very Low
Low
Moderate
High
Very High

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heat island, stormwater mitigation, and environmental need. The overall results for these three individual categories are presented in Table 23.

By overlaying all of these prioritized grid maps and adding the values at any given point, a composite prioritization scheme emerges (Table 24). Additional factors also considered for this final prioritization include publicly vs. privately-owned property and forest fragmentation.[1]

It is important to note that parks and other protected woodland areas were not excluded from the potential planting areas considered for three primary reasons.

- First, park and woodland trees provide measurable benefits to nearby neighborhoods. To exclude them would make it appear that these neighborhoods were receiving less benefits than they are.
- Secondly, parks and protected woodlands are relatively unthreatened by development. The growing environment in parks contributes to less mortality, faster maturity, and longer service lives of trees planted there.

Table 24. The Composite Planting Site Prioritization

Priority	Number of Areas	Acres
Very Low	186,691	1,891
Low	115,961	11,435
Moderate	78,628	9,314
High	142,780	31,336
Very High	50,164	11,761

Very Low
Low
Moderate
High
Very High

[1] Planting areas less than 100 square feet were eliminated from this analysis because they were found to not have enough suitable planting space. This equals a 240-acre difference in planting area.

FINAL DRAFT

- Lastly, by including parks in the neighborhood, census tract, council district and other land scales, a truer picture of priority tree planting areas is revealed. Areas without forested parks or other protected woodlands nearby need new trees more than those that have that resource.

A **map book** detailing these prioritized planting areas for each Council District area has been provided electronically.

Tree Planting Approaches and Related Costs

With this UTC analysis and prioritization of plantable areas complete, Louisville has better information upon which to initiate projects to achieve canopy goals. Increasing urban tree canopy means increasing the number of trees in Louisville. This can be accomplished in three ways:

Landscape Tree Planting. This solution generally involves procurement and installation of 2-3" caliper trees. The advantages of this method come from a larger crown at the time of planting, lower mortality rates, and the variety of aesthetics and design goals that can be incorporated into plantings. Disadvantages include the high costs and intensive labor required, and a longer establishment period needed after transplanting. It may also be impractical to plant large trees on steep topography and in poor soils, and nursery availability dictates whether desirable native and urban tolerant species can be obtained in sufficient quantities.

If the approximately 20,000 acres of RPA's (realistic plantable areas) needed to reach the 45% canopy goal in Louisville were planted with landscape-sized trees, it would require 1.3 million trees. Using the average cost of $480 per tree[2],the total cost to achieve 45% UTC using landscape trees in Louisville would be $634 million.

Reforestation. Reforestation, or artificial regeneration, is a technique long practiced by traditional foresters and land conservationists. This tree planting solution involves planting 2 to 3-year old, bare-root tree seedlings or saplings/whips by hand or by machine in areas currently with a grass, shrub, or bare ground cover. The advantages are that this method is less expensive, desirable native tree species in sufficient quantities are readily available, re-establishment after planting is quicker so land can become tree-covered faster, and it is a method that can be accomplished by both professional contractors and citizen volunteers. The disadvantages include higher mortality rates, protection and weed control is required for newly planted trees, and until the trees mature, reforested areas are not often aesthetically pleasing, especially if the surrounding area is more developed and maintained.

Assuming the average cost to reforest one acre of land is $350[3], the cost to reforest the approximately 20,000 acres of RPA's (realistic plantable areas) to achieve 45% UTC in Louisville would be $7 million.

Bigger isn't always better.

When thousands of trees need to be planted to achieve canopy goals, it is not always cost-effective or realistic to plant two-inch caliper landscape trees everywhere.

The good news is that smaller trees grow substantially faster. The smaller the tree is at planting, the faster it will establish and therefore increase in size. This means that sapling-size native species will create canopy faster and less expensively.

It is important to keep reforestation and smaller landscape trees in mind when working to reach canopy goals efficiently.

[2] Cost for tree and installation is at a retail rate, and was provided by the City of Louisville.
[3] Cost is based on a general estimate by Timberlands Unlimited Inc. and includes site preparation, tree seedlings, labor, and equipment. This is not an exact cost but one suitable to reach approximate costs. Source: http://www.timberlandsunlimited.com/reforestation.php

FINAL DRAFT

Natural Regeneration. As the term suggests, natural regeneration is simply allowing nature to take its course. Louisville's natural heritage is forestland. If left undisturbed by human activities, the vast majority of all land would revert back to native woodlands. The advantages are that this costs no money, involves no labor, and native trees would reappear in the landscape. The disadvantages are that while trees regenerate, aesthetics are often an issue, and competition from exotic and invasive weeds, shrubs, and trees (such as honeysuckle and callery pear) may require chemical, mechanical, or manual removal and intervention.

Table 25 compares the costs of each method if only one tree planting method was chosen to achieve various target canopy goals.

A Combination of Methods. Clearly, it is impractical to use only one tree planting method exclusively to achieve an increase to 40%, 45%, or even the maximum potential of 63% tree canopy cover in Louisville. For instance, it is unreasonable to expect over 4 million landscape trees will be planted at a cost of over $2 billion in the next decade. To be as efficient and realistic as possible, a strategy should be developed that involves a combination of these three tree planting methods and is based on land use, budget, and aesthetic considerations.

Table 25. Costs To Achieve Canopy Goals Per Method

	40% Canopy	45% Canopy	63% Canopy (Max)
Add'l Canopy Required to Meet Goal	*7,319 acres*	*20,041 acres*	*66,078 acres*
Landscape Trees Method	$231,683,382	$634,399,050	$2,090,716,327
Reforestation Method	$2,561,650	$7,014,350	$23,127,447
Natural Regeneration Method	$0	$0	$0

A further, higher-level, and detailed land use analysis is needed to determine areas most suitable for each of the three tree planting methods. A list of suggested areas suitable for each method is provided at below.

When a "tree planting suitability" analysis is complete, conversations with land owners and stakeholder groups can then occur and result in developing tree planting projects with clear goals, roles, budgets, and other needed resources. Such a "master tree planting action plan" will define these projects and can guide all landowners in a coordinated effort to reach UTC goals using the most appropriate method for the site and resources available.

Planting Method Suitabilities

Landscape Trees:
Streets
Suburban residential yards
Maintained park areas
Parking lots
Maintained commercial grounds
Cemeteries
School yards

Reforestation or Natural Regeneration:
Excess road rights-of-way
Urban vacant lots
Stream and river corridors
Idle/unused farmland
Excess industrial land
Naturalized park areas
Steep hillsides

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UTC Calculator Tool. Where planting landscape sized trees is required or needed, the UTC Calculator tool can help determine the number of trees needed and estimate the cost of those trees. Developed by Davey Resource Group, the Urban Tree Resource Analysis and Cost Estimator (UTRACE) tool utilizes current baseline percentages from the UTC assessment to generate possible planting scenarios. The tool is used to estimate future tree plantings to attain a particular canopy goal set by the user. The UTC Calculator is most useful on smaller scales, such as neighborhoods, business districts, or census tracts where landscape trees would likely be planted, but can also be used on large scales such as countywide or large watersheds as needed.

Louisville has received a customized, fully adjustable version of the UTRACE tree canopy calculator, allowing the Louisville Metro Government and regional partners to plan and consider additional planting strategies as conditions change or priorities shift.

The UTC calculator tool provides estimated planting numbers and costs for achieving canopy goals.

FINAL DRAFT

Public and Private Property Tree Planting

Using the land use designations in Louisville, "public property" was considered the combination of parks & open space, public/semi-public, and rights-of-way. The remaining designations were considered "private property." Table 26 presents some of the summary statistics between these two land ownership types.

Using the UTC goals of 40% and 45% canopy cover, and the statistics based on these designations, it would appear that planting all realistic plantable areas on public property would meet these goals and actually exceed them (assuming no further canopy loss, and not accounting for EAB effects). However, it is logical to assume that parks & open space acreage likely needs to remain open for future recreational fields and other types of desirable natural habitats, such as meadows and prairies. Pervious surface areas in public/semi-public lands may be needed for facilities, schools, or other uses for the public good and welfare. And, although trees can be planted on interstate and state route public rights-of-way, these areas are considered a last resort in many locations due to safety considerations and the poor soil quality for growing trees.

Consequently, it should be noted that there is greater opportunity and need for significant participation from private property owners to contribute to canopy increases beyond 40%. It is also very likely that the highest numbers of ash trees in Louisville are on privately-owned land, therefore planting on private property will likely become a high priority in the next five years.

The success of reaching UTC goals depends not only on governments planting trees on public lands, but on a cooperative public-private initiative. Creating public-private partnerships will include encouraging community participation, training volunteers, creating and supporting volunteer organizations, and educating property owners. Rewarding, or incentivizing, private property owners for any positive support for this endeavor can lead to greater success and likelihood of reaching the stated UTC goals. Louisville cannot achieve its UTC goals without the support of its residents and businesses, so that everyone can enjoy the many social, environmental, and economic benefits of trees.

Who owns it?

Table 26. Land Ownership

Who owns the land in Louisville?		Acres	% of Louisville
	Private	172,081	69%
	Public	74,335	31%

Who owns Louisville's current canopy?		Acres	% of Canopy
	Private	67,684	71%
	Public	26,422	29%

Who owns the realistic potential planting areas (RPAs) in Louisville?		Acres	% of RPAs
	Private	47,811	73%
	Public	18,036	27%

RECOMMENDATIONS & NEXT STEPS

Louisville Urban Tree Canopy Assessment

Recommendations & Next Steps

2015 **Louisville Urban Tree Canopy Assessment**

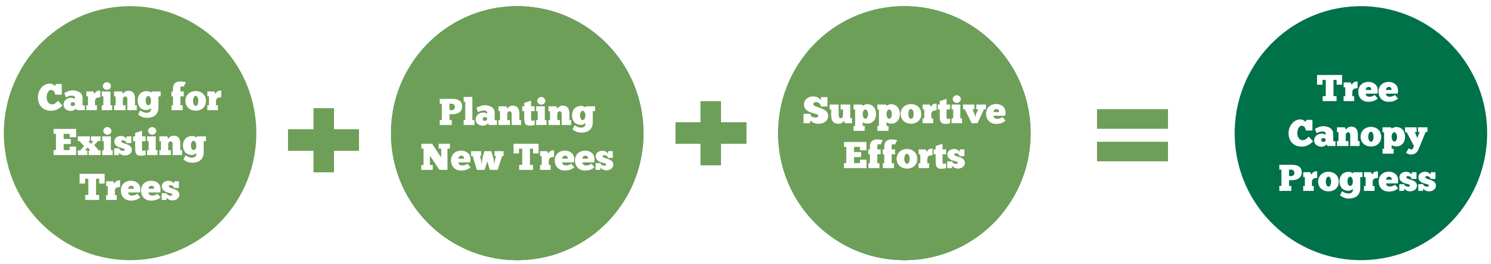
Louisville's urban tree canopy assessment and analysis provide a solid foundation for sustainable solutions to existing urban challenges.

Although the obvious solution to losing canopy is to plant more trees, a long-term solution requires more comprehensive efforts, including tree preservation.

Answers to Louisville's urban challenges (heat stress, combined sewer overflows, ash tree loss, etc.) will require further analysis of the drivers and barriers influencing policy and land use decisions related to the urban forest. And it will require a multifaceted approach inclusive of new or revised policies, programs, and well-defined strategic action plans to ensure future successes. Policy changes, education, and partnerships will all be crucial to a turnaround in Louisville's tree canopy.

Recommendations in this section are categorized in three broad areas:

- **Caring for Existing Trees**
- **Planting New Trees**
- **Establishing a Supportive Framework** to build and maintain a sustainable urban tree canopy.



Caring for Existing Trees

One key for success in reaching canopy goals is to protect the existing canopy. Current canopy should be protected and maintained in a safe and high-functioning condition so existing mature trees have the longest service lives possible. In doing so, tree canopy benefits will be maintained for decades, giving newly planted trees time to mature.

1. Tree preservation ordinances that reduce tree canopy loss and encourage land use planning that supports reforestation goals on development properties should be considered. The Maryland Forest Conservation Act (*http://www.dnr.state.md.us/forests/programapps/newFCA.asp*) and the Fairfax County, Virginia Tree Protection Ordinance (*http://www.fairfaxcounty.gov/dpwes/publications/pfm/chapter12.pdf*) are two good examples recommended for further study.

2. Review and compare all landscape and zoning codes, ordinances, policies and guidelines (in all land uses) to current industry standards for tree planting, species lists, and tree protection.

3. Consider empowering homeowner associations in new residential developments with the responsibility of maintaining trees within the public rights-of-way and within the development to minimize future maintenance impacts on municipal budgets and operations.

4. Promote the use of conservation easements to protect critical forest areas.

5. Routinely maintain public trees, and encourage private property owners to do so as well. Timely routine maintenance is important for maximizing tree health and longevity, for identifying and correcting defects or hazardous conditions that can threaten public safety, and for monitoring the tree population for destructive forest pests and diseases such as emerald ash borer. Consider performing timber stand improvement projects, such as removing diseased trees and invasive plants in forested areas for improved forest health.

6. Promote the treatment of ash trees where appropriate to preserve the benefits of their collective canopy while new trees are established.

7. Monitor landscape and woodland trees for the presences of insect and disease issues, particularly for Asian long-horned beetle.

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Planting New Trees

Increasing tree canopy in Louisville requires long-term dedication and significant efforts of local governments, non-profits, and private landowners to plant new trees. Specific areas need additional trees to mitigate stormwater issues and urban heat island effects, but all areas and all people will ultimately benefit from each tree planted. The important task at hand is to plant more trees and provide appropriate follow-up care so the majority of these new trees reach maturity and provide the greater canopy needed to maximize the ecosystem and economic benefits.

8. Focus landscape tree planting and reforestation projects in the next five years in areas designated as Very High Priority, particularly from the composite priority analysis provided in this assessment.

9. Plan urban heat island-related tree planting initiatives or policies that are informed by both surface temperature differentials and the comprehensive assessment of heat vulnerability of citizens based on the results of the Georgia Institute of Technology UHI study.

10. Perform a tree planting suitability analysis for areas/parcels to determine whether tree planting can or should be accomplished with landscape trees, reforestation and/or natural regeneration. Then create a master tree planting action plan on a council, sewershed or other Louisville subdivision level.

11. Plant trees in local business districts to not only provide increases in overall canopy in these areas, but also to gain the economic benefits trees afford business owners.

12. If neighborhoods lack sufficient space in the public rights-of-way for tree planting, then investigate whether landscape or green infrastructure/stormwater easements can be created on the private property that adjoins the street rights-of –way. If such easements are created, then the trees can be planted and maintained within that easement to increase tree canopy where it might not otherwise be possible.

13. Consider implementing parking lot greenspace and stormwater management policies that maximize tree canopy and minimize surface runoff.

14. Consider adopting reforestation policies for public lands with supporting funding that demonstrate a long-term commitment to growing and sustaining a vibrant urban forest. Review policies and ordinances that protect trees or require reforestation as part of the

Right-of-way tree planting.
Image Source: LouisvilleKY.gov

FINAL DRAFT

development process to assist in supporting Louisville's tree canopy and sustainability goals. (As these types of policies can impact site designs and project costs, a well-educated public supportive of new requirements will be needed.)

15. Establish a street tree planting program that includes a focus on residential streets when public right-of-way space allows.

16. Consider undertaking state route and interstate reforestation projects on excess, mowed areas where public safety or sight line visibility is not hindered.

17. Include tree planting guidelines for new right-of-way construction and infrastructure projects.

18. Seek opportunities to convert impermeable space such as asphalt playgrounds, under-utilized basketball or tennis courts, and abandoned structures to permeable space with trees.

19. Develop and implement streetscape design standards that increase available rooting space, capture street runoff and improve site growing conditions for large shade trees in densely developed areas. Consider focusing on the central business district and larger commercial areas with high percentage of impervious surfaces and heat island conditions.

20. Target tree planting in hot spot areas to address this county-wide issue.

21. Plant more landscape trees and/or perform reforestation in the sewersheds (CSOs #27,#142, #155,#160) with the least amount of canopy, and in the sewersheds reported to have the most problems, particularly CSOs #82, #106, and #137 where there is the least impervious surface percentage which thereby gives the greatest opportunity to plant trees.

22. Review opportunities to incentivize tree planting on private property including cost-share programs or stormwater fee credits.

23. Connect patch canopy areas where feasible to larger forested areas to create greenways, wildlife corridors, and ultimately more core canopy areas.

24. Establish tree planting goals for all 83 suburban cities in Louisville with the results of this analysis.

Relating and Supporting Efforts

Planting and maintaining trees will not be successful without supporting efforts, such as professional community forest planning, education campaigns, funding raising, forging new partnerships and strengthening existing ones, further GIS and data analysis, and field monitoring. Louisville Metro Government and its partners should assess existing capabilities and build its capacity to manage a large tree population.

25. Engage, educate and support private action. As 72% of the existing urban tree canopy in Louisville is privately owned, developing and expanding an effective outreach campaign to educate and engage the public in support of programs and policies that sustain a healthy and vibrant urban forest is a critical step in achieving canopy goals.

26. Support urban forestry advocacy organizations such as Brightside, Louisville Grows, and Re-Tree Shively in their efforts to promote the importance and need for tree plantings and increase their outreach and reforestation capabilities.

27. Broaden citizen volunteer and training programs to ensure that the hundreds of thousands of trees that will need to be planted over the next 40 years are properly planted and cared for.

28. Use tree advocacy groups to unify public messaging and maintain consistency with Louisville Metro Government policy by coordinating the efforts of these organizations. Synergistic benefits and increased collective effectiveness may be achieved, especially if the Tree Advisory Commission had more authority beyond an advisory capacity.

29. Create public education programs that build upon tree benefits that people intuitively enjoy but do not consciously think about. These efforts will help drive home the importance and benefits of urban trees as sustainable solutions to Louisville's challenges. Once the public begins to actively think about the tree canopy benefits experienced, they will be more supportive of tree planting initiatives and tree preservation policies.

Potential programs include:

- Bring attention to issues like urban heat islands effects and combined sewer overflows in a way that addresses citizens' needs and values directly.
- Design and customize education and planting projects to target groups disproportionately lacking tree canopy, as determined in the Socioeconomic analysis section of this study, those groups being the less educated, property owners of homes under $100,000 in value, and rental property owners. Providing or increasing financial support for volunteer planted trees in economically disadvantaged council districts and census tracts is also recommended.
- Use EAB statistics coupled with the findings in this study as compelling talking points to spur more public interest.
- Publicize the benefits of trees through media outlets such as radio and billboards. Arbor Day and Earth Day celebrations are ideal community events to promote and demonstrate community tree benefits. Many communities include free tree distributions as part of these events.

30. Develop partnerships with nurseries or cities to grow desirable urban tolerant shade trees for public distribution. This is a low cost way to engage the public and populate the urban forest with trees that will maximize benefits returned over their life. Work with nurseries to add tree canopy benefit information on the tree tag description at retail outlets so the public starts thinking about tree benefits as selection criteria in addition to physical characteristics (as with small ornamental trees).

31. Evaluate providing higher density incentives for developers who incorporate low impact and 'green' design concepts that increase tree planting, growth and longevity

32. Enhance minimum tree planting standards for any new residential or commercial development, including street trees.

33. Consider launching a county-wide tree planting initiative, such as Cincinnati's *Taking Root,* Los Angeles' *Million Trees*, and other grassroots-supported initiatives, possibly centered around an urban heat island mitigation goal. The initiative could have a website that enables residents and cities to report trees planted as a

FINAL DRAFT

means of measuring success toward tree planting goals (both landscape tree plantings and reforestation projects). The annual planting goals could be divided amongst the neighborhoods and suburban cities within Louisville to support citizen entry and progress tracking for their respective area. This may generate healthy intra-city competition that increases the accuracy of reporting and trees actually planted.

34. Investigate trends revealed by the UTC assessment. Louisville Metropolitan Government now has the ability to do multiple levels of further analysis as projects and efforts require it. Possibilities for further analysis include:

- Investigating further and remedying the significant loss in canopy on residential land, whether from land development and/or the decline of mature trees from insects, diseases, or lack of proper maintenance. Trees in residential areas provide the greatest direct benefits to people in terms of energy conservation, human health, and property value. The net canopy loss on residential land is 8%. As single-family residential is the predominant land use in Louisville, this loss equates to nearly 6,620 acres of tree canopy.
- Explore and identify further opportunities to promote additional tree planting in council districts and other geographic subdivisions like census tracts and CSO areas reporting low UTC cover
- Performing multi-layer analyses as projects require or as the need for specific information is requested, for example, by examining canopy by land use within census tracts and removing any large parks out of all neighborhoods to examine and compare just non-park urban canopy rates.
- Investigate census tract changes. Assess local knowledge to establish why sixteen census tracts had a 20% or greater decrease in canopy. Then take steps to reverse that canopy loss, and ensure other census tracts do not experience similar losses.

35. Perform further analysis using the UTC data and i-Tree tools to determine the public health benefits of tree canopy and tree plantings. This could be particularly useful for creating partnerships with public and private school districts and with the Louisville Metro Health Department, and achieving the goals of initiatives such as Healthy Louisville 2020.

36. Schedule UTC updates in five-year increments. Because of the predicted ash tree losses, an update may be needed sooner to reassess canopy and to evaluate progress towards reaching long term canopy goals.

37. Complete and maintain an accurate spatial public tree inventory. A public tree inventory is an important assessment and management tool needed to identify and prioritize future planting opportunities within the street rights-of-way, parks, and other public properties. It is also equally important

Tree inventory technician
Image Source: Davey Resource Group

from a maintenance perspective of existing canopy to have accurate information on the condition and maintenance needs of trees located on public properties. Trees should be inventoried, regularly inspected and maintained for safe public use and enjoyment. Modern tree inventory and management software applications also support tree inspection records, maintenance scheduling, and maintenance histories on an individual tree basis.

38. Initiate a tree management plan. Management plans are important for characterizing and assessing the forest population managed and for projecting maintenance priorities and costs. They can also include an operations analysis and specific recommendations in terms of staffing, equipment and financial resources needed to accomplish defined goals and objectives.

39. Strive to complete a community forest master plan. A forest master plan is a road map, providing detailed information, recommendations and resources needed to effectively and proactively manage and grow tree canopy. Master plans typically include a more comprehensive analysis of the urban forest at various scales and useful information on forest composition, forest condition, forest stocking density and tree size distributions.

40. Consider implenting an i-Tree ECO project to confirm the number of ash trees and the percent canopy at risk for EAB. This is highly recommended given the significant public safety, ecological and social risks associated with emerald ash borer. Additionally, Louisville Metro government should consider completing a hyperspectral analysis to map the location of ash trees to provide effective outreach and management of EAB. A spatial ash map can be used to supplement the Planting Plan mapbook for future reforestation planning.

41. Define roles within Louisville Metropolitan Government to accomplish the goals and many objectives of expanding the tree canopy. Identifying a central tree authority/project champion is recommended.

42. Explore creative financing opportunities for adding trees in densely developed business, commercial and neighborhood regions.

- Many communities have self-taxed business improvement districts or neighborhood tax improvement districts to fund community improvements such as tree planting and green stormwater infrastructure such as rain gardens or bio-swales.
- Partner with local businesses and institutions, such as the Louisville Slugger® brand and history to generate funding and form partnerships with MLB to combat EAB and assist with ash reforestation.
- Use the results of this study to seek grant funding for tree planting and public education, and to conduct further analyses, i.e. i-Tree ECO, i-Ped,

Final Thoughts

Louisville's tree canopy is a vital asset covering 37% of the land (26% in urban core) and providing $330 million in environmental and socioeconomic benefits every year. The management of this asset, however, can be challenging. Simultaneously balancing the recommendations of experts, the needs of residents, the pressures of local economics and politics, the concerns for public safety and liability issues, the physical aspects of trees, and the forces of nature and severe weather is a vitally important task.

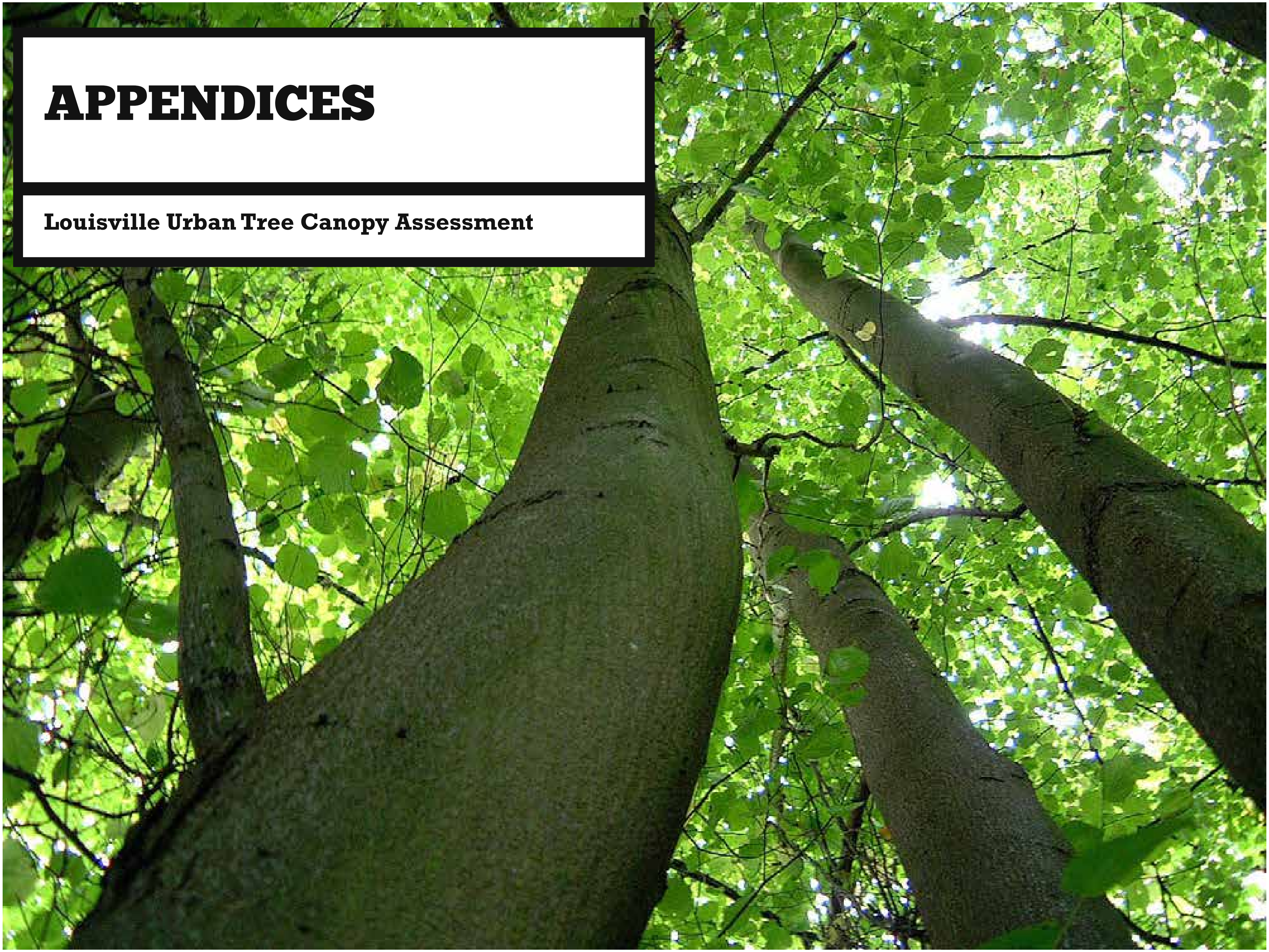
The Louisville Metropolitan Government must carefully consider each specific issue and balance these pressures with a local knowledge and an understanding of trees and their needs. If a balance is achieved, Louisville and Louisville's unique livability will grow stronger and the health and safety of its trees and residents will be maintained. With the completion of this UTC assessment, municipal and county leaders can now use the data to set goals towards increasing the amount of UTC within Louisville.

Reaching the desired UTC goals will be a challenge; however, preserving existing UTC, establishing realistic UTC goals, and harnessing the maximum amount of ecosystem benefits by planting large-growing trees are prudent, responsible, and rewarding endeavors.

Image Source: Davey Resource Group

APPENDICES

Louisville Urban Tree Canopy Assessment



Appendix A Methodologies

Appendix A Contents

Land Cover Classification

Davey Resource Group utilized an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution color infrared (CIR) aerial imagery and remotely-sensed data to identify tree canopy cover and land cover classifications. This process utilized NAIP imagery (National Agriculture Imagery Program) from the summer growing seasons of 2012, 2008 and 2004. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage. This supports responsible tree management, facilitates community forestry goal-setting, and improves urban resource planning for healthier and more sustainable urban environments.

Advanced image analysis methods were used to classify, or separate, the land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst™, an extension of ArcGIS®. Feature Analyst uses an object-oriented approach to cluster together objects with similar spectral (i.e., color) and spatial/contextual (e.g., texture, size, shape, pattern, and spatial association) characteristics. The land cover results of the extraction process was post-processed and clipped to Louisville's project boundaries prior to the manual editing process in order to create smaller, manageable, and more efficient file sizes. Secondary source data, high-resolution aerial imagery provided by Louisville Metro Government, and custom ArcGIS® tools were used to aid in the final manual editing, and quality assurance/quality checking (QA/QC) processes. The manual QA/QC process was implemented to identify, define, and correct any misclassifications or omission errors in the final land cover layer.

Classification Workflows

1) Prepare imagery for feature extraction (resampling, rectification, etc.), if needed.

2) Gather training set data for all desired land cover classes (canopy, impervious, grass, bare soil, shadows). Water samples are not always needed since hydrologic data are available for most areas. Training data for impervious features was provided by the Louisville Metropolitan Government.

3) Extract canopy layer only; this decreases the amount of shadow removal from large tree canopy shadows. Fill small holes and smooth to remove rigid edges.

4) Edit and finalize canopy layer at 1:2000 scale. A point file is created to digitize-in small individual trees that will be missed during the extraction. These points are buffered to represent the tree canopy. This process is done to speed up editing time and improve accuracy by including smaller individual trees.

5) Extract remaining land cover classes using the canopy layer as a mask; this keeps canopy shadows that occur within groups of canopy while decreasing the amount of shadow along edges.

6) Edit the impervious layer such as roads, buildings, parking lots, etc. to reflect actual impervious features.

7) Using canopy and actual impervious surfaces as a mask; input the bare soils training data and extract them from the imagery. Quickly edit the layer to remove or add any

features. Davey Resource Group tries to delete dry vegetation areas that are associated with lawns, grass/meadows, and agricultural fields.

8) Assemble any hydrological datasets, if provided. Add or remove any water features to create the hydrology class. Perform a feature extraction if no water feature datasets exist.

9) Use geoprocessing tools to clean, repair, and clip all edited land cover layers to remove any self-intersections or topology errors that sometimes occur during editing.

10) Input canopy, impervious, bare soil, and hydrology layers into Davey Resource Group's Five-Class Land Cover Model to complete the classification. This model generates the pervious (grass/low-lying vegetation) class by taking all other areas not previously classified and combining them.

11) Thoroughly inspect final land cover dataset for any classification errors and correct as needed.

12) Perform accuracy assessment. Repeat Step 11, if needed.

Automated Feature Extraction Files

The automated feature extraction (AFE) files allow other users to run the extraction process by replicating the methodology. Since Feature Analyst™ does not contain all geoprocessing operations that Davey Resource Group utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst™, Davey Resource Group created the training set data, ran the extraction, and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, Davey Resource Group uses additional geoprocessing tools within ArcGIS®. From the AFE file results, the following steps are taken to prepare the extracted data for manual editing.

1) Davey Resource Group fills all holes in the canopy that are less than 30 square meters. This eliminates small gaps that were created during the extraction process while still allowing for natural canopy gaps.

2) Davey Resource Group deletes all features that are less than 9 square meters for canopy (50 square meters for impervious surfaces). This process reduces the amount of small features that could result in incorrect classifications and also helps computer performance.

3) The Repair Geometry, Dissolve, and Multipart to Singlepart (in that order) geoprocessing tools are run to complete the extraction process.

4) The Multipart to Singlepart shapefile is given to GIS personnel for manual editing to add, remove, or reshape features.

Accuracy Assessment Protocol

Determining the accuracy of spatial data is of high importance to Davey Resource Group and our clients. To achieve to best possible result, Davey Resource Group manually edits and conducts thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process will be completed using ArcGIS® to identify, clean, and correct any misclassification or topology errors in the final land cover dataset. The initial land cover layer extractions will be edited at a 1:1500 quality control scale in the urban areas and at a 1:2500 scale for rural areas utilizing the most current high-resolution aerial imagery to aid in the quality control process.

To test for accuracy, random plot locations

are generated throughout the city area of interest and verified to ensure that the data meet the client standards. A 3x3 grouping of pixels will be compared with the most current NAIP high-resolution imagery (reference image) to determine the accuracy of the final land cover layer. Points will be classified as either correct or incorrect and recorded in a classification matrix. Accuracy will be assessed using four metrics: overall accuracy, kappa, quantity disagreement, and allocation disagreement. These metrics are calculated using a custom Excel spreadsheet.

Land Cover Accuracy

The following describes Davey Resource Group's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. *Random Point Generation.* Using ArcGIS, 1,500 random assessment points are generated. These points are utilized as "center points" of 3x3 pixel groupings. A box is drawn around the nine-pixel grouping. The 1,500 randomly generated groupings are used for the accuracy assessment. Using a 3x3 grouping of pixels provides more information for the accuracy assessment since adjacent pixels are also looked at, which increases the number of pixels assessed since nine pixels are assessed instead of just a single pixel. This method reduces the weight of the center pixel from 1 to 1/9 since the 3x3 grouping is assessed as a whole.

2. *Point Determination.* Each individual pixel of the 3x3 grouping is carefully assessed by the GIS analyst for likeness with the aerial photography. The number of pixels for each land cover type is recorded. The land cover class with the most pixels represented in the pixel grouping is determined to be the correct land cover class, unless visually disputed on high-resolution sub-meter imagery. To record findings, two new fields, CODE and TRUTH, are added to the accuracy assessment point shapefile. CODE is a numeric value (1–5) assigned to each land cover class (Table 1) and TRUTH is the actual land cover class as identified according to the reference image. If CODE and TRUTH are the same for all nine pixels assessed, then the point is counted as a correct classification. Likewise, if none of the pixels assessed match, then the point is classified as incorrect. If the location has been 100% egregiously misclassified (all nine pixels incorrect), then the results have the same outcome as using just a single pixel. The same is true for a correct classification.

App. Table 1. Land Cover Code Values

Classification	Value
Tree Canopy	1
Impervious	2
Pervious	3
Bare Soil	4
Open Water	5

In most cases, distinguishing if a point is correct or incorrect is straightforward. Points will rarely be misclassified by an egregious classification or editing error. Often incorrect points occur where one feature stops and the other begins. Using nine pixels for the accuracy assessment instead of only 1 pixel allows for better identification of transitional pixels and assignment of varying degrees of correctness. For example, if the center pixel of the nine-pixel box is considered incorrect, the other 8 pixels surrounding it may still be classified correctly. Thus, instead of the accuracy of this location being completely correct or completely incorrect, it can be classified as mostly correct as opposed to being classified completely incorrect.

3. *Classification Matrix.* During the accuracy assessment, if a point is considered incorrect, it is given the correct classification in the TRUTH column. Points are first assessed on the NAIP imagery for their correctness using a "blind" assessment—meaning that the analyst does not know the actual classification (the GIS analyst is strictly going off the NAIP imagery to determine cover class). Any incorrect classifications found during the "blind" assessment are scrutinized further using sub-meter imagery provided by the client to determine if the

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App. Table 2. Classification Matrix

Reference Data	Classes	Tree Canopy	Impervious Surfaces	Grass & Low-Lying Vegetation	Bare Soils	Open Water	Row Total	Producer's Accuracy	Errors of Omission
	Tree Canopy	529	7	21	0	0	557	94.97%	5.03%
	Impervious	2	340	23	0	0	365	93.15%	6.85%
	Grass/Vegetation	18	10	465	0	0	493	94.32%	5.68%
	Bare Soils	2	1	4	20	0	27	74.07%	25.93%
	Water	1	0	2	1	54	58	93.10%	6.90%
	Column Total	552	358	515	21	54	1,500		
	User's Accuracy	95.83%	94.97%	90.29%	95.24%	100.00%		Overall Accuracy	93.87%
	Errors of Commission	4.17%	5.03%	9.71%	4.76%	0.00%		Kappa Coefficient	0.9112

point was incorrectly classified due to the fuzziness of the NAIP imagery or an actual misclassification. After all random points are assessed and recorded; a classification (or confusion) matrix is created. The classification matrix for this project is presented in Table 2 above. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement, and confidence intervals (Table 3).

4. Following are descriptions of each statistic as well as the results from some of the accuracy assessment tests.

Overall Accuracy. Percentage of correctly classified pixels; for example, the sum of the diagonals divided by the total points ((529+340+465+20+54)/1,500 = 93.87%).
User's Accuracy – Probability that a pixel classified on the map actually represents that category on the ground (correct land cover classifications divided by the column total [529/552 = 95.83%]).
Producer's Accuracy. Probability of a reference pixel being correctly classified (correct land cover classifications divided by the row total [529/557 = 94.97%]).

Kappa Coefficient. A statistical metric used to assess the accuracy of classification data. It has been generally accepted as a better determinant of accuracy partly because it accounts for random chance agreement. A value of 0.80 or greater is regarded as "very good" agreement between the land cover classification and reference image.

Errors of Commission. A pixel reports the presence of a feature (such as trees) that, in reality, is absent (no trees are actually present). This is termed as a false positive. In the matrix above (Table 2), we can determine that 4.17% of the area classified as canopy is most likely not canopy.

Errors of Omission. A pixel reports the absence of a feature (such as trees) when, in reality, they are actually there. In the Omission/Commission Errors matrix (next page), we can conclude that 5.03% of all canopy classified is actually present in the land cover data.

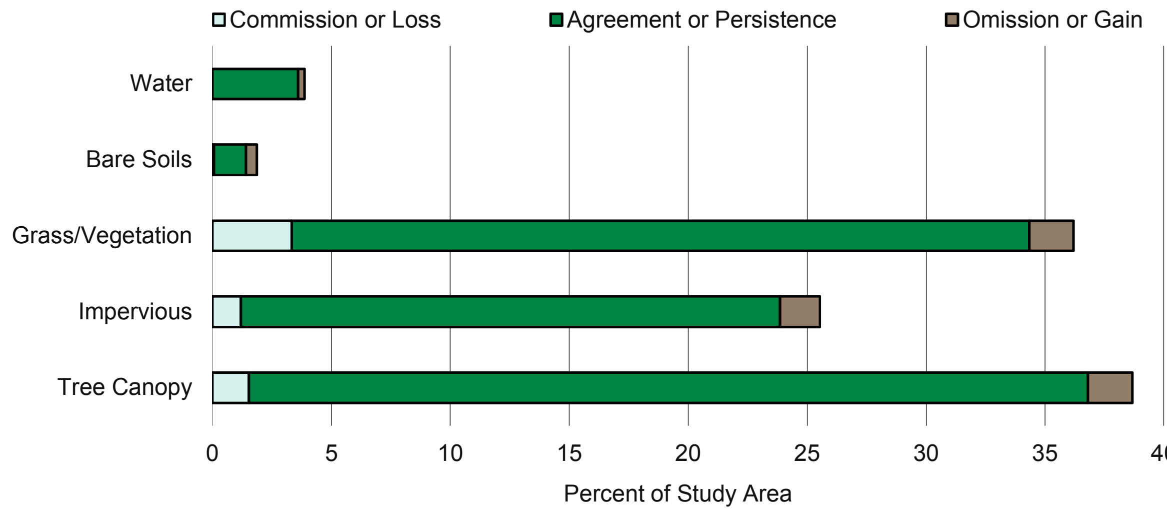
Allocation Disagreement. The amount of difference between the reference image and the classified land cover map that is due to less than optimal match in the spatial allocation (or position) of the classes.

Quantity Disagreement. The amount of difference between the reference image and the classified land cover map that is due to less than perfect match in the proportions (or area) of the classes.

FINAL DRAFT

Confidence Intervals. A confidence interval is a type of a population parameter and is used to indicate the reliability of an estimate. Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter based on the observed probability of successes and failures. Since all assessments have innate error, defining a lower and upper bound estimate is essential.

App. Figure 1. Omission/Commission Errors Matrix



App. Table 3. 95% Confidence Intervals, Accuracy Assessment, and Statistical Metrics Summary

Confidence Intervals

Class	Acreage	Percentage	Lower Bound	Upper Bound
Tree Canopy	94,462	37.10%	37.00%	37.20%
Impervious Surfaces	56,033	22.00%	21.90%	22.10%
Grass & Low-Lying Vegetation	88,525	34.80%	34.70%	34.90%
Bare Soils	5,316	2.10%	2.10%	2.10%
Open Water	10,113	4.00%	3.90%	4.00%
Total	254,449	100.00%		

Statistical Metrics Summary

Overall Accuracy =	93.87%
Kappa Coefficient =	0.9112
Allocation Disagreement =	5%
Quantity Disagreement =	1%

Accuracy Assessment

Class	User's Accuracy	Lower Bound	Upper Bound	Producer's Accuracy	Lower Bound	Upper Bound
Tree Canopy	95.80%	95.00%	96.70%	95.00%	94.00%	95.90%
Impervious Surfaces	95.00%	93.80%	96.10%	93.20%	91.80%	94.50%
Grass & Low-Lying Vegetation	90.30%	89.00%	91.60%	94.30%	93.30%	95.40%
Bare Soils	95.20%	90.60%	99.90%	74.10%	65.60%	82.50%
Open Water	100.00%	100.00%	100.00%	93.10%	89.80%	96.40%

Demographics & Socioeconomic Data

Data acquired for the socioeconomic analysis was provided by the U.S. Census Bureau at the census tract and census block levels, specifically 2006-2010 American Community Survey 5-Year Estimates. Table 4 lists exact U.S. Census table used.

App. Table 4. Demographic Data Sources

Variable	Table Number	Table Description
Age	B01001	Age of Population
Education Level	B15001	Educational Attainment Population 18+
Ethnicity	B02001	Ethnicity of Population
Median Income	B19013	Median Income of Population
Building Value	B25075	Value of Buildings
Building Age	B25034	Year Structure Built
Renter Occupied	B25003	Tenure of Occupied Housing Units
Owner Occupied	B25003	Tenure of Occupied Housing Units
Single Family Homes	B25024	Units in Structure(1-Detached)

How Tree Canopy Benefits Are Calculated

Air Quality. The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for air quality. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports air pollutant removal rates and monetary values for carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), and particulate matter (PM) (Hirabayashi 2014).

Within the i-Tree Canopy application, the U.S. EPA's BenMAP Model estimates the incidence of adverse health effects and monetary values resulting from changes in air pollutants (Hirabayashi 2014; US EPA 2012). Different pollutant removal values were used for urban and rural areas. In i-Tree Canopy, the air pollutant amount annually removed by trees and the associated monetary value can be calculated with tree cover in areas of interest using BenMAP multipliers for each county in the United States.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for each of the five listed air pollutants.

Carbon Sequestration. The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for carbon storage and sequestration. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports carbon storage and sequestration rates and monetary values. Methods on deriving storage and sequestration can be found in Nowak et al. 2013.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for carbon storage and sequestration.

Stormwater & Sewersheds. The i-Tree Hydro v5.0 (beta) Model was used to quantify the value of ecosystem services for stormwater runoff. i-Tree Hydro was designed for users interested in analysis of vegetation and impervious cover effects on urban hydrology. This most recent beta version (v5.0) allows users to report hydrologic data on the city level rather than just a watershed scale giving users more flexibility. For more information about the model, please consult the i-Tree Hydro v5.0 manual (www.itreetools.org).

To calculate ecosystem services for the study area, land cover percentages derived for Louisville were used as inputs into the model. Precipitation data from 2005 was selected within the model as that year closely represented the average rainfall (45.5") for the City of Louisville (NOAA 2014). Model simulations were run under a Base Case as well as an Alternate Case. The Alterative Case increased canopy by 1% and assumed that impervious and vegetation cover would decrease by 0.5% equally as plantings would ultimately reduce these land cover types. This process was completed to assess the runoff reduction volume associated with a 1% increase in tree canopy since i-Tree Hydro does not directly report the volume of runoff reduced by tree canopy. The volume (in cubic meters) was converted to gallons and multiplied by the current canopy percentage (37.1%) in Louisville to retrieve the overall volume reduced by the tree canopy.

Through model simulation, it was determined that tree canopy decreases the runoff volume in Louisville by 18,835,266,390 billion gallons during an average precipitation year. This equates to approximately 199,397 gallons per acre of tree canopy (18.8 billion/94,461 acres). To validate the model, the results were compared to the City of Indianapolis Municipal Forest Resource Analysis report (Peper et al. 2008) which detailed the ecosystem services of trees in the Lower Midwest STRATUM climate zone (U.S. Forest Service 2012). This report was consulted because the City of Louisville is located in this climate zone and the two cities are less than 120 miles apart in distance making their climate and weather patterns similar in nature. The Indianapolis study found that approximately 1,752 acres of street tree canopy reduced runoff volume by roughly 318.9 million gallons or 181,412 gallons per acre (Peper et al. 2008). On average, the City of Louisville has about 4.5 more inches of precipitation annually than does the City of Indianapolis (45.5" to 41.0"), which can mostly explain the additional 18,000 gallons of annual runoff reduction associated with an acre of tree canopy.

In order to assess runoff reduction volume on the census tract, council district, and sewershed level, the 199,397 gallons per acre value was used since i-Tree Hydro does not directly utilize boundaries other than watershed and city limits. To place a monetary value on stormwater reduction, the City of Louisville provided the price to treat a gallon of stormwater in 2014 ($3.34 per 1,000 gallons).

Energy Savings (Cooling). Trees have a profound effect on building energy and has been studies using various methods (Carver et al. 2004; McPherson and Simpson 2003). The process of estimating energy (electricity) savings starts with determining the number of one-unit structures by vintage (age) class within each census block group. Vintage refers to construction type for a building (i.e. average floor area, floor types, insulation (R-value), and number of stories) and was broken into three categories: pre-1950, 1950-80, and post-1980.

Census data obtained from the 2010 American Community Survey (Table B25024 – UNITS IN STRUCTURE and Table B25034 - YEAR STRUCTURE BUILT) was used to determine the number of one-unit structures. The data was based on 5-year estimates. Since the number of one-unit structures differed at the block group level, the number of one-unit structures was determined by vintage and block group by multiplying the percentage of units in

FINAL DRAFT

each vintage by the total number of one-unit structures in each block group (McPherson et al. 2013). For each block group, total energy savings were tallied for each block group using a function of percent UTC, vintage class, and energy saving coefficients (McPherson and Simpson 2003, McPherson et al. 2013).

To provide energy savings for council districts and sewersheds, block groups were assigned based on their spatial positioning related to the block group data. While the boundaries do not overlay perfectly, it does provide a rough estimate for these boundaries. Census tracts were calculated without assigning a block group because these data nested within each census tract. The kWh saved were summarized.

The monetary value for energy savings was valued by summing all estimated kWh saved for each vintage class and multiplied by the current 2014 electricity cost priced at $0.08076 per kWh.

Property Values. Many benefits of tree canopy are difficult to quantify. When accounting for wildlife habitat, well-being, shading, and beautification, these services are challenging to translate into economic terms. In order to provide some estimation of these additional services, this report calculated a property value based on the value of home prices for the City of Louisville. Limitations to this approach include determining actual value of individual trees on a property and extrapolation of residential trees to other land use categories (McPherson et al. 2013).

In a study completed in 1988, it was found that single-family residences in Athens, GA had a 0.88% increase in the average home sale price for every large front-yard tree on the property (Anderson and Cordell 1988). Using this study, the sales price increase was utilized as an indicator of additional tree benefits. While home sales vary widely, in 2012, the median home sales value in the City of Louisville was $120,575 ("Louisville, Kentucky" 2014). Using this median sales price and multiplying by 0.88%, the value of a large front-yard tree was $1,447. To convert this value into annual benefits, the total added value was divided by the leaf surface area of a 30 year old shade tree ($1,447/5,382ft2) which yields a base value of $0.27/ft^2. Using methodology from McPherson et al. 2013 to convert into units of UTC, the base value of tree canopy was determined to be $0.23 ft^2 UTC. Since this value was derived using residential land use designations, transfer functions were used to adapt and apply the base value to other land use categories. To be conservative in the estimation of tree benefits, the land use reduction factors calculated property value at 50% impact for single-family residential parcels, 40% for multi-residential parcels, 20% for commercial parcels, and 10% for all other land uses (Table 6). The price per unit of UTC values were multiplied by the amount of square feet of tree canopy within each land use category and summarized countywide, census tract, council district, and sewershed.

App. Table 5. Price Table

Prices for Ecosystem Services (2014)		Service Value
Energy Savings	$/MWh	80.76
CO_2 Storage	$/Ton	19.43
CO_2 Sequestration	$/Ton	19.43
CO	$/Ton	1,333.50
NO_2	$/Ton	851.54
O_3	$/Ton	3,645.87
SO_2	$/Ton	253.92
PM_{10}	$/Ton	6,268.44
Rainfall Interception	$/1,000 gals	3.34

App. Table 6. Land Use Reduction Transfer Function Values

Land Use Category	**Impact**	**Price per unit of UTC**
Single-Family Residential	50%	$0.12
Multi-Family Residential	40%	$0.09
Commercial	20%	$0.05
All Other	10%	$0.02

FINAL DRAFT

Urban Heat Island Analysis & Hot Spot Detection

Two methods were used to identify hot spots within the study area: surface temperatures and impervious to canopy land cover ratios.

Mapping Surface Temperature. Mapping Land Surface Temperature (LST) pinpoints land area with the hottest surfaces. For this project, Landsat 5 Thematic Mapper satellite imagery (image date July 5, 2010) was used to create a 30 x 30 meter LST grid for surface temperature throughout Louisville using methods from Sobrino et al 2004, and the surface temperature grid was converted to units of Fahrenheit. The temperature grid was resampled to 5 meter resolution in order to summarize average surface temperature for all potential planting sites. Temperature data was summarized using zonal statistics and given a ranking from very low to very high based on average surface temperature.
The land surface temperatures of the study area for the July 5, 2010 image ranged from 57.9°F to 124.6°F (Mean: 85.9°F and Standard Deviation: 5.6°F). Hot spots were distinguished and separated by breaking temperature data into five ranges using Natural Breaks. Using this method, temperatures were binned into a fairly even number of pixels per temperature range. The highest temperature range areas (94.5°F – 124.6°F) were designated as hotspots. These hot spots were further analyzed for potential tree plantings.

Impervious to Canopy Ratio. Another metric to identify urban heat island within the City of Louisville was the ratio of impervious surface to canopy cover in a grid of 100 X 100 meter squares. For each square, the amount of impervious surface and tree canopy was calculated. The amount of impervious area was then divided by the canopy cover yielding a ratio value for each grid cell. A larger ratio indicated areas of "hotter" surfaces or the presence of urban heat islands. These areas were synonymous with impervious surfaces such as buildings and parking lots. Small ratio values (less than 1) had a much greater presence of tree canopy.

Stormwater Priority Ranking

MSD Sewersheds. Identifying priority locations for stormwater management was essential to this project. The City of Louisville's Metropolitan Sewer District (MSD) currently has data which was utilized in the priority ranking process. MSD contained data which placed a dollar per square foot of impervious surface value for each of the 101 sewersheds. The top 10 MSD sewersheds were identified and discussed in this report (Table 7).

Stormwater Ranking. During the ranking process, data derived from the UTC analysis, data provided by MSD, and environmental data were used to prioritize census tracts, council districts, and sewersheds (Table 8). For location specific problem locations throughout Louisville, MSD provided data for the past two years where drainage issues (flooding, erosion, standing water) had occurred. The datasets were classified based on the value of "risk" from 0-4, with 4 posing the highest "risk" of contributing to stormwater runoff. Variables were weighted to produce a results grid. The grid was summarized using zonal statistics by each feature layer and given an average risk score. Higher priority areas received a larger risk score.

App. Table 7. Priority Sewersheds identified by MSD

Sewershed Unit ID Number	Total Value per Square Foot of Impervious Surface
CSO 141	$16.65
CSO 082	$5.00
CSO 120	$3.78
CSO 154	$2.82
CSO 153	$2.67
CSO 106	$2.61
CSO 137	$2.61
CSO 083	$2.51
CSO 119	$2.51
CSO 179	$2.49

FINAL DRAFT

App. Table 8. Stormwater Ranking Weights

Dataset	Weight	Source
Drainage Issues	0.35	Metropolitan Sewer District
Impervious Distance	0.25	Urban Tree Canopy Assessment
Slope	0.15	National Elevation Dataset
Floodplain	0.1	Metropolitan Sewer District
Soils	0.1	Natural Resource Conservation Service
Canopy Distance	0.05	Urban Tree Canopy Assessment

Potential Tree Planting Estimates

Potential Tree Planting Sites. By eliminating all non-suitable sites described previously, potential tree counts were estimated. The number of potential sites was calculated based on two types of planting sites – pervious and possible impervious. For each type, the number of gross and net sites was tabulated. The gross number was estimated by taking the area of planting space available (in square feet) and dividing by a medium-sized 29-ft crown diameter. This is the same crown size and area used to approximate the existing tree counts. The net total of potential planting sites was calculated by taking the gross number and multiplying it by the current canopy percentage over pervious surface and the current canopy percentage over impervious surface. During the assessment, it was found that 50% of all pervious surfaces (excludes impervious surfaces and water) were covered by tree canopy and approximately 5% of impervious surfaces were cover by tree canopy. Therefore, to find the best estimate and provide a reasonable count of potential planting sites, the number of potential trees in pervious planting areas was multiplied by 50% and the number of potential impervious sites was multiplied by 5%.

Existing Trees. The number of existing trees was calculated using an assumed average crown diameter of 29 feet (661 square feet) based on the results from the City of Indianapolis Municipal Forest Resource Analysis report by Peper et al. 2008 which found the sampled street trees to have an average crown diameter of 29 -feet across all tree species. The area of tree canopy was divided by the crown area (661 square feet) to receive the total number of trees. Existing tree counts were evaluated for block groups, census tracts, council districts, land use designations, suburban cities, neighborhoods, parcels, and sewersheds as well as countywide. Using the tree counts, additional metrics for tree density (trees per acre) and trees per capita were also derived. Trees per capita were only calculated for block groups, census tracts, and council districts due to population data not readily available at other levels.

FINAL DRAFT

Tree Planting Plan & Prioritization Methodology

All potential planting sites were not treated equal as some sites were considered to be more suitable than others. Through prioritization, sites were ranked by three factors: urban heat island effects, stormwater management and a combination of environmental sensitivities. Each of the three factors were weighted evenly.

Environmental Sensitivities. A number of features were considered in the environmental sensitivities factor, including:

Floodplains. A floodplain is an area of land adjacent to a stream or riverthat stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge. Floodplains can support particularly rich ecosystems, both in quantity and diversity. Protecting them is ecologically important.

Hydrologic Soil Group. Soils are assigned groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The soils have four groups (A, B, C, and D). A soils have a high infiltration rate (low runoff potential) while D soils have slow infiltration rates (high runoff).

Slope. Slope is a measure of change in elevation. It is a crucial parameter in several well-known predictive models used for environmental management. A higher degree of slope increases the velocity of stormwater runoff causing a greater risk of erosion due to sheeting, especially if slopes are bare.

Hardscape Proximity. Impervious surfaces vastly increase the amount of runoff during storm events. By identifying these locations and their surroundings, measures can be taken to reduce the amount of runoff by planting trees close to hardscapes.

Canopy Proximity. Canopy fragmentation has many ecological downsides by degrading the overall health of the trees and wildlife. It is essential to close as many gaps as possible and create more connectivity to increase biodiversity and canopy health.

Road Density. The amount of road density signifies how much noise and air pollution are being released in the atmosphere. Controlling these factors helps maintain quieter neighborhoods as well as reduced levels of air pollution emissions such as carbon dioxide, ozone, and particulate matter.

Population Density. Population density represents the number of people within a given area. Having greater amounts of people within an area attracts the need for more trees to aesthetically improve the urban landscape. By planting in areas with higher population density, there is more return on investment because more people receive this benefit.

Each feature was assessed using separate grid maps. Values between zero and four (with zero having the lowest runoff risk potential) were assigned to each feature/grid assessed. The grids were overlain and the values were averaged to determine the runoff risk potential at an area on the map. A runoff priority ranging from Very Low to Very High was assigned to areas on the map based on the calculated average.

Heat Island and Stormwater. The output grid of values from the environmental sensitivities was then overlayed with the urban heat island grid values (based on the surface temperature data method) and stormwater priority values, both described earlier in the appendix, to create the composite prioritization results.

Appendix B Contents:

A complete and extensive collection of data tables and shapefiles have been delivered to the Louisville Metro Government electronically for future use and analysis.

Council Districts: Existing & Potential Canopy

	Size (acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible
District 1	9,389	4%	30%	28%	27%	-9%	25%	52%
District 2	4,986	2%	26%	23%	22%	-14%	32%	54%
District 3	4,537	2%	23%	23%	21%	-9%	33%	54%
District 4	4,153	2%	13%	12%	12%	-4%	16%	29%
District 5	5,371	2%	25%	23%	23%	-6%	19%	43%
District 6	3,291	1%	20%	19%	18%	-12%	22%	40%
District 7	7,956	3%	45%	42%	40%	-11%	24%	64%
District 8	4,322	2%	45%	43%	40%	-12%	22%	62%
District 9	6,515	3%	37%	35%	33%	-11%	20%	53%
District 10	6,410	3%	30%	28%	25%	-16%	27%	52%
District 11	7,032	3%	34%	33%	32%	-6%	29%	60%
District 12	8,402	3%	31%	29%	29%	-5%	32%	61%
District 13	20,928	8%	50%	48%	48%	-4%	26%	74%
District 14	18,013	7%	47%	46%	46%	-1%	22%	68%
District 15	4,316	2%	33%	32%	31%	-6%	25%	56%
District 16	16,158	6%	43%	42%	40%	-7%	23%	63%
District 17	8,916	4%	39%	38%	36%	-9%	31%	67%
District 18	7,406	3%	31%	29%	27%	-10%	28%	56%
District 19	19,935	8%	43%	41%	39%	-8%	26%	65%
District 20	39,330	15%	53%	52%	51%	-3%	20%	72%
District 21	7,143	3%	19%	17%	16%	-17%	25%	40%
District 22	12,991	5%	38%	37%	35%	-8%	34%	69%
District 23	7,988	3%	37%	36%	34%	-8%	38%	73%
District 24	6,972	3%	31%	30%	29%	-7%	36%	65%
District 25	7,702	3%	48%	46%	45%	-8%	30%	75%
District 26	4,160	2%	28%	27%	24%	-14%	29%	54%

FINAL DRAFT

Suburban Cities: Existing & Potential Canopy

	Size (acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible
Anchorage	1,894	0.74%	64%	62%	57%	-11%	26%	83%
Audubon Park	209	0.08%	58%	56%	48%	-17%	27%	75%
Bancroft	98	0.04%	50%	47%	45%	-9%	31%	76%
Barbourmeade	251	0.10%	51%	45%	43%	-16%	30%	73%
Beechwood Village	177	0.07%	48%	41%	33%	-31%	32%	65%
Bellemeade	180	0.07%	50%	40%	36%	-28%	39%	75%
Bellewood	51	0.02%	70%	65%	53%	-24%	25%	78%
Blue Ridge Manor	117	0.05%	34%	31%	30%	-12%	26%	56%
Briarwood	59	0.02%	40%	34%	32%	-20%	32%	65%
Broeck Pointe	43	0.02%	51%	49%	46%	-9%	26%	72%
Brownsboro Farm	146	0.06%	61%	56%	57%	-7%	19%	76%
Brownsboro Village	46	0.02%	58%	55%	46%	-20%	27%	73%
Cambridge	35	0.01%	51%	51%	48%	-6%	31%	79%
Coldstream	141	0.06%	32%	23%	19%	-41%	51%	70%
Creekside	47	0.02%	46%	39%	38%	-19%	33%	70%
Crossgate	34	0.01%	41%	40%	35%	-15%	29%	64%
Douglass Hills	845	0.33%	37%	36%	34%	-7%	27%	62%
Druid Hills	52	0.02%	67%	65%	56%	-17%	20%	76%
Fincastle	133	0.05%	45%	43%	40%	-10%	36%	77%
Forest Hills	175	0.07%	30%	27%	26%	-12%	24%	50%
Glenview	921	0.36%	69%	69%	60%	-12%	27%	87%
Glenview Hills	74	0.03%	50%	48%	37%	-25%	33%	71%
Glenview Manor	54	0.02%	48%	44%	40%	-16%	35%	76%
Goose Creek	39	0.02%	48%	47%	43%	-11%	26%	68%
Graymoor/Devondale	472	0.19%	34%	30%	27%	-21%	37%	64%
Green Spring	168	0.07%	50%	49%	49%	-2%	29%	77%
Heritage Creek	292	0.11%	19%	23%	24%	24%	55%	79%
Hickory Hill	17	0.01%	27%	27%	22%	-18%	35%	57%
Hills and Dales	64	0.03%	57%	56%	55%	-3%	27%	82%
Hollow Creek	147	0.06%	49%	48%	41%	-15%	34%	76%
Hollyvilla	219	0.09%	60%	59%	57%	-5%	20%	78%
Houston Acres	92	0.04%	53%	52%	50%	-7%	26%	76%
Hurstbourne	1,146	0.45%	31%	31%	29%	-7%	25%	54%

FINAL DRAFT

Suburban Cities: Existing & Potential Canopy (continued)

	Size (acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible
Hurstbourne Acres	211	0.08%	27%	26%	25%	-7%	32%	57%
Indian Hills	1,252	0.49%	67%	67%	64%	-5%	20%	83%
Jeffersontown	6,372	2.50%	28%	27%	26%	-8%	31%	57%
Kingsley	44	0.02%	33%	31%	29%	-14%	34%	63%
Langdon Place	115	0.05%	25%	24%	23%	-8%	41%	64%
Lincolnshire	29	0.01%	45%	44%	41%	-9%	35%	76%
Louisville	218,979	86.06%	40%	39%	38%	-6%	25%	63%
Lyndon	2,317	0.91%	34%	31%	30%	-14%	33%	62%
Lynnview	116	0.05%	25%	22%	19%	-24%	38%	57%
Manor Creek	34	0.01%	58%	53%	50%	-15%	24%	73%
Maryhill Estates	25	0.01%	53%	52%	46%	-13%	27%	73%
Meadow Vale	117	0.05%	33%	27%	23%	-29%	31%	54%
Meadowbrook Farm	18	0.01%	42%	39%	39%	-8%	31%	70%
Meadowview Estates	51	0.02%	38%	37%	31%	-18%	28%	60%
Middletown	3,264	1.28%	40%	38%	35%	-13%	27%	62%
Mockingbird Valley	132	0.05%	75%	68%	70%	-7%	19%	89%
Moorland	59	0.02%	45%	37%	34%	-26%	37%	70%
Murray Hill	85	0.03%	47%	47%	46%	-3%	27%	73%
Norbourne Estates	49	0.02%	58%	53%	46%	-20%	25%	71%
Northfield	302	0.12%	39%	38%	31%	-20%	30%	61%
Norwood	74	0.03%	59%	48%	44%	-26%	24%	68%
Old Brownsboro Place	85	0.03%	45%	42%	40%	-10%	32%	72%
Parkway Village	56	0.02%	25%	24%	21%	-16%	32%	53%
Plantation	128	0.05%	35%	32%	28%	-21%	36%	63%
Poplar Hills	16	0.01%	14%	14%	13%	-6%	29%	42%
Prospect	2,514	0.99%	41%	41%	40%	-3%	25%	65%
Richlawn	65	0.03%	53%	48%	34%	-36%	30%	64%
Riverwood	132	0.05%	58%	57%	56%	-4%	23%	80%
Rilling Fields	150	0.06%	58%	57%	54%	-7%	23%	77%
Rolling Hills	121	0.05%	33%	25%	23%	-31%	34%	57%
Seneca Gardens	98	0.04%	49%	48%	44%	-10%	28%	72%
Shively	2,953	1.16%	24%	24%	22%	-9%	35%	57%
South Park View	77	0.03%	64%	7%	28%	-55%	66%	94%

FINAL DRAFT

Suburban Cities: Existing & Potential Canopy (continued)

	Size (acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible
Spring Mill	35	0.01%	40%	39%	35%	-12%	33%	68%
Spring Valley	126	0.05%	60%	55%	54%	-9%	22%	76%
St. Matthews	2,771	1.09%	32%	30%	26%	-19%	28%	53%
St. Regis Park	229	0.09%	37%	37%	35%	-6%	33%	68%
Strathmoor Manor	35	0.01%	51%	47%	40%	-22%	28%	68%
Strathmoor Village	65	0.03%	36%	34%	32%	-12%	31%	62%
Sycamore	10	0.00%	18%	18%	17%	-8%	24%	41%
Ten Broeck	141	0.06%	75%	71%	69%	-8%	24%	93%
Thornhill	29	0.01%	56%	55%	47%	-16%	25%	72%
Watterson Park	919	0.36%	24%	21%	15%	-37%	29%	44%
Wellington	57	0.02%	33%	29%	25%	-24%	35%	60%
West Buechel	412	0.16%	10%	11%	11%	9%	24%	35%
Westwood	79	0.03%	38%	33%	29%	-24%	38%	67%
Wildwood	46	0.02%	43%	41%	40%	-7%	31%	72%
Windy Hills	567	0.22%	46%	45%	39%	-16%	33%	72%
Woodland Hills	134	0.05%	38%	34%	31%	-20%	36%	66%
Woodlawn Park	161	0.06%	40%	35%	28%	-30%	36%	65%
Worthington Hills	158	0.06%	39%	38%	28%	-30%	40%	68%

FINAL DRAFT

Neighborhoods: Existing & Potential Canopy

	Size (acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible
Algonquin	763	2%	14%	14%	12%	*-13%*	26%	38%
Auburndale	392	1%	34%	32%	29%	*-16%*	40%	69%
Audubon	398	1%	34%	33%	29%	*-15%*	35%	64%
Audubon Park	206	1%	58%	56%	48%	*-17%*	27%	75%
Avondale Melbourne Heights	310	1%	37%	35%	29%	*-20%*	34%	64%
Bashford Manor	355	1%	26%	24%	23%	*-11%*	29%	52%
Beechmont	925	2%	29%	28%	26%	*-10%*	32%	59%
Belknap	506	1%	43%	40%	37%	*-13%*	26%	63%
Bon Air	789	2%	31%	30%	28%	*-12%*	32%	60%
Bonnycastle	209	1%	46%	44%	41%	*-11%*	25%	66%
Bowman	811	2%	19%	19%	18%	*-9%*	18%	35%
Brownsboro Zorn	505	1%	54%	52%	51%	*-7%*	23%	74%
Butchertown	588	1%	25%	26%	23%	*-7%*	29%	53%
California	787	2%	16%	14%	13%	*-21%*	22%	35%
Camp Taylor	267	1%	35%	35%	30%	*-14%*	30%	61%
Central Business District	758	2%	7%	7%	8%	*16%*	12%	20%
Cherokee Gardens	251	1%	58%	55%	53%	*-9%*	24%	77%
Cherokee Seneca	843	2%	58%	56%	55%	*-5%*	13%	67%
Cherokee Triangle	626	2%	48%	47%	41%	*-13%*	11%	53%
Chickasaw	779	2%	33%	33%	30%	*-10%*	32%	62%
Clifton	436	1%	43%	42%	39%	*-10%*	20%	58%
Clifton Heights	410	1%	43%	43%	40%	*-6%*	23%	64%
Cloverleaf	464	1%	28%	26%	23%	*-20%*	42%	65%
Crescent Hill	1,217	3%	41%	39%	37%	*-10%*	22%	59%
Deer Park	314	1%	27%	27%	24%	*-10%*	29%	53%
Edgewood	476	1%	33%	21%	16%	*-51%*	52%	68%
Fairgrounds	693	2%	6%	6%	6%	*-1%*	26%	31%
Gardiner Lane	190	0%	34%	32%	30%	*-13%*	29%	58%
Germantown	384	1%	25%	25%	22%	*-12%*	24%	46%
Hallmark	88	0%	25%	25%	22%	*-10%*	37%	60%
Hawthorne	281	1%	33%	32%	30%	*-9%*	32%	62%
Hayfield Dundee	377	1%	39%	37%	34%	*-12%*	27%	62%
Hazelwood	411	1%	36%	35%	31%	*-15%*	37%	68%

FINAL DRAFT

Neighborhoods: Existing & Potential Canopy (continued)

	Size (acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible
Highland Park	375	1%	12%	13%	12%	*-2%*	27%	39%
Highlands	117	0%	28%	28%	24%	*-13%*	20%	45%
Highlands Douglass	412	1%	45%	43%	40%	*-12%*	26%	65%
Hikes Point	573	1%	31%	30%	27%	*-13%*	32%	58%
Irish Hill	256	1%	41%	40%	38%	*-6%*	20%	58%
Iroquois	423	1%	28%	27%	24%	*-14%*	35%	60%
Iroquois Park	878	2%	71%	70%	68%	*-4%*	13%	81%
Jacobs	451	1%	23%	24%	22%	*-2%*	32%	54%
Kenwood Hill	331	1%	48%	47%	45%	*-7%*	28%	73%
Kingsley	46	0%	32%	30%	28%	*-14%*	33%	61%
Klondike	524	1%	30%	28%	26%	*-13%*	35%	61%
Limerick	145	0%	17%	17%	16%	*-6%*	24%	40%
Meadowview Estates	41	0%	41%	40%	34%	*-18%*	30%	64%
Merriwether	166	0%	22%	22%	20%	*-9%*	26%	47%
Old Louisville	767	2%	26%	26%	25%	*-6%*	15%	40%
Paristown Pointe	43	0%	16%	16%	14%	*-12%*	20%	34%
Park Duvalle	582	1%	20%	21%	19%	*-6%*	33%	51%
Park Hill	643	2%	17%	17%	15%	*-13%*	25%	40%
Parkland	521	1%	26%	25%	23%	*-9%*	25%	48%
Parkway Village	56	0%	25%	24%	21%	*-16%*	32%	53%
Phoenix Hill	373	1%	14%	11%	11%	*-22%*	17%	27%
Poplar Level	776	2%	46%	43%	42%	*-9%*	23%	65%
Portland	1,609	4%	26%	24%	25%	*-4%*	25%	50%
Prestonia	274	1%	24%	22%	20%	*-16%*	32%	52%
Rockcreek Lexington Road	383	1%	42%	40%	38%	*-10%*	23%	61%
Russell	898	2%	21%	20%	21%	*-1%*	22%	43%
Saint Joseph	387	1%	21%	21%	20%	*-6%*	24%	43%
Schnitzelburg	371	1%	23%	22%	21%	*-9%*	29%	50%
Seneca Gardens	100	0%	49%	47%	44%	*-10%*	28%	71%
Shawnee	1,376	3%	37%	35%	35%	*-6%*	26%	60%
Shelby Park	260	1%	20%	20%	19%	*-9%*	24%	42%
Smoketown Jackson	253	1%	17%	17%	16%	*-7%*	21%	37%

FINAL DRAFT

LOUISVILLE JEFFERSON COUNTY
DAVEY RESOURCE GROUP
A Division of The Davey Tree Expert Company

Neighborhoods: Existing & Potential Canopy (continued)

	Size (acres)	% of Study Area	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible
South Louisville	496	1%	14%	14%	13%	*-5%*	18%	31%
Southland Park	436	1%	18%	16%	15%	*-16%*	36%	51%
Southside	589	1%	18%	17%	16%	*-12%*	27%	43%
Standiford	175	0%	4%	4%	3%	*-23%*	8%	11%
Strathmoor Manor	36	0%	51%	46%	39%	*-22%*	28%	67%
Strathmoor Village	67	0%	35%	33%	31%	*-12%*	30%	61%
Taylor Berry	662	2%	28%	28%	26%	*-7%*	29%	55%
Tyler Park	329	1%	48%	48%	37%	*-24%*	19%	56%
University	522	1%	12%	12%	11%	*-9%*	16%	27%
Wellington	57	0%	32%	28%	25%	*-23%*	35%	60%
Wilder Park	237	1%	30%	31%	29%	*-2%*	25%	54%
Wyandotte	348	1%	26%	27%	25%	*-2%*	30%	56%

FINAL DRAFT

Sewersheds

	Size (acres)	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible	Impervious Surface % (2012)	Stormwater Runoff Reduced by Canopy (gallons)	Benefit Value ($)	Value / Acre
CSO015	7,417	23%	22%	21%	-8%	29%	50%	46%	306,012,524	$1,022,082	$137.80
CSO016	4	33%	35%	24%	-27%	36%	60%	37%	173,595	$580	$159.80
CSO019	1,095	26%	23%	24%	-5%	26%	50%	46%	52,746,723	$176,174	$160.93
CSO020	64	13%	12%	11%	-15%	16%	27%	72%	1,411,365	$4,714	$73.54
CSO022	63	3%	3%	4%	57%	5%	10%	90%	543,685	$1,816	$28.64
CSO023	15	10%	9%	11%	8%	5%	15%	84%	319,612	$1,068	$70.22
CSO027	9	2%	1%	1%	-44%	12%	13%	86%	20,634	$69	$8.09
CSO028	20	10%	11%	11%	8%	5%	16%	84%	436,130	$1,457	$73.36
CSO029	46	8%	8%	6%	-18%	9%	16%	84%	569,195	$1,901	$41.50
CSO031	9	31%	33%	30%	-3%	18%	48%	51%	554,520	$1,852	$202.60
CSO034	5	16%	15%	16%	1%	9%	24%	75%	162,268	$542	$104.94
CSO035	16	1%	3%	3%	110%	11%	14%	86%	87,068	$291	$18.19
CSO036	30	7%	7%	8%	23%	6%	14%	85%	486,707	$1,626	$55.10
CSO038	9	2%	4%	4%	136%	6%	10%	90%	73,870	$247	$27.86
CSO050	39	6%	7%	7%	16%	6%	13%	86%	545,212	$1,821	$46.37
CSO051	6	5%	6%	8%	70%	4%	12%	87%	91,845	$307	$52.69
CSO052	10	4%	3%	6%	36%	13%	19%	80%	109,623	$366	$37.92
CSO053	35	5%	5%	6%	41%	4%	11%	89%	449,131	$1,500	$43.14
CSO054	4	5%	11%	13%	171%	2%	15%	85%	101,301	$338	$88.39
CSO055	16	2%	3%	5%	161%	9%	14%	85%	166,257	$555	$34.80
CSO056	36	2%	3%	4%	155%	4%	8%	91%	285,188	$953	$26.18
CSO057	76	12%	11%	11%	-5%	12%	23%	77%	1,656,910	$5,534	$72.83
CSO058	121	10%	8%	7%	-31%	14%	21%	78%	1,713,101	$5,722	$47.19
CSO062	107	25%	25%	22%	-9%	35%	57%	41%	4,766,208	$15,919	$149.33
CSO082	13	37%	39%	35%	-5%	27%	62%	37%	913,135	$3,050	$236.21
CSO083	30	25%	25%	22%	-11%	18%	41%	58%	1,346,655	$4,498	$147.53
CSO084	146	27%	27%	23%	-14%	18%	41%	53%	6,703,284	$22,389	$153.07
CSO086	3	17%	19%	20%	22%	25%	45%	54%	133,607	$446	$135.14
CSO088	2	14%	23%	19%	38%	21%	41%	59%	86,674	$289	$128.43
CSO091	14	30%	30%	24%	-19%	31%	55%	43%	689,160	$2,302	$162.64
CSO092	10	26%	26%	25%	-4%	25%	50%	49%	511,330	$1,708	$165.27
CSO093	17	9%	10%	9%	-2%	14%	23%	76%	315,623	$1,054	$60.26
CSO104	69	36%	32%	28%	-23%	33%	61%	37%	3,786,492	$12,647	$184.56

FINAL DRAFT

Sewersheds (continued)

	Size (acres)	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible	Impervious Surface % (2012)	Stormwater Runoff Reduced by Canopy (gallons)	Benefit Value ($)	Value / Acre
CSO105	1,088	26%	25%	24%	-10%	27%	50%	48%	51,362,197	$171,550	$157.70
CSO106	10	66%	66%	43%	-35%	26%	69%	29%	842,860	$2,815	$285.33
CSO108	508	46%	44%	40%	-13%	26%	66%	33%	40,632,983	$135,714	$267.39
CSO109	101	30%	29%	27%	-9%	29%	56%	40%	5,453,744	$18,216	$180.36
CSO110	93	32%	31%	26%	-16%	25%	52%	34%	4,903,903	$16,379	$176.31
CSO111	88	25%	25%	22%	-10%	31%	54%	45%	3,902,025	$13,033	$148.89
CSO113	67	21%	21%	19%	-11%	33%	52%	44%	2,543,846	$8,496	$126.45
CSO117	73	27%	27%	25%	-7%	24%	49%	49%	3,592,755	$12,000	$163.96
CSO118	339	10%	9%	9%	-14%	18%	27%	72%	6,065,291	$20,258	$59.74
CSO119	4	12%	12%	11%	-13%	14%	25%	74%	95,145	$318	$71.16
CSO120	15	16%	16%	12%	-24%	18%	30%	68%	367,923	$1,229	$79.67
CSO121	102	13%	10%	10%	-21%	18%	28%	71%	2,079,596	$6,946	$68.33
CSO125	359	46%	41%	40%	-13%	21%	61%	34%	28,831,715	$96,298	$268.01
CSO126	37	59%	51%	44%	-26%	23%	66%	33%	3,258,565	$10,884	$291.34
CSO127	216	41%	40%	36%	-13%	19%	55%	37%	15,505,665	$51,789	$239.73
CSO130	16	14%	14%	13%	0%	12%	25%	73%	431,599	$1,442	$89.87
CSO131	30	28%	29%	24%	-14%	20%	43%	56%	1,436,481	$4,798	$157.53
CSO132	674	42%	41%	38%	-8%	22%	60%	37%	51,670,187	$172,578	$256.07
CSO137	72	27%	26%	23%	-16%	10%	32%	25%	3,239,408	$10,820	$149.93
CSO140	78	27%	27%	23%	-14%	23%	46%	52%	3,592,410	$11,999	$154.06
CSO141	9	11%	11%	10%	-3%	13%	24%	75%	183,740	$614	$69.93
CSO142	5	3%	3%	4%	28%	23%	26%	73%	34,719	$116	$24.58
CSO144	12	34%	31%	29%	-15%	26%	55%	44%	667,541	$2,230	$191.99
CSO146	98	20%	20%	19%	-6%	24%	43%	56%	3,651,211	$12,195	$125.04
CSO148	26	54%	54%	42%	-22%	27%	69%	30%	2,213,941	$7,395	$282.37
CSO149	418	28%	28%	26%	-9%	20%	46%	51%	21,677,773	$72,404	$173.24
CSO150	2	13%	15%	19%	42%	6%	24%	75%	64,513	$215	$124.33
CSO151	245	49%	48%	39%	-21%	23%	62%	33%	19,020,807	$63,529	$258.90
CSO152	242	31%	31%	25%	-20%	19%	44%	45%	11,931,379	$39,851	$164.47
CSO153	41	31%	30%	28%	-8%	23%	52%	47%	2,337,354	$7,807	$189.58
CSO154	35	18%	20%	16%	-8%	35%	51%	47%	1,117,214	$3,731	$107.41
CSO155	5	0%	7%	1%	1262%	14%	15%	84%	14,085	$47	$9.52
CSO160	2	0%	0%	1%	-	9%	10%	89%	3,103	$10	$4.59

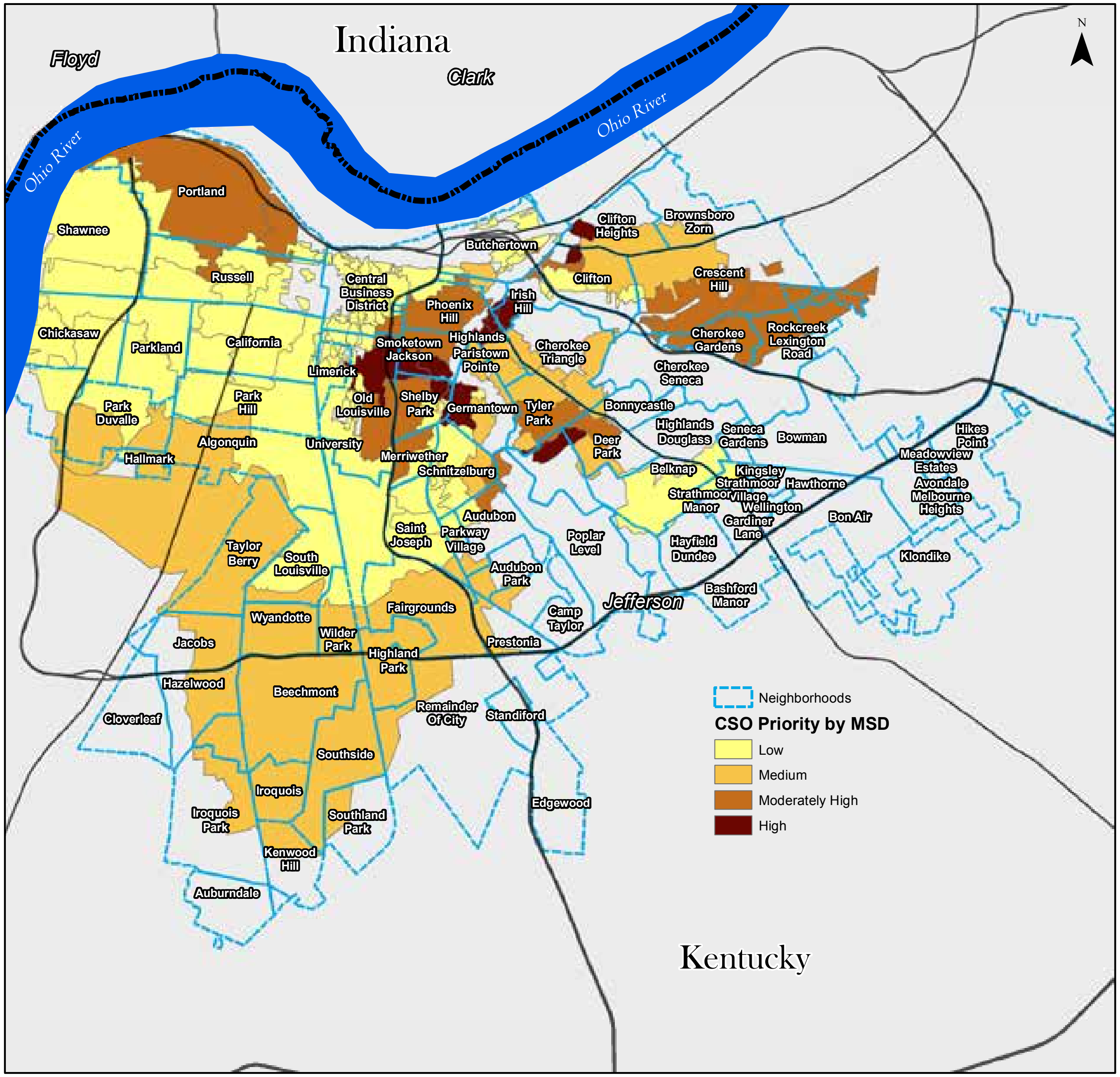
FINAL DRAFT

Sewersheds (continued)

	Size (acres)	2004 Canopy	2008 Canopy	2012 Canopy	Rate of Change 2004 to 2012	Additional Canopy Potential	Maximum Canopy Possible	Impervious Surface % (2012)	Stormwater Runoff Reduced by Canopy (gallons)	Benefit Value ($)	Value / Acre
CSO161	1	15%	14%	16%	7%	2%	18%	82%	46,144	$154	$105.05
CSO166	752	43%	40%	37%	-13%	23%	60%	36%	55,520,354	$185,438	$246.71
CSO167	21	23%	26%	21%	-10%	20%	41%	53%	884,917	$2,956	$140.29
CSO172	10	2%	9%	8%	247%	45%	53%	46%	174,925	$584	$56.45
CSO174	160	18%	18%	17%	-5%	29%	46%	52%	5,380,267	$17,970	$112.00
CSO178	39	6%	6%	6%	-13%	13%	18%	81%	431,550	$1,441	$36.71
CSO179	223	17%	18%	16%	-4%	19%	35%	64%	7,328,571	$24,477	$109.64
CSO180	31	18%	18%	17%	-6%	22%	40%	59%	1,049,697	$3,506	$113.47
CSO181	42	2%	3%	4%	77%	6%	10%	90%	361,767	$1,208	$28.44
CSO182	172	24%	24%	22%	-9%	31%	53%	43%	7,628,534	$25,479	$148.07
CSO183	4	27%	27%	24%	-13%	31%	55%	44%	192,604	$643	$159.06
CSO184	101	29%	28%	25%	-14%	30%	55%	38%	5,032,782	$16,809	$166.78
CSO185	164	22%	22%	21%	-7%	27%	48%	48%	6,741,598	$22,517	$137.34
CSO186	4	9%	9%	9%	-3%	10%	19%	80%	78,549	$262	$59.19
CSO187	6	19%	19%	15%	-23%	15%	29%	69%	176,993	$591	$96.68
CSO188	14	21%	21%	20%	-4%	41%	62%	37%	560,675	$1,873	$136.33
CSO189	1,186	30%	28%	29%	-5%	26%	55%	43%	67,879,983	$226,719	$191.09
CSO190	142	12%	11%	13%	4%	20%	33%	66%	3,620,037	$12,091	$84.90
CSO191	334	21%	22%	20%	-5%	32%	52%	46%	13,547,611	$45,249	$135.31
CSO193	18	32%	31%	29%	-9%	23%	53%	46%	1,043,097	$3,484	$196.11
CSO195	6	17%	21%	19%	12%	23%	43%	57%	219,345	$733	$129.54
CSO196	4	19%	16%	21%	11%	24%	45%	55%	172,167	$575	$142.44
CSO197	4	9%	13%	12%	29%	19%	30%	69%	86,428	$289	$77.86
CSO198	4	37%	40%	41%	10%	15%	56%	43%	289,030	$965	$269.91
CSO199	2	44%	43%	44%	0%	18%	62%	38%	177,633	$593	$292.63
CSO200	8	56%	52%	47%	-16%	14%	61%	39%	707,037	$2,362	$310.76
CSO201	10	13%	14%	17%	28%	18%	35%	64%	338,917	$1,132	$113.70
CSO202	6	32%	33%	32%	-2%	13%	45%	54%	374,178	$1,250	$210.58
CSO203	8	34%	34%	33%	-2%	19%	52%	47%	559,986	$1,870	$221.05
CSO205	8	19%	19%	18%	-8%	37%	54%	42%	298,978	$999	$118.61
CSO207	2	0%	8%	12%	-	1%	13%	86%	51,414	$172	$81.13
CSO208	10	34%	32%	32%	-7%	26%	58%	39%	632,133	$2,111	$212.22
CSO210	181	32%	32%	29%	-10%	31%	60%	35%	10,350,702	$34,571	$190.82
CSO211	3,709	17%	17%	15%	-7%	23%	39%	57%	113,842,313	$380,233	$102.51
Maple St.	675	20%	17%	17%	-16%	23%	40%	58%	22,685,363	$75,769	$112.17

FINAL DRAFT

Overlay of Sewersheds and Neighborhoods



FINAL DRAFT

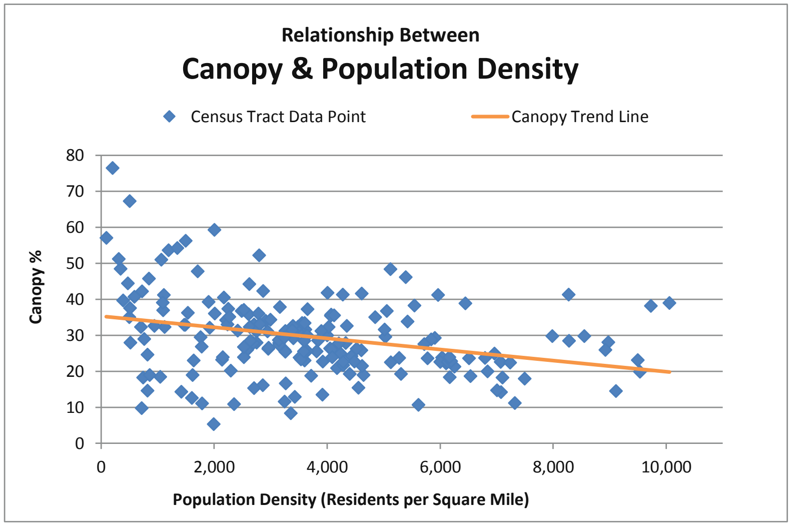
Tree Benefits by Council District

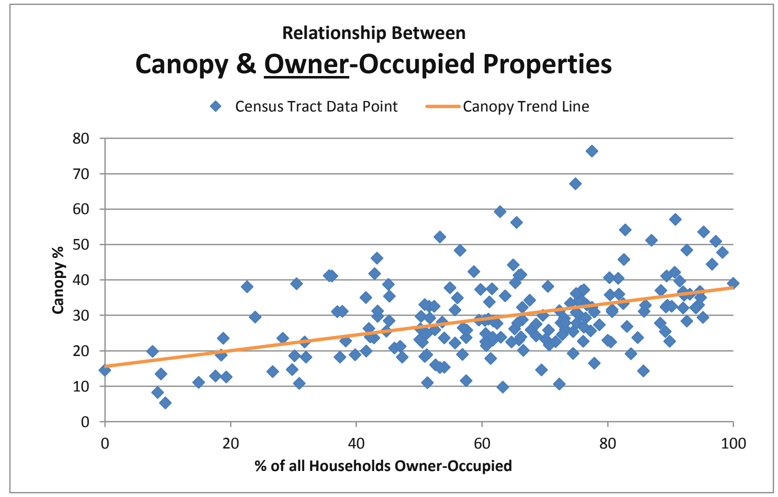
	Size	2012	Air Pollution		Total Carbon*		Stormwater		Energy		Property	Total	Benefits /
	acres	**Canopy**	*lbs.*	*value*	*tons*	*value*	*gallons*	*value*	*kWhs*	*value*	*value*	**Benefits**	**Acre**
District 1	9,389	27%	184,480	$326,764	331,257	$6,414,243	503,665,733	$1,682,244	2,228,223	$179,951	$5,469,811	$14,073,012	$1,499
District 2	4,986	22%	80,051	$141,793	143,759	$2,783,658	218,645,662	$730,277	1,907,587	$154,054	$3,419,855	$7,229,637	$1,450
District 3	4,537	21%	69,195	$122,539	123,860	$2,398,355	187,362,341	$625,790	2,311,806	$186,699	$3,198,419	$6,531,802	$1,440
District 4	4,153	12%	36,014	$65,144	66,634	$1,290,270	100,820,560	$336,741	1,726,242	$139,414	$1,221,920	$3,053,488	$735
District 5	5,371	23%	92,660	$164,108	164,726	$3,189,652	249,976,802	$834,923	3,200,041	$258,433	$2,983,410	$7,430,525	$1,384
District 6	3,291	18%	42,131	$74,639	76,669	$1,484,569	116,207,196	$388,132	2,624,470	$211,952	$1,732,600	$3,891,892	$1,183
District 7	7,956	40%	227,720	$403,309	413,100	$7,998,980	627,496,537	$2,095,838	3,099,788	$250,340	$10,427,460	$21,175,927	$2,662
District 8	4,322	40%	125,200	$221,737	226,574	$4,387,246	343,591,415	$1,147,595	4,080,870	$329,573	$5,043,212	$11,129,363	$2,575
District 9	6,515	33%	152,840	$270,698	278,776	$5,398,043	423,924,892	$1,415,909	3,980,568	$321,471	$6,255,606	$13,661,728	$2,097
District 10	6,410	25%	118,960	$210,671	210,020	$4,066,686	319,642,574	$1,067,606	2,819,189	$227,676	$4,500,380	$10,073,019	$1,571
District 11	7,032	32%	161,680	$292,429	290,130	$5,617,890	442,786,238	$1,478,906	2,192,613	$177,075	$7,040,259	$14,606,559	$2,077
District 12	8,402	29%	180,920	$319,516	320,330	$6,202,656	486,976,715	$1,626,502	2,095,378	$169,222	$6,090,942	$14,408,839	$1,715
District 13	20,928	48%	730,600	$1,293,914	1,301,612	$25,203,540	1,989,815,876	$6,645,985	2,973,180	$240,113	$21,243,585	$54,627,137	$2,610
District 14	18,013	46%	608,720	$1,078,055	1,089,537	$21,097,071	1,657,891,089	$5,537,356	2,625,073	$212,001	$15,959,913	$43,884,397	$2,436
District 15	4,316	31%	91,632	$175,562	172,139	$3,333,192	262,545,484	$876,902	2,670,190	$215,647	$3,008,409	$7,609,712	$1,763
District 16	16,158	40%	463,340	$820,560	839,688	$16,259,169	1,281,678,562	$4,280,806	2,745,555	$221,731	$18,441,492	$40,023,759	$2,477
District 17	8,916	36%	227,620	$403,954	418,863	$8,110,591	637,595,194	$2,129,568	2,260,489	$182,557	$10,847,858	$21,674,528	$2,431
District 18	7,406	27%	145,860	$258,333	266,412	$5,158,625	405,529,520	$1,354,469	2,478,973	$200,204	$6,866,253	$13,837,883	$1,869
District 19	19,935	39%	578,520	$1,024,610	1,026,341	$19,873,390	1,565,567,728	$5,228,996	3,018,617	$243,783	$20,208,063	$46,578,842	$2,337
District 20	39,330	51%	1,462,300	$2,591,117	2,660,313	$51,512,548	4,028,965,127	$13,456,744	3,144,293	$253,934	$43,342,162	$111,156,504	$2,826
District 21	7,143	16%	81,481	$144,293	144,013	$2,788,586	220,879,597	$737,738	2,347,657	$189,599	$3,491,474	$7,351,690	$1,029
District 22	12,991	35%	333,640	$590,877	597,369	$11,567,060	914,587,930	$3,054,724	1,842,415	$148,793	$11,694,229	$27,055,683	$2,083
District 23	7,988	34%	203,200	$359,841	362,369	$7,016,668	548,372,021	$1,831,563	2,191,365	$176,974	$7,948,402	$17,333,448	$2,170
District 24	6,972	29%	145,400	$257,499	261,045	$5,054,704	397,738,078	$1,328,445	2,257,589	$182,321	$5,873,061	$12,696,030	$1,821
District 25	7,702	45%	250,800	$444,206	452,451	$8,760,968	687,575,820	$2,296,503	2,609,323	$210,728	$10,096,286	$21,808,692	$2,832
District 26	4,160	24%	74,817	$132,494	133,260	$2,580,368	202,009,584	$674,712	2,217,831	$179,111	$3,491,620	$7,058,304	$1,697

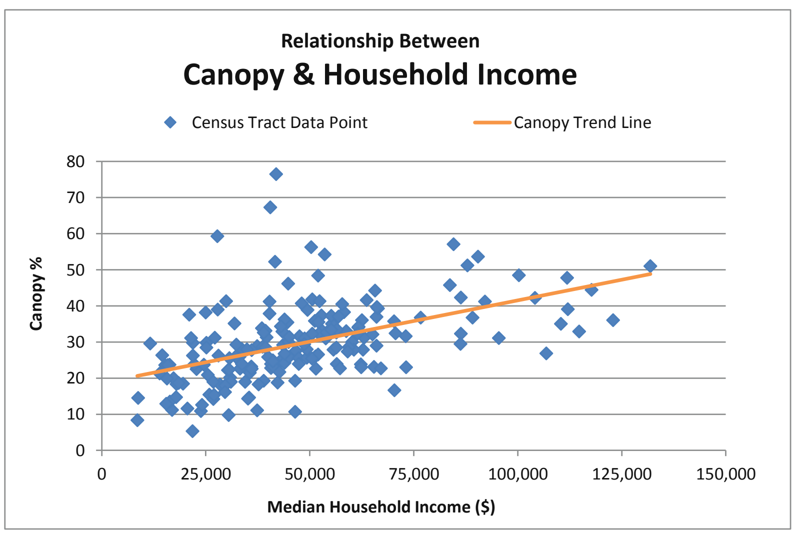
** Carbon includes annual benefits and carbon stored over lifetime of canopy.*

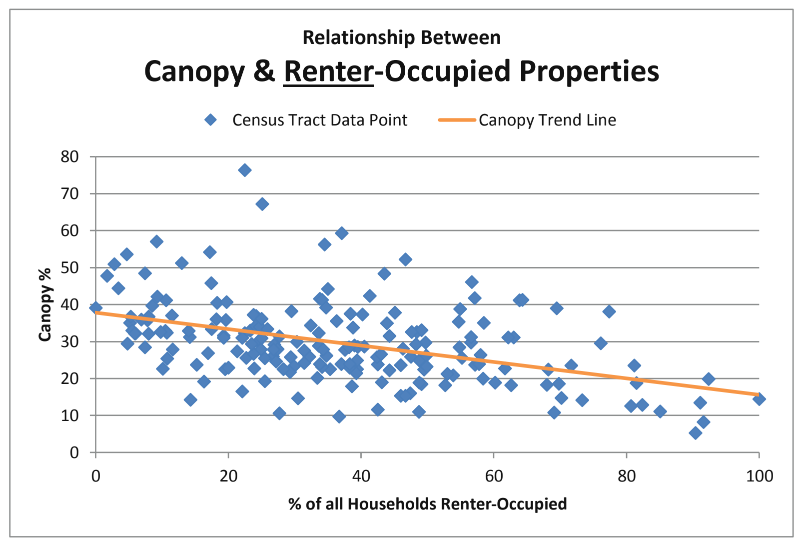
FINAL DRAFT

Canopy & Socioeconomic Trends: Scatterplot Charts









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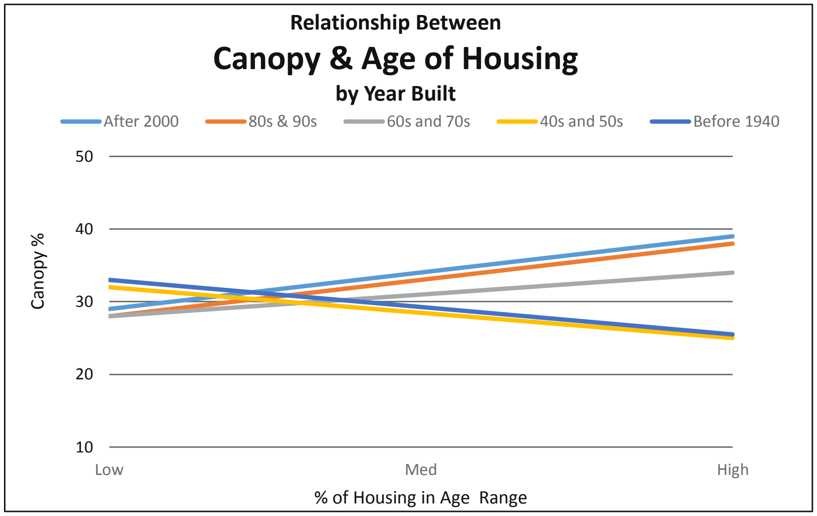
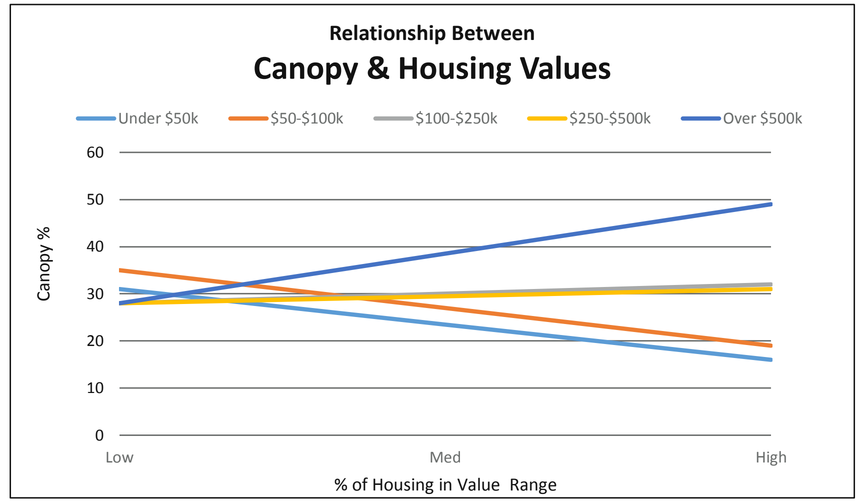
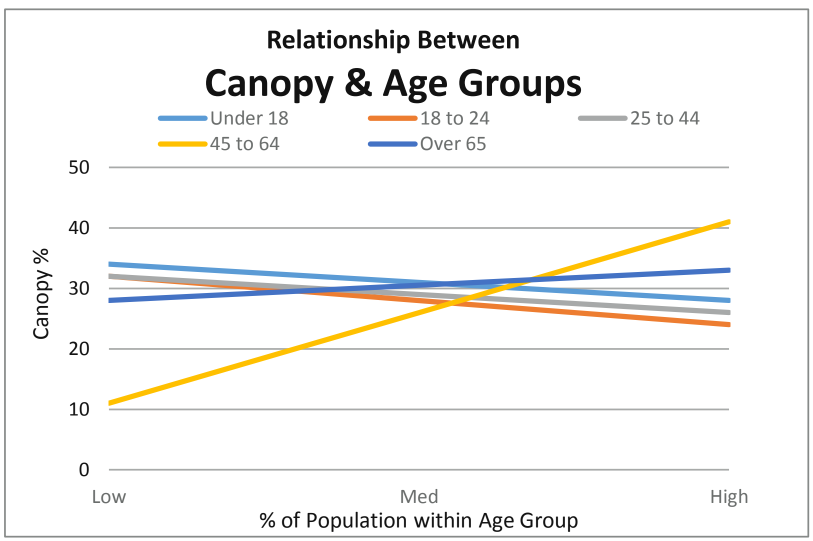
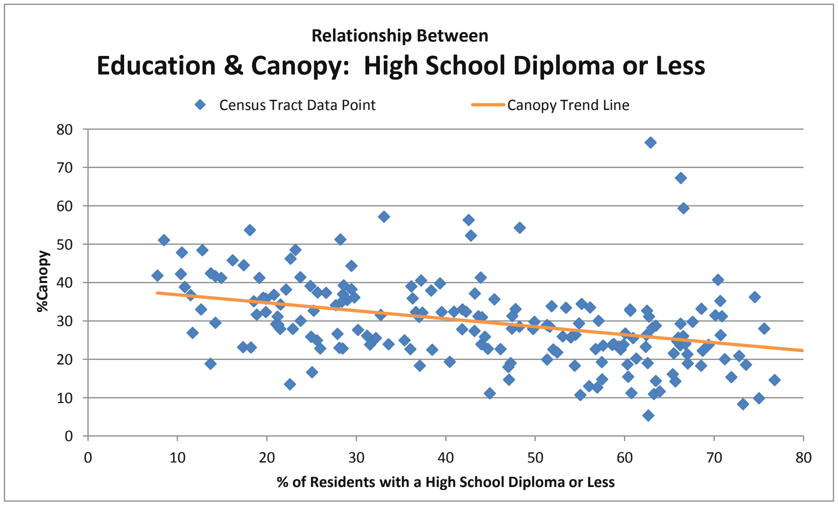
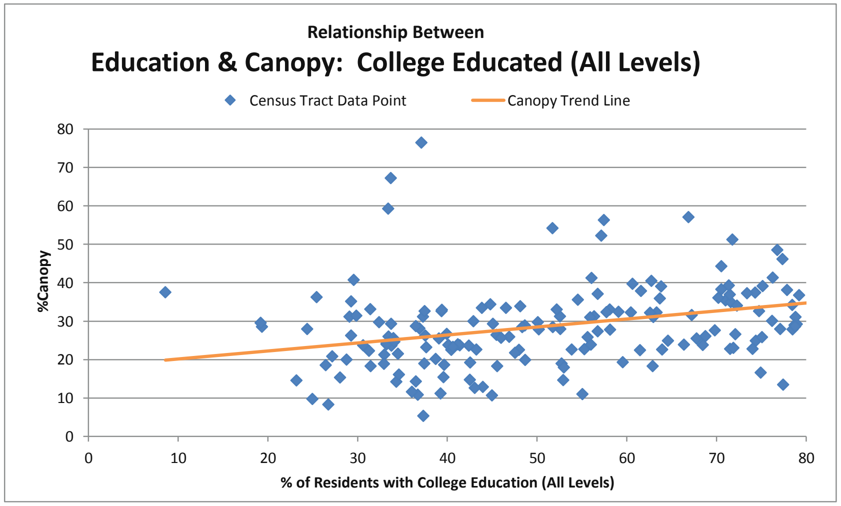

Relationship Between
Canopy & Age of Housing
by Year Built
After 2000
80s & 90s
60s and 70s
40s and 50s
Before 1940
50
40
30
20
10
Canopy %
Low
Med
High
% of Housing in Age Range


Relationship Between
Canopy & Housing Values
Under $50k
$50-$100k
$100-$250k
$250-$500k
Over $500k
60
50
40
30
20
10
0
Canopy %
Low
Med
High
% of Housing in Value Range


Relationship Between
Canopy & Age Groups
Under 18
18 to 24
25 to 44
45 to 64
Over 65
50
40
30
20
10
0
Canopy %
Low
Med
High
% of Population within Age Group

FINAL DRAFT


Relationship Between
Education & Canopy: High School Diploma or Less
Census Tract Data Point
Canopy Trend Line
%Canopy
0
10
20
30
40
50
60
70
80
% of Residents with a High School Diploma or Less


Relationship Between
Education & Canopy: College Educated (All Levels)
Census Tract Data Point
Canopy Trend Line
%Canopy
0
10
20
30
40
50
60
70
80
% of Residents with College Education (All Levels)

FINAL DRAFT

DAVEY RESOURCE GROUP
A Division of The Davey Tree Expert Company

Scenarios for Future Canopy

	SCENARIO 0: No Action				**SCENARIO 1a: Achieveing No Net Loss by Planting Only**					**SCENARIO 1b: Achieving No Net Loss by Planting AND Loss Reduction**					**SCENARIO 2a: Achieving 40% Canopy by Planting Only**				
Starting Canopy Acres: 94,462	Acres Planted	Canopy Acres Lost	Resulting Canopy	Resulting UTC %	Trees Planted	Acres Planted	Canopy Acres Lost	Resulting Canopy	Resulting Future UTC %*	Trees Planted	Acres Planted	Canopy Acres Lost	Resulting Canopy	Resulting Future UTC %*	Trees Planted	Acres Planted	Canopy Acres Lost	Resulting Canopy	Resulting Future UTC %*
Year 1	0	820	93,642	37%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	95,194	37%
Year 2	0	820	92,822	36%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	95,926	38%
Year 3	0	820	92,002	36%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	96,658	38%
Year 4	0	820	91,182	36%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	97,390	38%
Year 5	0	820	90,362	36%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	98,122	39%
Year 6	0	820	89,542	35%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	98,854	39%
Year 7	0	820	88,722	35%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	99,586	39%
Year 8	0	820	87,902	35%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	100,318	39%
Year 9	0	820	87,082	34%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	101,050	40%
Year 10	0	820	86,262	34%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	102,432	1,552	820	101,782	40%
Year 11	0	820	85,442	34%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 12	0	820	84,622	33%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 13	0	820	83,802	33%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 14	0	820	82,982	33%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 15	0	820	82,162	32%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 16	0	820	81,342	32%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 17	0	820	80,522	32%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 18	0	820	79,702	31%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 19	0	820	78,882	31%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 20	0	820	78,062	31%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 21	0	820	77,242	30%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 22	0	820	76,422	30%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 23	0	820	75,602	30%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 24	0	820	74,782	29%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 25	0	820	73,962	29%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 26	0	820	73,142	29%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 27	0	820	72,322	28%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 28	0	820	71,502	28%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 29	0	820	70,682	28%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 30	0	820	69,862	27%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 31	0	820	69,042	27%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 32	0	820	68,222	27%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 33	0	820	67,402	26%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 34	0	820	66,582	26%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 35	0	820	65,762	26%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 36	0	820	64,942	26%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 37	0	820	64,122	25%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 38	0	820	63,302	25%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 39	0	820	62,482	25%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
Year 40	0	820	61,662	24%	54,120	820	820	94,462	37%	27,060	410	410	94,462	37%	54,120	820	820	101,782	40%
TOTALS	**0** acres planted	**32,800** acres lost			**2,164,800** trees	**32,800** acres planted	**32,800** acres lost			**1,082,400** trees	**16,400** acres planted	**16,400** acres lost			**2,647,920** trees	**40,120** acres planted	**32,800** acres lost		

** Resulting Future UTC %: Scenario spans a forty year time period to allow for trees planted in the first ten years to reach full canopy levels. UTC is thus listed each year as a future canopy of acres planted.*

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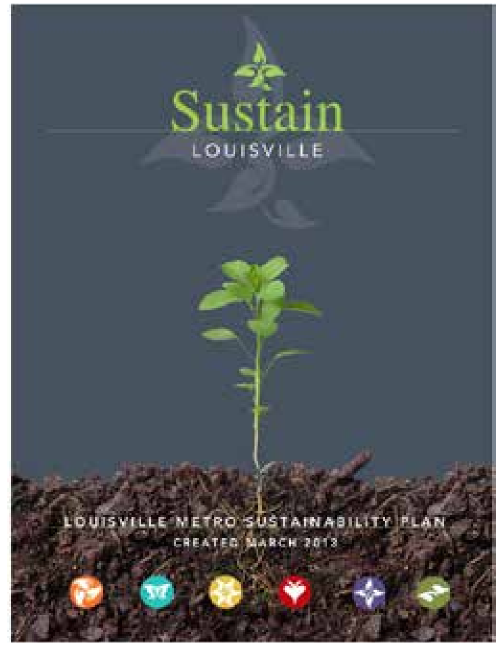
Scenarios for Future Canopy (continued)

	SCENARIO 2b: Achieving 40% Canopy by Planting AND Loss Reduction					SCENARIO 3a: Achieving 45% Canopy by Planting Only					SCENARIO 3b: Achieving 45% Canopy by Planting AND Loss Reduction				
Starting Canopy Acres: 94,462	Trees Planted	Acres Planted	Canopy Acres Lost	Resulting Canopy Acres	Resulting Future UTC %*	Trees Planted	Acres Planted	Canopy Acres Lost	Resulting Canopy	Resulting Future UTC %*	Trees Planted	Acres Planted	Canopy Acres Lost	Resulting Canopy	Resulting Future UTC %*
Year 1	75,372	1,142	410	95,194	37%	186,384	2,824	820	96,466	38%	159,324	2,414	410	97,198	38%
Year 2	75,372	1,142	410	95,926	38%	186,384	2,824	820	98,470	39%	159,324	2,414	410	99,202	39%
Year 3	75,372	1,142	410	96,658	38%	186,384	2,824	820	100,474	39%	159,324	2,414	410	101,206	40%
Year 4	75,372	1,142	410	97,390	38%	186,384	2,824	820	102,478	40%	159,324	2,414	410	103,210	41%
Year 5	75,372	1,142	410	98,122	39%	186,384	2,824	820	104,482	41%	159,324	2,414	410	105,214	41%
Year 6	75,372	1,142	410	98,854	39%	186,384	2,824	820	106,486	42%	159,324	2,414	410	107,218	42%
Year 7	75,372	1,142	410	99,586	39%	186,384	2,824	820	108,490	43%	159,324	2,414	410	109,222	43%
Year 8	75,372	1,142	410	100,318	39%	186,384	2,824	820	110,494	43%	159,324	2,414	410	111,226	44%
Year 9	75,372	1,142	410	101,050	40%	186,384	2,824	820	112,498	44%	159,324	2,414	410	113,230	45%
Year 10	75,372	1,142	410	101,782	40%	186,384	2,824	820	114,502	45%	159,324	2,414	410	115,234	45%
Year 11	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 12	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 13	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 14	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 15	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 16	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 17	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 18	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 19	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 20	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 21	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 22	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 23	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 24	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 25	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 26	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 27	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 28	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 29	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 30	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 31	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 32	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 33	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 34	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 35	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 36	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 37	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 38	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 39	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
Year 40	27,060	410	410	101,782	40%	54,120	820	820	114,502	45%	27,060	410	410	115,234	45%
TOTALS	**1,565,520** trees	**23,720** acres planted	**16,400** acres lost			**3,487,440** trees	**52,840** acres planted	**32,800** acres lost			**2,405,040** trees	**36,440** acres planted	**16,400** acres lost		

Appendix C
Other Information

Sustain Louisville Goals

(target date in parenthesis)



Energy

1. Decrease energy use citywide per capita by 25% (2025)
2. Decrease energy use in city-owned buildings by 30% (2018)

Environment

3. Mitigate the risk of climate change impacts (2018)
4. Achieve and exceed National Ambient Air Quality Standards (Ongoing)
5. Improve waterway quality (2018)
6. Increase recycling citywide by 25% (2015)
7. Achieve 90% residential recycling participation (2025)
8. Divert 50% of solid waste away from the landfill by 2025 and 90% by 2042 (2025)

Transportation

9. Decrease transportation-related greenhouse gas emissions by 20% (2020)
10. Reduce vehicle miles traveled by 20% (2025)

Economy

11. Provide opportunities for clean economy organizations and innovators and develop a qualified workforce to support it (2015)
12. Expand the local food system by 20% (2018)

Community

13. Increase access to healthy foods by 20% (2018)
14. Increase opportunities for active living (2015)
15. Incorporate sustainability into the Land Development Code and the Comprehensive Plan (2015)
16. Replace and reforest parks property and provide nature-based recreation (2018)
17. Expand green infrastructure incentives citywide (2018)
18. Establish a robust urban tree canopy and implement strategies to mitigate the urban heat island effect (2018)

Engagement

19. Engage the community in sustainability practices and principles (Ongoing)

FINAL DRAFT

Glossary

bare soil land cover: The land cover areas mapped as bare soil typically include vacant lots, construction areas, and baseball fields.

canopy: Branches and foliage which make up a tree's crown.

canopy cover: As seen from above, it is the area of land surface that is covered by tree canopy.

canopy spread: A data field that estimates the width of a tree's canopy in five-foot increments.

existing UTC: The amount of tree canopy present within the study boundary.

geographic information systems (GIS): A technology that is used to view and analyze data from a geographic perspective. GIS links location to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to give you a better understanding of how it all interrelates.

greenspace: A term used in land use planning and conservation to describe protected areas of undeveloped landscapes.

impervious land cover: The area that does not allow rainfall to infiltrate the soil and typically includes buildings, parking lots, and roads.

land cover: Physical features on the earth mapped from satellite or aerial imagery such as bare soils, canopy, impervious, pervious, or water.

mortality: tree loss from insects, disease, natural tree decline/death, severe weather events, removals by human activities, etc.

open water land cover: The land cover areas mapped as water typically include lakes, oceans, rivers, and streams.

pervious land cover: The vegetative area that allows rainfall to infiltrate the soil and typically includes parks, golf courses, residential areas.

possible UTC: The amount of land that is theoretically available for the establishment of tree canopy within the study boundary. This includes all pervious and bare soil surfaces.

rate of change: percentage change, comparing old values to current values using the following equation: $\frac{\text{current value - older value}}{\text{older value}} \times 100$

realistic plantable areas (RPA): The amount of land that is realistically available for the establishment of tree canopy within the town boundary. This includes all pervious and bare soil surfaces with specified land uses.

right-of-way (ROW): A strip of land generally owned by a public entity over which facilities, such as highways, railroads, or power lines, are built.

street tree: A street tree is defined as a tree within the right-of-way.

species: Fundamental category of taxonomic classification, ranking below a genus or subgenus.

tree: A tree is defined as a perennial woody plant that may grow more than 20 feet tall.

tree benefit: An economic, environmental, or social improvement that benefited the community and resulted mainly from the presence of a tree. Has associated value.

urban forest: All of the trees within a municipality or a community. This can include the trees along streets or rights-of-way, parks and greenspaces, and forests.

urban tree canopy (UTC) assessment: A study performed of land cover classes to gain an understanding of the tree canopy coverage, Typically performed using aerial photographs, GIS data, or LIDAR.

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