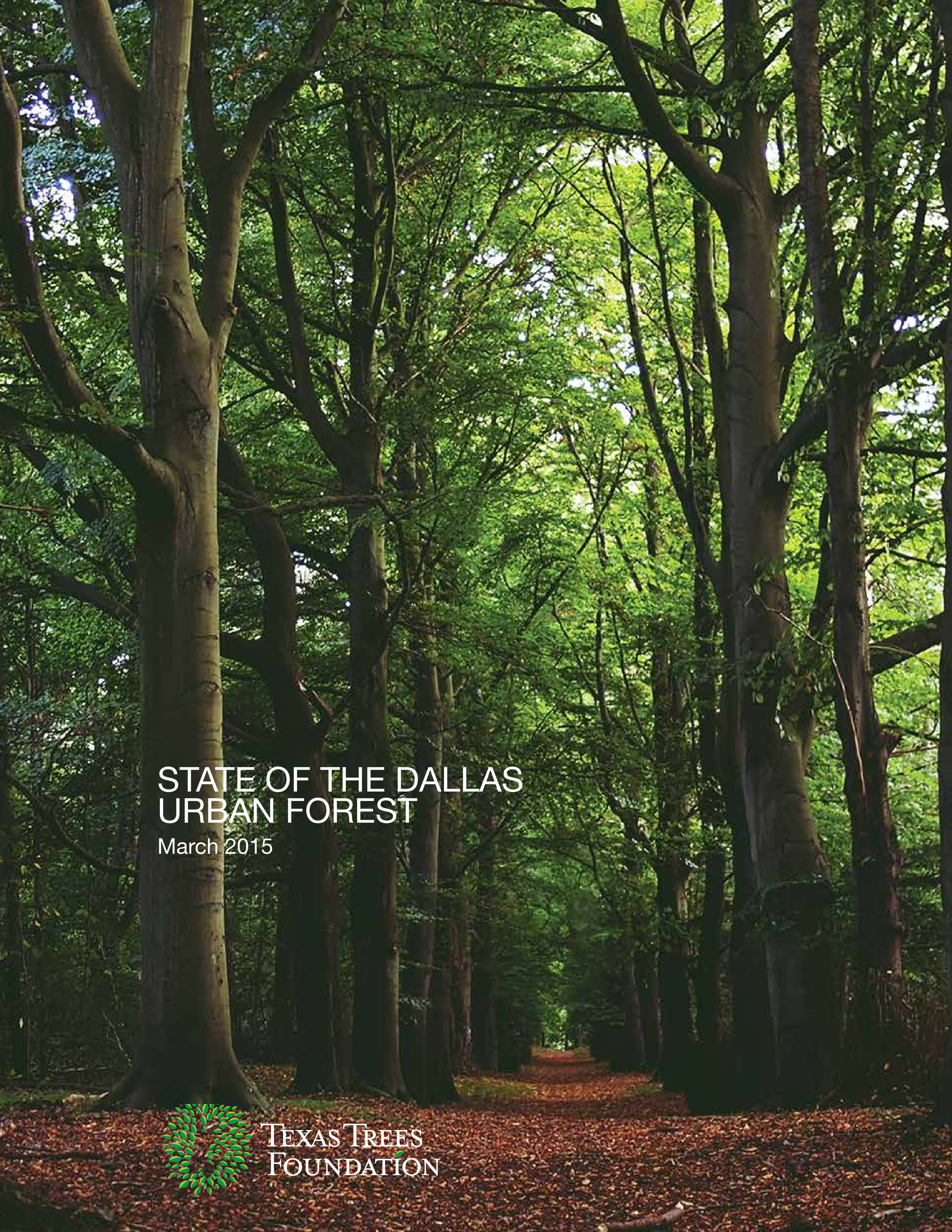

STATE OF THE DALLAS URBAN FOREST

March 2015

Texas Trees Foundation

STATE OF THE DALLAS URBAN FOREST

March 2015

Provided for the people of the City of Dallas by

Texas Trees Foundation

texastrees.org

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Texas Trees Foundation

The Texas Trees Foundation, formerly the Dallas Parks Foundation, was established as a 501(c)3 in 1982 as a resource to support the Dallas parks system. In 1998, the Foundation merged with Treescape/Dallas, Inc., a project that had been funded by the Dallas Junior League and the Central Dallas Association. The Texas Trees Foundation was known as the Dallas Trees and Parks Foundation. In 2003, the Foundation was renamed the Texas Trees Foundation to expand the area of focus from Dallas to the North Texas region to better address the environmental challenges. The Texas Trees Foundation has a rich history and is positioned to build on the traditions established by its founders and nurtured by its stewardship of the many foundations, corporations, agencies and organizations throughout Texas.

Mission

The Mission of the Texas Trees Foundation is (i) to preserve, beautify and expand parks and other public natural green spaces, and (ii) to beautify our public streets, boulevards and rights-of-way by planting trees and encouraging others to do the same through educational programs that focus on the importance of building and protecting the “urban forest” today as a legacy for generations to come. The Foundation will share its vision on a national level, but will focus its efforts and develop loyalties among communities in the North Central Texas area.

Vision

The Texas Trees Foundation has a vision for our community. It is a community comprised of beautiful, well maintained parks, shady tree-lined streets and boulevards, hiking, biking and nature trails, and other outdoor amenities that combine to form a living and working environment that enhances the economic value of its commercial areas and its neighborhoods, and nurtures the health, safety and quality of life of all its citizens; a community in which its citizens actively participate in building and sustaining its “urban forest.” The Foundation will serve as a catalyst in creating such a community.

Acknowledgements

City of Dallas

Mayor Mike Rawlings – *City of Dallas*
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Phil Erwin – *City Arborist*
Patrick Haigh – *Senior Landscape Architect*
Kevin Lefebvre – *Senior Environmental Coordinator, EMS and Sustainability*
Robert Curry – *Manager, Code Compliance*
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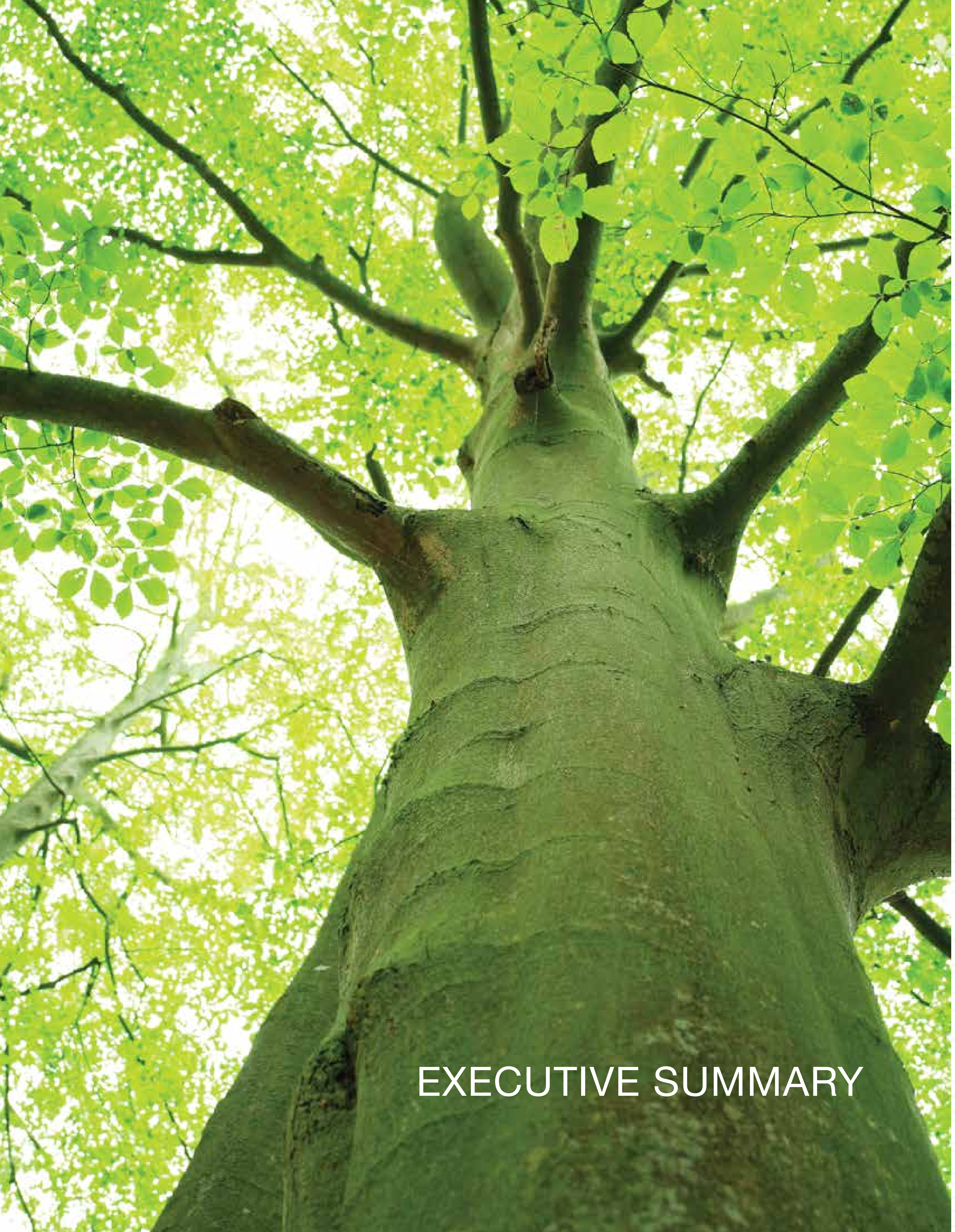


EXECUTIVE SUMMARY

Dallas' urban forest is comprised of the individual trees and groves in and around the places we live, work and play. Urban forest assessment provides a baseline from which to measure changes, trends and outcomes. Sound urban forest management includes tree maintenance, policy development and budgetary decisions – based upon understanding the current conditions.

Over the past six years, Texas Trees Foundation, in partnership with the City of Dallas, has compiled data from four studies with a goal of understanding Dallas' urban forest structure, function and value. These studies include:

Dallas Urban Heat Island Study: Dallas Sustainable Skyline Initiative – 2009 *(Environmental Protection Agency & Houston Advanced Research Center)*

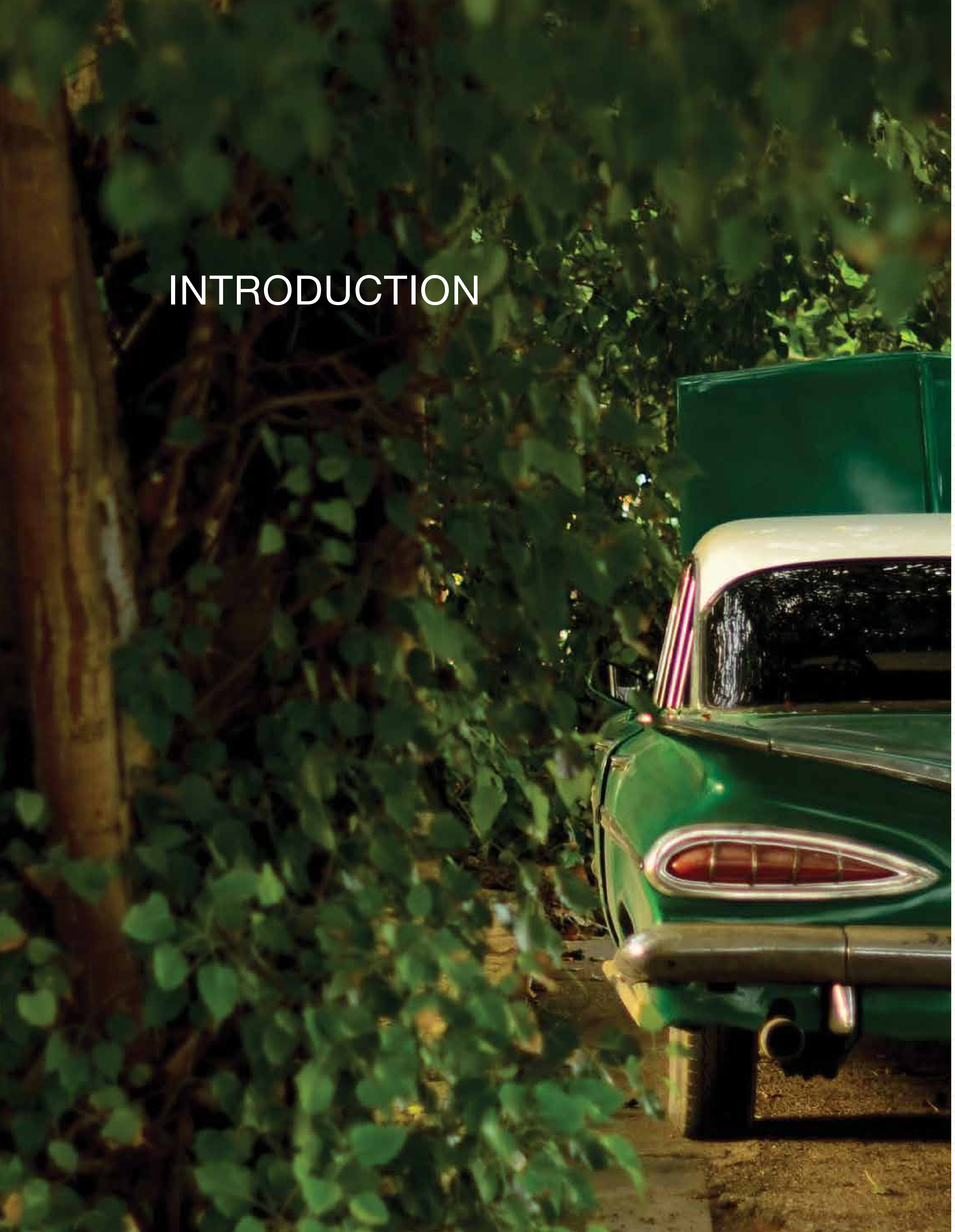
Roadmap to Tree Planting and Planning – 2010 *(Texas Trees Foundation)*

Evaluating Open Space and the Impact of Canopy Change – 2013 *(Texas Trees Foundation)*

i-Tree Eco Study – 2014 *(Texas Trees Foundation)*

The *State of the Dallas Urban Forest* Report is the first of its kind to focus on our most vital natural resource – trees.

Results have advanced our understanding of Dallas' urban forest and provide the framework for quantifying the value of the urban tree canopy to make informed decisions for the future. This data illustrates how trees impact the environment and enhance both human health and the quality of life throughout Dallas and the region.



INTRODUCTION

In 2006, the City of Dallas completed the *forwardDallas!* comprehensive plan. Within the Environmental Element section of the plan, citizens were asked their priorities and values for the future of Dallas. The environment ranked third in terms of critical priority, after education and public safety, and above jobs and neighborhood quality. In the survey, 81% of residents expressed concern about air pollution and 73% concern about water pollution. Dallas residents clearly equate a positive future with clean air, clean water and a clean environment.

*Dallas is part of a rapidly growing metropolis that grew faster than any other region in the country between July 2011 and 2012 (*U.S. Census Bureau*). North Texas is expected to add an additional 4.1 million people by 2030 (*North Central Texas Council of Governments: Vision North Texas*).*

The American Lung Association ranks Dallas 8th for the worst air quality for ozone in the country (*State of the Air: 2014 American Lung Association*) and the region is currently not in compliance with National Ambient Air Quality Standards (NAAQS) set by the Environmental Protection Agency (EPA). With an increasing number of people moving to the region, the need to strategically approach the care and replenishment of Dallas' urban forest has reached a critical point. Building on previous studies, the Texas Trees Foundation and the City of Dallas performed an i-Tree Eco Study in the summer of 2014 for the 385 square mile area.

This research provided extensive data about the urban forest's current condition. Trees play an important role in the health, quality of life, and the resiliency of our city. Economic development is important, but as Janette Monear, Texas Trees Foundation President and CEO states, "Economic development in the absence of environmental integrity is not sustainable!"

STUDY HIGHLIGHTS

- The 14.7 million trees within the City limits have a replacement value of $9.02 billion.
- There are nearly 1.8 million potential tree planting sites throughout Dallas.
- Trees provide annual savings of over $9 million through energy conservation.
- Trees capture 59 million cubic feet of stormwater runoff and save $4 million annually in repairs and additions to current stormwater management infrastructure.
- Trees clean the air by storing two million tons of carbon valued at $137 million.
- Dallas' trees provide $36.1 million annually in eco-system services.
- Over 35% of the surface area in Dallas is covered with impervious surface such as buildings, cement, roads, and parking lots.
- Over 25% of the surface area is covered in irrigated turf.
- The City's average tree canopy is 29%.
- The area South of I-30 represents 37% of the total tree canopy.
- The Great Trinity Forest accounts for nearly 20% of all tree benefits and covers one-sixth of the total area.

MAJOR FINDINGS

Dallas Urban Tree Canopy

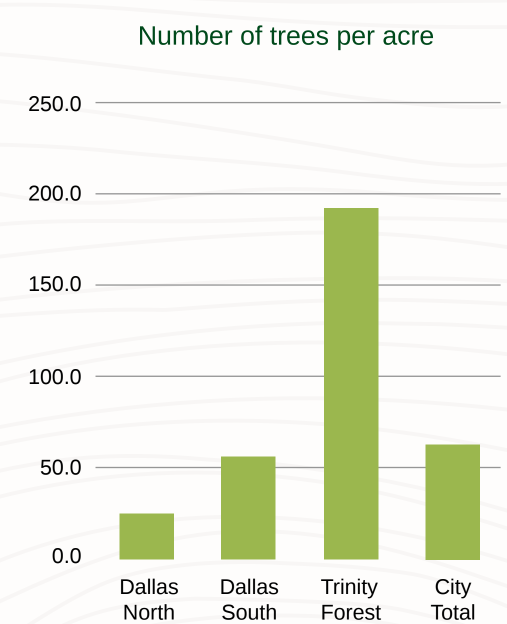
Urban tree canopy (UTC) is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Researchers estimate that tree canopy cover in urban and metropolitan areas across the U.S. averages 27% and 33%, respectively (*Dwyer and Nowak, 2000*).

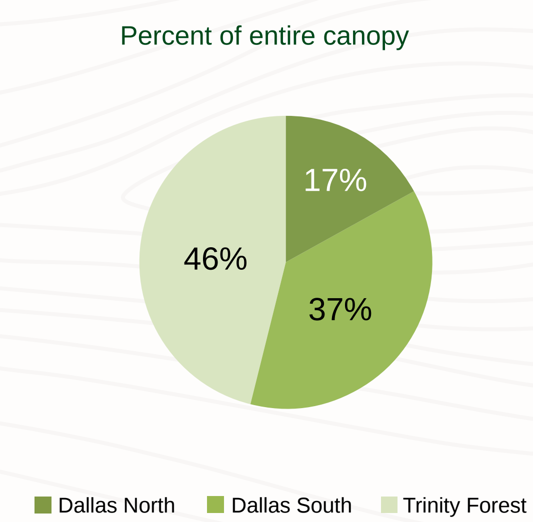
Additionally, trees are subject to a wide variety of stressors, which significantly shortens their lifespan. The i-Tree Eco Study revealed that Dallas' urban forest has 14.7 million trees with a UTC of 29%. This equates to 62.4 trees per acre.

However, like many urban areas cities, Dallas' trees are not evenly distributed throughout the city. Nearly half of all trees are in the Great Trinity Forest: 46% of the entire canopy. The remaining 54% of the canopy is heavily concentrated in areas zoned for residential and park land. Some commercially zoned parcels in Dallas have a UTC of less than 5%.

With such a large portion of the city's tree canopy focused in specifically zoned areas, it is important for Dallas to take steps to protect and enhance the urban forests by setting canopy goals. There is a strong correlation between land use and canopy cover.

Future zoning policies and land use decisions play a significant role in the abundance, distribution, and potential future location of Dallas' trees.





Dallas Urban Forest Diversity

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. The diversity of a forest is measured by the number of different species found in an area. High species diversity is characteristic of a healthy functional forest. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but can also pose a risk to native plants if some of the exotic species are invasive plants that out-compete and displace native species. In urban settings, both native and non-native species can be part of a resilient urban forest as long as there are plans in place to plant the right tree, in the right place, the right way.

The Foundation's study identified 80 different tree species, 60% of which are native to the North Central Texas region, while 27% of the population would be considered exotic. The remaining 13% of the tree population are considered native to North America but not necessarily this region. North of I-30 was represented with 57 different species, South of I-30 with 62, and the Great Trinity Forest had 28 different species represented.

Top 5 Species for the City of Dallas

Species	% Population	% Leaf Area	Importance Value
Hackberry spp	17.9	18.3	36.2
American Elm	13.9	12.4	26.3
Green Ash	13.1	13.0	26.1
Eastern Red Cedar	11.0	11.5	22.5
Cedar Elm	11.4	10.0	21.4

Top 5 Species by Geographical Region

South of IH 30	North of IH 30	Trinity Forest
Eastern Red Cedar	Hackberry spp	Green Ash
Hackberry spp	Crepe Myrtle	American Elm
Cedar Elm	Live Oak	Hackberry spp
American Elm	American Elm	Cedar Elm
Green Ash	Cedar Elm	Eastern Red Cedar

Age & Size

The size of trees, specifically the diameter at breast height (DBH), can be a good prediction of future trends in the structure and composition of an urban forest. Tree age is directly related to the condition of the site so it can be difficult to accurately measure a tree's age without intrusive measures such as taking core samples. It is possible however when DBH is compared with species growth curves to develop approximation of the age of a particular forest.

While larger trees provide substantially more ecosystem benefits, the space to grow and maintain large trees in an urban setting can be limited. In addition, trees will only grow to the size that current environmental conditions will allow. With harsh summers, limited soil volume, poor soil quality, and intermittent watering, other options need to be considered. This might include planting smaller species of trees that are better acclimated to our growing conditions and increasing the required soil volume required when planting new trees.

The study revealed that of the 14.7 million trees in Dallas, 61% have a diameter of less than 6 inches, while less than 15% have a diameter more than 12–inches. The relative size of trees provides important information of the region's forest. Tree size, along with forest diversity, allows us to examine trends and plan future planting. For example, of the 61% of the tree population that are less than 6-inches DBH, only 20% are species that will grow into quality, large trees at maturity.

Forest regeneration is an importation part of urban forest management. A mixed age class will ensure a sustainable canopy and allow urban forest professionals to better predict budgets and set management schedules.

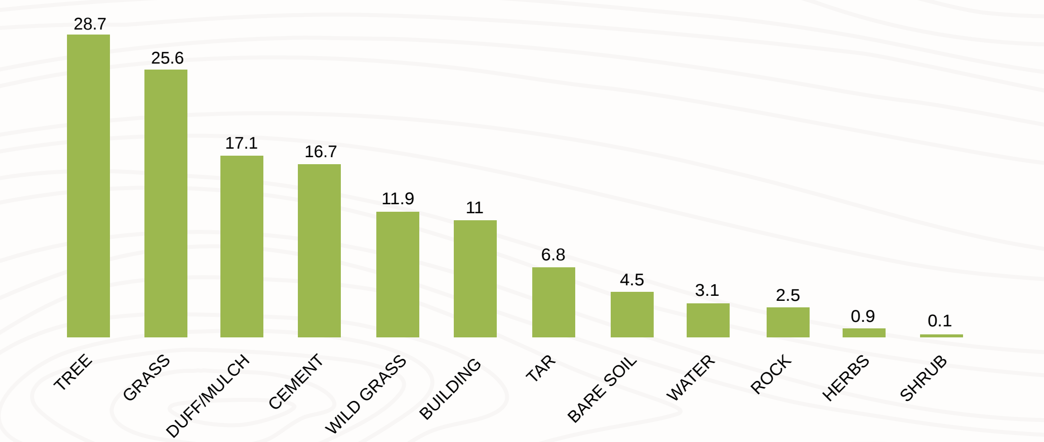
Ground Cover

Ground cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures. More importantly ground cover change is the process by which humans modify the land. People have been modifying land to obtain food for centuries, but at current rates and intensities ground cover change is now far greater than ever before, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. These changes are of great concern to urban eco-systems caused by loss of biodiversity, increased heat islands (reflected from hardscape and buildings), and the pollution of water, soils and air.

Urbanization tends to increase the rate of ground cover change making sustainable land practices essential in the sustainable management of the urban forest.

The i-Tree Eco Study revealed that 35% of all surface area in Dallas is hardscape with an additional 25% covered in grass. This means that over 50% of available land is covered with an impervious (or semi-impervious) surface making it more difficult to recharge the aquifers and slow stormwater flow.

Dallas Ground Cover by Percentage (%)



Urban Forest Functional Values

Dallas' urban forest provides community, economic, and ecosystem service benefits to its citizens. The i-Tree Eco Study calculated the extent of these values for four major benefits: pollution removal, carbon storage and sequestration, energy savings, and stormwater management.

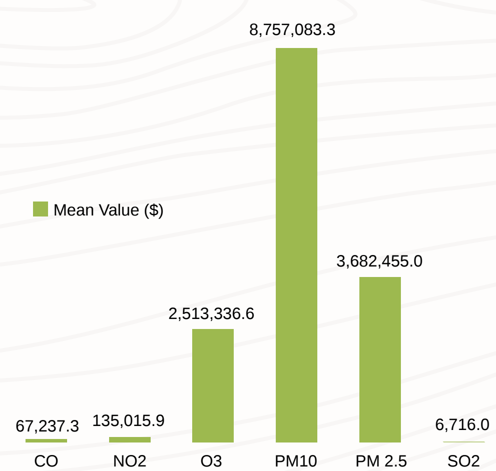
Pollution Removal

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscapes and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperatures, directly removing pollutants from the air, and reducing energy consumption in buildings through shading. The physical process by which trees help to clean our air is through the interception of particulate matter on leaf surfaces and absorption of pollutants.

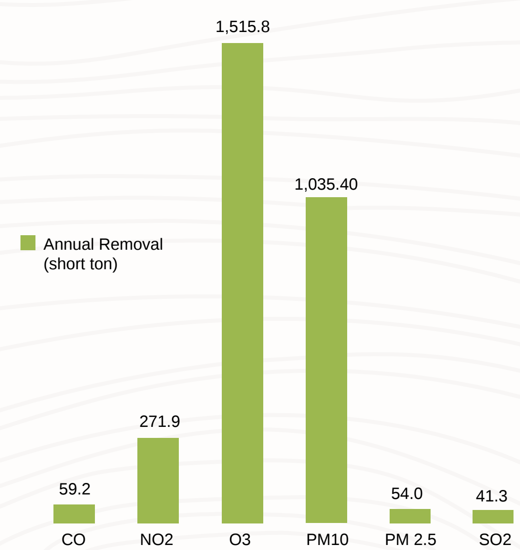
Pollution removal by trees in Dallas is estimated at 2,980 tons of air pollution annually with an associated value of $15.2 million dollars each year. Air pollutants removed include ozone, carbon monoxide, nitrogen dioxide and particulate matter.

Trees emit volatile organic compounds (VOCs) that contribute to ground level ozone formation making the overall effect trees play on air quality complex to calculate. Numerous studies have shown that increasing tree cover in an area can actually reduce ozone levels. "Vegetation can absorb as much as 20% of the global atmospheric ozone production, so the potential impact on air quality is substantial," says Dr. Emberson, a senior lecturer in the Environment Department at the University of York and director of SEI's York Centre.

Annual Pollution Removal ($)

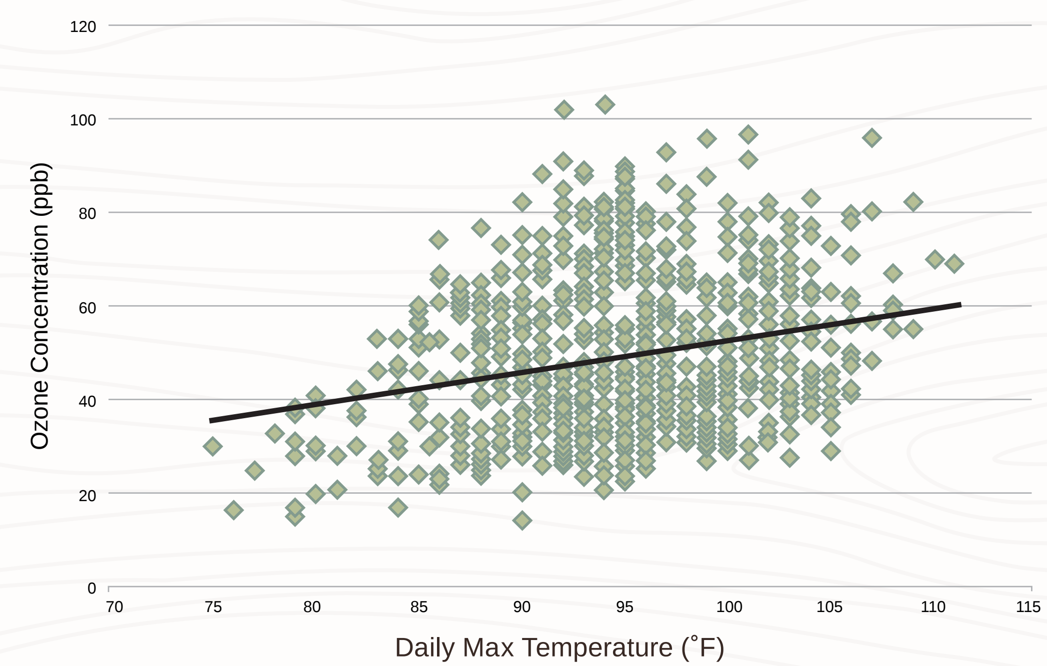


Annual Pollution Short Tons



Research has also shown a direct correlation between heat and ozone formation. (*Summers in the City: Hot and Getting Hotter – Climate Central*) With more than 80% of Americans living in urban areas, better land use strategies that incorporate more trees and parks, reflective roofs, and other alternative methods of "green" infrastructure can reduce the effects of a growing urban heat island and improve overall air quality.

Dallas: Hotter Temperatures, Higher Ozone



SOURCE: URBAN CLIMATE LAB, GEORGIA INSTITUTE OF TECHNOLOGY

Carbon Storage and Sequestration

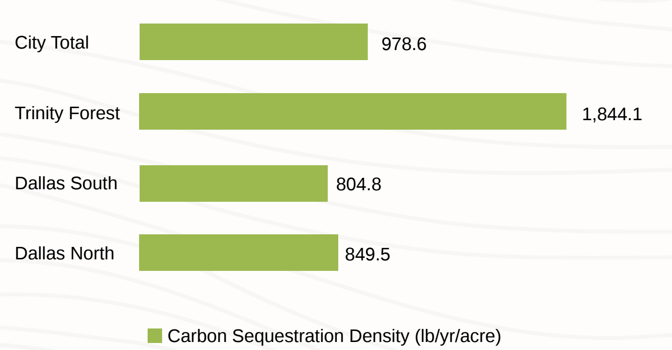
Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon a tree can sequester and store is increased with the size and health of the tree. Young, healthy trees sequester carbon at a much higher rate than older more mature trees, but large trees store significantly more carbon. For example, Live Oak represents 2% of the total tree population but accounts for 8% of the total carbon stored.

The Study calculated that Dallas' trees sequester 115,000 tons of carbon per year for an associated value of $8.19 million annually and store an additional 1.9 million tons valued at $137 million.

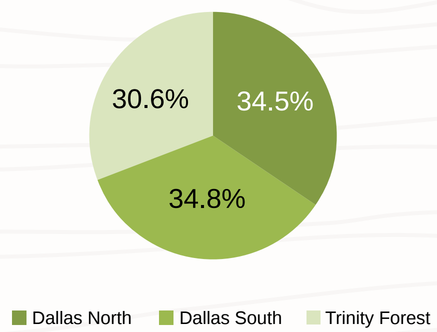
Carbon Storage: Refers to carbon stored (bound) in woody plant parts including roots, branches and stems.

Carbon Sequestration: The annual removal of carbon (CO2) through photosynthesis.

Carbon Storage by Region



Carbon Storage by Land Use



Energy Savings

Trees are valuable assets for homeowners because they increase property value, create curb appeal, improve air quality, and provide energy savings. Research has proven that carefully positioned trees can save up to 25% of a household's energy consumption for heating and cooling (*U.S. Department of Energy*). This is achieved through transpiration and by blocking the summer sun, which is especially important in Dallas. Tree size, proximity to a building, and whether they are evergreen or deciduous can have a tremendous effect on residential cooling and heating cost.

Energy estimates for this study involved measuring tree distance and direction from buildings, species, tree height, and percent canopy. Cost savings reflect local prices per kilowatt hour (kWh).

Dallas' trees are estimated to reduce energy-related cost from residential buildings by $8.93 million annually. Trees also produce an additional $1,264,635 in value by reducing the amount of carbon produced by fossil-fuel based power plants, a reduction of 17,800 tons of carbon emissions.

Units (kWh)

	Heating	Cooling	TOTAL
MBTU	-165,813.0	0.0	-165,813.0
MWH	-6,113.0	98,488.0	92.375.0
Carbon Avoided	-3,853.7	21,611.9	17,758.2

Energy Values ($)

	Heating	Cooling	TOTAL
MBTU	-1,683,072.1	0.0	-1,683,072.1
MWH	-702,383.7	11,316,271.2	10,613,887.5
Carbon Avoided	-274,436.0	1,539,071.0	1,264,636.0
TOTAL	**-2,659,891.8**	**12,855,342.2**	**10,195,450.4**

Carbon avoided value is calculated based on $71 per ton
Energy saving value is calculated based on the prices of $114.9 per MWH and $10.15 per MBTU

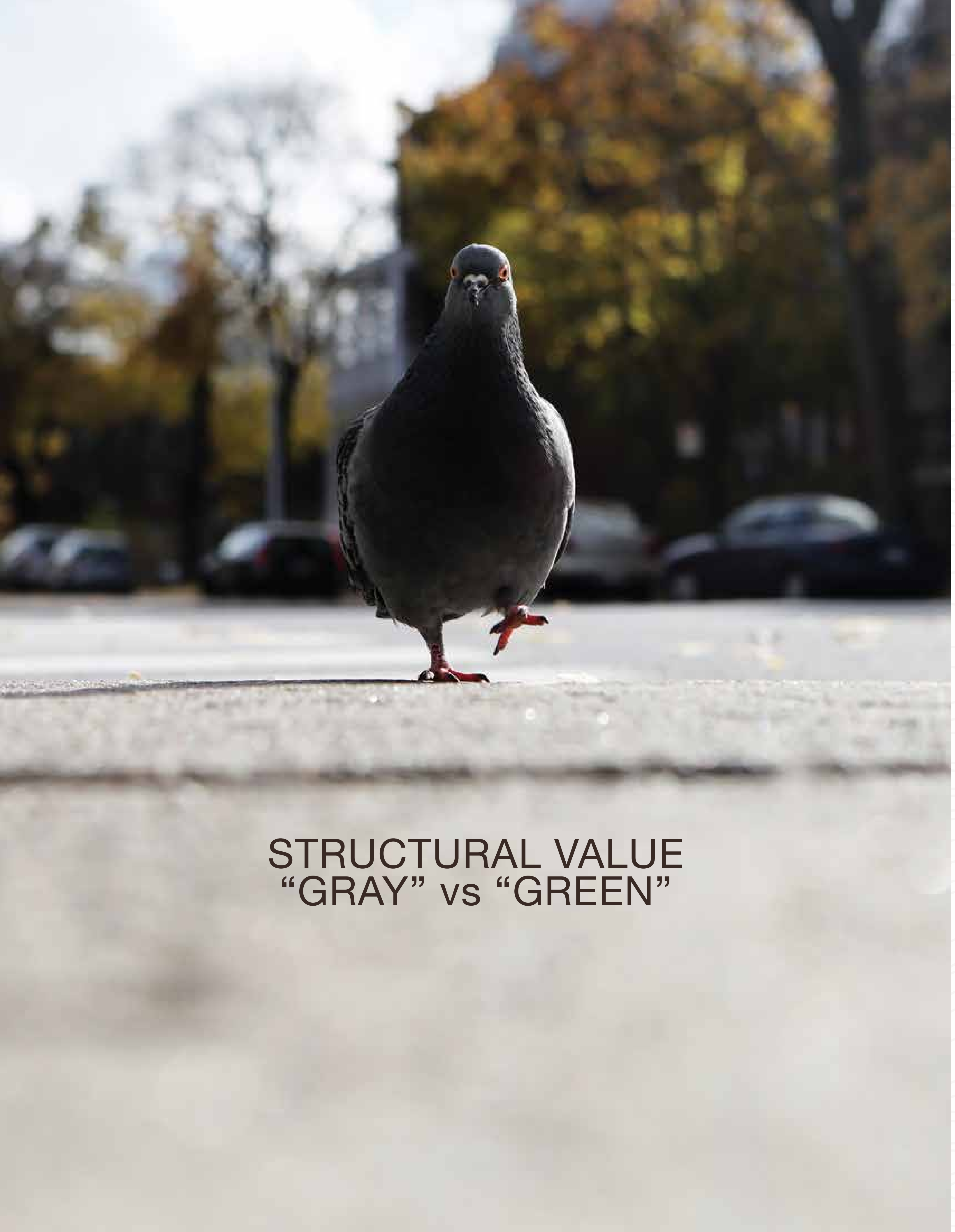
Stormwater Management

Stormwater runoff is rainfall that flows over the ground surface. It is created when rain falls on roads, driveways, parking lots, rooftops and other paved surfaces that do not allow water to soak into the ground. Stormwater runoff is the number one cause of stream impairment in urban areas. Where rain falls on paved surfaces, a much greater amount of runoff is generated compared to runoff from the same storm falling over a forested area. These large volumes of water are swiftly carried to our local streams, lakes, wetlands and rivers and can cause flooding and erosion, and wash away important wildlife habitat. (*Watershed Forestry Resource Guide: USDA Forest Service*).

Trees improve stream quality and watershed health primarily by decreasing the amount of stormwater runoff and pollutants that reach local water sources. Trees reduce runoff by capturing and storing rainfall in the canopy and releasing water into the atmosphere through evapotranspiration. In addition, tree roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil. This helps to replenish groundwater supplies and maintain streamflow during dry periods.

The Study found that Dallas' trees reduce runoff by an estimated 59,192,000 cubic feet a year with an associated value of $3.94 million.

Region	Tree Number	Leaf Area (mi2)	Avoided Runoff (ft3/yr)	Avoided Runoff Value ($)
Dallas North	2,478,571.0	115.7	15,148,781.7	1,008,554.7
Dallas South	5,486,301.0	164.2	21,507,911.6	1,431,924.1
Trinity Forest	6,713,000.0	172.1	22,534,900.5	1,500,297.6
Total	**14,677,872.0**	**452.0**	**59,191,593.7**	**3,940,776.4**



STRUCTURAL VALUE “GRAY” vs “GREEN”

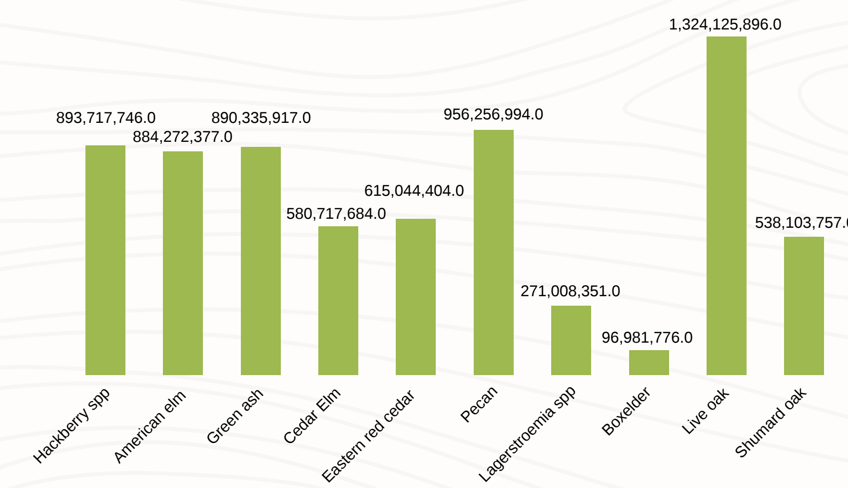
Infrastructure is essential for economic development but the balance between the built and natural environments is critical in creating sustainable resilient cities. The return on investing in green infrastructure, especially trees, provides a 3:1 ROI. Trees are a natural solution to water runoff, air quality, energy consumption, and mitigation of the urban heat island effect. They also protect and expand the life of the “gray”, or built environment.

The i-Tree Eco Study found the structural value of the 14.7 million existing trees in the City of Dallas is $9.02 billion. This calculation is based on current tree species, size, and condition at the time of this Study and reflects the benefits that the trees provide.

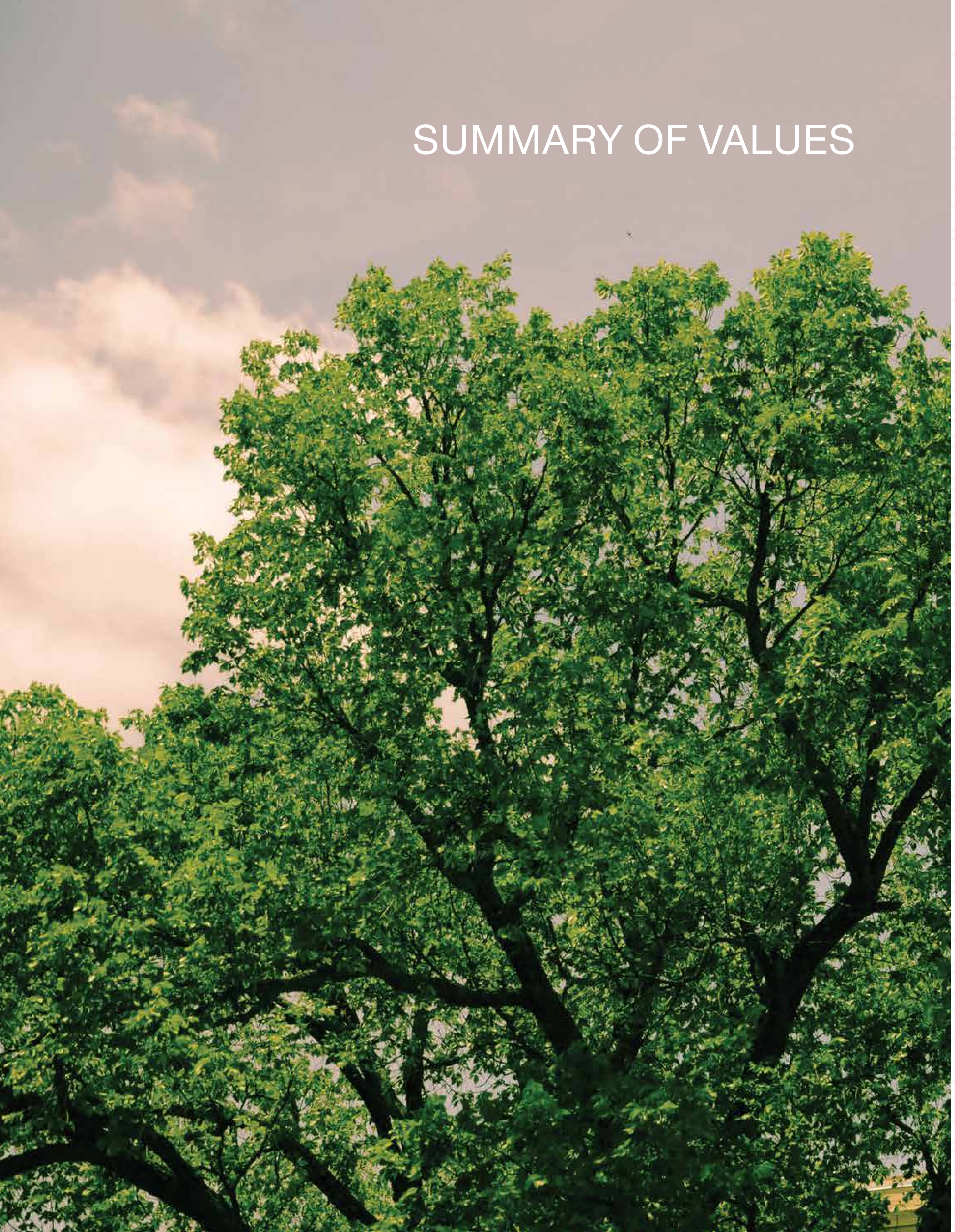
By protecting and managing this resource, the City of Dallas will continue to benefit from the environmental services of these “green civic servants” every day and their value will continue to increase.

Since green infrastructure can provide comparable benefits to gray infrastructure at reduced costs, a financial case can be made for investing in the conservation, sustainable management, and/or restoration of natural ecosystems to achieve development goals.

Top 10 Trees by Count of Total $ Value of Benefits



SUMMARY OF VALUES



Dallas' urban forest is comprised of 14.7 million trees with an urban tree canopy of 29%. These trees provide an estimated structural value of $9.02 billion at the time of this report. As these trees grow they will provide functional values (eco-system benefits) that total an additional $36.1 million annually.

Structural Value	Amount
Replacement Value	$9.02 Billion
Carbon Storage	$137 Million
Total Structural Value	**$9.1 Billion**

Annual Functional Value	Amount
Carbon Sequestration	$8.2 Million
Air Pollution Removal	$15.1 Million
Energy Savings	$8.9 Million
Stormwater Savings	$3.9 Million
Total Annual Functional Value	**$36.1 Million**

OBSERVATIONS AND RECOMMENDATIONS

This Report demonstrates the vital resource Dallas' urban forest represents for its residents, economy and environment. However, the urban forest is not static and does not function independently of the city's 1.2 million people.

Urban Tree Cover (UTC), or canopy cover, is the driving force behind the urban forest's ability to produce sustainable ecosystem service benefits to the City for generations to come. As trees grow and their canopy increases, so do their benefits. On average, a large tree removes more pollutants, provides more shade, intercepts more rainfall, and has a greater value than a small tree. For instance, trees greater than 20 inches in DBH account for only 5% of Dallas's entire tree canopy but produce 27% of the overall value.

The dominant contribution made by large trees to the overall value of Dallas' urban forest cannot be understated. The sustainability of this forest is in direct relation to the quality and extent by which it is managed. A sound urban forestry program based in science, technology, and research will allow the City to maximize the return on its investment.

Dallas Tree Canopy Map

SOURCE: Heat Island Study 2009 HOUSTON ADVANCED RESEARCH CENTER

With a canopy cover of 29%, Dallas' urban forest seems adequate compared to other urban centers. However, there is a large discrepancy within various regions of the City where canopy cover ranges from 7% to 60%.

The greatest threat to the existing canopy continues to be the land development process. Under current practices, the decrease in forest density and large native trees, and the increased presence of tree pest and non-native trees, is a strong probability. The City has an opportunity to develop strategies to preserve and protect this portion of its tree resource.

Tree preservation is only a piece of the puzzle. To ensure Dallas' urban forest will benefit future generations, long-range policies and programs for maintaining and expanding tree cover must be developed. Sixty seven percent of the total tree population is comprised of Hackberry, American Elm, Green Ash, Eastern Red Cedar, and Cedar Elm making the possibility of losing a large portion of the City's tree canopy in a single catastrophic event highly likely (e.g. Emerald Ash Borer, Dutch Elm Disease). In addition, over 20% of the top five species are greater than 20-inches in DBH which will lead to an annual net loss of trees through natural mortality over time.

Large-scale tree planting initiatives, improved landscape requirements and maintenance standards will help increase tree canopy. With over 450,000 planting locations located on single family residential lots, expanding tree planting on private property would be an easy place to increase overall tree canopy while avoiding increased maintenance cost to the City. In the long-term, strategic tree planting programs must include expanded species selection, updated landscape requirements, maintenance requirements, and cost.

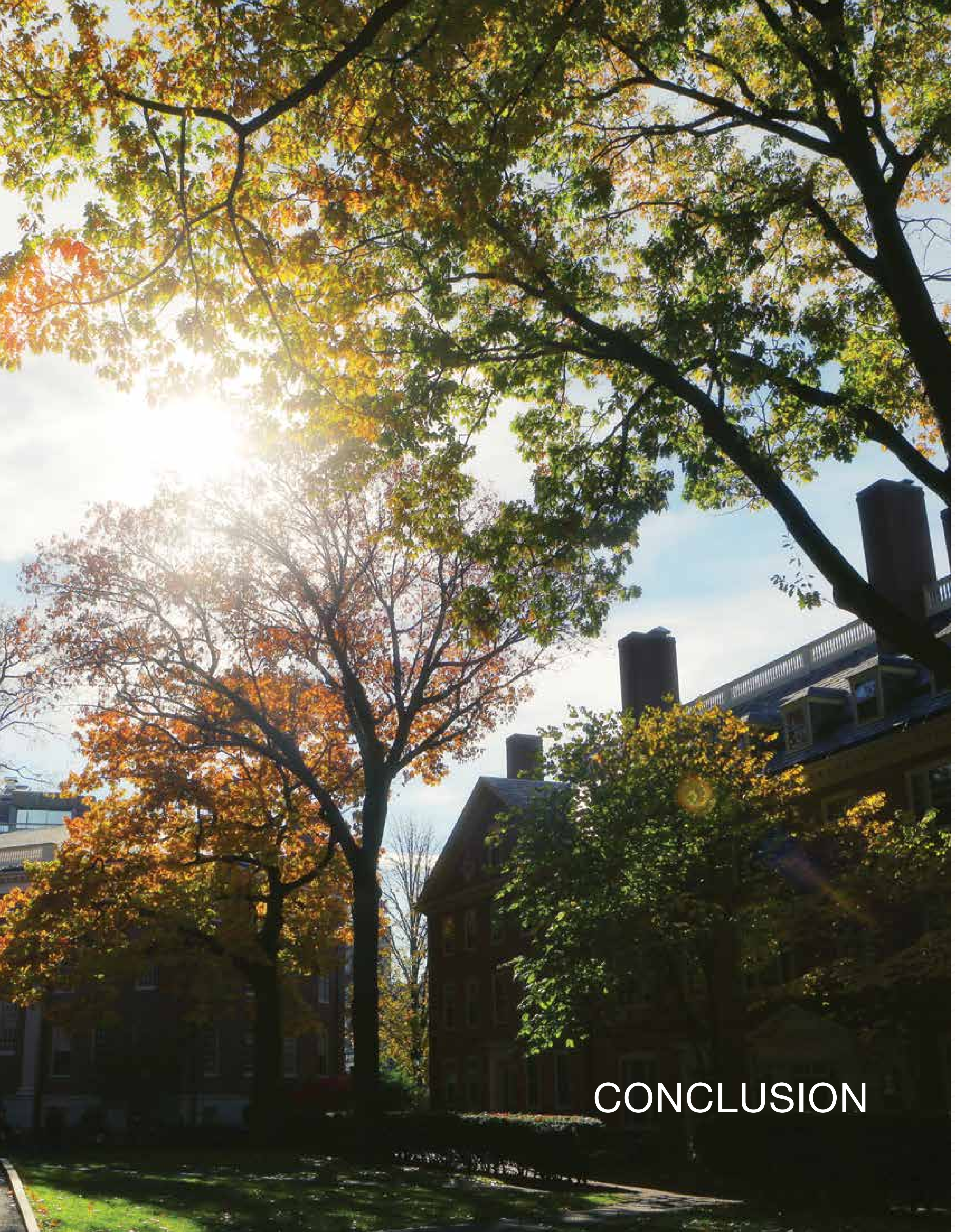
The following are observations and recomendations from the i-Tree Eco Study.

- Invest, expand, and develop Dallas' municipal urban forestry program.
- Establish tree canopy goals with minimum standards for parking lots and land use.
- Create comprehensive tree planting plans for watershed management, urban heat island mitigation, and streetscapes.
- Create an interdepartmental urban forestry task force.
- Develop expanded minimum soil volume requirements for newly planted trees in urban areas to establish and sustain large canopy shade trees to full maturity.
- Develop and implement storm water management practices that involve trees and other green infrastructure techniques.
- Develop and promote new adaptive landscaping standards to accommodate trees in urban settings.
- Improve policies and procedures to protect existing trees and groves of trees.
- Protect open space through conservation easements, parkland dedication, and land purchase.
- Identify and protect environmentally sensitive areas, and restore and manage riparian buffers.
- Update the Great Trinity Forest management plan.
- Ensure adequate funding levels for tree planting and maintenance required to meet set goals.
- Formalize a working relationship with the Texas Trees Foundation.

CONTINUED ASSESSMENT

Sound research, up-to-date technology, and good data are the keys to achieving an effective pro-active management of the urban forest. This assessment has benefited from those before it and provides a baseline for future studies. Forests are not static, they change over time, and the need for updated data will be ongoing. This should include:

- Complete public tree inventory to implement comprehensive maintenance programs, manage removal of damaged or unsafe trees, track customer requests, update new tree planting information, assist in budget planning and evaluate program effectiveness.
- Detailed comprehensive plans that lay out how the City can utilize trees to better manage stormwater.
- Updated Urban Heat Island maps showing canopy change over the past 10 years.



CONCLUSION

The *State of the Dallas Urban Forest* Report quantifies the ecosystem services and direct environmental benefits that trees provide. It does not capture the multitude of social, psychological, health and wildlife benefits that comprise the total ecosystem of the City of Dallas.

This Report provides the basis for better planning, protecting, managing, budgeting, and expanding the tree resource in Dallas. Through sound research, technology and good data, this report will help Dallas grow one of the most significant urban forests in the country. The Great Trinity Forest, which makes up 18% of Dallas total tree canopy, and is the largest contiguous urban forest in the country, serves as the backbone of the City's urban forest resource.

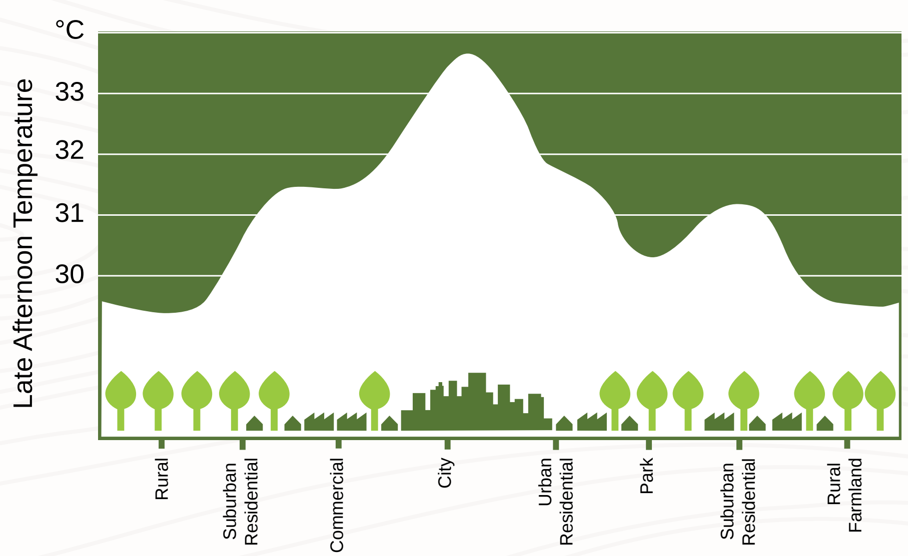
Study #1:

Dallas Urban Heat Island Study – 2009

In 2009, a report was prepared as part of the Dallas Sustainable Skyline Initiative, a project by the Houston Advanced Research Center (HARC) and U.S. Environmental Protection Agency (EPA). The study examined how and where heat island effects occur in Dallas and some of the basic tools for reducing impacts, such as expanded tree planting and conservation, use of cool roofing, and application of cool and porous paving. The study describes costs and benefits associated with these tools (*Dallas Urban Heat Island Study: Houston Advanced Research Center*).

According to Dr. Brian Stone, professor of City and Regional Planning at Georgia Tech University and Director of the Urban Climate Lab in Atlanta, GA, "Dallas is the third fastest warming city in the country." A key message in Dr. Stone's book, *The City and the Coming Climate: Climate Change in the Places We Live* (Cambridge University Press, 2012), is that cities are heating up at double the rate of global climate change with major implications for human health, including an increase in heat related deaths and an increase in ground level ozone. Managing urban heat is just as important a response as reducing greenhouse gas (GHG) emissions, and the benefits will be felt much sooner. Stone's research shows that cities should prioritize strategies to reduce both heat and GHG emissions, and trees and green infrastructure are at the top of that list. As cities develop, trees and vegetated areas are reduced, natural surfaces are paved, and buildings constructed. Together these changes produce the "urban heat island effect."

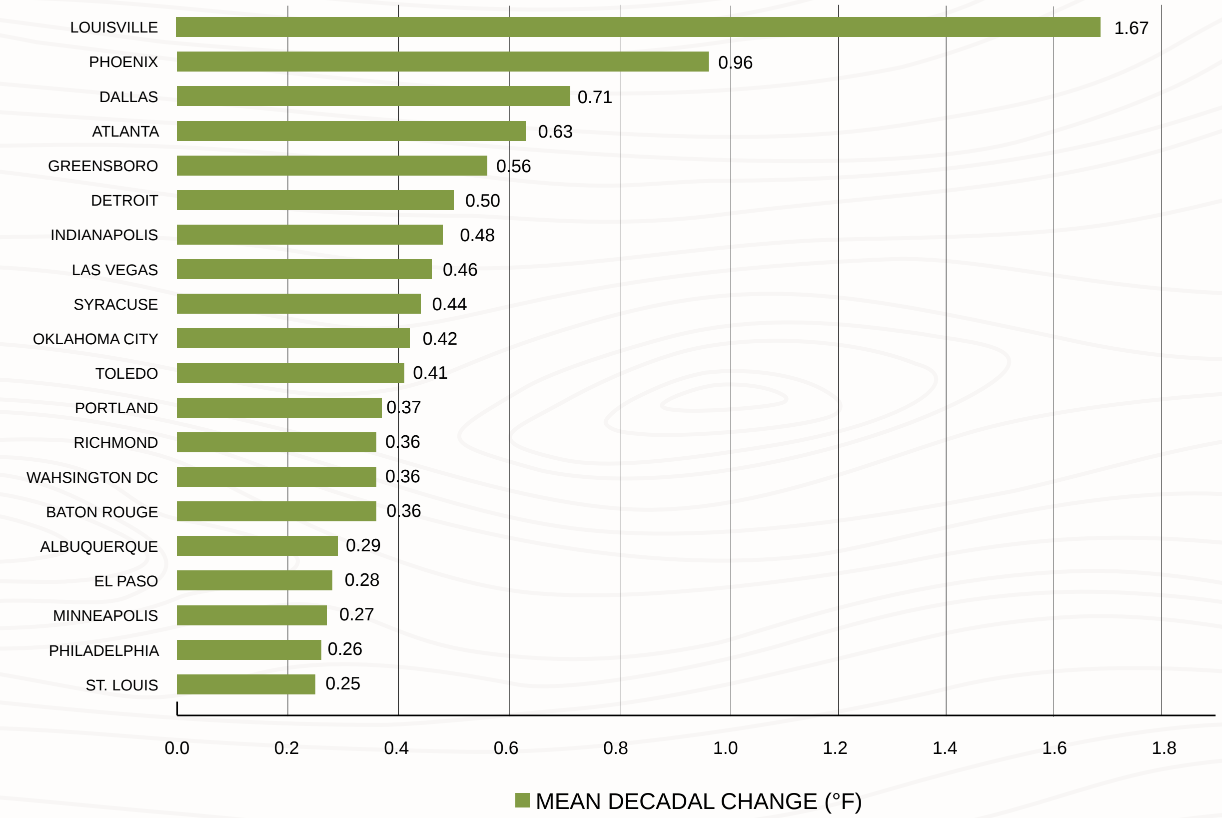
Dallas has recognized heat island concerns in plans and discussions, and there are several references in the 2006 Dallas Comprehensive Plan, *forwardDallas!* The Vision section of the plan mentions the heat island effect as follows:



Excerpt from *forwardDallas!*

"Central to this key initiative is identifying, inventorying and protecting important natural resources, sensitive ecosystems, open spaces and cherished views. Included are policies to mitigate the urban heat island effect, improve storm water management within the city, reduce smog, expand the absorption capacity of floodplains and allow the restoration and rehabilitation of Trinity River riparian corridors."

Top 20 Most Rapidly Growing Urban Heat Islands in United States: 1961-2010



SOURCE: URBAN CLIMATE LAB, GEORGIA INSTITUTE OF TECHNOLOGY

Study #2:

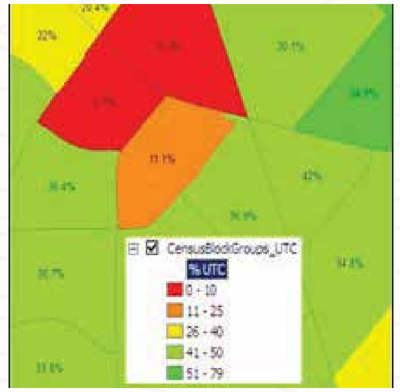
Roadmap to Tree Planting and Planning – 2010

In 2010, with a grant from ONCOR, the Texas Trees Foundation developed a geographic information systems (GIS) based model to assess the overall urban tree canopy cover for Dallas. As part of the study, the Foundation examined potential planting locations, making it the first project in which tree planting sites were identified and then prioritized by their environmental and economic factors. Results provided a framework for strategic urban tree planting and have impacted the case for funding support with policy makers, corporations and foundations.

The Roadmap project began by mapping existing tree canopy, impervious surface, grass/meadow, bare soil, and water using high resolution multispectral imagery. Land cover classes were mapped using 4-band (blue, green, red, and near-infrared) leaf-on imagery from the National Agricultural Imagery Program (NAIP) collected in the summer of 2008. GIS layers from the North Central Texas Council of Governments (NCTCOG) were incorporated to increase the accuracy of the land cover data. This included parking lots, transportation polygons, building footprints, medians, and hydrology layers.

The area and percent of existing Urban Tree Canopy (UTC) was calculated for the varying geographic boundaries: individual parcels, census block groups, city council districts, and the entire city. These GIS boundaries were queried based on either area or percentage of UTC, illustrated on the following page:

Tree Canopy Cover



UTC by Census Block

UTC by Parcel

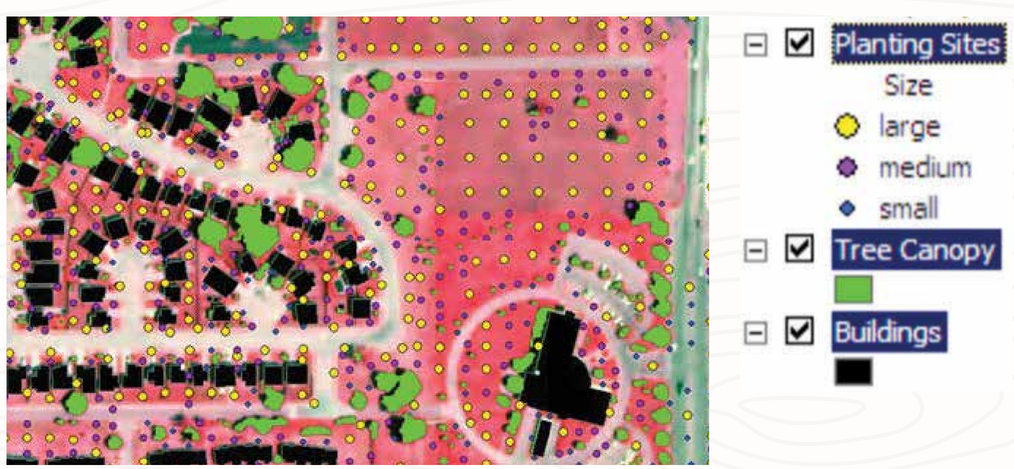
The Dallas Roadmap – Results at a Glance

Urban Tree Canopy (UTC): 29% - excluding water citywide and ranging from 16-39% within City Council districts (2010)

Number of Planting Sites by Roadmap Criteria:

Maximum Energy Savings Potential:	**332,194**
Single Family Residential (SFR) Property:	**458,850**
Public Rights-of-Way (PROW):	**480,790**
On Commercial Property:	**301,648**
On School Property:	**53,019**
In (or adjacent to) Parking Lots:	**84,577**
Lowest Income Range (<$20K):	**214,809**
Highest Urban Heat Island Range (>140F):	**19,097**
Total Potential Planting Sites:	**1,855,310***

**Planting sites falling in multiple criteria categories were only accounted for in one category*



Study #3:

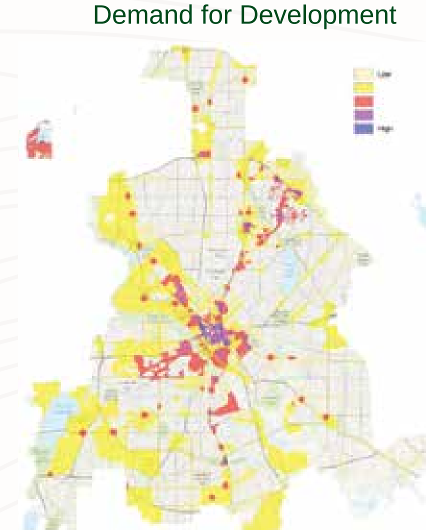
Evaluating Open Space and the Impact of Canopy Change – 2013

In 2013, the Foundation worked with Azavea, a spatial analysis firm, to analyze the impact of canopy change on undeveloped properties greater than 10 acres and less than 10 acres in size. Planting locations were also examined on these same parcels to prioritize projects. Using data sets provided by the Foundation and the City of Dallas, a series of maps, statistics, charts and tables were created that identified high pressure development areas (using a weighted sum model incorporating TIF boundaries, transportation corridors, Vision North Texas, etc.).

- High priority tree preservation sites derived from the pressure development map
- Endangered canopy on open space sites less than 10 acres
- Endangered canopy on open space sites greater than 10 acres
- Priority planting areas to spur development
- Added ecosystem service benefits from new tree plantings
- Environmental impact from loss of tree canopy
- Additional maps are provided in Appendix E

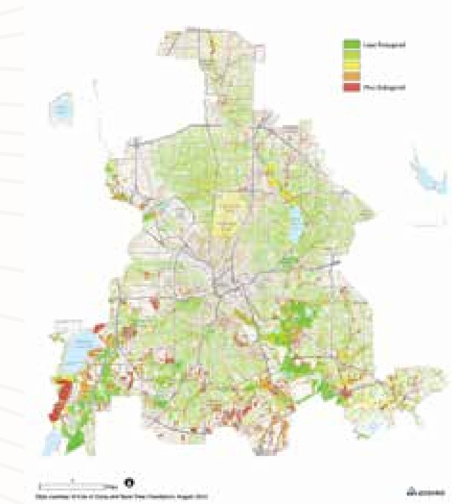
Results from this study evaluated the impact large scale canopy change would have on community health across Dallas. The Foundation identified high risk areas for canopy loss, areas that need to be preserved (e.g. riparian buffer zones), and potential areas for future tree planting to mitigate for trees lost in the development process. In addition we performed a more detailed analysis of the cost and benefits of large planting initiatives. Included is a list of sites that could handle large numbers of trees while maximizing their environmental benefits. This will enable us to engage stakeholders and provide data to determine clear numbers when determining the return on their investment. These locations could be buffer initiatives for riparian areas, the Great Trinity Forest, trails, and other green corridors.

Demand for Development



Demand for Development Pressure Map

Tree Canopy Preservation Sites



Most Endangered Tree Canopy (Derived from Development Pressure Map)

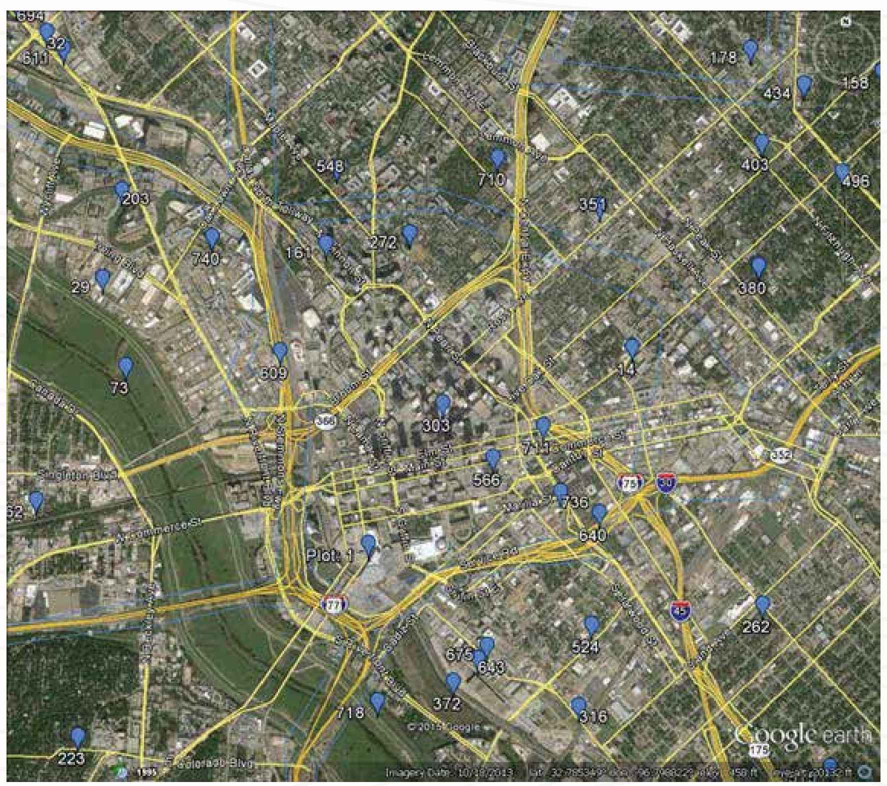
Study #4:

i-Tree Eco Study – 2014

To gain an objective view of the urban forest in a city the size of Dallas, 385 square miles, the use of aerial photography, satellite imagery and other remote sensing techniques is essential. Aerial photography shows the surface of the tree canopy while a more detailed picture, including species composition, age and health requires field measurements of individual trees.

i-Tree Eco is one tool in a suite of tools that provides a broad picture of the entire urban forest. i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools. i-Tree tools help communities of all sizes to strengthen urban forest management and advocacy efforts by quantifying the environmental services trees provide and the structure of the urban forest.

Developed by the USDA Forest Service, Davey Tree Expert Company, National Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, and Casey Trees have entered into a cooperative partnership to further develop, disseminate and provide technical support. (See Appendix A)



Dallas i-Tree Eco Plot Locations in and around Downtown Dallas

i-Tree Eco uses field data from randomly located plots and local hourly air pollution and meteorological data to quantify:

- Urban forest structure (e.g. species composition, tree density, tree health, leaf area, leaf and tree biomass, species diversity, etc.).
- Amount of pollution removed hourly by the urban forest. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter.
- Total carbon stored and net annual carbon sequestration by the urban forest.
- Effects of trees on building energy use through shading.
- Compensatory value of the forest, as well as the value of air pollution removal and carbon storage and sequestration.
- Potential impact of insects or disease to the urban forest (e.g., Asian Longhorned Beetles, Emerald Ash Bore, Oak Wilt or Dutch Elm Disease).

To provide statistically relevant data, 800 1/10th acre potential plots were randomly identified using i-Tree's plot generation tool, with a goal to collect data on at least 600 plots. These were then stratified using zoning maps allowing for an independent look at the Great Trinity Forest separate from the rest of the city. Plots were divided among the following regions of Dallas: North of I-30 (271 plots), South of I-30 (300 plots) and the Great Trinity Forest (50 plots) for a total of 621 plots measured.

During the summer of 2014, Texas Trees Foundation staff and five college interns colected data over eleven weeks. Plot measurements included tree species, diameter, tree height, various crown measurements and ground cover. With the goal to capture a sample representative of the entire urban forest, data collection on private property was an essential component of the study. In the event permission was not granted, the next randomly selected plot, within the same region, was selected for data collection. (For a complete list of field data measured on each plot see Appendix B.)



Pictures from Dallas i-Tree Eco plots

Appendix A: i-Tree Eco

i-Tree Eco uses standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects, including:

- Urban forest structure (e.g. species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns and <10 microns respectively).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian Longhorned Beetle, Emerald Ash Borer, Gypsy Moth, and Dutch Elm Disease.

In the field, 0.10 acre plots were randomly distributed. Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Within each plot, typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings.

Invasive species are identified using an invasive species list for the State in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species identified as invasive by the State invasive species list are cross-referenced with native range data. This helps eliminate species that are on the State invasive species list, but are native to the study area.

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth (from the appropriate genera, and diameter class and tree condition) was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1. Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States and converted to local currency with user-defined exchange rates.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition. Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature that were adjusted depending on leaf phenology and leaf area. Removal estimates of particulate matter less than 10 microns incorporated a 50 percent suspension rate of particles back to the atmosphere. Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values.

Air pollution removal value was calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter <2.5 microns using the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP). The model uses a damage function approach that is based on the local change in pollution concentration and population.

National median externality costs were used to calculate the value of carbon monoxide removal and particulate matter less than 10 microns and greater than 2.5 microns. PM10 denotes particulate matter less than 10 microns and greater than 2.5 microns throughout the report. As PM2.5 is also estimated, the sum of PM10 and PM2.5 provides the total pollution removal and value for particulate matter less than 10 microns. Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series. If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the

literature using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information. Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps from the Forest Health Technology Enterprise Team (FHTET) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch Elm Disease and Chestnut Blight. The range of these pests was based on known occurrence and the host range, respectively.

Appendix B: Plot Attributes

The following items were measured for each plot in the i-Tree Eco Assessment:

- Azimuth from plot center to tree
- Distance from plot center to tree
- Whether tree was planted or naturally growing
- Species
- Height at DBH
- DBH (or multiple diameters if multi-trunked)
- Total tree height in feet
- Height to the live crown on tree, if top was dead
- Height of the average base of the crown
- Width of crown, in feet, by North by South and East by West headings
- Percent of missing canopy from tree
- Amount of dieback as a percentage compared to whole
- Percentage of land under canopy which is impervious
- Percentage of land under canopy which has shrubbery under canopy
- Crown light exposure –number of sides of a tree which is receiving 90% of light from sun (5 sides total, N, S, E, W, top of crown)
- Distance and azimuth of trees which are 20 feet or taller and within 60 feet of building (distance and azimuth taken from corner of building)
- Noted, Yes or No, if tree is a street tree

Appendix C:
Top 5 Species for Each Region by Total Estimated Count from i-Tree Eco Assessment

		Number of Trees		Values ($)	
Land Use	Species	Val	SE	Val	SE
Dallas North	Hackberry spp	496429	106000	290930078	65577214
Dallas North	Lagerstroemia spp	314286	59897	217621624	44493365
Dallas North	Live oak	217857	35361	1208071852	251709713
Dallas North	American elm	196429	78064	160182481	93252705
Dallas North	Cedar elm	157143	70925	175195287	77975548

		Number of Trees		Values ($)	
Land Use	Species	Val	SE	Val	SE
Dallas South	Eastern red cedar	1297945	316142	413089169	94966799
Dallas South	Hackberry spp	866438	150288	393907289	86433683
Dallas South	Cedar elm	660959	230794	191768607	60831542
Dallas South	American elm	496575	201965	433418476	1.16E+08
Dallas South	Green ash	253425	65732	175934835	61367474

		Number of Trees		Values ($)	
Land Use	Species	Val	SE	Val	SE
Trinity Forest	Green ash	1547000	432761	581505990	149769307
Trinity Forest	American elm	1351000	418660	290671379	83417674
Trinity Forest	Hackberry spp	1260000	316679	208880379	60950870
Trinity Forest	Cedar elm	854000	391017	213753789	83051199
Trinity Forest	Eastern red cedar	266000	140546	138808314	89287266

Appendix D: Glossary of Key Terms

Diameter at Breast Height (DBH): a standard method of expressing the diameter of the trunk or bole of a standing tree.

Ecosystem Services: benefits people obtain from ecosystems. Healthy forest ecosystems are ecological life-supporting systems. Forests provide a full suite of goods and services that are vital to human health and livelihood.

Exotic: an introduced, alien, exotic, non-indigenous, or non-native species, or simply a species living outside its native distributional range, which has arrived there by human activity, either deliberate or accidental. Non-native species can have various effects on the local ecosystem. Introduced species that have a negative effect on a local ecosystem are also known as invasive species. Not all non-native species are considered invasive. Some have no negative effect and can, in fact, be beneficial as an alternative to pesticides in agriculture for example.

forwardDallas! **Comprehensive Plan:** this long-term plan was developed through community input and detailed analysis of economic, land use, housing and transportation trends. The purpose is to guide development, creating a city with many neighborhoods of unique character, safe parks, bustling transit centers, a thriving urban downtown and excellent employment opportunities.

Green Infrastructure: an approach that communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities. Unlike single-purpose gray storm water infrastructure, which uses pipes to dispose of rainwater, green infrastructure uses vegetation and soil to manage rainwater where it falls. By weaving natural processes into the built environment, green infrastructure provides not only storm water management, but also flood mitigation, air quality management, and much more.

Ground Cover/Land Cover: the physical material at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc.

Ground Cover Change: a general term for the human modification of Earth's terrestrial surface.

Impervious Surface: mainly artificial structures—such as pavements (roads, sidewalks, driveways and parking lots) that are covered by impenetrable materials such as asphalt, concrete, brick, and stone rooftops. Soils compacted by urban development are also highly impervious.

i-Tree: a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefit assessment tools. The i-Tree tool helps 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 Eco: a software application designed to use field data from complete inventories or randomly located plots throughout a community along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and value to communities. Baseline data can be used for making effective resource management decisions, develop policy and set priorities.

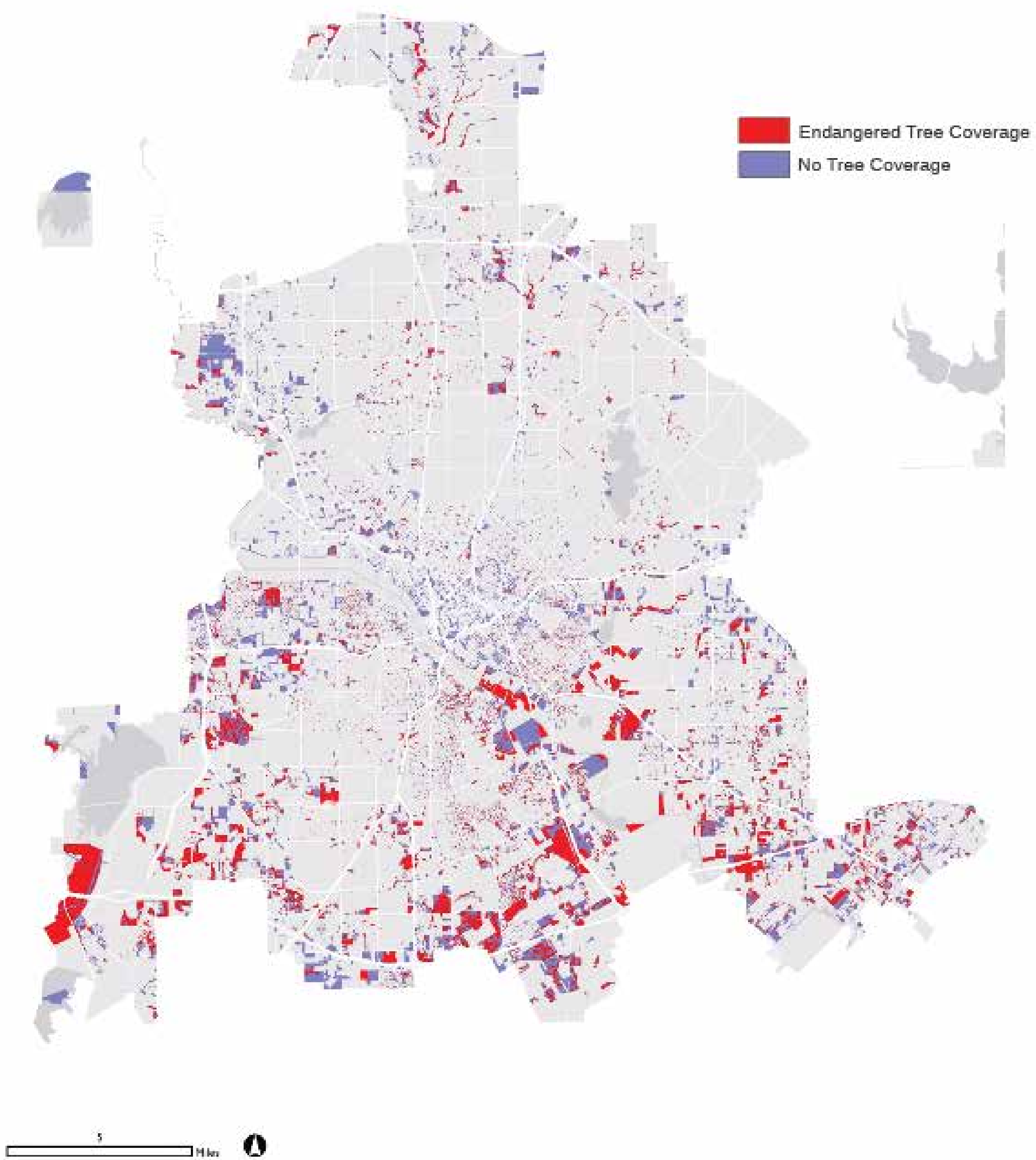
Land Use: is the human use of land. Land use involves the management and modification of natural environment or wilderness into built environment such as settlements and semi-natural habitats such as arable fields, pastures, and managed woods.

Tax Increments Finance Districts (TIF): A public financing method that is used as a subsidy for redevelopment, infrastructure, and other community-improvement projects in many countries, including the United States. Similar or related value capture strategies are used around the world.

Urban Forest: a forest or a collection of trees that grow within a city, town or a suburb.

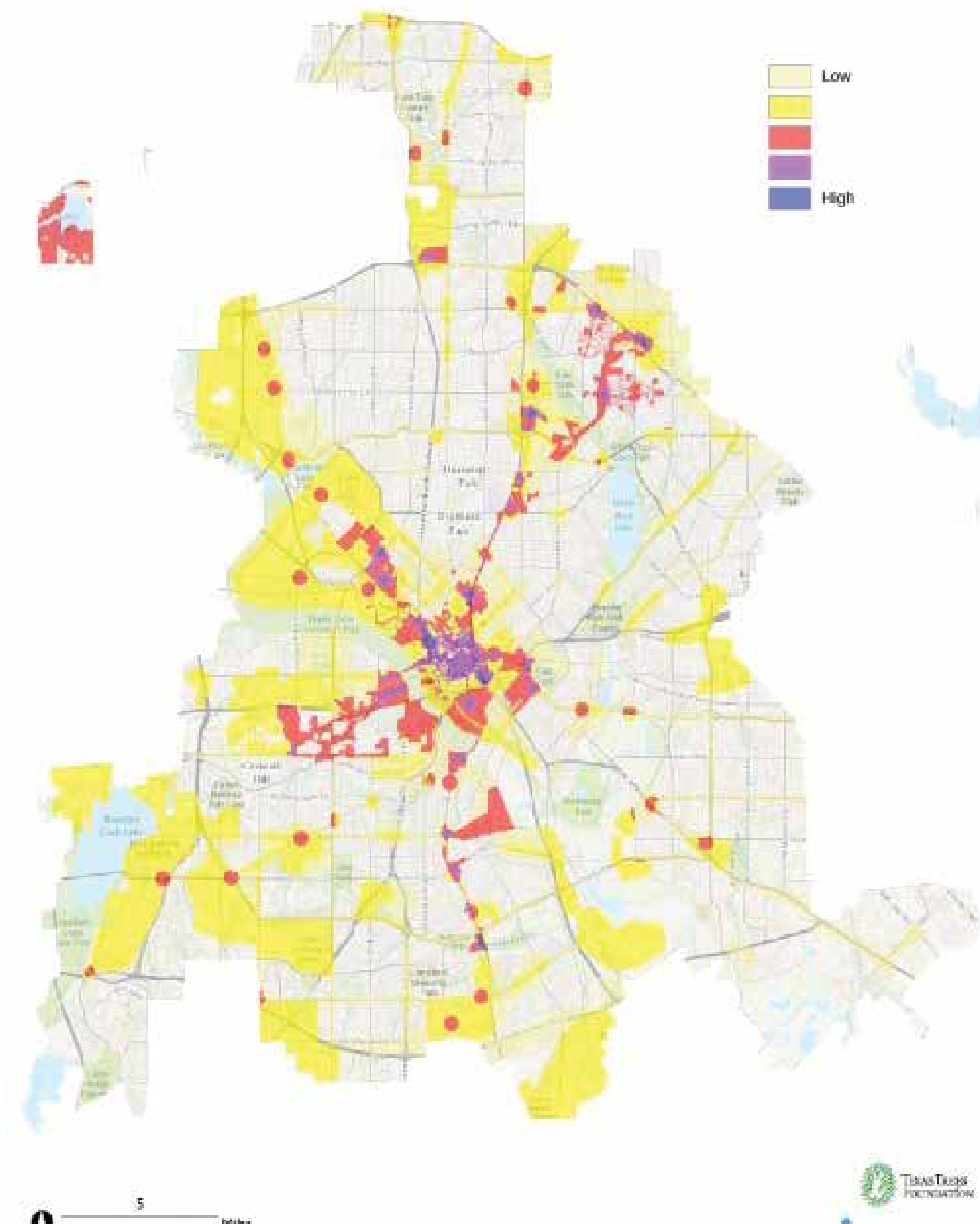
Appendix E: Additional Maps from Open Space Study

Vacant Land in Dallas



Data courtesy of City of Dallas and Texas Trees Foundation. August 2013.

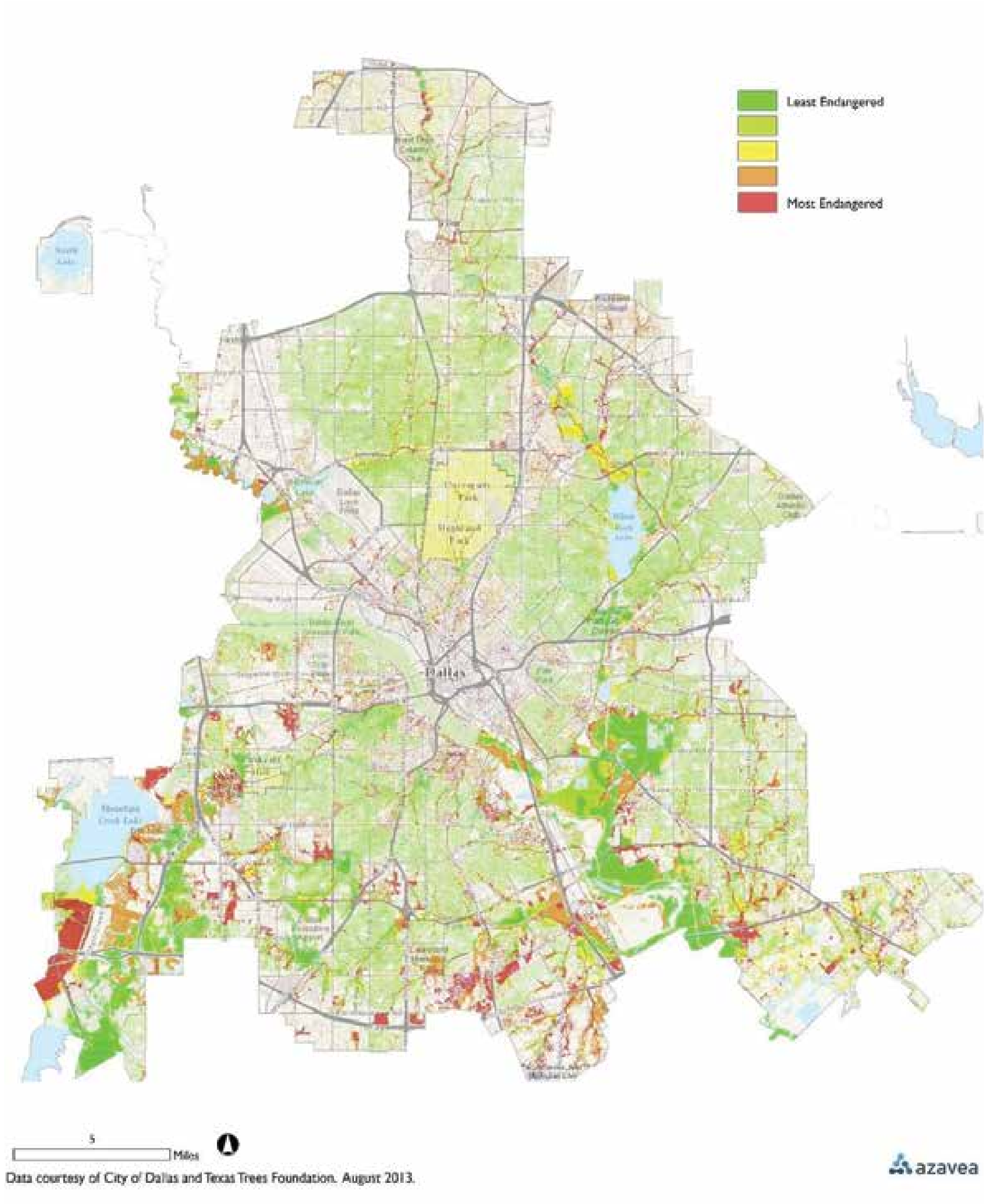
Demand Development Map for Dallas



Data courtesy of the City of Dallas and Bowman-Melton Associates, Inc. August 2013.

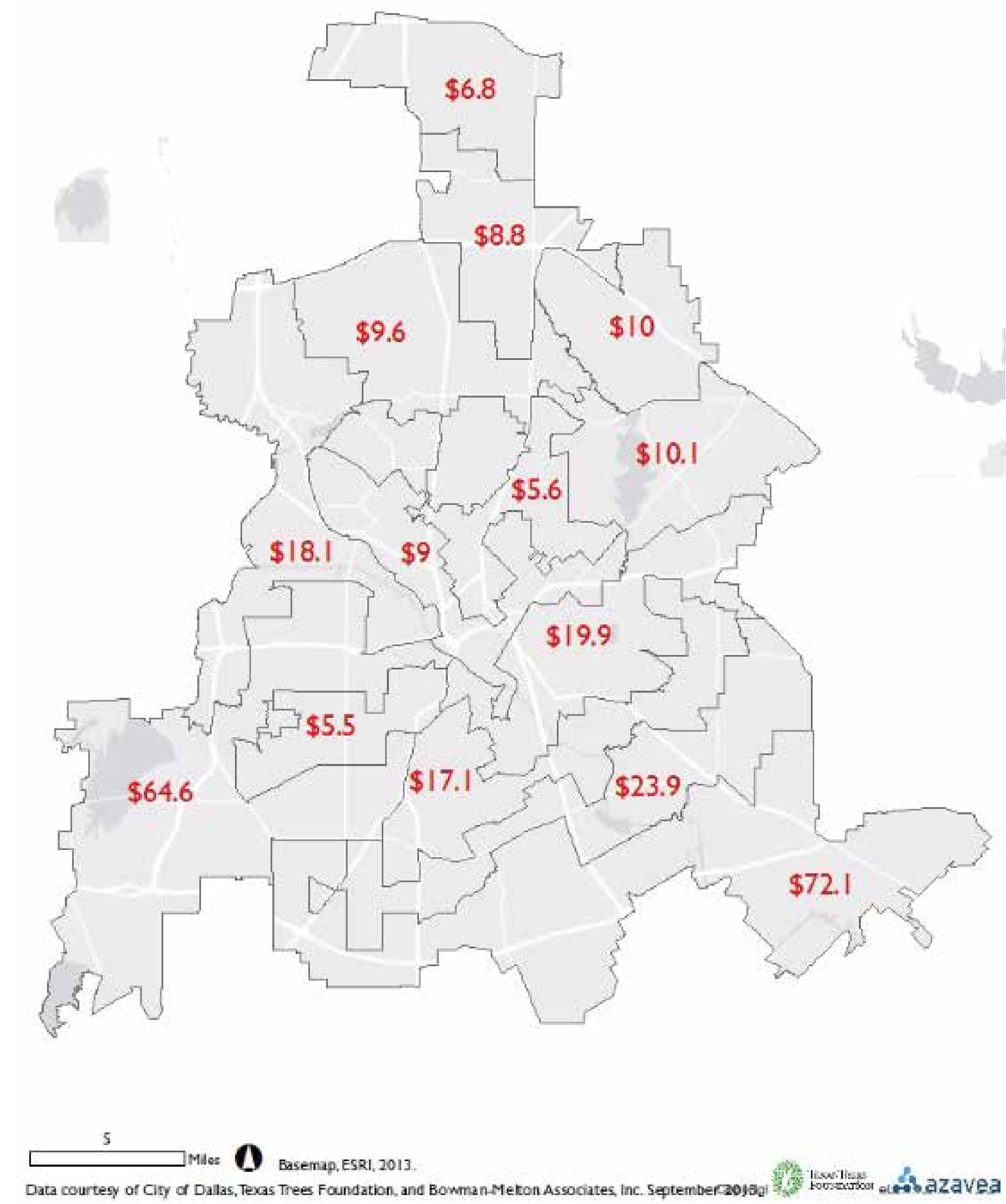
azavea

Endangered Tree Canopy



Potential Cost of Losing Endangered Trees

by Council District in Millions of Dollars



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