Executive Summary

The value of traditional goods and recreational opportunities, such as timber and hunting, from Texas forests has long been recognized to be of economic importance to society. This value is relatively straight forward to assign since there are direct markets for these products and services. Other ecosystem services that are essential to human survival and well-being, such as climate regulation, biological diversity, and watershed regulation, are much harder to quantify and value. Texas A&M Forest Service previously estimated the economic value of cultural and regulating services provided by Texas forests (*Texas Statewide Assessment of Forest Ecosystem Services*, 2013). However, this assessment utilized the USDA Forest Service Forest Inventory and Analysis (FIA) definition of forestland and thus focused on rural forests. This new effort augments that previous work to cover all urban and community forests in Texas, and focuses on the following ecosystem services:
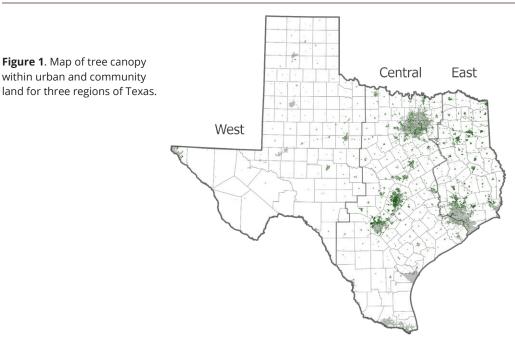
1. *Biological Diversity Regulation*: the capacity of forests to promote essential biological diversity that drives most other services, as well as provides a sustainable habitat for wild plants and animals, soil formation/conservation, and pollination.

2. *Climate Regulation:* the effect trees have on regional and local climates by absorbing greenhouse gases such as carbon dioxide and storing them long-term in forest biomass, and by avoiding emissions through reduced energy needs.

3. *Cultural:* the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, and aesthetic experience.

4. *Economic:* the financial benefit associated with strategically located trees, including increasing property values and reducing energy costs.

5. *Human Health:* the ability of trees to positively impact human physical health, mental well-being, and healing through exposure.

6. *Watershed Regulation:* the ability of forests to intercept, store, and utilize precipitation, resulting in a reduction in stormwater runoff.

Values are quantified for the state and three primary geographic regions (East – 48 counties, Central – 104 counties, and West – 102 counties) as shown in Figure 1. Previously assessed ecosystem service values for forests in urban areas were updated with newer methodologies used in this assessment.

URBAN AND COMMUNITY FORESTS IN TEXAS

According to the U.S. Census Bureau, there are 9.3 million acres of urban and community land in Texas. The majority of this area (62%) occurs in the Central Texas region, dominated by the Dallas-Fort Worth, Austin, and San Antonio metropolitan areas along the I-35 corridor. Not surprisingly, the West Texas region, characterized by wide open spaces, contains the smallest amount of urban and community land (11%).

Tree canopy, as determined by the 2016 National Land Cover Dataset, is present on 1.2 million acres of urban and community land and represents the resource area for this assessment. While the Central Texas region has the most urban tree canopy in the state (663 thousand acres), the forest rich area of East Texas has the highest relative proportion of urban and community forests (19.5% of its urban and community land).

Figure 1. Map of tree canopy within urban and community land for three regions of Texas.

BIOLOGICAL DIVERSITY REGULATING SERVICES

Biological diversity (biodiversity) is considered a valuable resource because it underpins all ecosystem functioning and concomitant ecosystem services (e.g., carbon sequestration, water filtration, etc.) that are essential in supporting human existence. To value biodiversity in Texas, the Regional Ecological Assessment Protocol (REAP) developed by U.S. Environmental Protection Agency (EPA) Region 6 was used to identify acres of urban forests classified as "hotspots" of ecological importance. Based upon the Willingness to Pay (WTP) values reported in the literature, a conservative value of $51.75/acre/year was assigned to the top 10% of ecologically significant acres accross EPA Region 6. Texas has 63,415 acres of tree canopy that fall within this category (i.e., "hotspots"), providing an annual ecosystem service value of $3.3 million/year.

CLIMATE REGULATING SERVICES THROUGH CARBON SEQUESTRATION

The valuation of carbon as an ecosystem service in climate regulation is a key contributor to determining the total value forests provide society. Forest carbon was assessed by stocks (current volume of carbon stored in trees) and accumulation (the rate at which carbon is removed from the atmosphere and fixed into trees through annual growth). Urban tree field data from 28 cities in six states were analyzed in i-Tree Eco and standardized per unit of tree cover to determine average carbon density for urban and community forests. These carbon density estimates were then applied to statewide urban tree cover measurements to determine total urban and community forest carbon storage and annual accumulation (growth).

Additionally, trees strategically located near commercial and residential buildings can reduce energy usage through reduced heating and cooling needs. The energy savings can be quantified in terms of avoided carbon emissions from energy generation. The current U.S. government calculated social cost of carbon ($51 per metric ton of carbon) was used to value carbon stocks, annual accumulation, and avoided emissions.

The total carbon stock (storage) estimated for all urban and community forests in Texas is 36.8 million metric tons. Carbon stocks were amortized over 20 years at a 3% discount rate to calculate an annualized value of $126.2 million/year. The total annual carbon accumulation (growth) across Texas community forests was 1.8 million tC/year, providing an annual economic value of approximately $66.5 million/year. Energy savings from urban and community forests resulted in avoided carbon

emissions valued at $99.1 million annually. Collectively, the total economic value of carbon stocks, carbon accumulation, and avoided emissions equaled $291.8 million/year.

CULTURAL SERVICES

People enjoy the opportunities that forests provide towards spiritual enrichment, mental development, and leisure. Texas forests are a critical source for science, culture, art, and education. These non-material benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, and aesthetic experience are called cultural services.

To capture the cultural values associated with Texas urban forests, a self-administered web survey through Qualtrics was distributed to randomly selected Texas residents to determine their preferences and opinions about Texas urban and community forests. The survey included a choice experiment in which respondents were asked to choose their preferred place of residence. Participants were given two neighborhood choices with varying attributes, such as quantity of tree cover, distance to green space, and additional cost. A total of 560 web-based survey questionnaires were collected.
The results for respondents' perceptions and experiences with urban and community forest ecosystems services were:

76% believe urban forests **increase property value and desirability**

56% thought the presence of urban forests can **enhance the shopping experience**

82% agree that urban forests help **with temperature moderation** in cities

77% believe urban forests **increase physical activity and reduce obesity**

78% felt that being able **to see trees** was an important **personal benefit** of urban forests

60% believe **clean air** is an important **personal benefit** of urban forests

Data from the choice experiment questions were analyzed using a mixed logit model to estimate the annual willingness to pay. Each U.S. Census block group within the project area was analyzed to determine the average tree canopy percent and number of households. The number of households was then multiplied by the annual willingness to pay and average tree canopy percent for the block group. Values for all U.S. Census block groups were calculated and summed to estimate the cultural value of urban and community forests.

Results indicated that Texans were willing to pay more to live in a neighborhood having abundant trees. An average household in Texas was willing to pay an additional $2.09 per month for a one percent increase in canopy cover. The total assessed cultural value of Texas urban and community forests to the residents of Texas is approximately $1.8 billion/year.

ECONOMIC SERVICES

Urban and community forests are known to increase property value and reduce energy. Research shows that trees can increase residential property value between 3% and 15%, depending on tree location and size. For this assessment, a conservative estimate of 3% was used, where shade trees were present. This percent was applied to the median sale price of a single-family home in Texas, standardized by average real estate lot sizes, and multiplied by the percent of homes sold annually on low and medium developed land with at lease 10% tree cover. This assessment found a statewide total of $258.6 Million of Texas residential property sales is attributed to urban trees, annually.

For energy savings, a value of $508 per hectare of tree canopy was applied to Texas urban and community land resaulting in a total statewide value of $243.2 million/year.

HUMAN HEALTH SERVICES

Exposure to trees can have substantial benefits to human health, including physical, mental, and even healing benefits. Numerous studies show that treescapes in neighborhoods and access to treed green spaces reduce risk of obesity and chronic disease in children and adults alike. Additionally, people who spend time in treescapes and natural areas, particularly those with high biodiversity, report better psychological health. Trees themselves remove carbon monoxide, ozone, sulfur dioxide, nitrogen dioxide, and fine particulate matter from the atmosphere, improving air quality. An outcome of this improved air quality, treescape accessibility, and lower disease risk is a reduction in medical expenses related to these health issues.

The primary indicators utilized in this assessment to value human health services from community forests are the reduction in hospitalization due to stroke, the reduction in rate of obesity, and the reduction in cases of depression each year. The estimated rate and reduction of annual excess medical costs associated with obesity, average cost of a stroke-related hospital stay, and cost to treat depression was applied to the population who live within neighborhoods of the highest relative tree cover for each county in Texas (obesity and stroke) or within 250 meters of a REAP biologically diverse hotspot (depression). The estimated value of reduced obesity, stroke and depression-related medical expenses due to community forests in Texas is over $3.3 billion annually. An additional $63 million in healthcare savings occurs from the reduction in air pollution. The estimated value of human health services from Texas' urban forests is $3.4 billion annually.

WATERSHED REGULATING SERVICES

Healthy forests are critically important to protecting water resources, providing the cleanest water of any land use. They also absorb rainfall, recharge aquifers, slow and filter stormwater runoff, and maintain watershed stability and resilience. Urban and community forests play an essential role in this overall process, helping break up large areas of impervious cover that are common in the built environment.

Annual avoided runoff was the primary watershed function used to quantify and value watershed services provided by urban and community forests. This function refers to the ability of trees and vegetation to increase infiltration, store, utilize, and return precipitation to the atmosphere, thereby reducing the amount of stormwater runoff that can result in flooding and/or nonpoint source water pollution.

To assess this function, i-Tree Eco was used to calculate annual avoided runoff estimates attributed to tree cover for every county in the state. A national average dollar value for stormwater control was then applied to these estimates and totaled by region and for the entire state. Urban and community forests in Texas mitigate 11.9 billion gallons of stormwater runoff annually, valued at $106.3 million/year.

VALUE FOR TEXAS

The annual contribution of the assessed services to the citizens of Texas is an estimated $6.1 billion (Table 1). If represented on a per acre basis, urban forests in Texas provide $5,183 worth of ecosystem services annually. The Central Texas region contributed 69% ($4.3 billion/year), East Texas region contributed 28% ($1.7 billion/year) and the West Texas region provided 3% ($172.6 million/year) of the total value. Human health services provided the most value statewide, followed by cultural, economic, climate, watershed, and biodiversity, respectively (Figure 2).

Table 1. Value of ecosystem services provided by trees and forests in urban and community areas

	CENTRAL	EAST	WEST	STATEWIDE
- Acres -				
Area of Interest[1]	5,787,213	2,546,624	1,003,273	9,337,110
Tree Canopy	663,114	495,561	24,221	1,182,896
Tree Canopy Percent[2]	11.5%	19.5%	2.4%	12.7%
- Dollars/Year -				
Biodiversity	2,278,228	949,498	53,993	3,281,719
Climate	163,560,223	122,232,635	5,974,183	291,767,041
Cultural	1,230,619,902	572,963,314	28,862,369	1,832,445,585
Economic	302,643,372	184,767,569	14,394,749	501,805,689
Human Health	2,495,392,006	778,320,058	121,129,385	3,394,841,449
Watershed	59,585,502	44,529,732	2,176,414	106,291,648
Total	**4,254,079,233**	**1,703,762,806**	**172,591,093**	**6,130,433,131**
- Dollars/Acre/Year -				
Biodiversity		2	2	3
Climate	247	247	247	247
Cultural	1,856	1,156	1,192	1,549
Economic	456	373	594	424
Human Health	3,763	1,571	5,001	2,870
Watershed	90	90	90	90
Total	**13,123**	**8,263**	**16,714**	**11,162**

1 Area of Interest includes urban and community areas as defined by U.S. Census Urban Areas and Place boundaries.
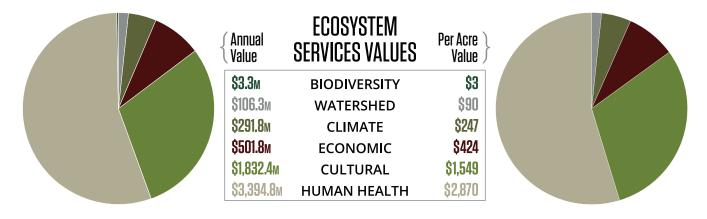2 Percent of area of interest that is under tree canopy.

ECOSYSTEM SERVICES VALUES

Annual Value		Per Acre Value
$3.3M	BIODIVERSITY	$3
$106.3M	WATERSHED	$90
$291.8M	CLIMATE	$247
$501.8M	ECONOMIC	$424
$1,832.4M	CULTURAL	$1,549
$3,394.8M	HUMAN HEALTH	$2,870

Figure 2. Relative contribution of individual services to the statewide total value