Rowlett Urban Forest Ecosystem Analysis

November 2018

Texas Trees Foundation

Parks & Recreation
The City of Rowlett

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Executive Summary

Rowlett's urban forest plays a crucial role in the livability and sustainability of the city. Rowlett's 340,000 trees impact everything from economic development to the overall health and livability of the people that live, work, and play in Rowlett every day.

Understanding an urban forest's structure, function, and value can promote effective policy decisions, sound management planning, and help to set and anticipate future budgetary requirements. During the summer of 2018 the City of Rowlett partnered with the Texas Trees Foundation to perform the most detailed and comprehensive study of Rowlett's urban forest resource ever conducted.

Two state-of the art urban forestry assessments were conducted, along with an online tool that will allow the City to quickly view areas of high vs. low tree canopy and priority areas based on the canopy assessment. Each one independently only tells half the story but combined proved the most accurate and detailed urban forest data available. Each one is explained in more detail below:

1) I-Tree Eco Assessment: i-Tree is one tool in a suite of tools that provides a broad picture of the entire urban forest, both on public and private property. I-Tree is a state-of-the art peer-reviewed software suite from the USDA Forest Service that can be used to provide an urban and community forestry analysis and environmental benefits assessments. I-Tree tools help communities of all sizes to strengthen urban forest management and advocacy efforts by quantifying both the structural and environmental services trees provide.

2) Urban Tree Canopy (UTC) Assessment: UTC assessments utilize detailed land cover data derived from high-resolution aerial imagery to determine a very precis and accurate picture of the extent of the tree canopy, impervious surfaces, and available planting space.

3) Tree Canopy Planner Online Tool: This online tool will allow the City to quickly view areas of high vs. low tree canopy and priority areas based on the canopy assessment. This tool will help when making long-term planting decisions and will help the City in developing a strategic tree planting plan.

The State of the Rowlett Urban Forest Report provides detailed information to help Rowlett advance their understanding of their urban forest population and provides the framework to make more informed decisions about the future management of this important community asset.

KEY FINDINGS

The key findings for the 2018 City of Rowlett Urban Forest Resource Assessment are below. This data represent a snapshot of both the structural and functional characteristics and values of the city's urban trees. They are provided to aid in the planning and management of this increasingly important resource. The quantification of the benefits of Rowlett's urban forest should serve as a reliable advocacy tool to help educate community leaders and the public about the importance of investing in professional planning and management for Rowlett's trees.

- Rowlett's 340,000 trees have a structural value of $310 million
- Rowlett's tree canopy cover is 21.5 %
- Rowlett's trees provide roughly $650,000 annually in environmental services
- 340,000 trees provide 5,000 tons of Oxygen per year to Rowlett
- 42% of Rowlett's canopy is on residential property, while
- Less than 1% of the overall canopy is on undeveloped land
- 20,000. Number of new trees needed to raise Rowlett's urban tree canopy by 5%
- Rowlett's most common tree species are Cedar elm, common Crape myrtle, and Boxelder.

Introduction

The area of interest (*AOI*) of this study is the City of Rowlett, Texas. The AOI has an area of 19.96 mi² or 12,774.4 acres. Located in North Texas within the Blackland prairie ecoregion at 32º54’25” N 96º32’51” W (32.906944, -96.5475). The first post office in the area known today as, Rowlett, was opened on April 5, 1880. It was called “Morris Post Office” after Postmaster Austin Morris. The town was later named “Rowlett,” after Rowlett Creek, a major tributary of the east fork of the Trinity River. After the Civil War railroads began to spread westward. The Greenville & Dallas Railroad reached Rowlett in 1889. The City of Rowlett was incorporated in 1952 by a vote of 84 citizens. Today, Rowlett is home to roughly 62,000 residents.

Over the past decade there has been an increase in the knowledge of the ecosystem services and social benefits of urban forests, as well as the availability of quantitative tools, such as iTree, for the measurement and communication of them. In fact, iTree is now being promoted and used internationally. To date, there have only been seven (7) other iTree Eco studies completed in Texas.

- 2005 Houston Regional UFORE
- 2009 City of Arlington Eco
- 2012 City of Mesquite Eco
- 2013 El Paso Eco
- 2014 City of Plano Eco
- 2015 City of Dallas State of the Urban Forest
- 2016 City of Denton State of the Urban Forest
- *2018 City of Rowlett State of the Urban Forest*

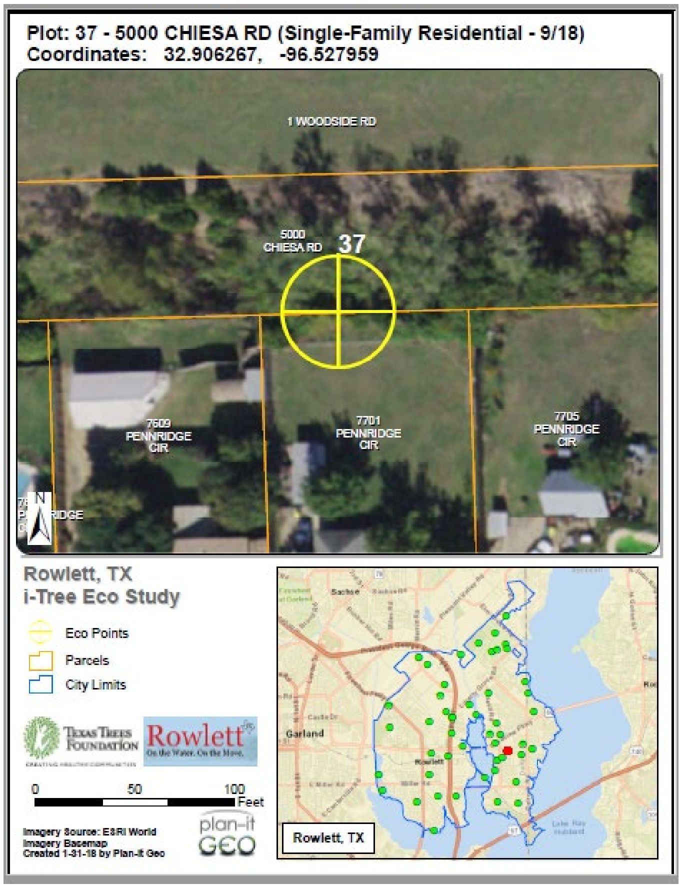
The following report defines the scale and diversity of Rowlett’s urban forest, highlights the monetary value of this tremendous community asset, and provides relevant management concerns and strategies to enhance the resources and its many benefits.

(insert plot pictures…get from Taylor)

Methods

i-Tree Eco

Study design and field data collection protocol were developed by the U.S. Forest Service, Northeast Research Station *(Appendix 1*). Using geographical information system (*GIS*) technology and ArcMap 10.x software, 60 tenth-acre circular plots were created and randomly established within the AOI on both public and private property. Study plots were also stratified by land use categories using 2010 National Land Classification Database (*NLCD*) imagery. There was a total of thirteen land use classes identified within Rowlett. For logistical planning and operational purposes, the study area was ultimately divided into four quadrants, in which Texas Trees Foundation staff and interns collected data on 54 plots within the Northeast, Northwest, Southeast and Southwestern quadrants.



Study plot centers were located in the field using three map books containing all plots within each respective third. Where plots or portions of plots fell on private property, permission to access private properties for plot measurement was obtained prior to data collection.

Plot and tree level data was recorded on paper forms and archived following data entry. In addition, study plots were designed as permanent measurement locations using global positioning system (*GPS*) units by recording exact plot center locations, the reference point for all measurements. Plot centers can easily be relocated for future measurements using either recorded latitude and longitude values or by triangulating their positions by using the distance and direction of two reference points for each plot center. In addition, a minimum of two (2) photos were taken of plot center for each plot.

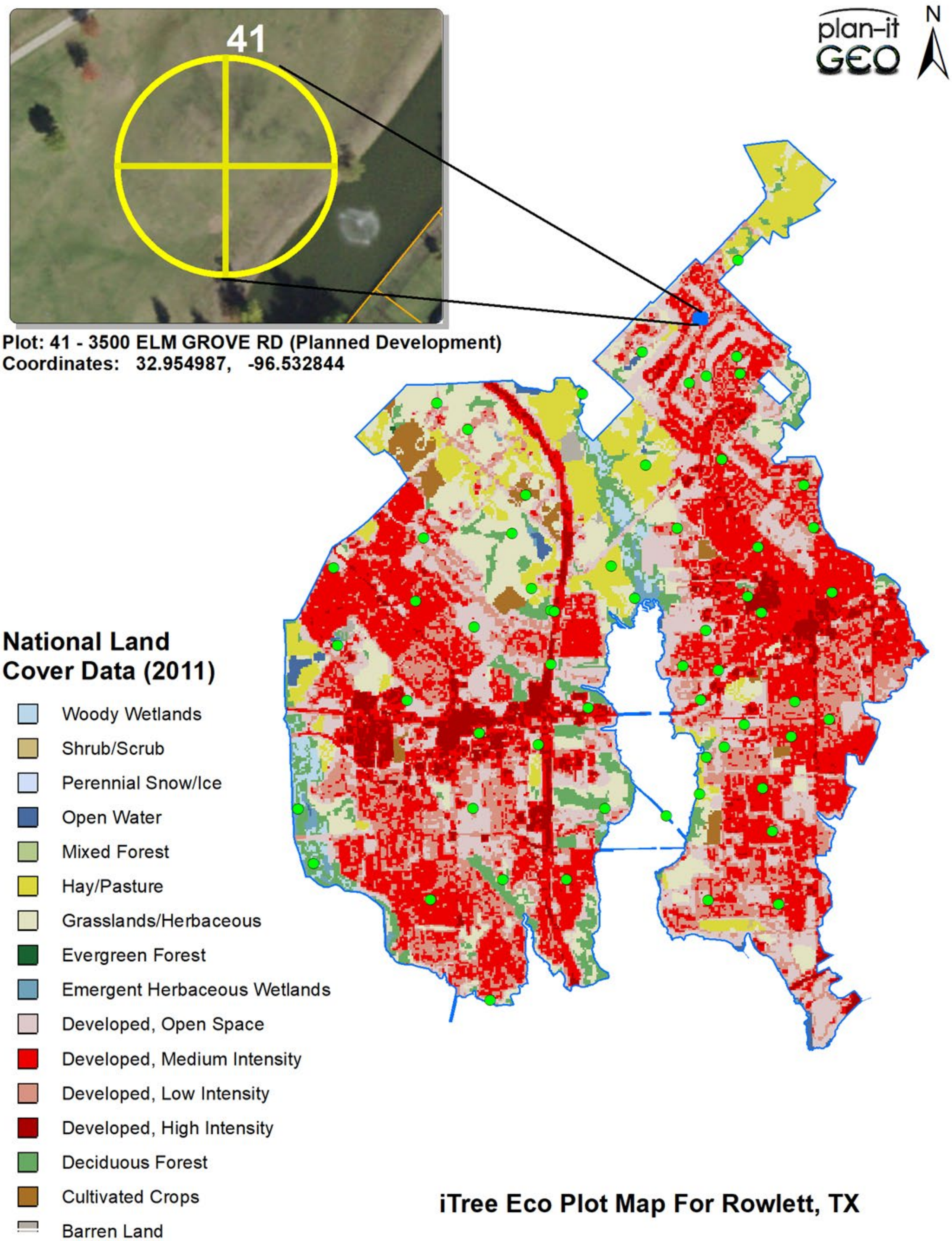


Figure 1. Study plot design for Rowlett Urban Forest Ecosystem Study

Mapping Land Cover

An essential component of this UTC assessment is the creation of an initial land cover data set. High-resolution (1-meter) aerial imagery flown in 2016 from the USDA's National Agricultural Imagery Program (NAIP) was used for this assessment. An object-based image analysis (OBIA) software program called Feature Analyst (ArcGIS Desktop) was used to classify land cover types through an iterative approach, analyzing spectral signatures across four bands (blue, green, red, and near-infrared) as well as elevation, texture, and spatial patterns. This process resulted in five initial land cover classes as shown in Figure 2. After manual classification improvement and quality control, additional data layers from the city, such as buildings, roads, and other impervious surfaces, were utilized to capture finer feature detail and further categorize the land cover data set.

Figure 2: Five Primary Land Cover Classes generated from Aerial Imagery-based Analysis

Urban Tree Canopy
Tree cover when viewed and mapped from above

Bare Soil
Not included in possible planting areas

Non-Canopy Vegetation
Grass and open space vegetation

Water Bodies
Bodies of water removed from total land cover

Impervious Surfaces
Hard surfaces where rainfall cannot permeate

Visualizing Urban Tree Canopy (UTC) Results

Maps showing UTC in this report express levels of canopy as a percentage of land area (not including water). UTC levels are divided into meaningful categories for each of the assessments areas boundaries and may vary slightly depending on the distribution within the target geographies. For parcels, UTC levels are broken up into five classes: 25% or less UTC, 25-35% UTC, 35-45% UTC, 45-55% UTC, and greater than 55% UTC. Figure 3 provides visual examples of what that varying levels of UTC look against the aerial imagery.

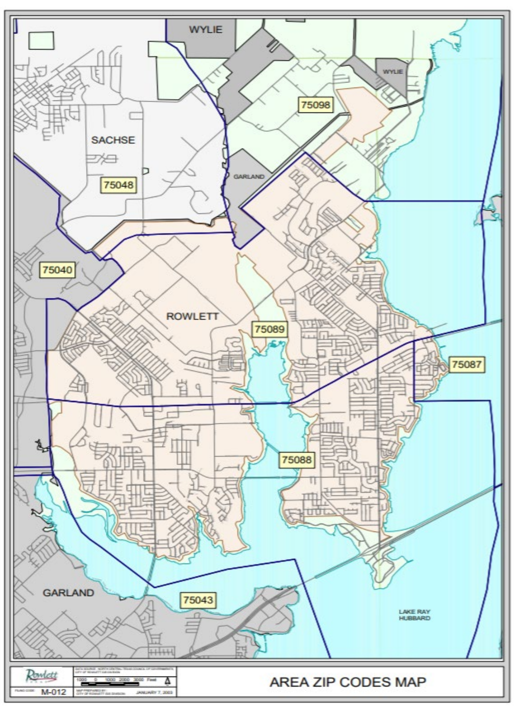
Figure 3: Examples of Relative Canopy Coverage by Parcel

14% UTC (low) | *27% UTC* | *56% UTC* | *82% UTC*

Defining Assessment Levels

To better inform various stakeholders (city officials, city staff, and citizens), UTC associate information were calculated for a variety of geographic boundaries. For Rowlett these included:

- city limits
- census block groups
- zoning classes
- zip codes



Assessment Results

The urban forest of the City of Rowlett has an estimated 340,000 trees with a tree cover of 22%. This section presents the key findings and results of both assessments, including the land cover base map, as well as the canopy analysis results, which were analyzed across various geographic assessment boundaries. These results, or metrics, provide a benchmark of the current forest cover and can assist in developing a strategic approach towards identifying future planting areas. Complete UTC assessment results for all target geographies, including maps and graphs can be found in the appendix.

i-Tree Eco Results

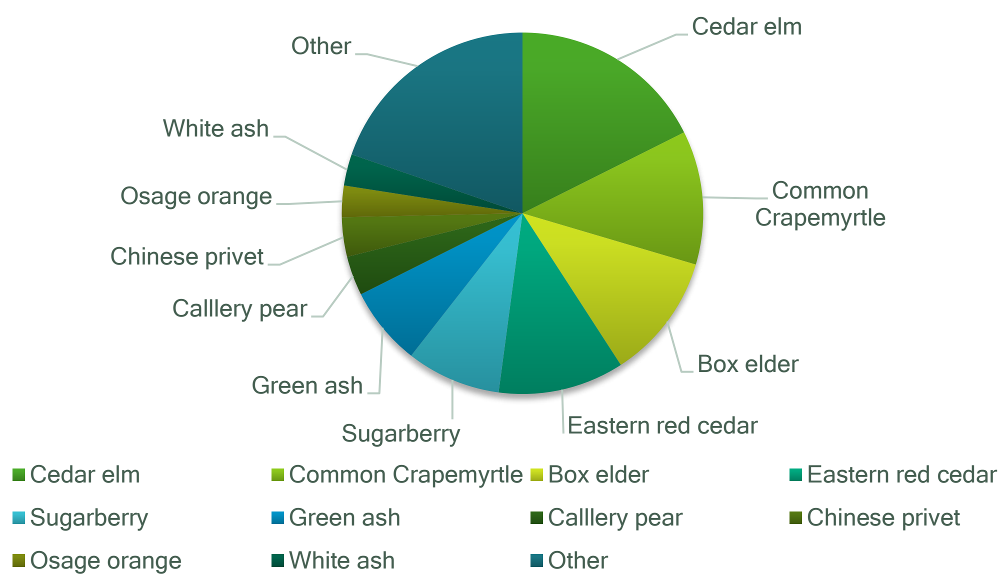
Tree Characteristics of the Urban Forest

While the UTC assessment focused on the overall canopy cover for the city using high resolution imagery, the i-Tree Eco assessment requires direct measurements through the collection of field data to better understand the species, size, health and overall composition of Rowlett's urban forest.

Urban forests by nature have a higher tree diversity than surrounding native landscapes, often with a mix of native and exotic tree species. The level of species diversity can have major implications on resource management. Increased tree diversity, for example, can minimize the overall impact or destruction by a host-specific insect or disease. However, it can also pose risk to native plants if some of the exotic species are invasive plants that potentially out-compete and displace more desirable native species. In Rowlett, about 96% of the trees are species that are both native to North America and the State of Texas. Species exotic to North America make up only 3% of the total population, an indicator of the overall good health of Rowlett's urban forest (Appendix V).

The urban forest of the City of Rowlett has an estimated 340,000 trees with a tree cover of 21.5 percent. The three most common species are Cedar elm (17.6 percent), Common crapemyrtle (12.0 percent), and Boxelder (11.3 percent).

Figure 4: Tree species composition in the City of Rowlett



In Rowlett, TX the most dominant species in terms of leaf area are Cedar elm, Boxelder, and Sugarberry. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Species Name	*% Population*	*% Leaf Area*	*IV*
Cedar elm	17.6	23.5	41.1
Boxelder	11.3	12.9	24.1
Sugarberry	8.5	10.7	19.1
Common Crapemyrtle	12.0	2.2	14.2
Ash	9.8	13.0	22.8
Eastern red cedar	11.3	1.3	12.6
Chinkapin oak	1.4	7.6	9.0
Pecan	2.1	4.2	6.3
American sycamore	0.7	4.8	5.5

Relative Tree Age and Size

The size of Rowlett's trees can be a good prediction for future trends in the structure and composition of the urban forest. While larger trees provide 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 the current environment conditions will allow. This study revealed that off all of Rowlett's trees, 59% had a diameter of less than 6 inches. The relative size/age of trees in a community, combined with other observable species trends, enables more informed management and planning for future planting projects. For example, of the 59% of the tree population that had less than 6-inches in truck diameter, approximately 42% were species that will attain a relatively large size at maturity if properly protect and cared for.

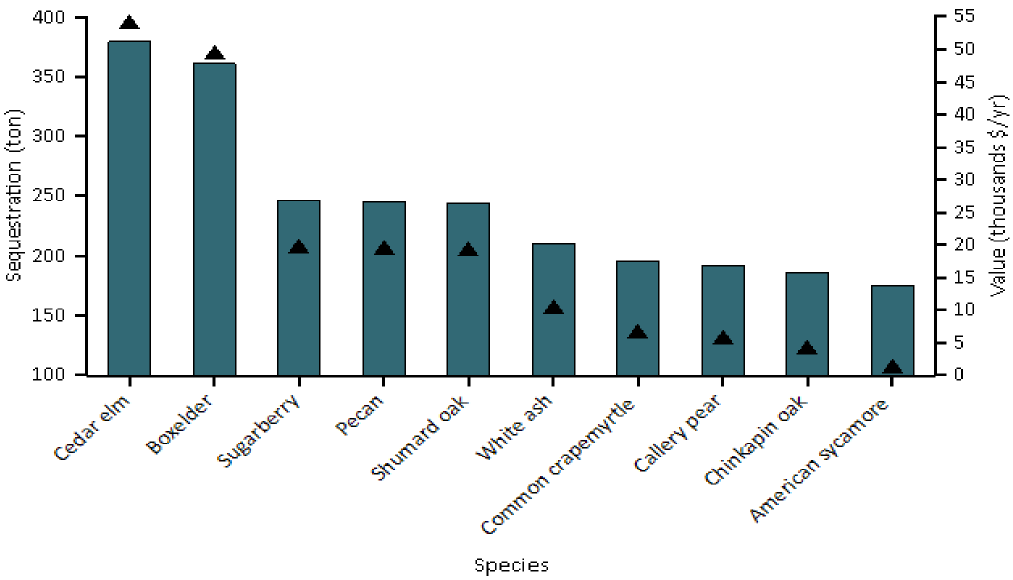
Figure 5: Percent of tree population by diameter class (DBH - stem diameter at 4.5 ft)

The Value of Rowlett's Urban Forest

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (*Nowak and Dwyer 2000*).

Pollution removal by trees and shrubs in the City of Rowlett was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (*Figure _*). It is estimated that trees and shrubs remove 63.84 tons of air pollution (*ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), and sulfur dioxide (SO2)*) per year with an associated value of $212 thousand [1](*see Appendix I for more details*).

Figure 9. Estimated carbon storage (points) and value (bars) for urban tree species with the greatest storage, Rowlett, TX



[1] *Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.*

Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (*from carbon dioxide*) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (*Abdollahi et al 2000*).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of the City of Rowlett trees is about 2.475 thousand tons of carbon per year with an associated value of $321 thousand. Net carbon sequestration in the urban forest is about 1.982 thousand tons. See Appendix I for more details on methods.

Trees in Rowlett, TX are estimated to store 58200 tons of carbon *($7.55 million*). Of the species sampled, Black willow stores the most carbon (*approximately 14.6% of the total carbon stored*) and Cedar elm sequesters the most (*approximately 15.9% of all sequestered carbon*.)

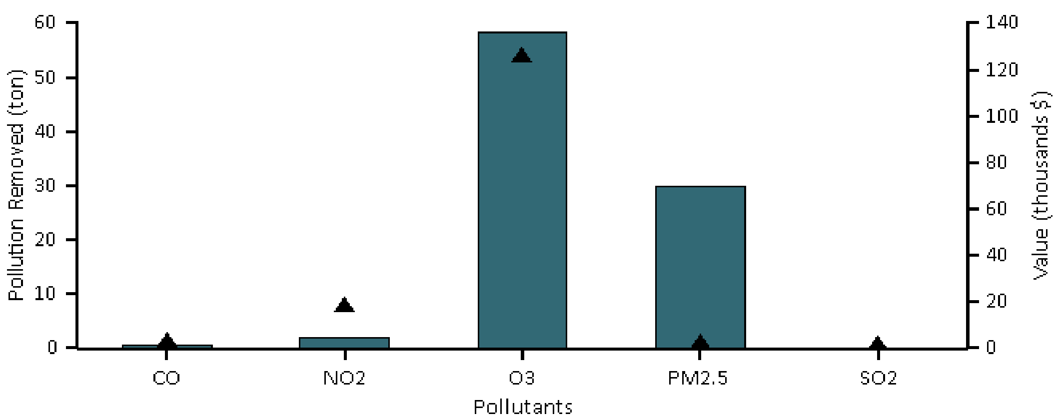


Figure 7. Annual pollution removal (points) and values (bars) by urban trees,

Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The net annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Rowlett, TX are estimated to produce 5.285 thousand tons of oxygen per year[2]. However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (*Broecker 1970*).

Species	Oxygen (ton)	Net Carbon Sequestration (ton/yr)	Number of Trees	Leaf Area (acre)
Boxelder	937.12	351.42	38,305	843.70
Cedar elm	901.89	338.21	59,852	1,542.41
Shumard oak	502.04	188.26	4,788	231.82
Sugarberry	499.54	187.33	28,729	702.18
Pecan	497.29	186.48	7,182	273.97
Common crapemyrtle	335.91	125.97	40,699	145.20
Callery pear	328.24	123.09	11,970	88.47
Chinkapin oak	305.96	114.74	4,788	496.16
American sycamore	259.06	97.15	2,394	313.25
Osage orange	232.43	87.16	9,576	105.53
White ash	225.17	84.44	9,576	452.16
Green ash	199.17	74.69	23,941	398.27
Chinese privet	83.95	31.48	11,970	78.69
Silver maple	80.21	30.08	2,394	125.19
Eastern cottonwood	77.74	29.15	2,394	132.96
Southern magnolia	58.91	22.09	4,788	31.47
Laurel magnolia	44.66	16.75	2,394	74.84
Photinia	25.50	9.56	2,394	47.10
Yaupon	25.22	9.46	2,394	3.87
cypress spp	25.13	9.42	2,394	66.99

Table 2. Rowlett's top 20 oxygen production species.

[2] A negative estimate, or oxygen deficit, indicates that trees are decomposing faster than they are producing oxygen. This would be the case in an area that has a large proportion of dead trees.

Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (*trees and shrubs*) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (*Hirabayashi 2012*). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of the City of Rowlett help to reduce runoff by an estimated 1.47 million cubic feet a year with an associated value of $98 thousand (*see Appendix I for more details*). Avoided runoff is estimated based on local weather from the user-designated weather station. In the City of Rowlett, the total annual precipitation in 2015 was 23.1 inches.

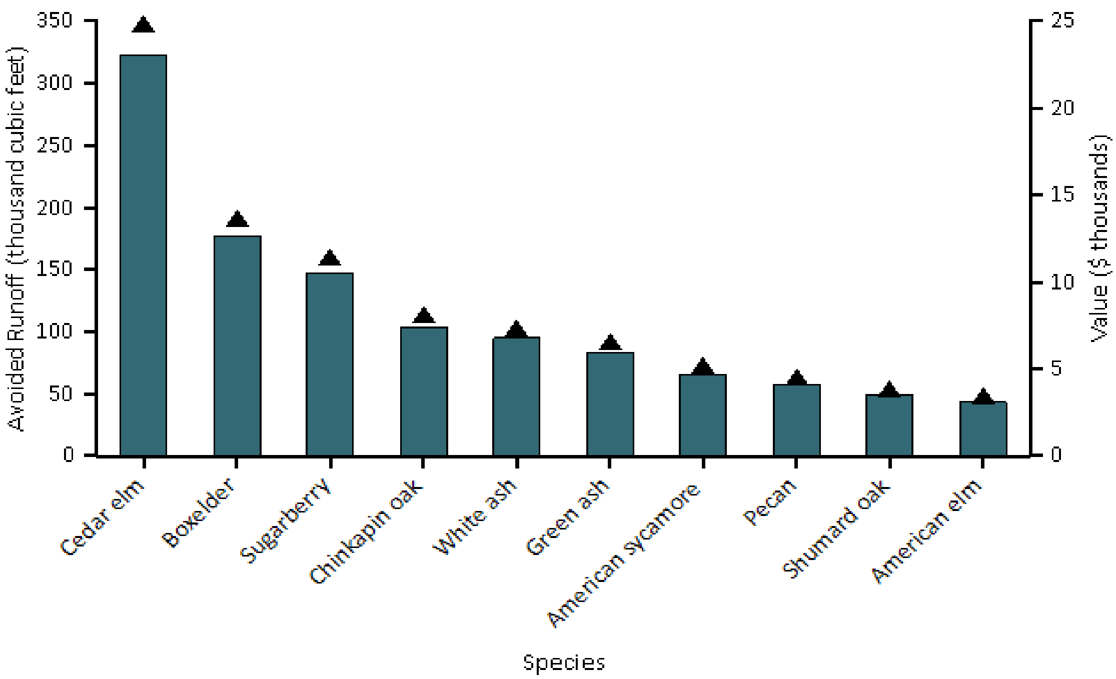


Figure 10. Avoided runoff (points) and value (bars) for species with the greatest impact on runoff, Rowlett, TX

Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (*McPherson and Simpson 1999*).

Trees in Rowlett, TX are estimated to reduce energy-related costs from residential buildings by $13,500 annually. Trees also provide an additional $-545 in value by reducing the amount of carbon released by fossil-fuel based power plants (*a reduction of -4.2 tons of carbon emissions*).

Note: negative numbers indicate that there was not a reduction in carbon emissions and/or value, rather carbon emissions and values increased by the amount shown as a negative value[3].

	Heating	Cooling	Total
MBTU[a]	-5,337	N/A	-5,337
MWH[b]	-221	859	638
Carbon Avoided (tons)	-160	156	-4

Table 3. Annual energy savings due to trees near residential buildings, Rowlett, TX

	Heating	Cooling	Total
MBTU[b]	-57,708	N/A	-57,708
MWH[c]	-24,708	95,910	71,202
Carbon Avoided	-20,737	20,192	-545

Table 4. Annual savings ($) in residential energy expenditure during heating and cooling seasons, Rowlett, TX

[3] *Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.*

VIII) Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

<u>Urban trees in Rowlett, TX have the following structural values:</u>

- Structural value: $310 million
- Carbon storage: $7.55 million

<u>Urban trees in Rowlett, TX have the following annual functional values:</u>

- Carbon sequestration: $321 thousand
- Avoided runoff: $98.3 thousand
- Pollution removal: $212 thousand

Energy costs and carbon emission values: $12.9 thousand American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Rowlett, TX Rowlett TX could possibly lose 19.0 percent of its trees to this pest ($65.8 million in structural value).

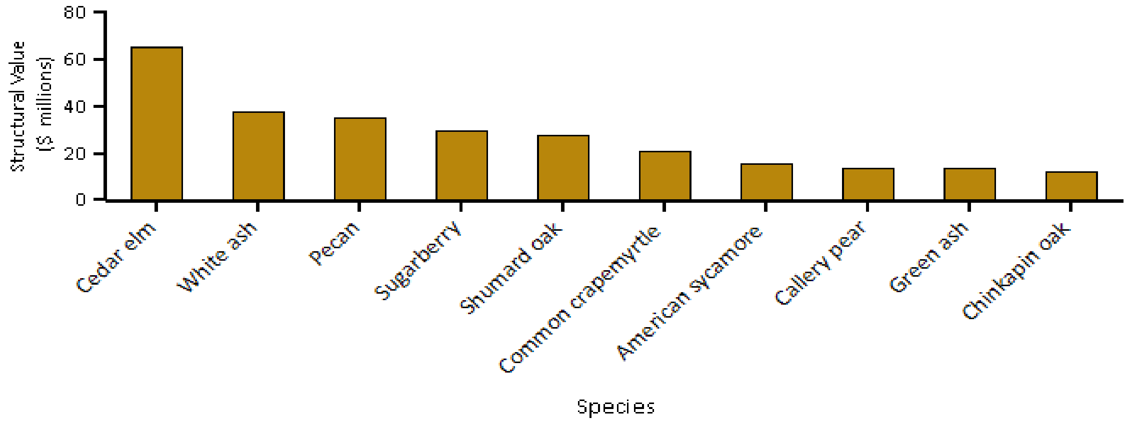


Figure 11. Tree species with the greatest structural value in the City of Rowlett

(Note: negative value indicates increased energy cost and carbon emission value)

Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities. Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Dallas County. Two of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

In the City of Rowlett, the greatest opportunity for loss related to pests and associated diseases is from Dutch elm disease and oak wilt disease, potentially affecting 17% and 5% of the total population worth $65 million and $15 million, respectively.

Emerald ash borers have caused the death of tens of millions of ash trees in the Midwest and should be a serious concern for tree managers in the DFW region, as the presence of the pest was recently confirmed in East Texas (Harrison County) in early 2016. While the impact of losing Rowlett's ash population may not be as devastating as it has been in Michigan and Ohio cities, ash is the sixth most populous species in Rowlett with approximately 10% of all trees. The potential loss of value, should Rowlett lose its ash trees, was estimated to be approximately $50 million. Thus, protecting high value landscape specimens of this species should be a priority.

Urban Tree Canopy Assessment Results

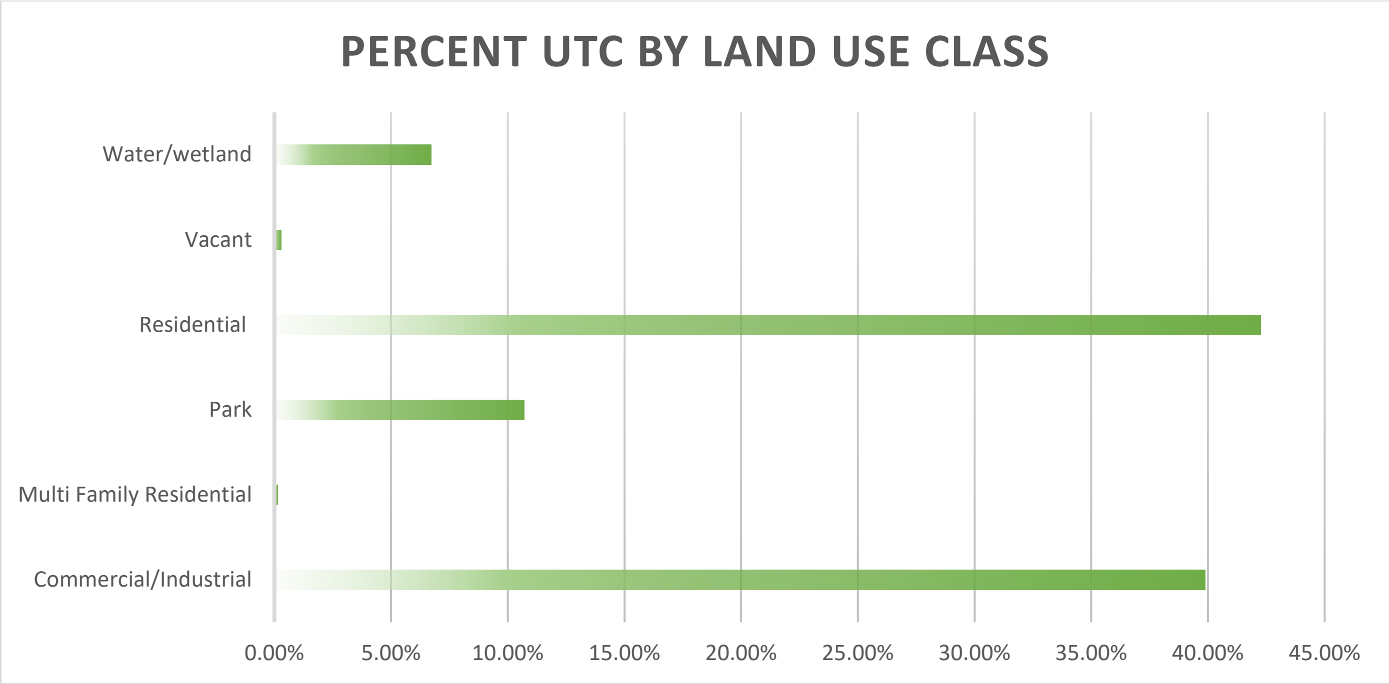
Citywide Land Cover

In 2018, 21.5% of Rowlett was covered by tree canopy, 55.4% was non-canopy vegetation, and 36.5% was impervious. Further dividing the impervious surface areas into more detailed classifications shows that 19.6% of the city was covered by buildings, 16.9% was covered by other Impervious surface such as roads and parking lots. With this amount of impervious surface, issues such as the urban heat island effect and flash flooding could increase.

Land Use

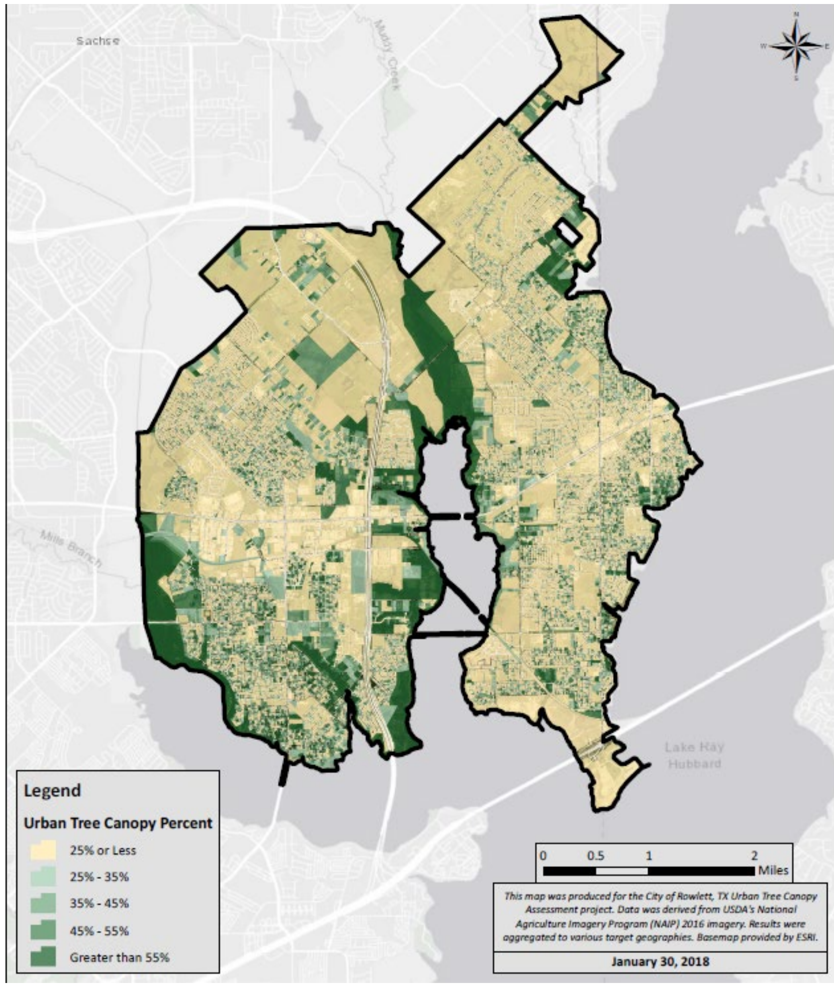
Many of the policies, regulations, ordinances, and actions influencing tree canopy in Rowlett are dependent on land use classes. To provide data that advances UTC policy and management, 6 land use classes were assessed (Figure 12).

The Single-Family Residential and Commercial/Industrial land use classes had the highest individual canopy coverage with 45% and 38%, respectively. These two classes combined constituted 74% of all the UTC in the city, while Vacant, Multi-Family Residential, and Parks/Open Space land use classes only accounted for 22%. Only 1% of total citywide urban tree canopy is located on undeveloped property that is labeled as vacant placing a very small portion of Rowlett's urban forest at risk during future develop. But almost 7% of the citywide canopy is in floodplain and wetland areas. This indicates the City should pay special attention to any development that happens around riparian areas.



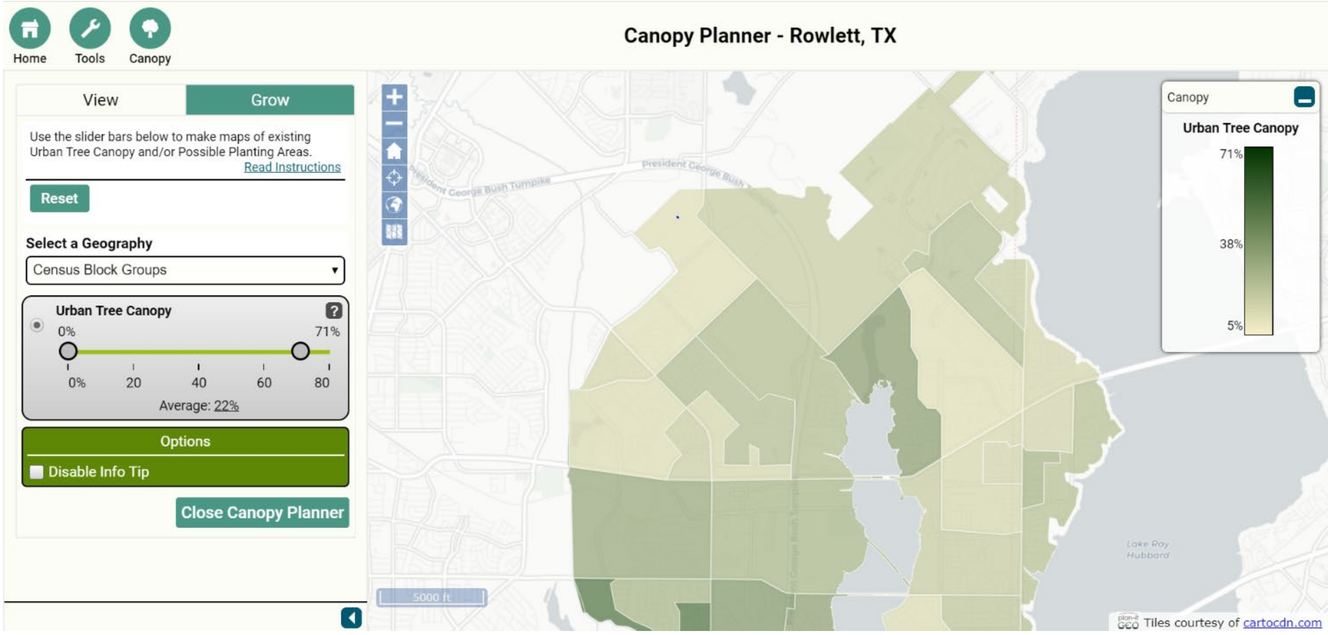
Parcel

The most detailed assessment geography analyzed for this study was the parcel layer. This study calculated UTC totals for each individual property (parcel. Due to the size of the data set, comprehensive data have been provided to the city in GIS format, and are not included in tabular format in this report.



Urban Tree Canopy Planner

As part of this plan we included an on-line app that will allow the City to plan and assess future tree planting efforts. The urban forest is a critical component of the City's green infrastructure and contributes to environmental quality, public health, water resource management, local economies, and the beautification of often harsh, paved landscapes. Texas Trees Foundation mapped and assessed the City's tree canopy cover in 2017 to provide a top down view of the urban forest and quantify this resource at various geographic scales.



Through this plan we were able to estimate that approximately 24% of the available space in Rowlett is suitable for future tree planting. This tool allows the City to begin prioritizing areas and calculating the benefits for future tree plantings.

Discussion

The Rowlett urban forest provides multiple benefits to the residents of the city and creates a sense of community. An increase in the understanding of these benefits and their associated economic values can improve both local planning and management and ultimately improve the overall condition or quality of the forest leading to increased benefits. With 21.5% canopy cover across the city there is a clear opportunity for continued growth. In fact, since a majority of the city's trees are 6" or less in diameter most trees are relatively young and with proactive care should grow, expanding the coverage of canopy over the community and providing heightened benefits over time. However, the city should be conscious of which trees make up their canopy since some trees are less desirable either due to higher susceptibility to pest and disease or because they are relatively short lived. Furthermore, nearly 53% of all trees were represented by only four species. Thus, diversifying species selection in future planting initiatives is recommended to enhance the forest's quality and resilience.

Ultimately, an inventory of all city owned trees should be conducted to facilitate management decisions that may improve the health and condition of the trees as well as to reduce risk in the event of tree loss/failure during storm events. It is recommended that the city of Rowlett develop an Urban Forest Management Plan that outlines goals and the tasks necessary to reach them. Establishing measurable goals will allow the urban forest program staff to establish work priorities, monitor progress and develop appropriate budgets annually.

Rowlett represents only the seventh community in the state to complete an iTree Eco study and only the fifth in the DFW Metroplex. So, how does the urban forest of Rowlett compare to other Texas communities?

While a direct comparison to other communities is interesting on an empirical basis it is important to recognize the many physical (*e.g. types of infrastructure, level/extent of development etc….*), social (*e.g. political support for program etc….*), and natural (*e.g. species availability and growth rates, climate etc….*) attributes that control the level and quality of any community's urban forest. Furthermore, the year each study is completed does impact the results to a small degree since regression equations that provide leaf area estimates and benefit values, as well as other local inputs such as energy costs, are sometimes adjusted with the release of new iTree software versions.

See Appendix III. for a comparison of Rowlett's urban forest with other North American cities.

Appendix

APPENDIX I. I-TREE ECO MODEL AND FIELD MEASUREMENTS

i-Tree Eco is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (*Nowak and Crane 2000*), 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.
- 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 sources.
- 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.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. 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 (*Nowak et al 2005; Nowak et al 2008*).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (*e.g., ash*) or species groups (*e.g., hardwood*). In this report, tree species, genera, or species groups are collectively referred to as tree species.

<u>Tree Characteristics:</u>

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (*Watershed Protection Development Review*) 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 that are 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.

<u>Air Pollution Removal:</u>

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (*PM10*) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (*PM2.5*) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

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 (*Baldocchi 1988; Baldocchi et al 1987*). 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 (*Bidwell and Fraser 1972; Lovett 1994*) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (*Zinke 1967*). 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 (*Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011*).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (*Nowak et al 2013*). This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (*e.g., with no rain*), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is 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 less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (*BenMAP*) (*Nowak et al 2014*). 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 (*Murray et al 1994*).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (*van Essen et al 2011*) or BenMAP regression equations (*Nowak et al 2014*) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,380 per ton (*carbon monoxide*), $2,523 per ton (*ozone*), $639 per ton (*nitrogen dioxide*), $193 per ton (*sulfur dioxide*), $91,198 per ton (*particulate matter less than 2.5 microns*).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. 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 (*Nowak 1994*). 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.

Carbon sequestration is the removal of carbon dioxide from the air by plants. 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 (*U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015*) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $130 per ton.

Oxygen Production:

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 (*Nowak et al 2007*). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

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 (*McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008*).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft³.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (*McPherson and Simpson 1999*) 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.

For this analysis, energy saving value is calculated based on the prices of $111.59 per MWH and $10.81 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (*e.g., the cost of having to replace a tree with a similar tree*). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (*Nowak et al 2002a; 2002b*). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (*FHTET*) (*Forest Health Technology Enterprise Team 2014*) 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 (*Eastern Forest Environmental Threat Assessment Center; Worrall 2007*).

<u>Relative Tree Effects:</u>

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (*Carbon Dioxide Information Analysis Center 2010*). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (*Bureau of Transportation Statistics 2010; Heirigs et al 2004*), PM2.5 for 2011-2015 (*California Air Resources Board 2013*), and CO2 for 2011 (*U.S. Environmental Protection Agency 2010*) were multiplied by average miles driven per vehicle in 2011 (*Federal Highway Administration 2013*) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (*Energy Information Administration 2013; Energy Information Administration 2014*)

- `CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (*average used to represent LPG*), Fuel #4 and #6 (*average used to represent fuel oil and kerosene*) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (*tons*) from (*British Columbia Ministry 2005; Georgia Forestry Commission 2009*).

APPENDIX II. RELATIVE TREE EFFECTS

The urban forest in the City of Rowlett provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Rowlett, TX in 71 days
- Annual carbon (C) emissions from 41,200 automobiles
- Annual C emissions from 16,900 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 10 automobiles
- Annual carbon monoxide emissions from 29 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 1,090 automobiles
- Annual nitrogen dioxide emissions from 493 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 4,940 automobiles
- Annual sulfur dioxide emissions from 13 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Rowlett, TX in 3.0 days
- Annual C emissions from 1,800 automobiles
- Annual C emissions from 700 single-family houses

APPENDIX III. COMPARISON OF URBAN FORESTS

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	% Tree Cover	Number of Trees	Carbon Storage	Carbon Sequestration	Pollution Removal
			(tons)	(tons/yr)	(tons/yr)
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON, Canada	29.1	1,908,000	147,000	6,600	190
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	Number of Trees/ac	Carbon Storage	Carbon Sequestration	Pollution Removal
		(tons/ac)	(tons/ac/yr)	(lb/ac/yr)
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON, Canada	78.1	6.0	0.27	11.0
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

APPENDIX IV. GENERAL RECOMMENDATIONS FOR AIR QUALITY IMPROVEMENT

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (*Nowak 1995*):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (*VOC*) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (*Nowak 2000*). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include *(Nowak 2000):*

Strategy	Result
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

APPENDIX V. INVASIVE SPECIES OF THE URBAN FOREST

The following inventoried tree species were listed as invasive on the Texas invasive species list (*Watershed Protection Development Review*):

Species Name	Number of Trees	% of Trees	Leaf Area (ac)	Percent Leaf Area
Chinese privet	11,970	3.5	78.7	1.2
Total	**11,970**	**3.52**	**78.69**	**1.20**

- *Species are determined to be invasive if they are listed on the state's invasive species list*

APPENDIX VI. POTENTIAL RISK OF PESTS

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	7	Chinkapin oak																																				
	7	Shumard oak																																				
	7	Black willow																																				
	6	Cedar elm																																				
	6	American elm																																				
	6	River birch																																				
	5	Green ash																																				
	4	White ash																																				
	3	Boxelder																																				
	2	Callery pear																																				
	2	Eastern cottonwood																																				
	2	Silver maple																																				

Note:

Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight: Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Dallas county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Dallas county
- Green indicates pest is outside of these ranges

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