Urban Tree Canopy Assessment & Planting Plan

Hartford, Connecticut

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AMERICAN FORESTS

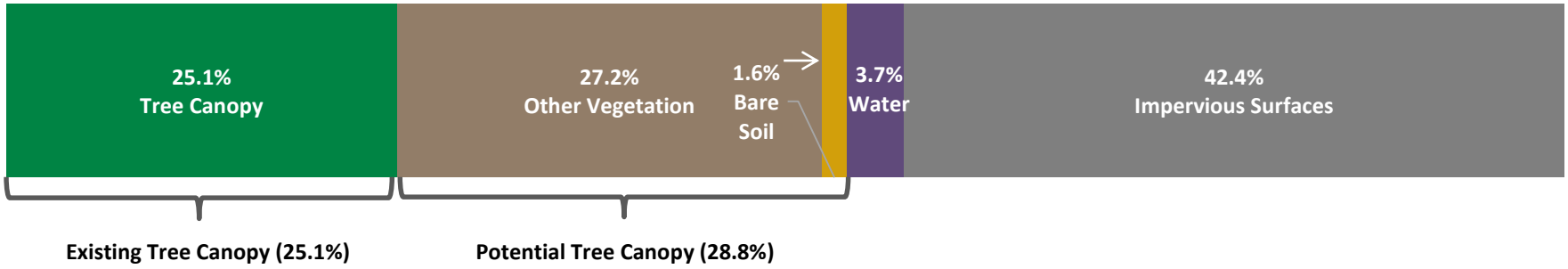
Executive Summary

This report was developed for the City of Hartford and local non-profit KNOX, by American Forests in partnership with Davey Resource Group, a division of The Davey Tree Expert Company. The primary goals of this assessment and report were to establish baseline data on the extent and function of the existing urban forest, analyze recent changes and trends, and provide tools, data, and other resources to guide future community forest management and reforestation efforts.

An urban tree canopy (UTC) assessment was completed using 2014 aerial imagery of Hartford. The results were compared to a 2010 study that used 2008 imagery. The ecosystem benefits and functions provided by the community's trees were quantified using i-Tree Vue and stormwater modeling equations. A prioritized planting plan was developed based on the UTC assessment and other available community geographic information systems (GIS) data. These assessments were completed to aid in determining a reforestation plan for future tree planting based on goals established by the community.

The UTC assessment found that tree canopy covers 25.1% of the City's 11,577 acres, and impervious surfaces cover 42.4%. There was a small amount of change (0.3% increase) in UTC from 2008 to 2014. If all suitable and realistic plantable locations were covered in tree canopy, Hartford's maximum potential UTC tree canopy cover would reach 53.9%.

Summary of Hartford's 2014 Urban Tree Canopy and Other Land Cover



Tree canopy cover provides benefits to the entire community by removing pollutants and carbon from the air and reducing peak stormwater flows. The annual benefits Hartford received from its tree cover in 2014 was estimated to be at least $5,487,213. Tree canopy in Hartford removed an estimated 147,780 pounds of pollutants and 11,264 tons of carbon from the air while slowing more than 590 million gallons of stormwater from entering storm drains during peak storm events. The benefits provided by Hartford's urban forest will increase every year as existing trees mature and new trees are planted.

Nearly 50,000 planting areas were assessed and prioritized; these areas are preferred because planting these locations will maximize ecological and public health and safety services, such as stormwater interception and urban heat island mitigation. These priority planting areas can be assessed individually for their suitability, potential capacity for new trees, and species selection to purposefully maximize the benefits provided by Hartford's tree canopy.

It is not enough to simply plant more trees to increase canopy cover and benefits. Planning and funding for tree care and management, public outreach, and education must complement planting efforts to ensure the success of new plantings and to ensure the benefits desired are being realized through strategic urban forest management and partnerships. To make a difference, the City of Hartford, its residents, and partners can support the urban forestry program by promoting the benefits that trees offer to the community, fulfilling routine maintenance for both public and private trees, and maximizing the space available for new trees.

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Acknowledgements

Funding for this project has been made possible by American Forests, the Bank of America Charitable Foundation, and the U.S. Forest Service.

This report and other urban forestry efforts in Hartford would not be possible without the strong partnership between the City of Hartford and the local non-profit, KNOX. Their continued leadership throughout the community is essential to accomplishing community forestry goals.

American Forests also thanks The Davey Tree Expert Company for the consultation and analysis they contributed to this project.

About American Forests

American Forests restores and protects urban and rural forests. Founded in 1875, it is the oldest national nonprofit conservation organization and has served as a catalyst for many milestones in the conservation movement including the founding of the U.S. Forest Service and the national forest and national park systems. American Forests has conducted thousands of forest ecosystem restoration projects and public education efforts; since 1990 it has planted more than 45 million trees in all 50 states and in 44 countries, resulting in cleaner air and drinking water, restored habitat for wildlife and fish and the removal of millions of tons of carbon dioxide from the atmosphere. Learn more at www.americanforests.org.

About Bank of America's Corporate Social Responsibility

The Bank of America Charitable Foundation's commitment to corporate social responsibility (CSR) is a strategic part of doing business globally. The bank's CSR efforts guide how it operates in a socially, economically, financially and environmentally responsible way around the world, to deliver for shareholders, customers, clients and employees. Its goal is to help create economically vibrant regions and communities through lending, investing and giving. By partnering with stakeholders, the Bank of America Charitable Foundation creates value that empowers individuals and communities to thrive and contributes to the long-term success of its business. The Bank of America Charitable Foundation has several core areas of focus for its CSR, including responsible business practices; environmental sustainability; strengthening local communities with a focus on housing, hunger and jobs; investing in global leadership development; and engaging through arts and culture. As part of these efforts, employee volunteers across the company contribute their time, passion and expertise to address issues in communities where they live and work. Learn more at www.bankofamerica.com/about and follow Bank of America Charitable Foundation on Twitter at @BofA_Community.

About the U.S. Forest Service

The mission of the Forest Service is to sustain the health, diversity and productivity of the nation's forests and grasslands to meet the needs of present and future generations. The agency manages 193 million acres of public land, provides assistance to state and private landowners and maintains the largest forestry research organization in the world. Public lands managed by the Forest Service contribute more than $13 billion to the economy each year through visitor spending alone. Those same lands provide 20 percent of the nation's clean water supply — a value estimated at $7.2 billion per year. The agency also has either a direct or indirect role in stewardship of about 80 percent of the 850 million forested acres within the U.S., of which 100 million acres are urban forests located in or near areas where most Americans live.

Introduction

American Forests launched Community ReLeaf in spring 2013 as a replicable three-stage program which combines assessments, strategic restoration and capacity-building for outreach and education in targeted cities across the country. Reaching geographically and culturally diverse communities, American Forests aims to bring national attention to the value of our urban forests and plans to be working in 20 major cities by 2020.

Community ReLeaf is currently working in eleven cities: Asbury Park, N.J.; Atlanta; Austin; Chicago; Detroit; Hartford; Miami; Nashville; Oakland; Pasadena, Calif; and Washington, DC.

Using the best available scientific measures and methods, the results of the assessments provide insight for urban forestry practitioners, city officials and the general public into the overall condition of each city's urban forest and the environmental and socioeconomic benefits it provides at both the local and national levels — thereby informing strategic preservation and restoration activities.

Photograph 1. Volunteers planting trees. The City of Hartford has pledged to plant 20,000 trees in 20 years.

Complicated by declining budgets, low tree diversity, and substantial economic challenges, Hartford's urban forest has suffered a significant decline across the last half-century. In recent years, the City of Hartford has accomplished an amazing turnaround in its urban forestry efforts. Rising to the challenge, a powerful partnership has been forged between the City of Hartford and the local non-profit KNOX to improve the City's urban forest resources.

Kickstarting renewed enthusiasm, newly elected Mayor Pedro Segarra determined that trees are a community priority following heavy losses during Winter Storm Alfred (2011) and Hurricanes Irene (2011) and Sandy (2012). With support from KNOX, the City of Hartford pledged to plant 20,000 trees in 20 years—a significant investment in the City's urban forest. To help guide these efforts, the community hired its first dedicated city forester in 10 years. In 2010, Hartford completed a UTC assessment using 2008 data, which led to adopting a community goal to increase tree canopy by 10%. Combined, these actions have displayed incredible support and a powerful commitment to the community's trees.

Through these and other efforts, Hartford recognizes that trees are a major component of the City's infrastructure to provide much more than traditional values of aesthetics and shade. From watershed protection to improving property values, trees provide numerous quantifiable environmental, economic, and human health benefits. In particular, trees are key to reducing air pollution and particulate

matter, which results in reduced asthma rates in dense urban environments. Properly placed trees can assist in cooling cities, reduce the urban heat-island effect, and assist in mitigating the impacts of climate change, which also results in fewer respiratory illnesses. Trees have received significant attention for their positive impact on stormwater management. In short, an optimized tree canopy is a significant and valuable asset that addresses multiple community goals and priorities. Regardless of recent successes, Hartford's urban forest continues to face significant challenges. Severe weather in 2011 and 2012 led to substantial tree damage and losses. Increasing development pressure and aggressive utility pruning following storm-related power outages are likely to affect the community's tree cover. Moreover, the larger threats of climate change and invasive pests challenge even the most well-established urban forest.

To receive the environmental benefits a community has come to expect from its green resources, an urban forest must be properly cared for and managed. In recognition of this principle, Hartford is embarking on a process to collect and analyze meaningful data, develop comprehensive strategies, and work together to protect, enhance, and expand Hartford's urban forest.

Purpose

The intent of this project is to provide Hartford with valuable data that will support efforts to develop community goals, prioritize tree planting and other on-the-ground projects, and establish the importance of the community's tree resources among its other assets. This UTC and planting plan will be especially valuable to develop data-backed strategies and plans for the area's current and future urban forest and green infrastructure.

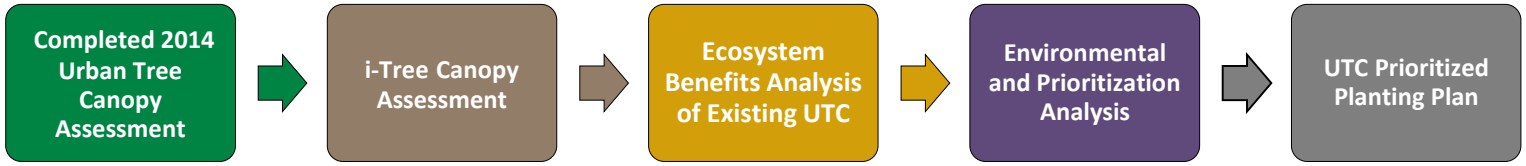
This assessment establishes tree canopy cover baseline information, identifies and quantifies the current contributions of urban trees, examines canopy gains and losses between 2008 and 2014, and develops a prioritized planting plan based on environmental factors that support community goals.

The information contained within this report is only part of initiatives that are needed to support Hartford's continued investment in its urban forest. The UTC data and maps and other management tools (e.g., tree inventories and management plans) are all necessary components that help guide community reforestation efforts to maximize ecological benefits and urban forest sustainability. As management progresses, Hartford is encouraged to refer back to these results, utilize these data for additional analyses, and continue to seek new tools and information to measure progress, report accomplishments, and inform management decisions.

Process and Methods

This UTC analysis and planting plan was accomplished using a well-established GIS-based process: first, a land cover extraction was completed using the 2014 National Agriculture Imagery Program (NAIP) photography. A series of random plots were generated and manually inspected to ensure accuracy. As an added level of comparison, an i-Tree Canopy assessment, which closely reflected the results of the land cover extraction, was completed. Next, the canopy data from the land cover extraction were analyzed using i-Tree models to generate an estimate of ecosystem benefits provided by the existing tree canopy. Finally, a realistic estimate of potential canopy was created by eliminating unplantable areas such as impervious surfaces or water. These data were used to develop recommendations to achieve Hartford's goals of using trees to mitigate stormwater, reduce the urban heat island, and improve air quality. Finally the data were analyzed to complete a summary report which was delivered to Hartford to assist in the management of their urban tree resources.

This study used a variety of data, tools, and analytical methodologies from various sources, including United States Department of Agriculture aerial imagery, census data, remote sensing technology, locally supplied data, scientific studies, and previous canopy analyses. These sources will be briefly mentioned or referenced throughout the remainder of this report.



Urban Tree Canopy Assessment Results

Based on the most recent aerial imagery, Hartford's current urban tree canopy is 25.1%, which compares favorably with other northeastern cities.

Tree canopy is just one of five land cover classifications generated by this assessment. Additional land cover data, including other vegetation, impervious, bare soils, and water, were created using Hartford's city boundary as the project area. Collectively, this information can be used to gain an understanding of Hartford's tree canopy distribution (Figure 1).

Once an overall canopy analysis is completed, these data can be segmented and examined further to identify trends, including:

- canopy by political boundaries or neighborhoods
- land use
- environmental problems of interest (flooding, excessive heat)
- correlations with the people who reside and work throughout the community (socioeconomics and demographics)

Contained in this report is an analysis of some of the general findings and trends of Hartford's UTC assessment. However, these data can be examined and analyzed in a multitude of different and more specific ways. Hartford is encouraged to further explore these data as new ideas, interests, or priorities arise. Simply, this study represents only a subset of a vast array of information and findings that can be gleaned from the further analyses of the data generated by this assessment.

Table 1. Comparison of Tree Canopy in Several Northeastern Cities

Community	Tree Canopy (%)
Newark, NJ	15%
Pawtucket, RI	23%
Hartford, CT	25%
Bridgeport, CT	27%
Syracuse, NY	28%
Cambridge, MA	30%
New Haven, CT	38%

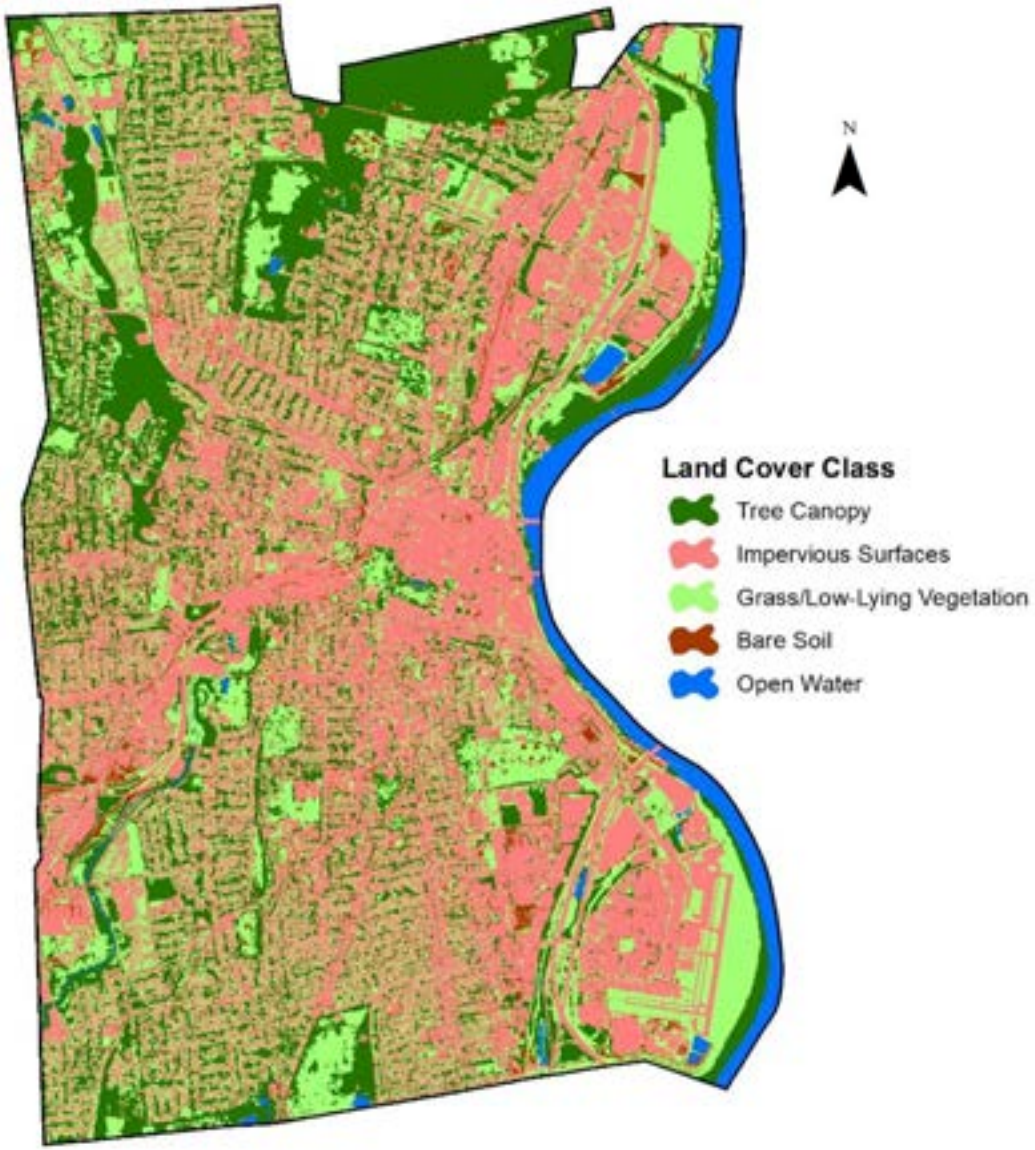


Figure 1. 2014 land cover in Hartford, Connecticut.

i-Tree Canopy Analysis

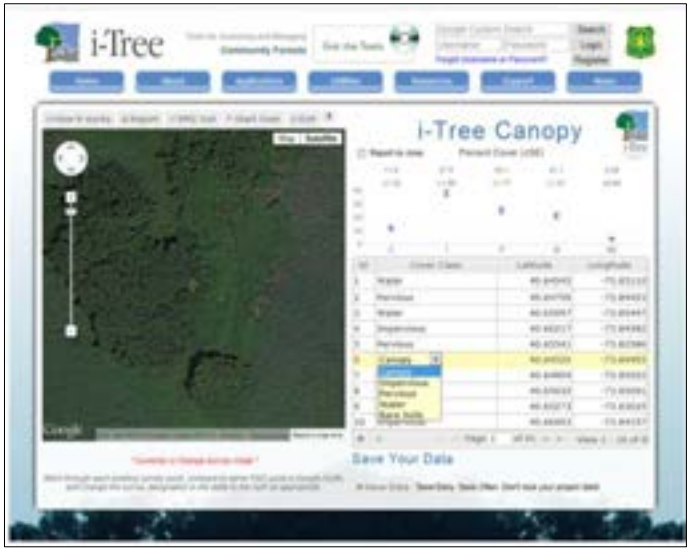
As a comparison, i-Tree Canopy was used to estimate land cover percentage for the project area. Based on the underlying methodology, i-Tree Canopy results are likely to be less accurate than those generated by a complete UTC assessment.

The benefit of the i-Tree Canopy tool is that it allows users to easily interpret Google® Earth aerial imagery for areas of interest and produce statistical estimates of tree cover and other cover types. The tool also calculates levels of uncertainty for the land cover estimates provided. This tool provides a quick and inexpensive means for communities and forest managers to assess their tree canopy cover.

For future, less-rigorous assessments, Hartford can use the i-Tree Canopy tool to complete land cover assessments and compare results using new aerial imagery as it becomes available in Google® Maps. The initial random point locations derived from i-Tree Canopy can be re-imported in future works to produce a statistically valid estimate of land cover over time. Hartford can use the i-Tree Canopy tool to quickly measure land cover changes and progress towards canopy goals between more thorough and complete urban tree canopy assessments.

Table 2. Comparison of i-Tree Canopy and 2014 UTC Assessment Results

Land Cover Class	Land Cover Classification (%)	
	2014 UTC Assessment	i-Tree Canopy
Tree Canopy	25.1%	24.8%
Other Vegetation	27.2%	27.0%
Bare Soil	1.6%	1.8%
Water	3.7%	3.4%
Impervious Surfaces	42.4%	43.0%



Photograph 2. Screenshot of the i-Tree Canopy tool.

Historical Land Cover Change

Results from the study completed by the University of Vermont in 2010, which used 2008 data, were compared to those generated by the 2014 UTC analysis. This comparison yields an historic UTC change assessment between these two studies. Figure 3 illustrates tree canopy changes between 2008 and 2014. Results of the land cover change analysis from 2008 to 2014 are reported in Table 3.

Between 2008 and 2014, the City of Hartford gained 0.3% of tree canopy, increasing from 24.8% to 25.1%. A portion of this modest increase may be attributed to trees that have been added. Since 2012, Hartford and KNOX have planted 1,000 trees a year. A greater portion is likely due to growth and expansion of existing trees. However, the increase in tree canopy would likely be larger if not for significant storm damage in 2011 and 2012, as well as increases in development and the decline of old trees or poor tree species.

Interestingly, the greatest differences between 2008 and 2014 land cover classification are in the other vegetation and impervious surfaces classifications. This result may be due to local trends in development but signifies opportunities for additional planting or canopy expansion.

Table 3. 2008 and 2014 Land Cover Results for Hartford

Land Cover Classification	Land Cover Classification (%)		
	2008	2014	Gain / Loss
Tree Canopy	24.8%	25.1%	+0.3%
Other Vegetation	23.4%	27.2%	+3.8%
Bare Soil	0.7%	1.6%	+0.9%
Water	3.5%	3.7%	+0.2%
Impervious Surfaces	47.6%	42.4%	−5.2%

Figure 2. Sample view of canopy change from 2008 to 2014.

Figure 3. Changes in tree canopy between 2008 and 2014.

Neighborhood Tree Canopy

Urban tree canopy results were further examined by neighborhood boundaries. Neighborhoods are often used to understand tree canopy as they tend to reflect geographies that are well understood by community members and social institutions. Exploring canopy distribution at this level can help facilitate community outreach and education activities as well as develop a deeper understanding of tree canopy at a meaningful community scale.

Current and past canopy coverage by Hartford's 17 neighborhood geographies are identified in Table 4. Figure 4 shows the distribution of neighborhood canopy levels across the city.

Northeast, West End, and South West have the highest levels of tree canopy at 47.3%, 43.0%, and 35.4%, respectively. These neighborhoods are primarily residential in nature or contain significant parks, both of which often contribute to high levels of tree canopy. Of note, these neighborhoods represent a combined 22.8% of the City's land area.

Conversely, the Downtown and South Green neighborhoods have the lowest levels of tree canopy at just near 10.0%. Not surprisingly, these neighborhoods are within the City's urban core where dense development often does not leave much room for trees or other greenery. Combined, these neighborhoods represent 12% of the City's land area.

Between 2008 and 2014, North Meadows and Upper Albany lost the greatest tree canopy, each dropping at least 3%. As reported by the City of Hartford, these neighborhoods correspond with those that contained significant populations of large declining *Acer platanoides* (Norway maple). The removal of these trees likely contributed to canopy loss. That said, most of Hartford's neighborhoods have either remained relatively stable or slightly gained tree canopy since 2008.

Table 4. Neighborhood Tree Canopy Results and Changes from 2008 to 2014

Neighborhood Tree Canopy	Urban Tree Canopy Assessment (%)		
	2008	2014	Gain/Loss
Asylum Hill	25.4%	25.5%	+0.1%
Barry Square	18.5%	20.0%	+1.5%
Behind the Rocks	25.1%	26.7%	+1.6%
Blue Hills	30.6%	29.5%	−1.1%
Clay-Arsenal	21.0%	20.2%	−0.9%*
Downtown	9.8%	10.4%	+0.6%
Frog Hollow	19.4%	20.8%	+1.3%*
North Meadows	20.5%	17.5%	−3.1%*
Northeast	47.9%	47.3%	−0.6%
Parkville	15.9%	14.9%	−1.0%
Sheldon-Charter Oak	12.9%	13.5%	+0.6%
South End	20.3%	21.5%	+1.2%
South Green	10.0%	11.2%	+1.2%
South Meadows	13.3%	12.6%	−0.7%
South West	34.0%	35.4%	+1.4%
Upper Albany	23.2%	20.1%	−3.0%*
West End	43.5%	43.0%	−0.5%

**** Canopy gain and loss values appear slightly different than expected due to rounding.***

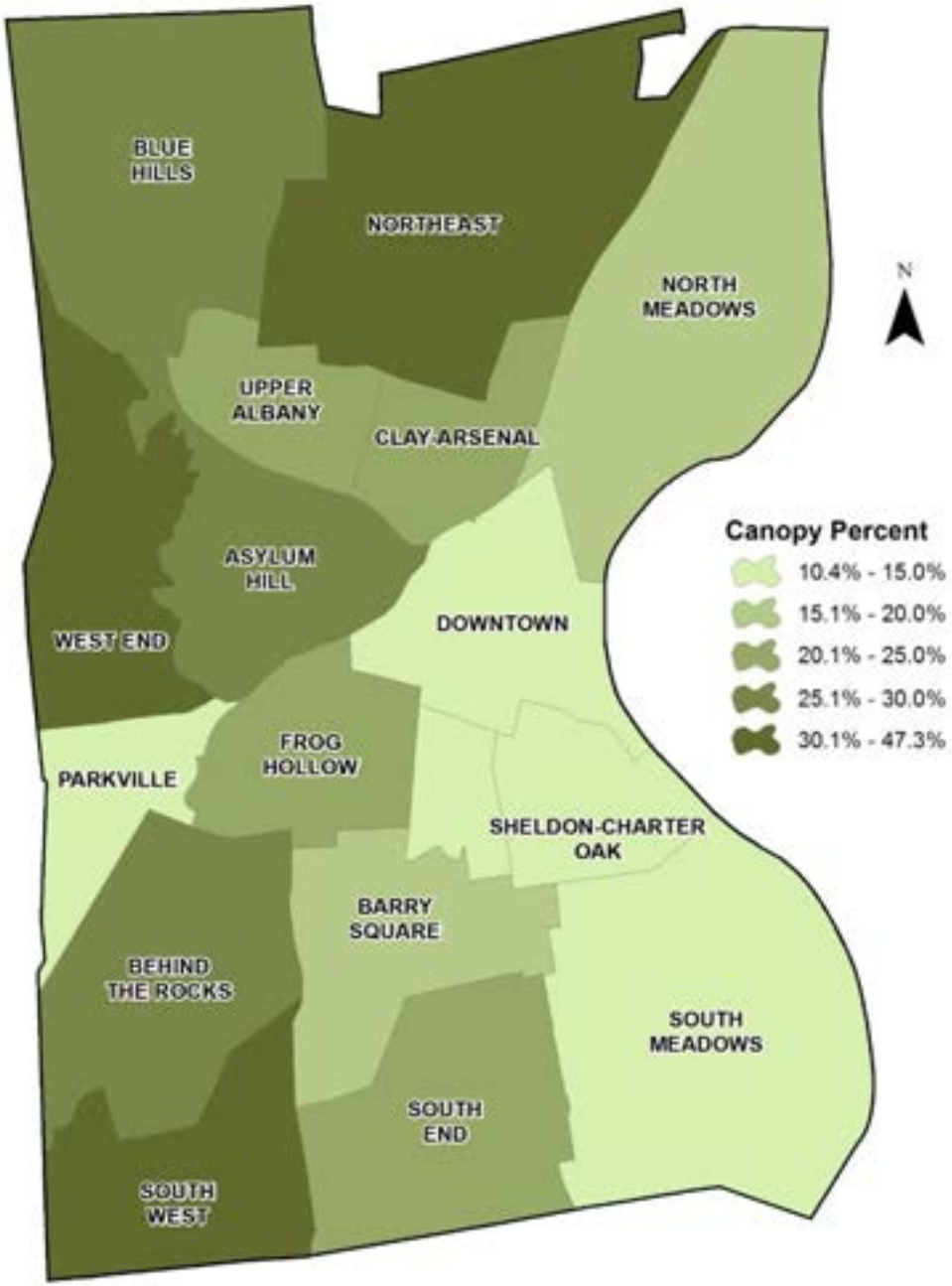


Figure 4. Tree canopy by Hartford neighborhoods.

Watershed Tree Canopy

Due to the unquestionable role of trees in mitigating stormwater and improving water quality, watersheds receive significant attention in regards to tree canopy. Changes in tree distribution across watersheds can have substantial impacts on water quality or stormwater challenges during severe storm events. Likewise, understanding opportunities to improve or enhance tree cover in specific watersheds is an important part of a strategy to improve water quality.

Current and past canopy coverages by Hartford's 14 watershed units are identified in Table 5. Figure 5 shows the distribution of tree canopy in watersheds or sub-basins across the city.

Folly Brook (4005-00) and Park River (4400-00) are the largest watersheds by area and have a tree canopy cover of 18.1% and 26.9%, respectively. Together, these watersheds represent 40.7% of the City's land area.

The highest level of tree canopy is within the Connecticut River (4000-25 and 4000-24) watersheds at 83.6% and 51.8%, but these watersheds represent only 2.4% of the City's land area.

Lowest tree canopies levels are in the Connecticut River (4000-28 and 4000-22) watersheds at 2.9% and 8.0% tree canopy cover. However, these watersheds comprise only 0.2% of the City's land area and are the only two watersheds with less than 15% tree canopy.

The Connecticut River (4000-24) watershed had the largest tree canopy gain at 1.6%. On the other hand, the North Branch Park River (4404-11) watershed lost 6.3% tree canopy, while the Connecticut River (4000-00) watershed lost 3.5%. Changes in most other watersheds or sub-basins were slight by comparison.

Table 5. Tree Canopy by Hartford Watersheds

Watershed Tree Canopy	Urban Tree Canopy Assessment (%)		
	2008	2014	Gain/Loss
Connecticut River (4000-00)	18.7%	15.1%	−3.5%*
North Branch Park River (4404-00)	35.5%	35.2%	−0.3%
Connecticut River (4000-22)	7.0%	8.0%	+1.1%*
Connecticut River (4000-24)	50.3%	51.8%	+1.6%*
North Branch Park River (4404-12)	30.3%	28.6%	−1.7%
Park River (4400-00)	27.7%	26.9%	−0.8%
Connecticut River (4000-25)	82.2%	83.6%	+1.4%
Connecticut River (4000-26)	20.0%	19.7%	−0.3%
North Branch Park River (4404-11)	37.7%	31.4%	−6.3%
Park River (4400-01)	22.9%	23.9%	+0.9%*
Folly Brook (4005-00)	17.1%	18.1%	+1.0%
Park River (4400-02)	31.7%	32.9%	+1.1%*
Piper Brook (4402-00)	38.4%	38.2%	−0.2%
Connecticut River	3.0%	2.9%	−0.2%*

**** Canopy gain and loss values appear slightly different than expected due to rounding.***

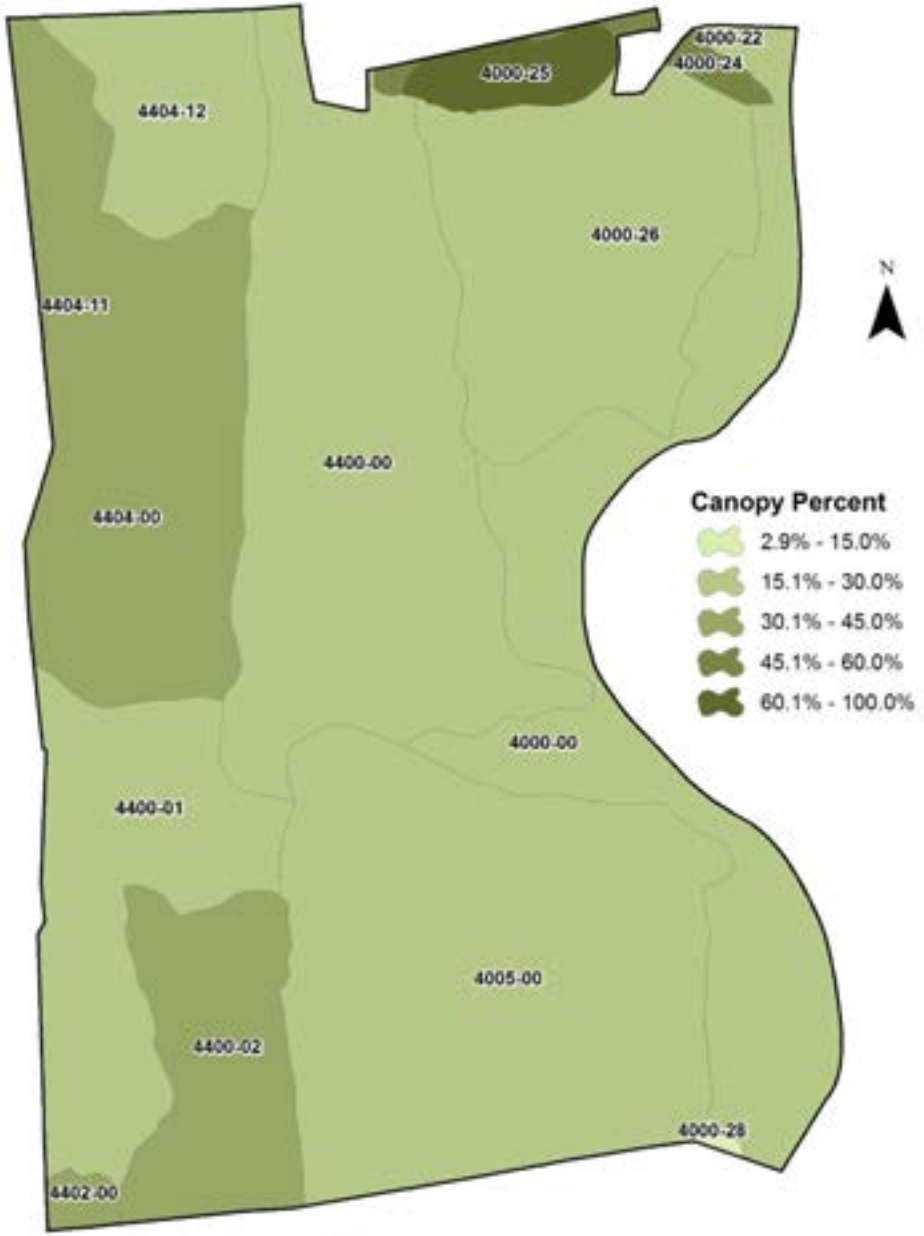


Figure 5. Tree canopy by Hartford watersheds.

Land Use/Zoning Tree Canopy

It is well established that tree canopy levels correlate with land use types. Industrial and commercial areas tend to have much lower levels of tree canopy than residential areas of a community. Understanding this relationship across a community can help identify policy concerns or highlight a need for new outreach and education programs that might appeal to or influence specific landowners or property types.

Current and past canopy coverages across Hartford's zoning classifications are identified in Table 6. Figure 6 shows the distribution of canopy levels by zoning classification across the city.

Zoning classifications with the highest percentage of tree canopy are R-8 (57.4%), P (46.1%), and R-7 (37.3%). These classifications are used for public (including cemeteries and parks) and residential properties which tend to have more trees.

Lowest levels of tree canopy are in the B-1, I-1, and B-3 land uses at 5.4%, 8.0%, 9.0%, respectively. These classifications represent more commercial and industrial land uses, which are often located in dense urban cores or contain large buildings or other facilities, leaving little room for trees.

General Business (B-3), Three-Family Residential (R-4) and Residence-Office (RO-3) classifications each lost more than over 1% tree canopy. The remaining zoning classifications remained relatively stable, without significant gains or losses.

Table 6. Zoning District Tree Canopy Results and Changes from 2008 to 2014

Zoning District Tree Canopy	Urban Tree Canopy Assessment (%)		
	2008	2014	Gain / Loss
Downtown Development (B-1)	6.1%	5.4%	−0.7%
Downtown Perimeter (B-2)	9.6%	9.9%	+0.3%
General Business (B-3)	10.7%	9.0%	−1.6%*
Neighborhood Business (B-4)	13.3%	13.5%	+0.2%
Commercial (C-1)	13.0%	13.2%	+0.2%
Industrial (I-1)	8.2%	8.0%	−0.1%*
Industrial (I-2)	11.1%	11.3%	+0.2%
Public Property and Cemeteries (P)	46.1%	46.1%	+0.0%
High Density Residential (R-1)	16.0%	15.6%	−0.3%*
High Density Residential (R-2)	24.7%	24.5%	−0.2%
Medium Density Residential (R-3)	23.2%	23.4%	+0.3%*
Three-Family Residential (R-4)	27.6%	25.9%	−1.7%
One and Two Family Residential (R-5)	32.4%	32.7%	+0.2%*
One Family Residential (R-6)	27.0%	27.0%	+0.0%
One Family Residential (R-7)	37.4%	37.3%	−0.1%
One Family Residential (R-8)	57.4%	57.4%	+0.1%*
Residence-Office (RO-1)	17.5%	17.0%	−0.4%*
Residence-Office (RO-2)	26.6%	26.5%	−0.1%
Residence-Office (RO-3)	19.7%	18.6%	−1.2%*

**** Canopy gain and loss values appear slightly different than expected due to rounding.***

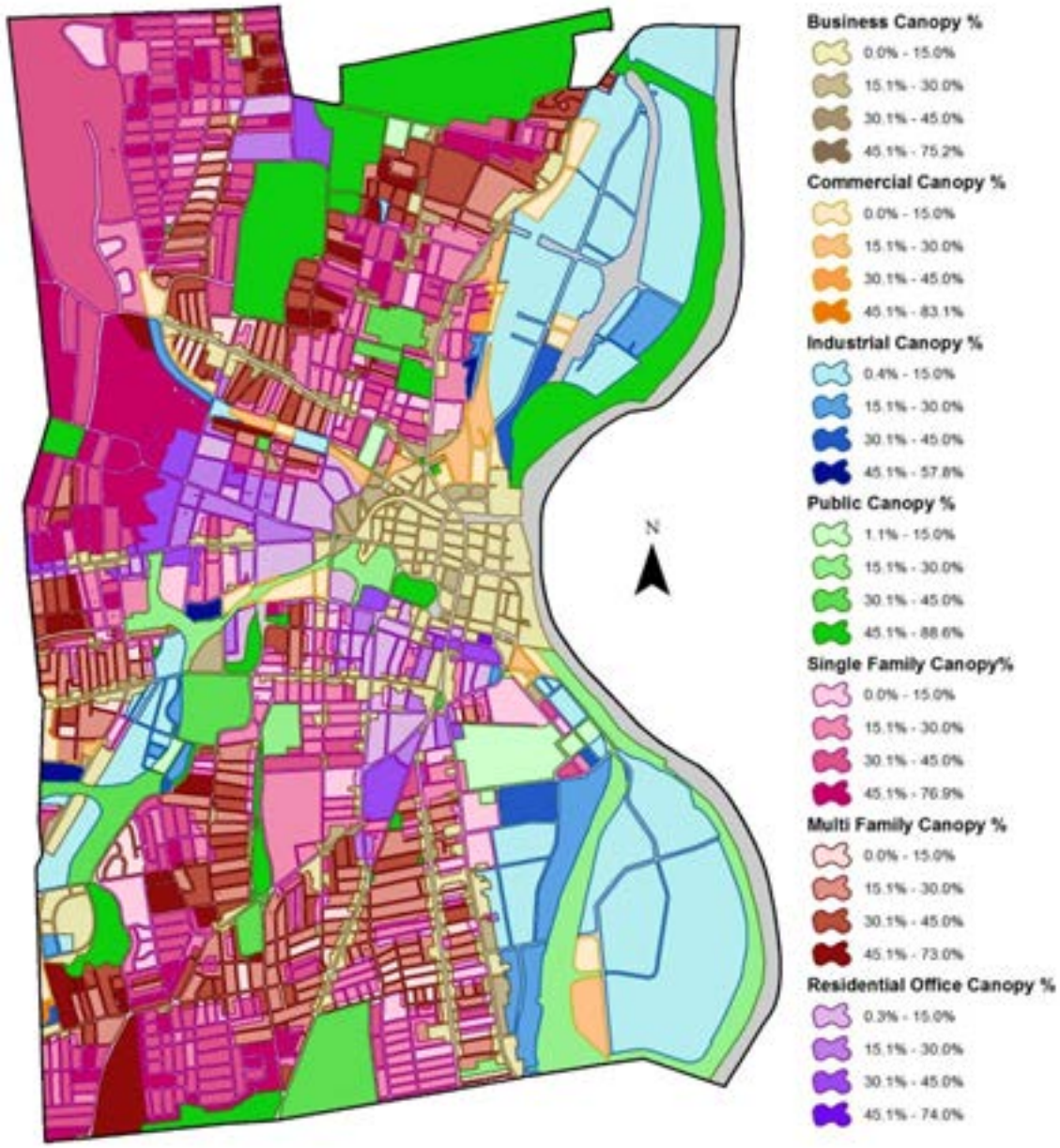


Figure 6. Hartford's tree canopy by zoning district.

Right-of-Way Tree Canopy

Rights-of-way (ROW) often represent the few portions of a city's land area that the city government can influence directly. Unlike private property, cities can simply target ROWs with low tree canopy levels for their tree planting program. Understanding the distribution of tree canopy across a community's ROWs can help to prioritize a city's tree planting and preservation activities.

In 2008, Hartford's ROW tree canopy was 16%. Using a 75-foot buffer along public roads, Hartford's ROW tree canopy is estimated to be 17.8% in 2014.

Figure 7 shows Hartford's tree canopy across the street ROWs. This map suggests that tree canopy is significantly lower along major streets and corridors, while residential and neighborhood streets appear to have higher levels of tree canopy.

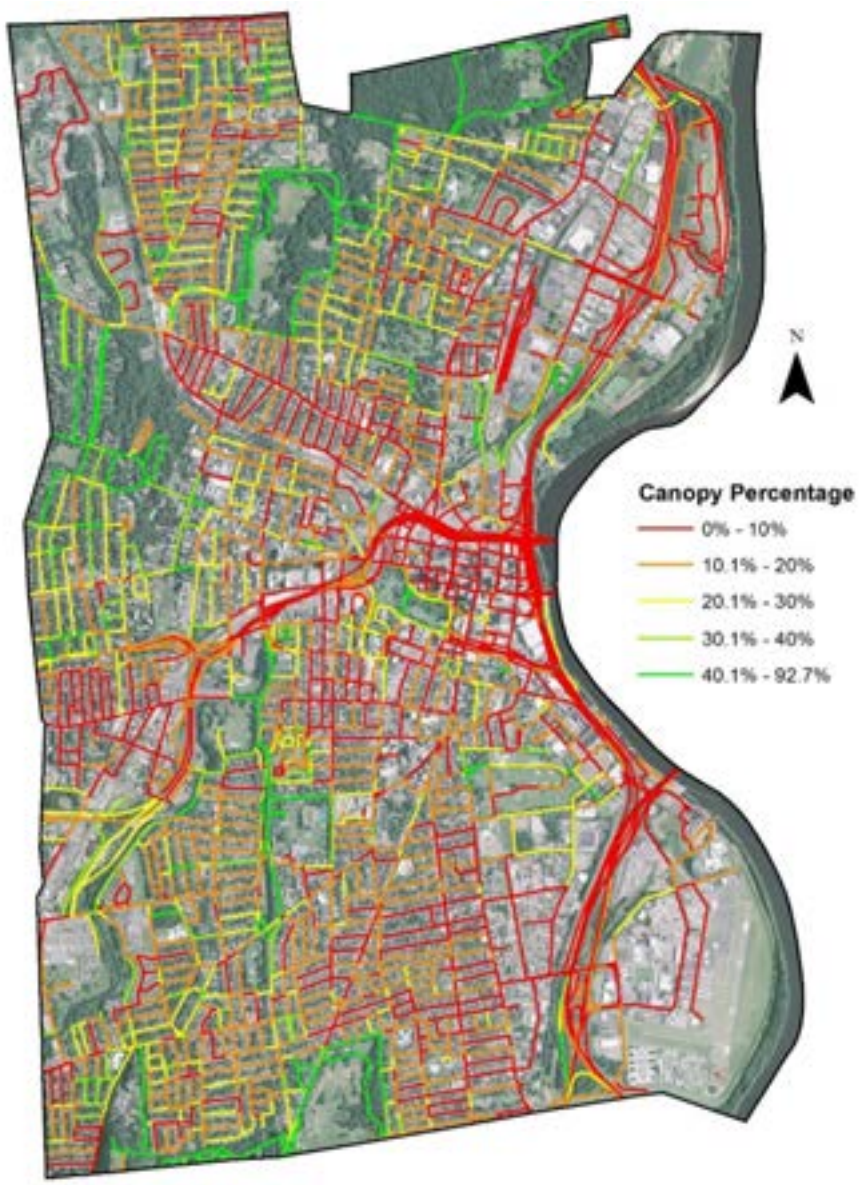


Figure 7. 2014 Hartford tree canopy by street right-of-way.

Ecosystem Benefits Analysis

Trees provide a myriad of benefits to Hartford. Trees conserve energy, reduce carbon dioxide levels, improve air quality, and mitigate stormwater runoff. In addition, trees provide numerous economic, psychological, and social benefits.

In total, Hartford's UTC provides approximately $5,487,213 each year in ecosystem benefits. These benefits were quantified using the i-Tree Vue model and TR-55 hydrologic equations. i-Tree Vue estimates carbon storage and sequestration and air pollutant removal. Air pollutants included in estimates are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10}), and sulfur dioxide (SO_2). TR-55 hydrologic equations model stormwater runoff.

Aside from annual benefits, Hartford's urban forest is currently valued at $18,665,630 in contributions to property values and stored carbon.

Photograph 3. As this tree grows, it will increasingly provide benefits to the community. Trees of all ages and shapes and sizes draw pollutants, sequester carbon from the air, and protect water quality while helping to manage stormwater.

Stormwater Interception

Trees intercept rainwater by capturing water droplets on their leaves and bark. A tree's expansive root system also absorbs water from the surrounding soil, increasing the soil's water holding capacity. Combined, these processes result in reducing or slowing the amount of stormwater runoff. Without trees, cities would have to invest in significantly more stormwater infrastructure to handle the additional water flow that would otherwise be captured by trees.

Hartford's trees capture an estimated 591,022,346 gallons of stormwater annually. That's enough water to fill 895 olympic-size swimming pools. This benefit is calculated to provide approximately $4,728,178 in infrastructure value.

Air Quality Improvements

Not only do trees take in carbon dioxide and produce oxygen, but they can also capture fine pollutants and particulate matter on the surfaces of their leaves. Combined, these actions can improve a city's air quality. Recent studies have shown a strong correlation between total tree canopy and reduced rates of pulmonary and cardiovascular disease.

Every year, Hartford's urban forest removes 147,780 lbs. of pollutants from the air. These include: 5,400 lbs. of carbon monoxide (CO), 15,260 lbs. of nitrogen dioxide (NO_2), 109,020 lbs. of ozone (O_3), 2,920 lbs. of sulfur dioxide (SO_2), and 15,180 lbs. of dusts, soot, and other particulate matter. Combined, this equates to $256,090 in value annually.

Carbon Reduction

Trees store massive amount of carbon in their woody tissue. Forests—both urban and rural—are an important carbon sink, helping to mitigate climate change. In total, Hartford's urban forest stores 373,709 tons of carbon which equates to $7,474,180 in value.

Energy Savings

The cooling benefit provided by trees is easily recognized; simply stand in the shade in a hot day. But this cooling effect also means less energy is needed to keep buildings cool during the hot summer months. Each year, Hartford's trees save 3,843,654 kWhs in energy use. This savings translates to $277,665 in value each year.

Table 7. Estimated Ecosystem Benefits Provided by Harford's Tree Canopy in 2014

Hartford Tree Canopy Ecosystem Benefits	Annual Ecosystem Benefits	
	Quantity	Value
Air: CO removed	5,400 lbs.	$3,600
Air: NO_2 removed	15,260 lbs.	$6,466
Air: O_3 removed	109,020 lbs.	$198,218
Air: SO_2 removed	2,920 lbs.	$369
Air: particulate matter removed	15,190 lbs	$47,437
Carbon sequestered	11,264 tons	$225,280
Stormwater: reduction in runoff	591,022,346 gallons	$4,728,178
Energy: savings from cooling	3,843,654 kWhs	$277,665
Total Annual Benefits		**$5,487,213**
Current stored carbon*	362, 445 tons	$7,248,900
Property: increase in property values*	-	$11,416,730
Total		**$18,665,630**

Current stored carbon and contribution to property value are measures of total contribution, not an annual value.

Prioritized Planting Plan

While a UTC analysis is helpful to understand existing tree canopy distribution and value, communities are often interested in expanding tree canopy to optimize the suite of ecosystem benefits provided by the urban forest. Therefore, it is common to start by calculating possible planting area based on the total of all land cover that is open ground—such as lawns, golf courses, and sports fields.

Understandably though, it does not make sense to plant trees in all of these "possible planting areas", such as in sports fields. Some locations are clearly better suited to meeting community goals than others. Therefore, this study analyzed additional data to develop a prioritized planting plan that seeks to maximize the ecosystem services provided by trees, such as capturing stormwater and reducing the urban heat island effect.

Based on the UTC data and Hartford's priorities, 20,516 potential planting locations (Table 8) have been identified that are considered High or Very High priority for helping advance Hartford's goals. These locations represent approximately 943 acres or 8.1% of Hartford's land area.

Figure 8 shows the distribution of priority planting areas across the city. Primary areas of High and Very High planting locations appear to be concentrated along the Connecticut River corridor or in commercialized and industrial areas. It is worth noting that several of these planting priority areas align with areas of canopy loss between 2008 and 2014.

It is important to note that these prioritized planting locations are located both on public and private lands. While Hartford owns and can expand tree canopy on a significant portion of the city, fully realizing potential tree canopy coverage will require the cooperation of business owners and private residents.

The following sections of this report explore planting opportunities that target specific environmental benefits, which represents a small subset of ways these UTC data can be examined. Hartford is encouraged to consider additional strategies and utilize the data generated by this assessment for future analyses.

Table 8. Planting Priority Areas that Maximize Hartford's Goals

Planting Priorities	Planting Opportunities	
	No. of Locations	Area (acres)
Very Low	4,282	265
Low	12,330	706
Moderate	12,466	598
High	16,692	774
Very High	3,824	169
Total Opportunities	49,594	2,512

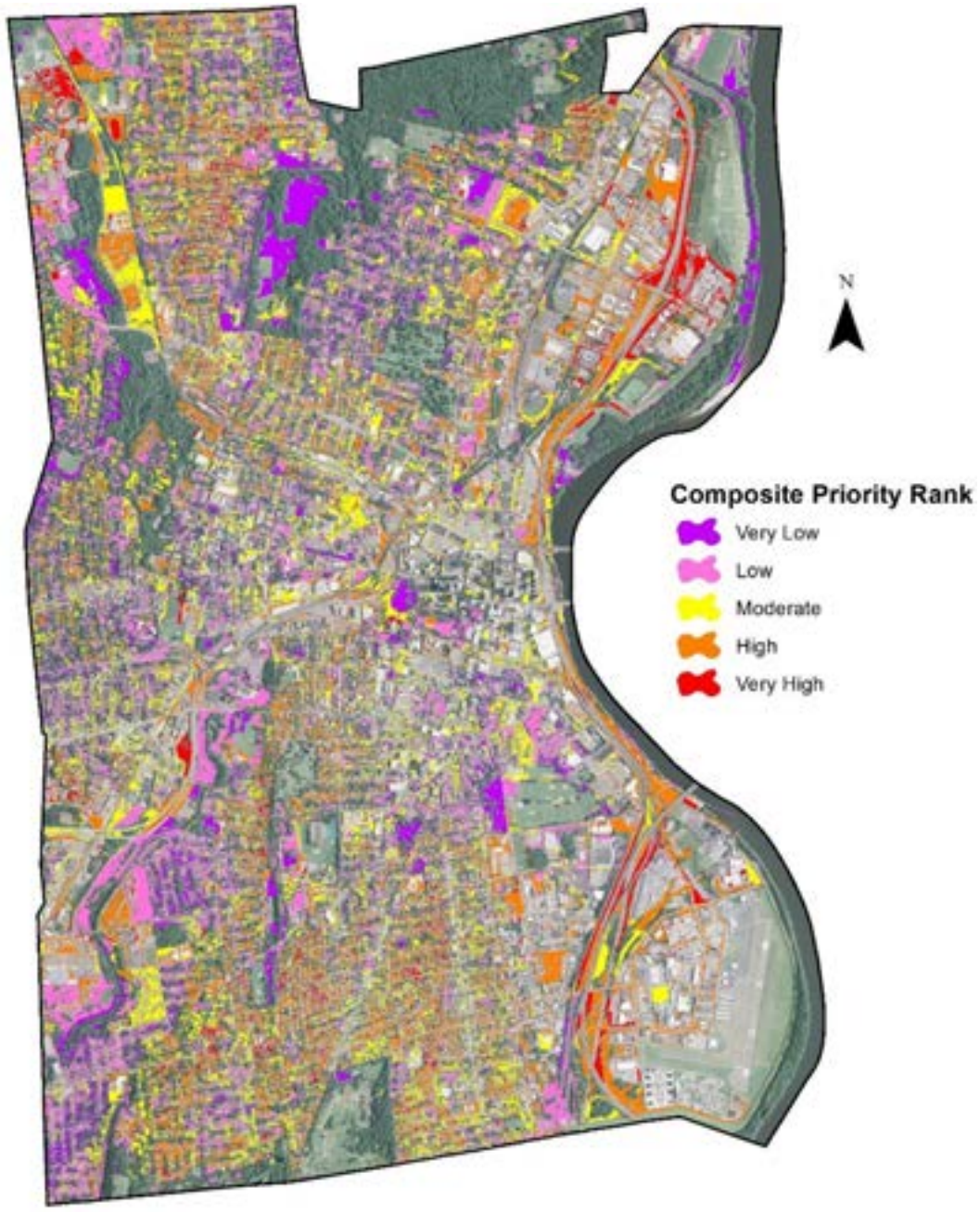


Figure 8. Planting priority areas that maximize Hartford's goals.

Stormwater Interception

One of the most valuable benefits provided by the urban forest is its capacity to mitigate and intercept stormwater. Without trees, cities would have to undertake massive expansions of their stormwater systems to handle the increase in stormwate runoff. In fact, many cities are utilizing trees as part of a comprehensive approach to updating their stormwater systems and achieving compliance with local and federal regulations.

To identify and prioritize stormwater runoff risk potential, a number of environmental data were assessed, including proximity to hardscape, soil permeability, location within a floodplain, slope, and a soil erosion factor (K-factor). Overlapping these data produced a runoff priority rating ranging from Very Low to Very High based on a calculated average. Through this prioritization, sites were ranked based on stormwater reduction.

While all available planting sites in Hartford may ultimately be planted over the next several decades, the trees that are planted in the next several years should be planned for areas of greatest need and sites that will provide the most benefits and return on investment.

Based on this analysis, Hartford has an estimated 14,437 planting spaces that should be considered High or Very High priority planting areas to maximize stormwater interception. In total, these locations represent 717 acres or approximately 6.2% of the city's land area.

Figure 9 shows priority planting locations across the city. It appears that many of the High priority areas are located in commercialized or industrial districts or along the Connecticut river corridor. Specifically, the SouthWest, South End, North Meadows, Behind the Rocks, and Blue Hills neighborhoods have significant opportunities for plantings that target stormwater interception.

These planting locations are citywide and may represent both public and private properties. Regardless, these priority locations show a significant opportunity to expand tree canopy and improve Harford's urban forest stormwater interception capacity.

Table 9. Planting Priority Areas that Maximize Stormwater Interception.

Priority for Stormwater	Planting Opportunities	
	No. of Locations	Area (acres)
Very Low	10,174	438
Low	12,298	749
Moderate	12,685	608
High	6,125	418
Very High	8,312	299
Total Opportunities	49,594	2,512

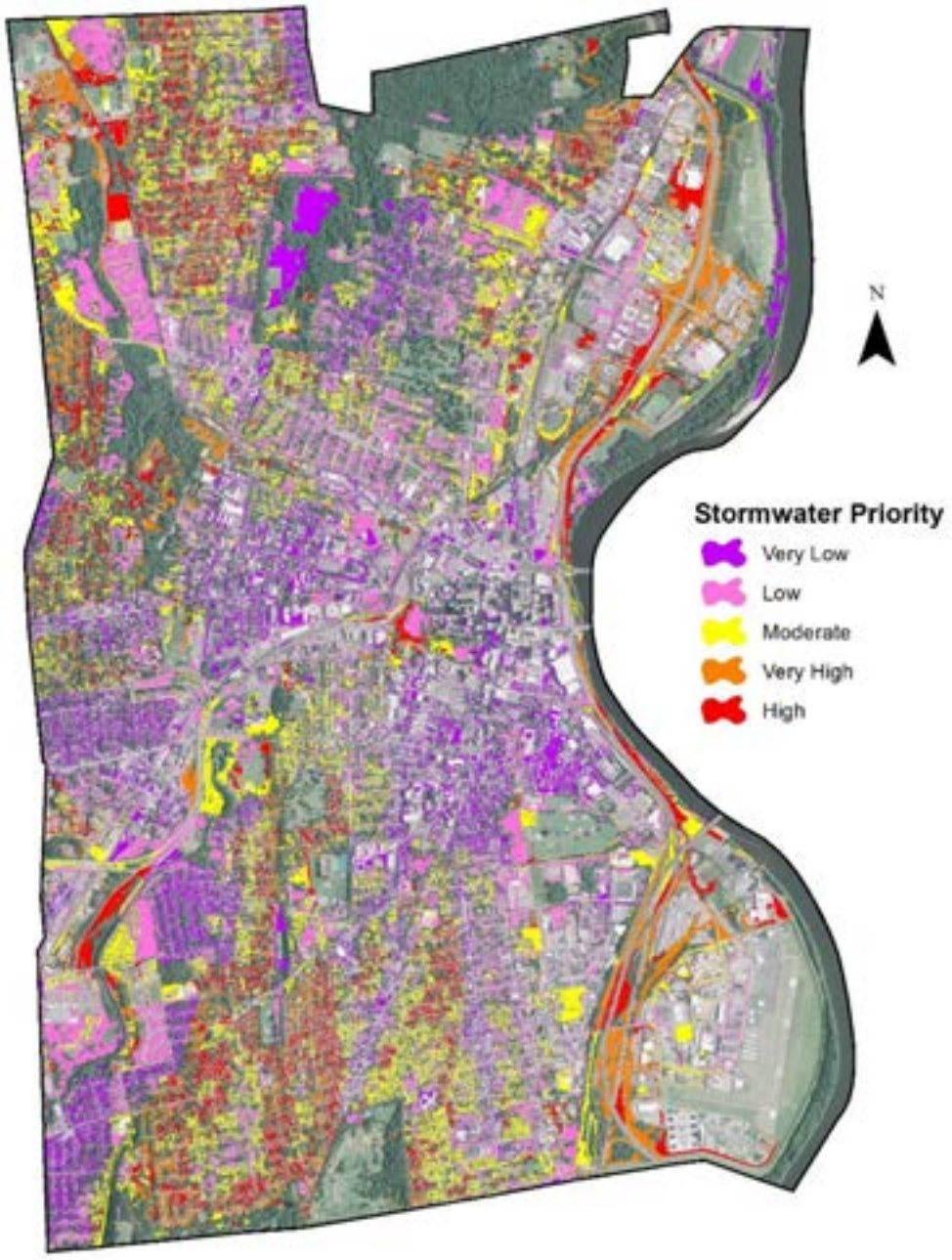


Figure 9. Planting priority areas that maximize stormwater interception.

Urban Heat Island

The urban heat island refers to the tendency of cities and other urban cores to be higher in ambient temperature compared to surrounding areas. Generally, this effect is due to modifications in land surfaces, such as greater degrees of pavement or other impervious surfaces that change the reflectivity of the ground surface. While the difference may be only a degree or two, the urban heat island effect can significantly impact air quality, water quality, and even local weather patterns. Expanding tree canopy can help to mitigate the urban heat island by absorbing greater degrees of sunlight and returning natural cover to the land.

Data generated by the UTC analysis were overlaid with available urban heat island information to produce a priority rating that ranged from Very Low to Very High based on a calculated average. Through this prioritization, sites were ranked based on their potential impact to reducing the effects of the urban heat island

The data show that Hartford has an estimated 20,761 planting spaces of High or Very High priority to positively impact the urban heat island effect (Table 10). Combined, these spaces represent 1,069 acres or 9.2% of Hartford's land area.

Figure 10 shows the distributon of planting sites across the city. Priority planting locations are relatively evenly distributed across Hartford. However, small pockets of High-priority areas appear to be clustered along major travel corridors and business areas, as well as along the Connecticut River corridor.

Urban heat island is created by the reflectivity of pavement and other developments. Therefore, the heat island is likely to be greatest in areas of dense development, which tends to be commercial centers of a city. Due to a lack of "open" land, significant tree planting may require exploring various technologies or infrastructure that can help support tree growth, such as structural soils, suspended sidewalk, or de-paving.

Table 10. Planting Priority Areas that Maximize Impacts to the Urban Heat Island

Priority for Heat Island	Planting Opportunities	
	No. of Locations	Area (acres)
Very Low	10,115	417
Low	2,621	418
Moderate	16,097	609
High	3,904	521
Very High	16,857	548
Total Opportunities	49,594	2,513

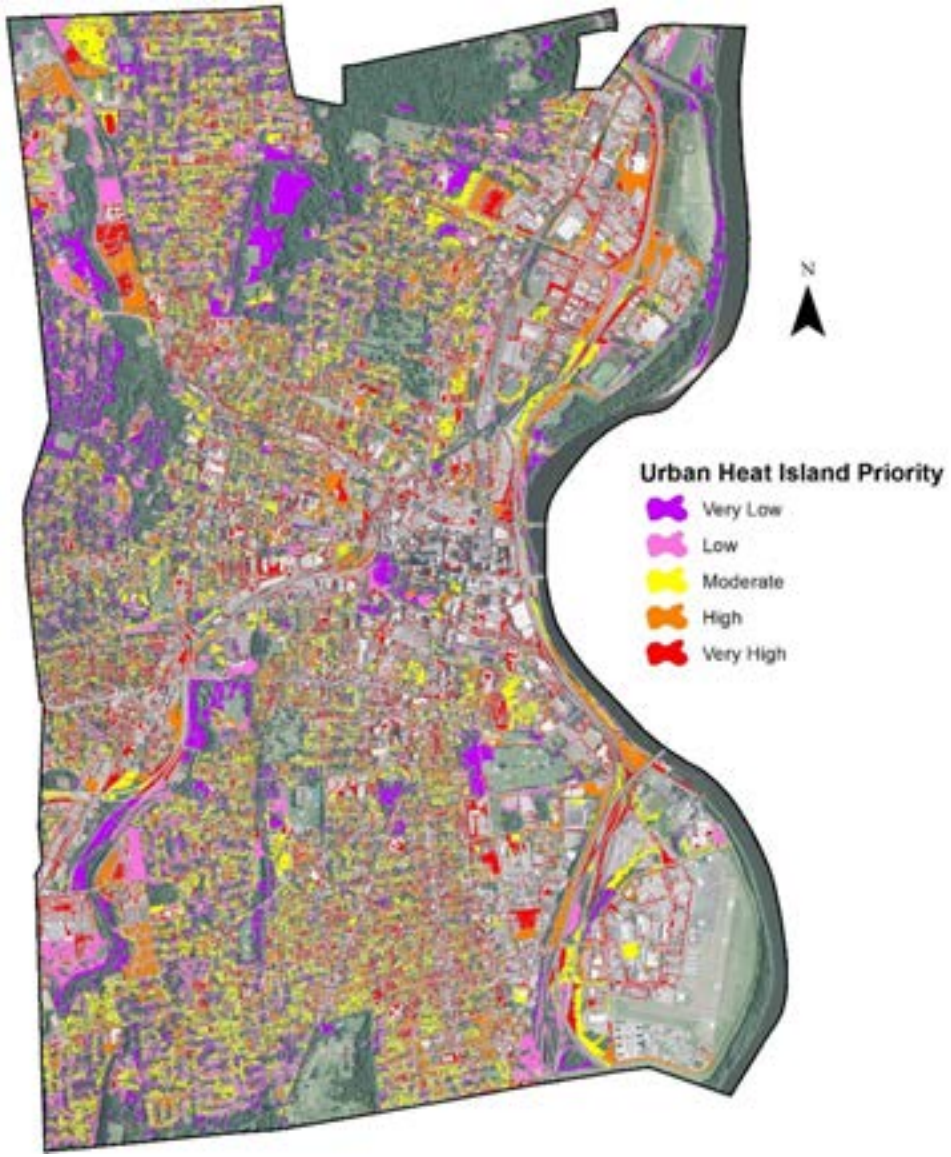


Figure 10. Planting priority areas that maximize impacts to the urban heat island.

Planting Recommendations

While the prioritized planting plan is a great guideline for finding planting locations based on community goals, it does not take into account specific site factors, neighborhood preferences, or on-the-ground realities. Prior to planting, Hartford will need to assess these planting locations for factors that may limit a location's suitability for trees.

All plantings should follow the "right tree in the right place" mantra. Before selecting a tree for planting, make sure it is the right tree—know how tall and wide it will be at maturity. It is equally wise to consider factors such as road salt, soil conditions, or existing hardscape that might limit the suitability of a tree for a specific location.

Photograph 4. Trees should be selected to improve species diversity, and plant the right tree in the right place. Here, KNOX is getting ready to add new trees within Hartford.

As exhibited by recent losses of Norway maple, too much of a single tree species can lead to significant canopy losses. Therefore, Hartford is encouraged to improve tree diversity. Low species diversity (large number of trees of the same species) can lead to severe losses in the event of species-specific epidemics, such as the devastating results of Dutch elm disease (*Ophiostoma novo-ulmi*), emerald ash borer (*Agrilus planipennis*), and Asian longhorned beetle (*Anoplophora glabripennis*). The composition of a tree population should follow the 10-20-30 Rule for species diversity: a single species should represent no more than 10% of the population, a single genera no more than 20%, and a single family no more than 30%.

A list of suggested tree species is provided in Table 11. These tree species are specifically selected to help meet Hartford's goals of intercepting stormwater, mitigating the heat island, and improving air quality. This list is not exhaustive, but can be used as a guideline to enhance Hartford's planting palette to meet community objectives.

Table 11. A Selection of Tree Species Suitable for Hartford that Contribute to Intercepting Stormwater, Mitigating Heat Island Effects, and Improving Air Quality

Tree Species* and Mature Size			Ecosystem Benefit Contribution		
Scientific Name	Common Name	Size	Stormwater	Heat Island	Air Quality
Acer rubrum	red maple	large	yes		
Acer × freemanii	Freeman maple	large	yes		
Aesculus × carnea	red horsechestnut	medium			yes
Aesculus flava	yellow buckeye	large	yes		yes
Betula nigra	river birch	medium	yes		yes
Carpinus betulus	European hornbeam	large	yes		yes
Celtis occidentalis	common hackberry	large	yes		yes
Cercidiphyllum japonicum	Katsuratree	large	yes		
Corylus colurna	Turkish hazelnut	large	yes		
Liriodendron tulipifera	tuliptree	large	yes		yes
Magnolia acuminata	cucumber tree magnolia	large	yes		yes
Magnolia macrophylla	bigleaf magnolia	large	yes		
Magnolia tripetala	umbrella magnolia	small	yes		
Ostrya virginiana	eastern hophornbeam	medium	yes		yes
Phellodendron amurense	Amur corktree	medium	yes		
Platanus × acerifolia	London planetree	large	yes		
Platanus occidentalis	American sycamore	large	yes	yes	
Quercus alba	white oak	large		yes	
Quercus macrocarpa	bur oak	large		yes	
Quercus shumardii	Shumard oak	large	yes		
Tilia americana	American linden	large	yes		yes
Tilia cordata	littleleaf linden	large	yes		
Tilia tomentosa	silver linden	large	yes		yes
Zelkova serrata	Japanese zelkova	large	yes		yes

This species list is not inclusive of all trees recommended and/or suitable for Hartford's climate. While all trees will contribute ecosystem benefits to some degree, these species were simply identified by i-Tree researchers as being in the top 10% of species for each ecosystem benefit identified.

Conclusion

Hartford's urban forest is an important community asset that provides numerous environmental benefits. With the appropriate care, Hartford's urban forest is expected to increase in value over time. Recent actions, including a commitment to plant 20,000 trees in 20 years, exhibit Hartford's deep commitment to growing its tree canopy by 10%. With a strong partnership between the City and KNOX, Hartford is embarking on significant efforts to protect and expand its urban forest.

Since 2008, Hartford's urban tree canopy has increased by 0.3%. Assuming this rate of increase continues, it would take Hartford almost 200 years to increase its tree canopy by 10%. Unfortunately, in the face of climate change, severe weather events, and invasive pests, urban forests are facing more threats than ever before. To achieve the goal of a 10% increase in urban tree canopy, it is not enough to simply plant trees. Instead, Hartford will need to develop a multifaceted approach to expanding tree cover that includes emphasis on tree planting and also maintenance, tree preservation, and community outreach and education to develop wide public support for Hartford's efforts.

This analysis was designed to help document Hartford's urban forest, quantify the value and benefits that it provides, and develop recommendations for future planting efforts. This study should be considered as a starting point—a place from which to begin conversations and the exploration of opportunities that seek to enhance the City's tree canopy. Based on this analysis, some key recommendations emerge:

- In the face of noticeable losses of aging Norway maple, it is apparent that Hartford needs to increase tree species diversity. Hartford is encouraged to adhere to the 10-20-30 planting rule and expand its planting palette to include new tree species.
- Many opportunities for impacting Hartford's priorities of intercepting stormwater and mitigating the urban heat island are within core commercial and industrial areas. To meaningfully expand canopy, Hartford should explore opportunities to improve infrastructure that support trees and engage property and business owners in community forestry efforts.
- Planting is only part of the equation to expand tree canopy. Preserving or protecting old established trees can often have a greater impact on urban canopy levels while the newly planted trees are growing. Hartford should examine policies to identify any barriers or potential incentives to protecting and expanding tree canopy communitywide.
- The prioritized planting plan in this report provides a great starting point for urban greening efforts that will have immediate impacts on managing stormwater and reducing the urban heat island. Hartford should use these data to strategically plant trees in a way that provides the greatest community benefits.
- This report represents one way in which these data can be analyzed. With additional datasets or new questions, these data can further be used to help Hartford manage its urban forest. Therefore, Hartford is encouraged to continue to use these data to analyze additional relationships and connections that can help develop community objectives, understand challenges, and frame management decisions.

Glossary

bare soil 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 UTC present within the city boundary.

family: A level in the classification hierarchy above genus; indicated by the suffix *aceae*.

genera: A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature, the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.

geographic information systems (GIS): A technology that is used to view and analyze data from a geographic perspective. The technology is a piece of an organization's overall information system framework. 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 land use planning and conservation term used to describe protected areas of undeveloped landscapes.

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

i-Tree Canopy: The i-Tree Canopy tool allows users to easily photo-interpret Google aerial images of their area to produce statistical estimates of tree and other cover types along with calculations of the uncertainty of their estimates. A simple, quick, and inexpensive means for cities and forest managers to accurately estimate their tree and other cover types.

i-Tree Tools: State-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.

i-Tree Vue: The i-Tree Vue tool makes use of freely available National Land Cover Data (NLCD) maps to assess land cover, including tree canopy, and some of the ecosystem services, carbon storage and sequestration, and air quality provided by the current urban forest. The effects of planting scenarios on future benefits can also be modeled using Vue.

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

nitrogen dioxide (NO_2): Nitrogen dioxide is a compound typically created during the combustion processes and is a major contributor to smog formation and acid deposition.

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

other vegetation: Pervious cover or a vegetated area (grass, shrubs, etc.) that allows rainfall to infiltrate the soil; typically includes parks, golf courses, and residential areas.

ozone (O_3): A strong-smelling, pale blue, reactive toxic chemical gas with molecules of three oxygen atoms. It is a product of the photochemical process involving the Sun's energy. Ozone exists in the upper layer of the atmosphere as well as at the Earth's surface. Ozone at the Earth's surface can cause numerous adverse human health effects. It is a major component of smog.

particulate matter (PM_{10}): A major class of air pollutants consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, and mists.

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

possible UTC—impervious: The amount of land within the city boundary covered by impervious surface that is theoretically available for the establishment of tree canopy. This excludes all buildings and all pavement within the public right-of-way (ROW).

possible UTC: The amount of land that is theoretically available for the establishment of tree canopy within the city boundary. It is the combination of Possible UTC - Vegetation and Possible UTC - Impervious.

possible UTC—vegetation: The amount of land within the city boundary covered by non-tree vegetation that is theoretically available for the establishment of tree canopy.

riparian: Of or relating to or located on the banks of a river or stream.

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 and consisting of related organisms capable of interbreeding.

sulfur dioxide (SO_2): A strong-smelling, colorless gas that is formed by the combustion of fossil fuels. Sulfur oxides contribute to the problem of acid rain.

tree: A tree is defined as a perennial woody plant that may grow more than 20 feet tall. Characteristically, it has one main stem, although many species may grow as multi-stemmed forms.

tree benefit: An economic, environmental, or social improvement that benefited the community and resulted mainly from the presence of a tree. The benefit received has real or intrinsic value associated with it.

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 assessment (UTC): A study performed of land cover classes to gain an understanding of the tree canopy coverage, particularly as it relates to the amount of tree canopy that currently exists and the amount of tree canopy that could exist. Typically performed using aerial photographs, GIS data, or Lidar.

vegetative swale: Constructed open-channel drainageways used to convey stormwater runoff. Vegetated swales are often used as an alternative to, or an enhancement of, traditional storm sewer pipes.

Reference

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