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**Tree Planting in Austin, Texas:**

**An Analysis of the Austin Community Tree Program**

**Prepared by:**

**Green City GeoTech**

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**1. INTRODUCTION**

1.1 SUMMARY

The rapid increase in urban populations in recent years requires more residential areas, roads, and other services. The swift development of the landscape turns surfaces that were once permeable and vegetative to concrete surfaces that are impermeable and dry. The materials used to pave absorb heat from daytime insolation and continue to emit it into the late afternoon and evening which results in a higher atmospheric temperatures than those of nearby surrounding rural areas. This phenomenon is known as the Urban Heat Island (UHI). The consequences of elevated temperature from UHIs have negative effects on communities and quality of life, such as high peak energy demand during cooling seasons, air pollution and greenhouse gas emissions, heat-related illness and mortality, and diminished water quality.

Many communities have implemented various strategies to reduce urban heat islands, one of which is increasing urban tree canopy. Scientific analysis has shown that trees cool their environment by providing shade and through evapotranspiration, block warm winds, and reduce air pollution. The Austin Community Tree (ACT) Program seeks to mitigate urban heat island effects by distributing young trees to residents of chosen neighborhoods. Residents plant the trees on their property and maintain them, thereby substantially increasing urban tree canopy and ultimately increasing energy conservation and the sequestration of carbons that would otherwise pollute the air.

1.2 PURPOSE

In cooperation with the City of Austin Development Services and Planning and Zoning Departments, Green City GeoTech will analyze the effectiveness of the Austin Community Tree program in providing benefits such as shading, energy conservation, and CO2 sequestration in thirteen neighborhood planning areas. This will be accomplished by overlaying the canopy tree cover from 2006 and 2010 to measure the percentage of canopy change. Energy conservation and carbon sequestration will be quantified using the National Tree Benefit Calculator (NTBC), a tool that uses minimal input data to model various benefits of different tree species. Rates of canopy growth will be calculated for each species using the NTBC, and growth rates will in turn be used to extrapolate canopy cover extent in 2025.

1.3 SCOPE

This study will focus on the 13 neighborhood planning areas where ACT trees were delivered: Coronado Hills, Crestview, East Cesar Chavez, East Congress, Franklin Park, McKinney, Montopolis, Old West Austin, Rosewood, St. John, Sweetbriar, West Congress, Wooten (Appendix I). These neighborhoods predominantly occupy the area directly east of I-35 corridor in the northern and southern parts of the city and the area west of 1-35 and south of Highway 71. This study does not consider neighborhoods containing isolated points as those data are either errors or exceptions and their environmental effects would likely be negligible.

**2. PROPOSAL**

2.1 LITERATURE REVIEW

*2.1.1 Benefits of Urban Forestry*

The body of literature examining the efficacy of urban forestry programs generally evaluates the provision of shade, carbon sequestration, and the conservation of energy. Analyses show a direct correlation between tree canopy cover and the latter three: as the biomass that makes up a tree increases, the tree is able to sequester ever greater volumes of carbon, and because of the cooling effects of shade trees, less energy is required to cool urban structures. Akbari (2001) demonstrated the correlation between canopy cover and carbon sequestration by using existing data of tree diameter at breast height (d.b.h.), crown area, and height of tree species in Twin Cities, MN to model the volumes of the live wet and dry biomass that sequesters carbon. Model trees sequestered 4.5 kg/year and peaked at 11 kg/year once they reached their maximum crown area of 50 m2. Furthermore, greater numbers and sizes of trees better serve cooling energy conservation by shielding structures from hot winds and generating an “oasis effect” through evapotranspiration. Studies Akbari cited calculated millions of dollars saved and a 3 K decrease in temperatures. Pandit and Laband (2010) quantified the correlation between tree shade and energy conservation by calculating kW h/day from homeowners’ electricity bills and comparing those rates to *in situ* measurements of shade extent and intensity. They found that in cooling seasons “every 10% of shade coverage on average reduces electricity consumption by 1.29 kW h/day” (p. 1327). Departing from Akbari, Pandit, and Laband, Stark (2011) used CITYgreen software that operated on established models for environmental impact. Figures derived from vector polygons representing canopy cover were supplied to CITYgreen in order to generate estimates of such benefits as rainfall, air pollution, and carbon sequestration. CITYgreen did not provide estimates for energy conservation.

It is evident, then, that extent of tree shade determines the extent of urban forestry’s benefits and, for that reason alone, a great deal of research has been conducted to evaluate methods of measuring tree canopy cover and change. Canopy assessment has largely been the province of classification of remotely sensed imagery. Walton, Nowak, and Greenfield (2008) compared different classification techniques: normalized difference vegetation index (NDVI) which fails to separate trees from other types of vegetation, pixel- and object-based classification which fails to account for heterogeneous content within canopies, and subpixel estimation which does account for heterogeneity. Moskal, Styers, and Halabisky (2011) addressed the problem of heterogeneity in pixel-based classification by conducting object-based imagery analysis (OBIA) and generating an algorithm that measures both tree extent *and* spatial location.

However, Bertolo, dos Santos, de Agar, and de Pablo (2015) evaluated mosaics (outside the scope of this study and therefore not discussed here) and overlay as viable methods for assessing canopy cover change. Land-use maps from 1962 and 2009 were overlain to highlight areas of positive change, where land surface was not formerly canopied but later was, and negative change, where canopy was lost over the decades. The study showed that the overlay method only provided a general (and thus imprecise) sense of the extent and location of change. To quantify extent and location with any reliability, transition matricies were applied that calculated the probability of changes. Stark also used overlay to register canopy cover change, but because canopy cover was represented by vector polygons created in ArcGIS, Stark’s study did not suffer the lack of precision that Bertolo, dos Santos, de Agar, and de Pablo’s did. Areas of canopy gain were derived by eliminating segments from the 2007 canopy that intersected with segments from the 1994 canopy, and canopy loss was derived by eliminating segments from the 1994 canopy that intersected with the 2007 canopy.

*2.1.3 Evaluating the Efficacy of Urban Forestry Programs*

In 2008, the United States Department of Agriculture Forest Service Center for Urban Forest Research conducted research on behalf of the City of Los Angeles to asses current tree canopy and analyze the environmental and monetary benefits of urban forestry and the potential for tree canopy growth in Los Angeles’ urban spaces. As the project only began in 2006, the assessment *predicted* efficacy rather than analyzing realized results. To assess existing canopy cover, McPherson, Simpson, Xiao, and Wu depended on remote sensing data and software just as the studies mentioned here did: unsupervised K-means classification of Quickbird data (which segregates pixels based on minimum distance to means in spectral distribution) was performed and then supervised classification to further sort mixed pixel classes. A confusion matrix was applied during the accuracy assessment phase. Energy conservation was calculated entirely through modeling of climate and shading effects on residential properties with potential planting sites. Findings for dollar savings in electrical and natural gas energy relied on electricity and natural gas pricing, similar to the Pandit and Laband, and amounted to $0.11304. Potential carbon sequestration was calculated based on existing data from live and decomposing biomass in coastal and inland areas, and it was anticipated that energy savings from carbon reduction would amount to $6.68 per ton. Like Akari’s study, biomass was calculated based on tree size, specifically d.b.h.

Green City GeoTech’s evaluation of the ACT Program’s efficacy will provide information to the City of Austin Forestry Division that is similar to that of the Los Angeles 1-Million Trees assessment. Like the Los Angeles case, our canopy cover assessment will rely on raster data of segregated pixel classes, but like the Bertolo, dos Santos, de Agar, and de Pablo study, we will perform an overlay that isolates areas of growth between 2006 and 2010. And rather than generating our own models to calculate carbon sequestration and energy conservation, with the addition of tree canopy growth, we will use the National Tree Benefit Calculator which provides the models and requires minimal data input, similar to the CITYgreen software used by Stark.

2.2 DATA

The primary data to be used in the tree canopy overlay are the 2006 and 2010 Canopy Cover polygons, ACT Tree Planting Deliveries points, and Neighborhood Planning Boundaries (to show spatial extent of the study) (Table 1). The overlay will be conducted on ArcGIS Desktop 10.3. Attribute data from the delivery address layer will be entered into the NTBC to calculate carbon sequestration, energy conservation, and Leaf Surface Area (LSA). Additional data, such as water feature and street center line shapefiles, will be used for visual reference in the composition of the map book and will not form the basis of any analysis. The projection of all data is UTM Zone 14, according to the Texas State Plane Coordinate System Central Zone and acquired from the City of Austin, except for the 2006-2010 canopy change layer, which is to be produced by Green City GeoTech.

Table 1. Data List

|  |  |
| --- | --- |
| **Data** | **Source** |
| ACT Tree Planting Deliveries | Alan Halter |
| Canopy Cover 2006 and 2010 vector files |
| Neighborhood Planning Boundaries | City of Austin GIS Data Downloads |
| Lakes and Ponds |
| Street Center Lines |
| Austin Parks |
| Building Footprints |
| Change in Tree Canopy from 2006 to 2010 | To be generated by Green City GeoTech |

2.3 METHODOLOGY

The analysis will be divided into three primary phases: calculation of the percentage of tree canopy growth between 2006 and 2010; calculation of carbon sequestration, energy conservation, and LAS; and extrapolation of future canopy growth.

To calculate canopy growth, the 2006 canopy will be overlain with the 2010, and a simple Erase tool will be used to eliminate parts of the 2010 canopy that overlap with the 2006, the output being spatial and attribute data of tree cover that was present in 2010 but not present in 2006. The output layer and delivery address points will be overlain to visualize a comparison of tree planting sites and tree land cover. Dividing the area of the remaining growth by the total 2006 canopy area will provide us with the percentage of positive or negative growth.

Energy conservation and carbon sequestration benefits provided by ACT trees will be measured using the NTBC. This tool uses tree size and species data provided by the user in order to assign an economic and environmental value to a tree. ACT tree species and tree diameter have already been entered into the NTBC to determine pounds (lbs.) of carbon sequestered and kilowatts per hour (kW h) conserved in a year. These derived values will be multiplied by the number of years those trees have been planted in order to find the cumulative energy of each individual tree between 2006 and 2015. The cumulative benefits will then be multiplied by the number of trees delivered to calculate the carbon sequestration and energy conservation of all ACT trees. This calculation will be performed separately for each tree species. The annual benefits of each species will be multiplied by the number of years from 2006 to 2015 to find the total benefits provided by each species to date and then all species’ benefits will be added together to find the entirety of benefits provided by all ACT trees.

To extrapolate the tree canopy extent of ACT trees 10 years from now, it will be assumed that all tree species increase in diameter by 1 inch per year. Increasing diameters will be entered into the NTBC to find the yearly increase in LSA, and the yearly increase will be multiplied by ten to determine total growth in 2025. Again, calculations will be performed for each individual species and then added together to reach a cumulative value.

Finally, significance testing will be conducted for benefits and extrapolated growth.

2.4 RESULTS

The outcome of our analysis will demonstrate the environmental benefits afforded by the tree delivery services of the ACT Program—the reduction of carbon sequestration and the conservation of electrical energy. Change in tree canopy cover, conservation, and sequestration are expected to increase significantly over time. Projected growth in tree canopy should provide a general sense of how much tree benefits will increase by 2025. Results for individual neighborhood planning areas will be spatially visualized in map books, and significance testing will show the level of efficacy of the ACT Program.

2.5 BUDGET

**Data Collection**

 Total Hours (5 hr/wk \* 6 wk \* 4 consultants) 120

 Hourly Rate $30

 Total $3,600

**Data Analysis**

 Total Hours (5 hr/wk \* 10 wk \*4 consultants) 200

 Hourly Rate $40

 Total $8,000

**System Management**

*Project Manager*

Total Hours 50

 Hourly Rate $30

 Pay $1,500

*GIS Analysts*

 Total Hours 30

 Hourly Rate $20

 Number of Analysts 3

 Pay $1,800

 Total $3,300

**Equipment Costs**

 Supplies ($50/workstation \* 4 stations) $200

 Maintenance ($60/workstation \* 4 stations) $240

 Depreciation

($100,000 [total value of equipment]/36 (equipment life in months) \* 2.5 months $6,945

 Software License for 10 weeks $1,500

 Total Equipment Costs $8,885

**TOTAL COSTS $23,785**

2.6 TIMELINE

The project has been divided into four phases: Data Collection, Processing, Data Analysis, and Interpretation

Table 2. Timeline

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Dates | Aug 24 | Aug 31 | Sep 7 | Sep 14 | Sep 21 | Sep 28 | Oct 5 | Oct 12 | Oct 19 | Oct 26 | Nov 5 | Nov 12 | Nov 19 | Nov 26 |
| Data Collection | X | X | X | X |  |  |  |  |  |  |  |  |  |  |
| Processing |  |  |  |  | X | X | X | X |  |  |  |  |  |  |
| Data Analysis |  |  |  |  |  |  |  |  | X | X | X |  |  |  |
| Interpre-tation |  |  |  |  |  |  |  |  |  |  |  | X | X | X |

* **Phase 1 – Data Collection:** In the first four weeks, we have planned the project and prepared the proposal. We have collected data from the City of Austin and assured consistency of projection and coordinate systems.
* **Phase 2 – Processing:** The second phase will involve conducting the 2006/2010 canopy and tree delivery overlay, calculating tree benefits for individual species and ACT Program trees as a whole, and extrapolating canopy cover to 2025.
* **Phase 3 – Data Analysis:** The third phase will consist of conducting significance testing of canopy growth and tree benefits
* **Phase 4 – Interpretation:** The fourth phase will be dedicated to composing and compiling the map book and other final deliverables.

2.7 FINAL DELIVERABLES

Final deliverables to the City of Austin Forestry Division will include:

* Written report on the efficacy of the ACT Program
* A .pdf map book displaying
	+ Study area with neighborhood boundaries
	+ 2006-2010 Overlay and visual comparison with tree delivery locations and percentage growth
	+ Total number of trees delivered to Austin residents within the study area
	+ Maps of carbon sequestration (lbs.) and energy conservation (kW h) for the year of 2015 represented in graduated color by parcel (1 map per benefit per neighborhood)
	+ Anticipated canopy growth to 2025 (sq. ft.)
	+ Results of significance testing in charts and figures
* Geodatabase of all data and analysis outcomes
* Outcomes of significance testing in .docx and .xlsx
* Poster in .pptx

**3. CONCLUSION**

As Austin grows, so does the threat that UHI island effects pose to its residents. With this study, Green City GeoTech aims to evaluate the effectiveness of the ACT Program based on 1) the significance of tree canopy growth and the resulting increase of carbon sequestration in live biomass and electrical energy conservation through reduced demands on air conditioning and 2) to project the potential tree canopy growth as residents nurture and maintain the trees they have planted on their property. We expect to find from its study that the urban tree canopy’s mitigation of UHI effects is significant and will be so in the future. Green City GeoTech’s ultimate goal is to provide information that helps the City of Austin Forestry Division to make important decisions about its urban forestry efforts.

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**5. PARTICIPATION**

|  |  |  |
| --- | --- | --- |
| Team Member | Title | Tasks |
| Brietta Perez | Project Member, GIS Analyst | Literature Review, Methodology, Timeline, Final Deliverables, Conclusion, References, editing and proofreading, quality assurance, compilation, and submission |
| Mujahid Hussain | Assistance Project Manager, GIS Analyst | Summary, Purpose, Scope, Literature Review, Methodology, editing and proofreading, quality assurance |
| Jeffrey Cuevas | GIS Analyst | Literature Review, Methodology, Results |
| Nick Waters | GIS Analyst | Literature Review, Neighborhood Planning Area: Study Extent, Data, Budget, Timeline |

**APPENDIX I.** Neighborhood Planning Area: Study Extent



**Figure 1.** The base map shows neighborhood planning areas selected for the ACT Program. Water, parks, and streets provide reference. Source: City of Austin GIS Data Downloads.