TEXAS A&M FOREST SERVICE

APRIL 2022

Texas Statewide Assessment of Urban Forest Ecosystem Services

A COMPREHENSIVE ANALYSIS OF SERVICES PROVIDED BY TEXAS URBAN AND COMMUNITY FORESTS




Texas Statewide Assessment of Urban Forest Ecosystem Services

A COMPREHENSIVE ANALYSIS OF SERVICES PROVIDED BY TEXAS URBAN AND COMMUNITY FORESTS

April 2022

Hughes Simpson, Chief Operating Officer
TEXAS A&M FOREST SERVICE

Gretchen Riley, Department Head
TEXAS A&M FOREST SERVICE

Omkar Joshi, *(formerly)* Forest Economist
TEXAS A&M FOREST SERVICE

Brad Barber, Geospatial Systems Manager
TEXAS A&M FOREST SERVICE

Rebekah Zehnder, Geospatial Analyst
TEXAS A&M FOREST SERVICE

Dayziah Petruska, Staff Forester
TEXAS A&M FOREST SERVICE

Eric Taylor, Silviculturist
TEXAS A&M FOREST SERVICE

Produced by

TEXAS A&M FOREST SERVICE

200 Technology Way, Suite 1281
College Station, TX 77845-3424

(979) 458-6650

TEXAS A&M FOREST SERVICE

Abbreviations

ac	acre	**t**	metric ton (tonne or Mg)
C	carbon	**tC**	metric tons of carbon
CO_2e	equivalent carbon dioxide	**U&CF**	Urban and Community Forests
EPA	Environmental Protection Agency	**USD**	United States dollars
FIA	Forest Inventory and Analysis	**USDA**	United States Department of Agriculture
GDP	Gross Domestic Product	**UTC**	Urban Tree Canopy
GSP	Gross State Product	**VOC**	Volitile Organic Compound
Kg	Kilogram	**WTP**	willingness to pay
NLCD	National Land Cover Dataset	**yr**	year
REAP	Regional Ecological Assessment Protocol		

Urban Forest and Tree Canopy in Texas

Urban and Community Land – *the geographical area that encompasses the U.S. Census Bureau defined Urbanized Areas (50,000 or more people) and Urban Clusters (2,500 to 50,000 people), and the political boundaries of incorporated communities.*

Urban and Community Forest – *a general term referring to the collection of trees and associated vegetation found throughout cities, towns, and communities, including in parks, green spaces, school and corporate campuses, along streets, and even neighborhoods.*

Urban Tree Canopy – *The layer of leaves, stems, and branches within cities and towns that cover the earth when viewed from above.*

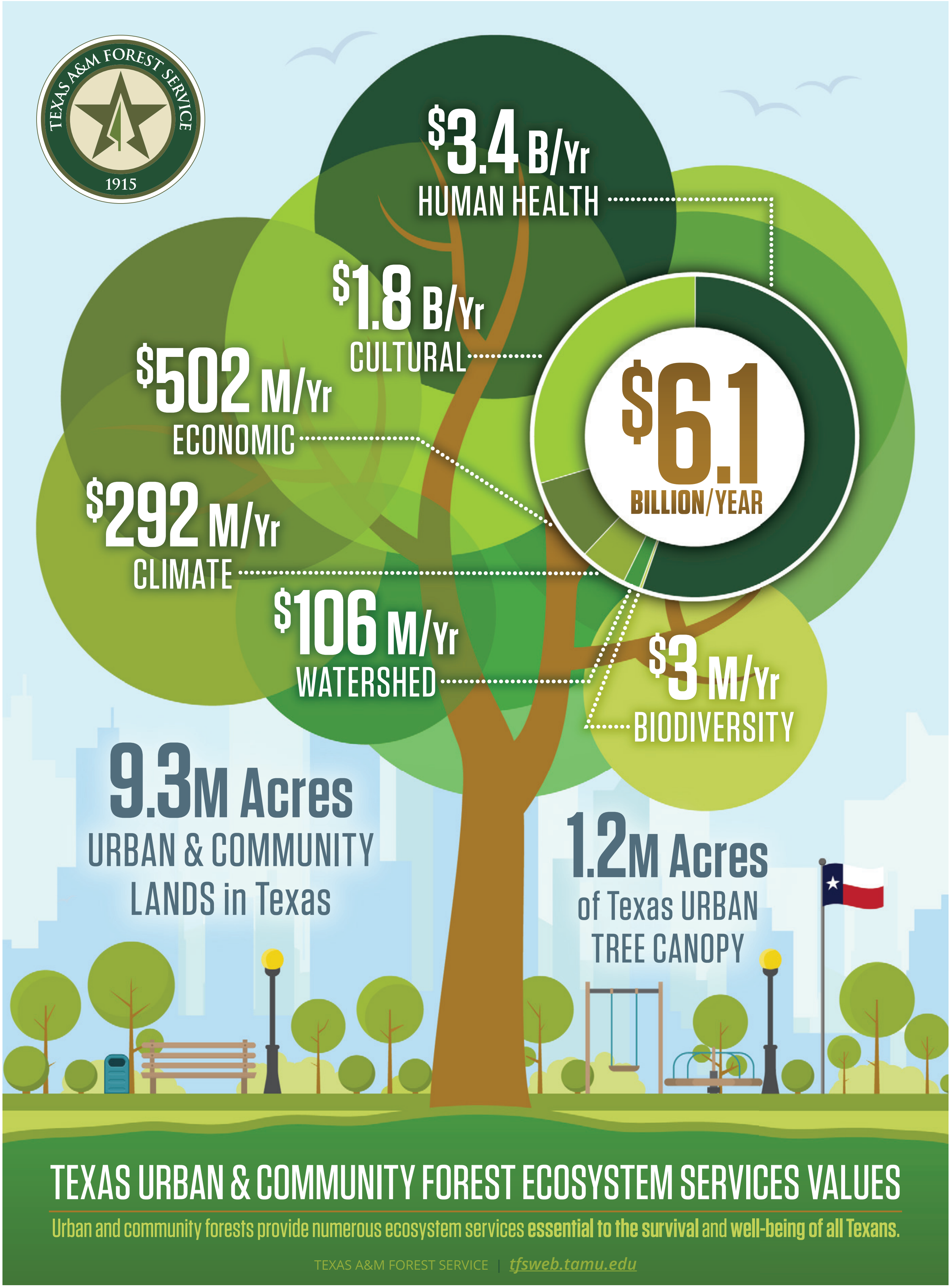
Urban and Community Land in Texas = *9.3 million acres*

Urban Tree Canopy in Texas = *1.2 million acres*

Table of Contents

List of Tables

List of Figures


TEXAS A&M FOREST SERVICE
1915
$3.4 B/Yr
HUMAN HEALTH
$1.8 B/Yr
CULTURAL
$502 M/Yr
ECONOMIC
$292 M/Yr
CLIMATE
$106 M/Yr
WATERSHED
$3 M/Yr
BIODIVERSITY
$6.1
BILLION/YEAR
9.3M Acres
URBAN & COMMUNITY
LANDS in Texas
1.2M Acres
of Texas URBAN
TREE CANOPY
TEXAS URBAN & COMMUNITY FOREST ECOSYSTEM SERVICES VALUES
Urban and community forests provide numerous ecosystem services essential to the survival and well-being of all Texans.
TEXAS A&M FOREST SERVICE | tfsweb.tamu.edu

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).

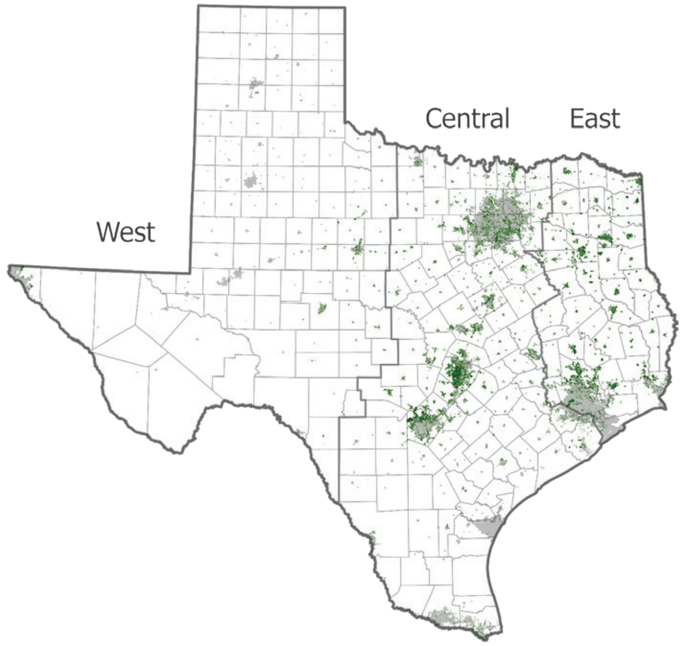


Figure 1. Map of tree canopy within urban and community land for three regions of Texas.

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.

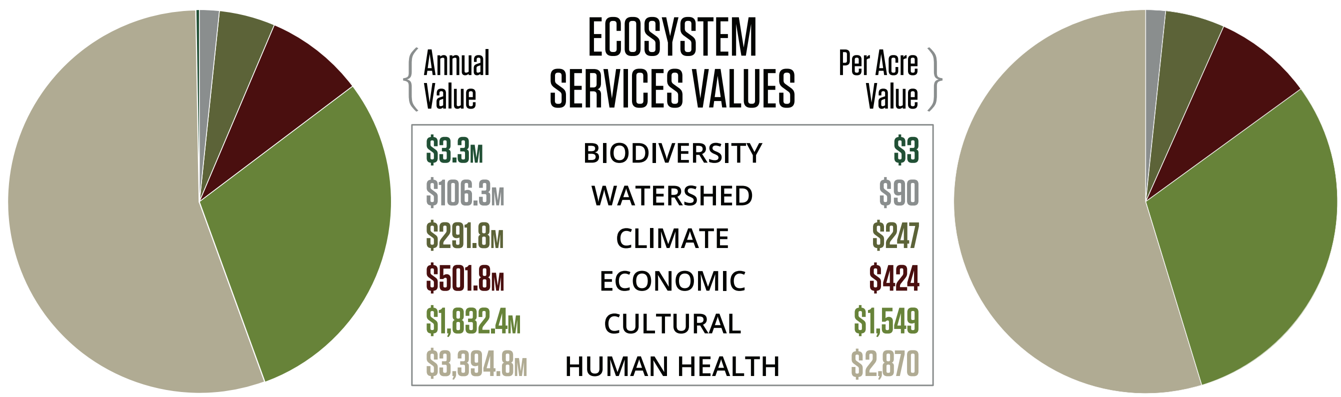


Figure 2. Relative contribution of individual services to the statewide total value

Introduction

From the lush Pineywoods of East Texas to the inland waterways, wetlands, and extensive coastline to the arid and mountainous regions of the west, Texas is famous for its rich diversity and wide-open spaces. The state has more than 60 million acres of forestland, which includes the ever-important urban and community forests (U&CF) where Texans live, work, and play. Urban and community forests represent the collection of trees and associated vegetation found throughout communities, including in parks, green spaces, school and corporate campuses, and even neighborhoods. These forests occur on public and private land and form the basis of a community's green infrastructure network.

Traditional forests and woodlands have been studied extensively to quantify and value their economic, environmental, and social benefits. Texas A&M Forest Service has a long history of tracking timber price information, dating back to 1984. Additionally, economic contribution studies of the Texas forest sector have been conducted regularly since 1999, with the most recent analysis (2019) documenting that this sector directly contributed $18.9 billion of industry output to the Texas economy Furthermore, the original and comprehensive *Texas Statewide Assessment of Forest Ecosystem Services* (2013) valued the largely rural forest-based cultural and regulating services at $93 billion annually.

Urban and community forests have historically not undergone the same level of analysis as their rural counterparts. In 2019, Texas A&M Forest Service conducted the first ever statewide economic contribution study of this sector in Texas, documenting that urban and community forests directly contribute $4.7 billion to the Texas economy. The 2013 statewide forest ecosystem services assessment included values for forests in urban areas; however, a large portion of the urban and community forest was not included as it did not meet the Forest Inventory and Analysis (FIA) definition of forestland.

For these reasons, Texas A&M Forest Service set out to quantify the services provided by urban and community forests in Texas and to estimate the associated value of these benefits. This study, therefore, extends the previous assessment of the ecosystem services on FIA-defined forests in Texas to all urban and community forests. Understanding these values is paramount to smart land use planning, resource management, and the long-term sustainability of Texas forests. All values used in this report, unless otherwise noted, are expressed in year 2020 United States dollars (USD).

DEFINING URBAN FOREST ECOSYSTEM SERVICES

Forest ecosystems provide a wide array of services that benefit society. These services can be placed within three broad categories (Table 2): 1) provisioning, 2) regulating, and 3) cultural (Millennium Ecosystem Assessment [MEA] 2005). Provisioning services are the material goods provided by nature that already have an economic value. Some of these, such as food (e.g., crops, livestock, and fisheries) and fiber (e.g., timber, cotton, and wood fuel) are familiar to Texans. Regulating and supporting services, from an anthropogenic point of view, control environmental processes that are essential to the survival of humans. Because of their complexity and grand scale, regulating services cannot effectively be replaced by current technology. Lastly, cultural services are the non-material benefits people obtain from ecosystems through aesthetic values, social relations, reflection, recreation, spiritual enrichment, and cognitive development.

The scope of this project encompasses all urban and community forestland in Texas, including both private and public ownership. Based on a literature review, the benefit transfer approach was used to estimate the value (2020 USD/acre) for some generally accepted ecosystem services. This approach produces ecosystem service estimates by transferring available information from similar studies already completed in another location and/or context. Through original research, a non- market valuation approach (choice experiment) was used to estimate per acre cultural values of forests. This approach relies on the use of public surveys to ask beneficiaries their preference regarding hypothetical changes in the provision of ecosystem services.

Table 2: Description of the ecosystem services evaluated in this assessment

BIOLOGICAL DIVERSITY	
Biodiversity	Storehouse of genetic material, contribution to natural pest and disease control, pollination of essential plants, threatened and endangered species
CLIMATE	
Carbon Storage	The ability of trees and forests to hold carbon within wood for long periods of time
Carbon Accumulation	The ability of trees and forests to absorb carbon dioxide through photosynthesis as part of the growth process
Avoided Emissions	The reduction in carbon emissions due to energy savings from strategically placed trees
CULTURAL	
Social/Spiritual	Non-material, emotional benefits people obtain from ecosystems through social relations, reflection, recreation, spiritual enrichment and cognitive development
ECONOMIC	
Property Value	The increase in residential value as a result of mature landscape trees
Energy Savings	The reduction in building heating and cooling energy usage resulting from strategically placed trees
HUMAN HEALTH	
Air Pollution	The influence trees and forests have on improving air quality by trapping soot (particulate matter), nitrogen oxides and other pollutants
Obesity and Stroke	The reduction in medical expenses related to obesity and stroke hospitalization attributed to living in neighborhoods of higher relative tree cover
Health Biodiversity	The reduction in depression-related medical expenses attributed to living near highly diverse treescapes
WATERSHED	
Avoided Runoff	The ability of trees and forests to mitigate stormwater runoff through rainfall interception, evapotranspiration, and infiltration

WHY URBAN FORESTS IN TEXAS AND WHY NOW?

Trees and forests in urban and community areas represent valuable natural and cultural resource systems. They contribute to human well-being by providing scenic beauty, recreational opportunities, community revitalization, positive physical and mental health influences, clean air and water, climate regulation, carbon capture, energy savings, and storm water mitigation, as well as economic benefits. Unlike rural forests, the millions of trees in urban forests are maintained with the primary objectives of service rather than commodity.

Texas is the second most populous state in the country, trailing only California. The state's population is projected to exceed 47 million by 2050, an increase of 62% from the 2010 Census (Figure 3). As Texas becomes more urbanized, an ever-increasing demand for resources will impact the ability of these systems to provide services that are essential to life and well-being.

Placing a value on these services and educating policymakers about these values may help put incentives in place to encourage sustainable management of these resources. This, in turn, will have additional benefits to the quantity of services provided by these lands, minimize the potential for catastrophic loss from insect, disease, and extreme weather events that have huge social costs, and reduce land conversion and fragmentation during land-use planning. To address these needs, the project's goals were to:

1. Identify key forest-based ecosystem services of high importance.
2. Quantify the ability of forests to provide key ecosystem services annually using existing data.
3. Estimate the conservative economic value of critical services.
4. Use this information to report changes in values following natural disasters, land conversion and the implementation of management efforts.
5. Develop a framework so values can be updated periodically with new data.

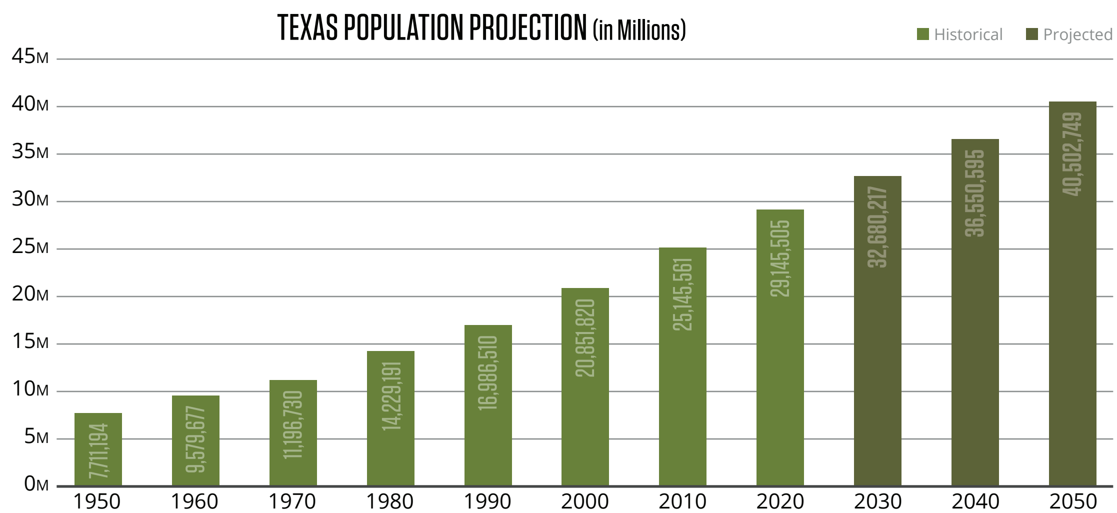


Figure 3. *Texas population projections through 2050*

(U.S. Census Bureau)

PREVIOUS URBAN FOREST ECOSYSTEM SERVICE ASSESSMENTS

Traditional methods for calculating ecosystem service values of urban and community forests have focused on the replacement cost of individual trees (Guide for Plant Appraisal, 2018). Computer models (USDA Forest Service's i-Tree and Urban Forest Inventory and Analysis) using data from tree inventories and/or photo interpretation points have been used to evaluate the functional values of trees in cities, including air pollution removal, energy savings, stormwater runoff, and carbon sequestration and storage.

Several Texas cities, in conjunction with Texas A&M Forest Service, have conducted urban forest ecosystem service (i-Tree) studies and street tree inventories in order to guide management decisions. Additionally, the Urban Forest Inventory and Analysis Program has been fully implemented in Austin, Houston, and San Antonio. Results of these assessments are updated periodically and can be viewed through the My City's Trees web application (http://mycitystrees.com).

Research studies have also estimated other values attributed to urban and community forests, such as real estate (property), recreation, human health, psychological well-being, and aesthetic appeal. Recently the Arbor Day Foundation quantified certain ecosystem services values in conjunction with their economic contribution study. The USDA Forest Service Northern Research Station is a leader in the subject, routinely publishing regional and statewide summary reports on select urban forest benefits (Table 3).

Table 3. Sample of existing statewide ecosystem services assessments

STATE	CLIMATE	ECONOMIC	WATERSHED	HEALTH	CULTURAL	*TOTAL*
	Millions of Dollars					
Tennessee[1]	402.1	66.0	—	203.9	—	***672.0***
California Street Trees[2]	10.3	940.1	41.5	18.2	—	***1,010.0***
Texas[3]	291.8	501.8	106.3	3,394.8	1,832.4	***6,127.1***
Conterminous U.S.[4]	123,802.7	5,400.0	—	5,400.0	—	***134,602.7***
United States[5]	65,200.0	604,200	3,300.0	4,900.0	—	***677,600.0***

1. Nowak USDA FS 2009; 2. McPherson 2016; 3. Current study 2020; 4. Nowak USDA FS 2018; 5. Arbor Day Foundation 2020.

As previously mentioned, the *Texas Statewide Assessment of Forest Ecosystem Services (2013)* included "forests in urban areas" in the overall project scope, where those lands met the FIA definition of forestland *(forested areas that are not developed for nonforest land uses, are at least an acre in size and 120' in width and contain a Live Plus Missing Canopy Cover of at least 10%)*. Ecosystem service values for air pollution removal, biodiversity, carbon sequestration, cultural, and watershed services were estimated for this limited subset of the urban forest. Until now there has not been a comprehensive, statewide assessment of the urban and community forests in Texas.

DETERMINING URBAN AND COMMUNITY LAND AREA

Urban and community land is present in all 254 counties in Texas. Urban land or areas, defined by the U.S. Census Bureau, are densely settled cores of census tracts or blocks that meet minimum population density requirements. Urban land accounts for approximately 5% of the land area in Texas. Community land is based on jurisdictional or political boundaries delimited by the U.S. Census Bureau definition of places. These areas are places of established human settlement that may be comprised of all, some or no urban land.

There are 9.3 million acres of urban and community land in Texas, of which approximately 12.7% is under tree cover. The total acre figure is up from 4.4 million acres of urban and community land in 2000 with 14.8% under tree cover (Nowak and Greenfield, 2010).

URBAN TREE CANOPY / SPATIAL REPRESENTATION

The 2016 National Land Cover Dataset tree canopy layer was used to estimate urban and community forests in Texas. This tree canopy layer is a 30-meter raster geospatial dataset that contains percent tree canopy estimates for each pixel across all land covers and types. To define urban and community forests, tree canopy data within the 2010 U.S. Census Bureau's urban areas and clusters was extracted. Urban tree canopy was calculated for the state and three broad regions. For a detailed discussion on this method, see Appendix A.

URBAN FORESTS AND THE TEXAS ECONOMY

The urban forest sector contributes substantially to the state's economy not only through the creation of green jobs and associated spending, but also tax revenue and value added impact. In 2017, the urban forest industry directly contributed $2.4 billion of industry output to the Texas economy, employing 43,470 people with a payroll of $1.4 billion, reported in 2019 dollars. The state received $1.6 billion in value added impact directly from this sector through payroll, other employee compensation, and property taxes.

Supplying industries of this sector indirectly contributed $788 million of industry output to the state's economy, providing 4,076 jobs with $256 million of labor income and $445 million in value added. Together, these generated the induced effects of $1.5 billion output, 10,100 job opportunities, $503 million in labor income, and $882 million in value added to the Texas gross domestic product (GDP). Including direct, indirect, and induced impacts, the urban forest sector had a total economic contribution of $4.7 billion in industry output, supporting 57,645 jobs (2.04 jobs/1,000 Texans) with a payroll of $2.1 billion and $2.9 billion in value added.

A Social Accounting Matrix (SAM) multiplier reflects the additional jobs, labor income, value added, and industry output created by a sector to the local economy. Applying the SAM multiplier, every job created by the Texas urban forest sector resulted in an additional 0.33 jobs, $0.55 in payroll and $0.82 in value added in Texas. While not additive, ultimately, every dollar generated by this sector contributed an additional $0.96 to the rest of the state economy.

Value of Urban Forest Biodiversity Services

Urban and community forests are biologically rich and diverse. They provide a robust ecological system, hosting a multitude of life forms intertwined with non-living chemical and physical factors in the environment. Urban and community forests provide living space for plants and animals. Diverse forest systems remain quite stable and productive and are at reduced risk to pest and disease outbreaks. Thus, biodiversity is a source of value in urban and community forests.

Biodiversity is defined as "the variability among living organisms from all sources, including among other things, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems" (CBD, 1992). In short, biodiversity indexes species richness (the number of different species present in an area), their relative abundance, composition, and presence of key species (Hooper et al 2005).

Biodiversity may be considered a valuable resource for the single reason that it underpins all ecosystem functions and associated ecosystem services (e.g., carbon sequestration, water filtration, etc.) that are essential in supporting human existence (Christie et al 2006, Costanza et al 1997, Daily 1997, MA 2005, Sachs et al 2009, Hooper et al 2005). This section assesses the economic contribution of forest biodiversity, illustrating the importance of biologically diverse urban and community forests and the ecosystem services they provide. A monetary value placed on biodiversity may provide decision-makers with quantitative data to estimate the costs and benefits of programs intended to conserve, alter, or eliminate forest biodiversity.

METHODS

Ecosystem Services Considered Under Biodiversity Valuation

Numerous studies are available that report the value of biodiversity but use varying definitions for biodiversity services. It appears that the valuation of biodiversity is one of the most significant and quickly evolving areas of research. This is likely due to the escalating need to build more comprehensive representation of ecological values for policy formulation and the decision-making process (Turner et al 2003).

To simplify efforts to estimate the biodiversity value of the urban and community forests in Texas, many services were grouped instead of being assessed individually as previous studies have done (de Groot et al 2002, Liu et al 2010, Moore 2009, Salles 2011, Tilman 1997). In the context of this assessment, biodiversity services are defined as the contribution towards the conservation of species communities in their natural forest habitat such that all species within the forest can co-evolve and interact with each other. Under this definition, forest biodiversity services consider, among other factors, the functions of distribution (habitat/refugia), representation (richness), sustainability, pollination, soil formation, area size requirements, genetic resource, medicinal resource (drugs and pharmaceuticals), and others that are often addressed individually. Biodiversity services were assessed for the state, three broad regions (East, Central, and West Texas), and individual municipalities.

Assessing Ecologically Important Areas

Trees and forests are key to providing ecological diversity essential for numerous goods and services to society. However, some areas may have additional contributions towards biodiversity. It is important to assess these "hotspots" of ecological importance so that policy makers may have the appropriate data to prioritize opportunities for avoiding potential impacts on these higher-value areas before loss occurs. For these reasons, the Regional Ecological Assessment Protocol (REAP) Composite information was included in this assessment. REAP is an ecoregional assessment geospatial dataset developed by the U.S. Environmental Protection Agency, Region 6 (Osowski et al 2011).

Tree canopy from NLCD 2016 was compared to REAP's composite layer to estimate the number of urban and community forest acres falling within REAP's top 10% level of ecologically significant acres. Current literature presents a hugely broad range of associated economic values and/or costs for conserving ecologically significant areas (Hooper et al 2005). Most values reflect a study group's Willingness to Pay (WTP) for conserving and/or protecting habitat of threatened or endangered species. These values vary greatly depending upon region and species and range from $0 to greater than $10,000/acre/year (Loomis and Ekstrand 1998; Mendoza-González et al 2012, Mullan and Kontoleon 2008, Elodie Brahic and Jean-Philippe Terreaux 2000, Polasky et al 2001, Ando et al 1998, Huang and Kronrad 2001). Mullan and Kontoleon (2008) report the global average opportunity cost of conserving forest biodiversity to be $209 acre/year, reflecting the costs to society if the product (in this case, ecosystem service/function) is lost. However, they also report that case studies estimate the opportunity costs of protecting forest biodiversity to range from $24 to $250 in the U.S.

For this report, the conservative value of $51.75/acre/year was assigned to the top 10% of ecologically significant acres ("hotspots") coinciding with tree canopy. More specifically, the proportion of an area on the ground (in this case, 30x30-meter pixel), that is covered by tree canopy was multiplied by the value of $51.75/acre. For example, a pixel with 50% tree canopy was assigned a value of 0.50 × $51.75/acre × 0.22 acre/pixel = $5.75. Not only does this value fall on the conservative end of the reported range, but this value is validated from comparable, published Willingness-to-Pay (WTP) values (Czajkowski et al 2009; Kroeger et al 2012) and should conservatively represent the acceptable cost of conserving forest biodiversity in ecologically significant areas.

RESULTS

Across the entire state, only 79,881 acres of urban and community landfell within the top 10% rank of composite scores for the entire five-state region (AR, LA, NM, OK, TX) included in EPA's Regional Ecological Assessment Protocol (REAP). Of these acres, 63,415 contain tree canopy (79%).

The analysis resulted in values of $0 for biodiversity ecosystem services for 889 of the 1,220 municipalities in Texas. Of the 331 municipalities with positive values, West Lake Hills shows the greatest city-wide biodiversity value—$18.13/acre of municipality/year. When expressed on a per acre basis of tree canopy, Kyle shows the greatest value—$44.03/acre/year. Both cities are suburbs of Austin, which incidentally, has the greatest total value for biodiversity. Respective values for Austin are $2.59/acre/year and $8.25/acre tree canopy/year.

When U.S. Census Metropolitan Statistical Areas are compared, Austin-Round Rock-Georgetown exhibited the high of $2.11/acre/year ($8.34/acre tree canopy/year). On the basis of tree canopy, Laredo exhibited the highest value—$13.78/acre/year ($0.38/acre of municipality/year).

Table 4. Estimated values of biodiversity services provided by urban tree canopy in Texas

	CENTRAL	EAST	WEST	STATEWIDE
	Dollars/Year			
Biodiversity	2,278,228	949,498	53,993	3,281,719

DISCUSSION

Due to the small amount of area considered to be a biodiversity hotspot, biodiversity within the urban and community forest exhibits the least monetary value of the various ecosystem services analyzed in this study. Statewide, the biodiversity ecosystem service is valued at $3.3 million compared to $6.1 billion for all six services considered. This amounts to only 0.025% of the total. When expressed on a basis of per acre of tree canopy, monetary value appears even less significant—$2.77/acre compared to overall total of $5,183/acre, still 0.025%.

Among the three regions, the greatest biodiversity value is in the Central region, followed by the East and West regions, respectively. This is due primarily to the amount of tree canopy, which is based on both the total area within the urban and community forest for these areas and the percentage of the total areas that are treed. Total biodiversity value is $2.3 million for the Central region, $94.9 thousand for the East region, and $54 thousand for the West region. The Central region contains 69% of the total biodiversity values for urban and community forest within the state. This compares to less than 2% for the West region.

Value of Urban Forest Climate Services

Since the industrial revolution, human activities have released an increasing amount of carbon dioxide (CO_2) into the atmosphere. As a result, the natural carbon cycle of the earth is being altered not only by adding CO_2 to the atmosphere but also by reducing natural carbon sinks (e.g., forests) that remove CO_2 from the atmosphere. With greater attention on the consequences of increased greenhouse gases in the U.S. and around the world, there is interest in the use of natural systems to mitigate atmospheric carbon levels.

Forests have a significant role in the global effort to mitigate greenhouse gases because of their ability to sequester and utilize atmospheric carbon. The use of a forest as a carbon sink is one of the most effective mechanisms for offsetting CO_2 emissions (U.S. EPA 2005, Gonzales-Benecke et al 2011, Sundquist 2008, Sedjo 1995).

The annual incremental increase of carbon stored is becoming an increasingly valuable component in assessing the true value of urban and community forests. Trees have long been recognized as one of the best renewable natural resources. Now, the importance of urban and community forests to provide carbon sequestration and other ecosystem services is emerging as a strategy for enhancing climate resilience. This section estimates the economic values of climate services provided by urban and community forests in Texas.

METHODS

Urban forest climate services were quantified and valued for storage, accumulation (growth), and avoided emissions through energy savings resulting from trees strategically located near buildings and residences. On average, urban trees store 7.69 kg C and annually accumulate 0.272 kg C per square meter of tree cover (Nowak 2013). These values were multiplied by the social cost of carbon ($51/tC) and applied to urban tree cover in Texas to determine the value of carbon sequestration. Carbon storage was amortized over 20 years at a 3% discount rate to annualize the value.

Valuation of Carbon Storage and Carbon Accumulation

While cumulatively referred to as carbon sequestration, there is a conceptual and value difference between carbon storage and carbon accumulation. Much of the economic value of carbon storage in the forest ecosystem is lost if the vegetation sustains damage from insects, disease, and extreme weather events or if the forest is converted to other uses. Therefore, the value of carbon storage is a snapshot at a given point in time. The value of carbon accumulation, on the other hand, is the value of the net annual fixation of carbon in a growing forest.

A significant volume of research exists that estimates the value of carbon based on the economic cost to society. This concept is referred to as the social cost of carbon. This social cost of carbon (the value of carbon accumulated and stored in forests) used in this assessment is $51/tC. As with all markets, the value of carbon will fluctuate over time. However, $51/tC is considered a conservative approximation of the long-term average.

Avoided Emissions through Energy Savings

Numerous studies report the impact of urban trees on energy savings. There are avoided emissions as a result of the reduction in energy use. The accepted value for avoided emissions through energy savings, $207/hectare of tree canopy in urban and community areas (D. Nowak, personal communication, January 12, 2021) was applied, resulting in a maximum potential avoided emissions value of $18.63 per 30 x 30-meter pixel. This maximum potential value was multiplied by the perccent urban tree canopy of each pixel to determine the value of avoided emissions through energy savings, provided by trees.

RESULTS

The total value of Climate Services provided by Texas urban and community forests is $291.8 million/year (see Figure 4). This represents an estimated total carbon stock of 36.8 million tC throughout 1.2 million acres of tree canopy. This provides a statewide value of $247/acre/year of climate services. Total value of carbon storage for urban and community forests in Texas is $1.9 billion. Amortized over 20 years at 3%, this is an annual value of $126.2 million/year. Total value of carbon accumulated by Texas urban and community forests is $66.5 million/year with an annual accumulation of 1.8 million/tC. Through avoided emissions, Texas urban and community forests save Texans about $99 million/year.

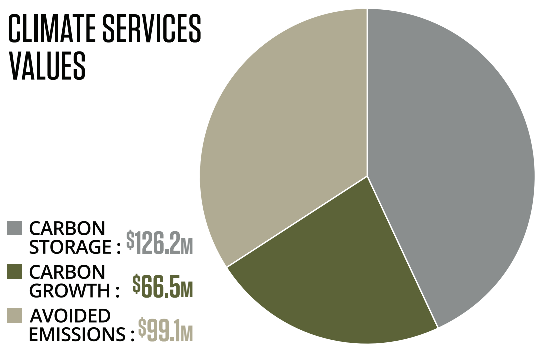


Figure 4. Value of climate services provided to Texans through urban and community forests

DISCUSSION

With forest land density varying across the state, the values are broken up by geographic region: Central, East, and West. Central Texas provides the highest value of climate services with carbon sequestration (storage and accumulation) at about $108.0 million/year and avoided emissions at about $55.5 million/year. East Texas holds the middle spot with carbon sequestration valued at $80.7 million/year and avoided emissions with a value of about $41.5 million/year. West Texas provides the lowest value of climate services with carbon sequestration valued at $3.9 million/year and avoided emissions of $2.0 million/year. These values are detailed in Table 5.

Table 5. Estimated values of climate services provided by urban tree canopy in Texas

	CENTRAL	EAST	WEST	STATEWIDE
	Dollars/Year			
Carbon Storage	70,741,597	52,866,960	2,583,900	126,192,457
Carbon Growth	37,269,656	27,852,544	1,361,307	66,483,507
Avoided Emissions	55,548,970	41,513,131	2,028,976	99,091,077
Total	***163,560,223***	***122,232,635***	***5,974,183***	***291,767,041***
	Tons			
Carbon Storage	20,636,309	15,422,028	753,760	36,812,096
Carbon Growth[1]	730,778	546,128	26,692	1,303,598

1 Per year

Urban forests play a key role in climate regulation through carbon storage, carbon accumulation, and avoided emissions through energy savings. The values climate services provided by each region are respective to the total acreage of urban tree canopy present. Central Texas, with the largest acreage of urban tree canopy, provides the largest amount (56%) of climate services to Texas compared to East (42%) and West Texas (2%) regions respectively (Figure 5).

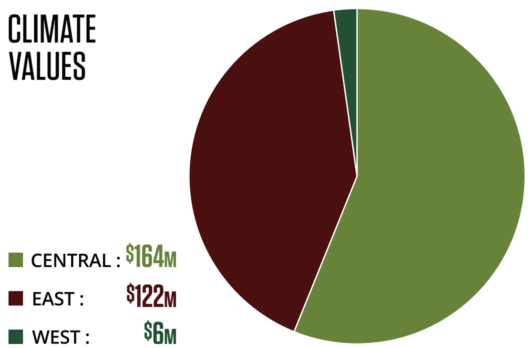


Figure 5. Total annual value of climate services provided by urban and community forests, by region

Value of Urban Forest Cultural Services

Cultural services reflect the interaction of human culture, religion, and knowledge with nature and guide us to appreciate the goods and services that are intrinsic in nature and cannot be easily quantified in marketplace (Sarukhan and Whyte 2005, Milcu et al 2013). With the growing importance of cultural identity (i.e., the feeling of belonging to one or more distinct social group) among societies, importance and concomitant value of cultural services is increasing and expected to continue to increase into the future (Milcu et al 2013).

The Millennium Ecosystem Assessment (MEA 2005), an international assessment of the consequences of ecosystem change for human well-being, defined cultural services as "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience." Cultural services provided by forest ecosystems are normally less tangible than other forest ecosystem services and goods such as regulating, functioning, and provisioning services. MEA and a group of other studies, however, suggest that cultural values are as important as environmental and economic values of our forests both for rural and urban communities, and increasingly include cultural values in regional forest ecosystem service valuation (MEA 2005, Costanza et al 1997, Wilson 2008, Moore et al 2011, Liu et al 2010).

METHODS

Econometric Model

To better estimate the value placed on the cultural service provided by Texas' urban forests, an original study was conducted based on a choice experiment analysis. In a choice experiment setting, a survey respondent is provided with options with varied attributes and is asked to select the one option that he or she prefers. The mixed logit model, a fully general statistical model for examining discrete choices, was used for survey analysis since the choices presented (e.g., selecting a preferred neighborhood) are likely influenced by many things, possibly with some unknown or unnoticed attributes.

Data Source and Variables: Survey Design and Implementation

A self-administered web survey was developed using Qualtrics. The survey was designed specifically to understand and quantify respondents' perceptions concerning non-market ecosystem services provided by urban and community forests in Texas. The first section of the survey focused on Texas urban residents' general perceptions about social, economic, environmental, and health related benefits (or nuisances) associated with urban forests. The second section contained a choice experiment in which participants were asked to choose their preferred place of residence. Each neighborhood option varied by the following attributes; quantity of tree cover, type and availability of facilities, level of environmental health concerns, distance to public green space, and additional cost. Each attribute had three levels, generally representing a low, medium, or high option. In the third and final section, survey respondents were asked about their socio-demographic information such as age, education, gender, work focus, employment status, home ownership, and ethnicity.

Following web-based survey protocols, a 320-member review panel was established for testing prior to survey deployment. Comments from the review panel were incorporated into the final version of the survey before distribution. After distributing the survey, responses were collected in two steps: a) soft launch as a check point in which 68 respondents completed the surveys, b) full launch which resulted in 500 completed responses.

In the choice experiment, respondents were asked to consider a move from their current residence to two distinct neighborhoods. The new neighborhoods were assumed to be acceptable and attractive in terms of housing, quality of schools, transportation, and other factors. However, each neighborhood had differences in urban forest attributes, which were explained in detail on the survey. Respondents were asked to choose their preferred neighborhood, which could include staying at their current residence that did not have any urban forest attributes. A detailed explanation on attributes and their levels is presented in Table 6. A sample version of the survey is in the Appendix.

Among all of the attributes, tree cover was expected to increase a respondent's willingness to pay for the neighborhood having urban forest characteristics. Tree cover represented the density of trees in the neighborhood and surrounding areas and was categorized as: sparse tree cover (with 10% crown cover), moderate tree cover (35% crown cover) and dense tree cover (70% crown cover). Aerial photographs were incorporated into the survey to provide the respondent a visual representation of the forest attributes.

Table 6. Description and the level of the attributes used in the choice experiment model

ATTRIBUTES	DESCRIPTION	LEVEL		
Tree Cover	The density of trees in the neighborhood and surrounding areas	Sparse (10%)	Moderate (35%)	Dense (70%)
Facilities	The available facilities for recreational activities and enjoyment	No Playground	Small Playground	Big Playground
Environmental Health Concerns	Allergy, hay fever and other health concerns that some may experience when living in the neighborhood	Minimal Concerns	Moderate Concerns	High Concerns
Distance to Public Green Space	The walking distance from the new home that you are considering to the closest public green space	5 Minute	20 Minute	40 Minute
Additional Cost	The additional monthly costs that you would be required to pay to livein the neighborhood	$40/Month	$60/Month	$80/Month

The second attribute used in the choice experiment was facilities. Available facilities for recreational activities were categorized as: no playground, small playground and big playground. It was hypothesized that the presence of recreational facilities (such as a playground) would have a positive impact on a respondent's choice for the neighborhoods with urban forests attributes (i.e., moderate to dense tree crown cover).

Another attribute evaluated in the choice experiment was environmental health concerns. This attribute referred to allergy, hay fever and other health concerns that some may experience if living in a neighborhood with urban forest attributes. The options included: *minimal concerns, moderate concerns*, and *high concerns* and were categorical variables in the model. The attribute level minimal concern was treated as a base category and the other two levels, therefore, were expected to have a positive coefficient.

The distance from the new home to the closest public green space was also used as an attribute defining an urban neighborhood in the choice experiment model. The options were 5-minute, 20-minute, and 40-minute walk from place of residence to the nearest public green space. The attribute level was considered as a continuous variable and expected to have a negative coefficient.

Finally, the additional cost that respondents would be required to pay if living in the neighborhood of choice was also included as a variable in the model. Three additional costs considered for this model were: *$40 per month, $60 per month,* and *$80 per month*. The cost attribute was treated as a continuous variable and was expected to have a negative coefficient.

A total of 18 orthogonal choice sets were created. Due to the number and complexity of the experiment, the choice sets were divided into six groups, with each group containing three choice sets. The survey presented each respondent with a single, randomly selected group, but also ensured that each of the six groups would be fully represented (about 94 respondents per group).

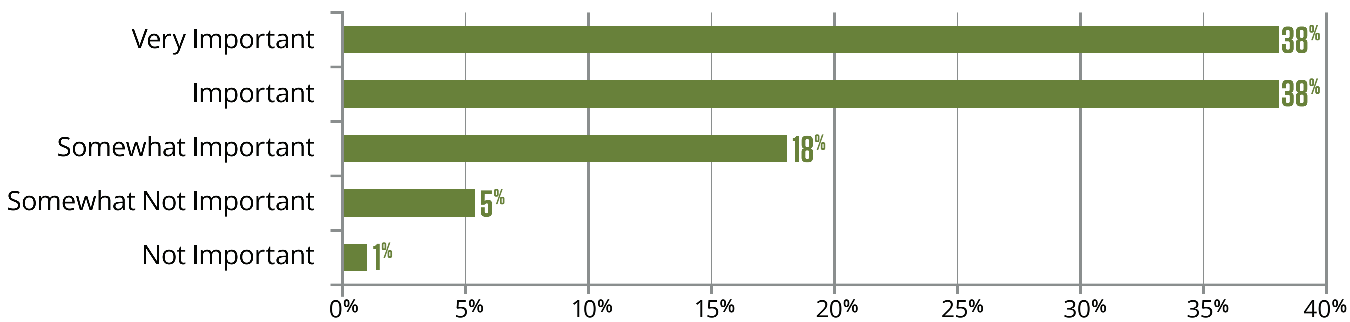
RESULTS

This study used 560 completed questionnaires. The survey respondents generally represented a younger group, with only 17% above 60 years old. Among respondents, 46% had full-time employment and 53% owned a home. The largest%age of survey respondents had a college degree and the vast majority (71%) felt that establishing and maintaining urban forests on nonresidential property is a local government responsibility. In terms of their preference for the neighborhood, 69% preferred to move into a neighborhood with urban forests even if it would cost them at least $40/month more. Respondents had a strongly positive opinion with social, economic, environmental, and health related benefits of urban forests and many thought that there were not enough drawbacks to complain about.

Role of Urban Forests in Increasing Property Value and Desirability

Survey respondents were asked to rate the role of urban forests in increasing property value and desirability in the Likert scale of 1 (not important) to 5 (very important). Among respondents, 76% felt that the presence of urban forests are somewhat or very important in increasing value and desirability of a property. Only 6% did not feel its importance.

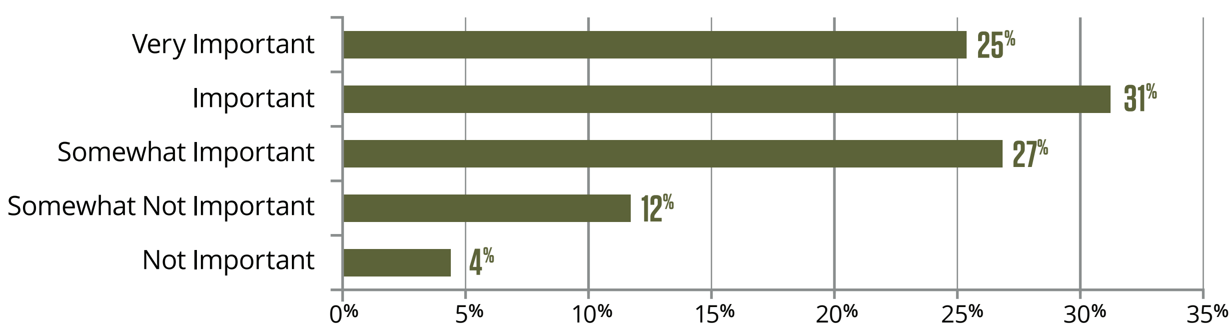
Figure 6. Survey respondents' rating on the importance of urban forests in increasing the value and desirability of property.



Role of Urban Forests to Improve Shopping Experience

The Likert scale ratings suggest that the majority of respondents (56%) strongly felt that the presence of urban forest can improve the shopping experience.

Figure 7. Survey respondents' self-evaluated rating on role of urban forests to improve shopping experience



Role of Urban Forests in Temperature Moderation

Respondents largely (82%) felt that urban forests were instrumental in temperature moderation in cities. This observation was consistent with the fact that urban forests help reduce energy demand.

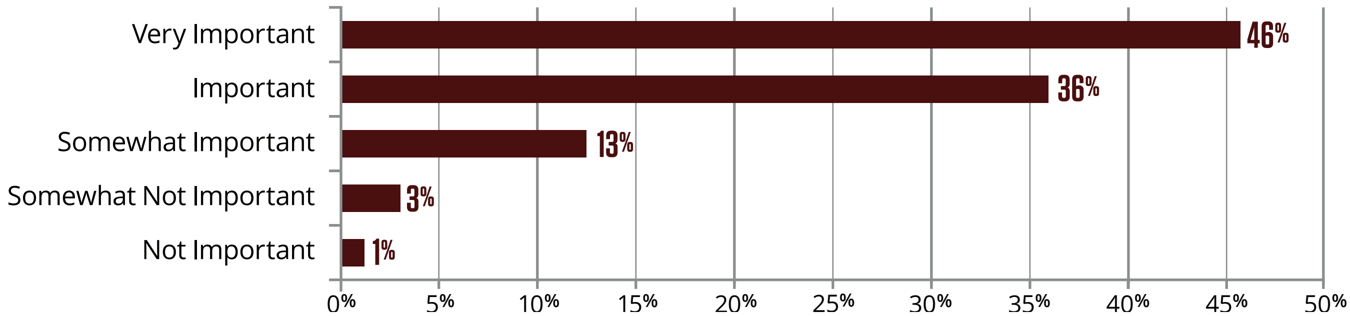


Figure 8. Survey respondents' self-evaluated rating on role of urban forests in temperature moderation

Role of Urban Forests in Improving Physical Health and Decreasing Obesity

Besides aesthetic appeal, urban forests are known for improving the overall quality of human health. Respondents generally or overwhelmingly (77%) believed that urban forests can improve physical health as well as be helpful in reducing obesity.

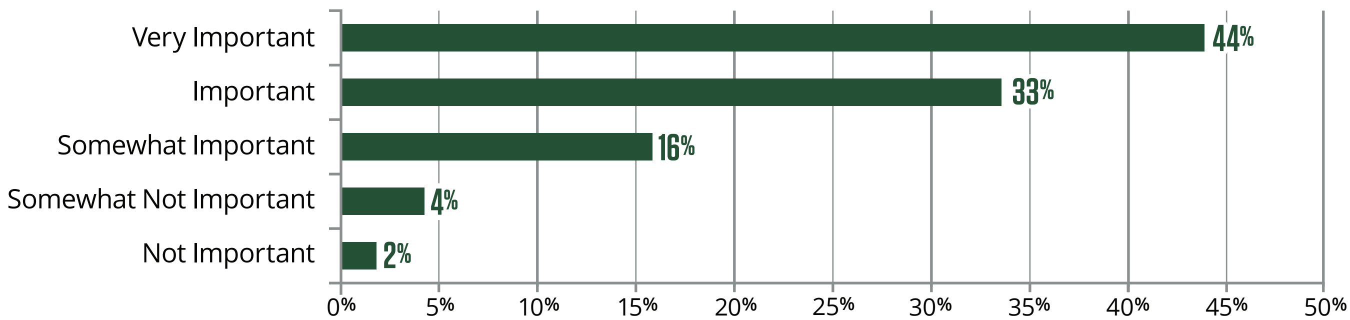


Figure 9. Survey respondents' self-evaluated rating on role of urban forest in improving physical health and reducing obesity

Personal Benefits of Urban Forests

Most respondents (78%) felt that being able to see trees was an important personal benefit of urban forests. Similarly, 60% believed that they receive cleaner air and 55% believed that urban forests can provide peacefulness and noise reduction.

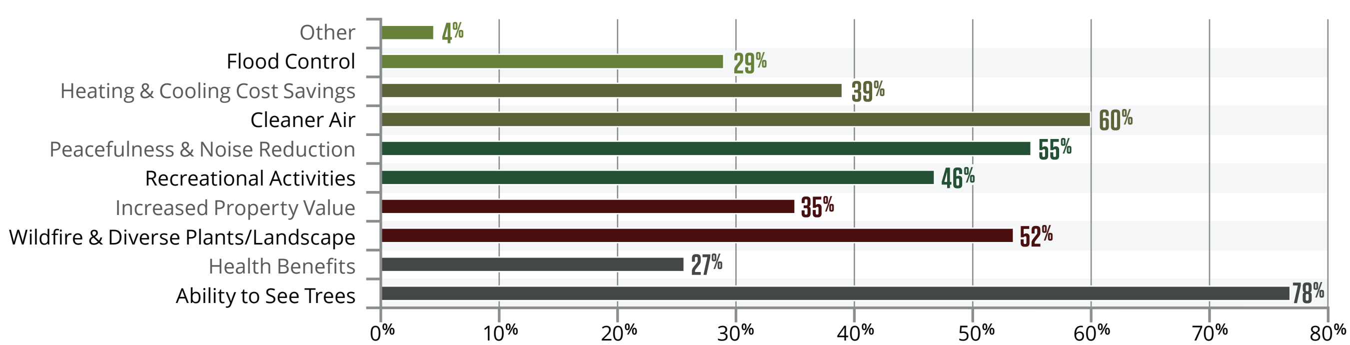


Figure 10. Survey respondents' evaluation of personal benefits they receive from urban forests

The results of the choice experiment were analyzed using a mixed logit model and are reported in Table 7. Positive coefficient values indicate the respondent's willingness to pay would increase with the increase in the attribute of interest, whereas negatives values reflect that the WTP would decrease as the attribute of interest increases.

The negative value for the Alternative Specific Constant indicated a respondent's general aversion towards the status quo (stay in current residence) and preference for a neighborhood with urban forest characteristics. The coefficient for variable 'tree cover' was positive and significant at the one percent level. The model results indicated that Texans were willing to pay more to live in a neighborhood having abundant trees. In terms of willingness to pay, Texans were willing to pay an additional $2.09 per month for a one percent increase in tree cover.

Table 7. Results based on mixed logit model and associated willingness to pay (WTP) for the attributes defining urban neighborhood

ATTRIBUTES	COEFFICIENT	IMPLIED WTP (per Month/Household)
Tree Cover	0.009**	2.09
Small Playground	-0.017	-3.92
Big Playground	0.217**	49.70
Minimum Environmental Health	0.268	61.34
Moderate Environmental Health	-0.048	-11.10
Distance to Public Green Space	-0.003*	-0.78
Additional Cost	-0.004*	
Alternative Specific Constant (ASC)	-0.255*	

**significant at 1% *significant at 10%

Similarly, the variable 'big playground' was positive and significant at the one percent level. However, the variable 'small playground' was not significant enough to influence a respondent's decision to move to a neighborhood having urban forests. Similarly, none of the variables capturing negative health concerns with urban forests were significant enough to influence a respondent's decision to move to a neighborhood having urban forests.

As expected, the variable representing distance from the new home to the closest public green space had a negative value and was in the borderline of significance at 10%. The results suggested that a one-minute additional walk for urban green space will reduce a resident's willingness to pay by 78 cents. Finally, the coefficient associated with the variable 'cost value' was negative and statistically significant at the 10% level meaning that residents were less interested to move if cost of living in a neighborhood having urban forests became higher.

DISCUSSION

The incremental willingness to pay for tree cover was aggregated to estimate the cultural services value placed by Texas residents on existing urban forests in their neighborhood. Table 8 reports total willingness to pay for urban forests in Texas. 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 by census block group was obtained from the 2014 American Community Survey conducted by the U.S. Census Bureau. The average percent tree canopy was computed for each block group. 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 total cultural value of urban and community forests.

AVERAGE TREE CANOPY (%)	TOTAL # HOUSEHOLDS (in Thousands)	ANNUAL WTP (Million $/Year)
0	476.3	0.0
0-10	4,894.5	330.0
10-20	1,528.2	452.6
20-30	772.3	366.7
30-40	476.6	296.1
40-50	294.4	213.0
50-60	193.6	126.1
60-70	88.6	42.4
70-80	26.4	5.5
80-90	2.6	0.1
90-100	0.3	0.0
Total	***8,753.8***	***1,832.4***

Table 8. Distribution of average willingness to pay (WTP) according to household numbers living in urban tree canopy in Texas

The study results suggest that Texans place the total dollar value of $1.8 billion per year to live in an area having some form of urban forests. Residents showed a strong sense of affection for social, economic, environmental and health-related benefits of urban forests. The descriptive and choice experiment-based results do not suggest any serious drawbacks associated with existing forms of urban forests in the state.

Value of Urban Forest Economic Services

The economic value of urban trees has historically been difficult to determine due to the lower product-based nature of urban and community forests compared to rural forests. There are numerous economic drivers derived from community trees, such as preference to shop at commercial districts with treescapes, increased property values, reduction in energy bills, and mulch and other products from urban wood. Of these and other economic benefits, there is sufficient literature to quantify the influence of trees on property value and energy savings, an important determinant of economic value from Texas urban and community forests.

METHODS

Property Value

A review of the research literature shows that residential trees can increase property values between 3% and 15%, depending on a number of factors, including size and species of tree and location of tree on lot (Donovan and Butry 2009, Bridges et al 2020). The increase in value extends to adjacent properties as well, with additional value decreasing as distance to tree decreases, becoming insignificant beyond 100 meters. This study utilized a conservative 3% impact on property value on low- and medium-intensity development lamd with trees present.

According to the Texas Real Estate Center, the median home price in Texas in 2020 was $275,800. To conservatively obtain the potential value due to the presence of trees, $275,800 was divided by 1.03 and the result was subtracted from $275,800, yielding a value of $8,033 per lot. This value was annualized by multiplying by the percent of single-family homes sold (65%) annually to give an annual value of $391.94. Two NLCD development classes are composed primarily of single-family homes: low-intensity developed and medium-intensity developed. Statistics show that median lot size in the low-intensity development class is <1.0 acre and that median lot size for medium-intensity development class is 8,100 ft^2, or 0.186 acres. Using these estimates, the potential value for a low-intensity development pixel is $87.17, and the potential value for a medium-intensity development pixel is $468.76 (Table 9).

Table 9. Potential property value due to trees per development class

DEVELOPMENT INTENSITY	ACRES / LOT	# OF 900m^2 PIXELS/LOT	ANNUAL VALUE /LOT	POTENTIAL ANNUAL VALUE / PIXEL
Low	1.000 ac	4.497	$391.94	$87.17
Medium	0.186 ac	0.836	$391.94	$468.76

To determine the value that trees add to property value, these per pixel values were applied in the respective development classes where tree canopy was at least 10%.

Energy Savings

Trees provide shade, wind protection, and changes in micro-climate humidity, influencing ambient and surface temperatures inside and outside of heated and air-conditioned buildings. An analysis of regional attributes (e.g., climate, average tree size and diameter, building composition and age) by Nowak et al (2017), set an average value of $508 in residential energy savings per hectare of tree canopy in Texas urban and community lands. For a 30-meter pixel, there is a maximum potential value of $45.72. This value was multiplied by the percent tree canopy within each 30-meter pixel to determine the value of energy savings provided by Texas urban and community forests.

RESULTS

The total annual value of the economic services provided by Texas urban and community forests is $502 million. This represents an estimated $5,424/acre/year of economic services. The contribution to property value across Texas by urban and community forests is $259 million, annually. Property value from trees is largest in Central Texas with a total of $166 million/year. This is followed by East Texas with added property value of $83 million/year through urban forest canopy. West Texas, with the least amount of urban and community lands, had added property value of $9.4 million/year. These results are detailed in Table 10.

The total energy savings provided to Texas residents through reduced energy use attributed to urban and community forests is $243 million/year across the state. Central Texas has annual energy savings of $136 million/year, with urban tree canopy providing annual energy savings in East and West Texas of $102 million and $5 million, respectively. Figure 11 represents the value of economic services relative to region.

Table 10. Estimated values of economic services provided by urban tree canopy in Texas

	CENTRAL	EAST	WEST	STATEWIDE
	Dollars/Year			
Property Value	166,320,294	82,889,934	9,415,427	258,625,654
Energy Savings	136,323,078	101,877,635	4,979,322	243,180,035
Total	***302,643,372***	***184,767,569***	***14,394,749***	***501,805,689***

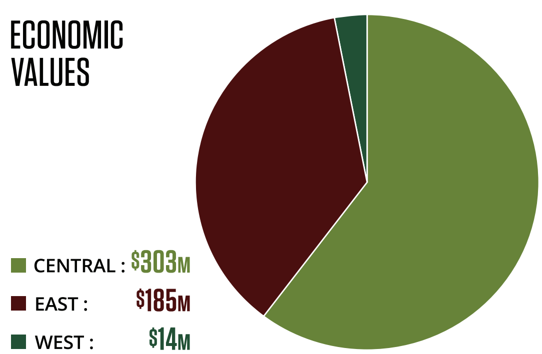


Figure 11. Total estimated annual value of economic services provided by urban tree canopy to residential areas in Texas by region

DISCUSSION

Trees strategically located near commercial and residential buildings can reduce energy usage through reduced heating and cooling needs and increase property value when a mature tree is located within 100 meters of a residence. When applied to single family residences, it is clear that urban tree canopy provides economic benefits to Texas residents. The significance of urban tree canopy for property value and energy savings are represented in the relationship between urban forest acreage and the monetary value given to each region. Central Texas has the largest acreage of urban forest and the largest totals of property value and energy savings while West Texas, with the smallest quantity of urban forest acreage, also has the smallest addition of property value and energy savings. As a limited and conservative approach to estimating economic ecosystem sevices value was used, it is likely that the economic value of urban and community forests surpasses the estimated value of $502 million annually.

Value of Urban Forest Human Health Services

As public health concerns of obesity, mental health and premature death from chronic diseases rise, understanding the connection between community trees and human health is more critical than ever. While many intuitively understand that living near trees and associated greenspace encourages feelings of well-being, numerous studies substantiate the positive connection between healthy trees and healthy lives.

Importantly, exposure to treed areas has been shown to have beneficial effects on psychological health (Kaplan 1995) and attention-deficit disorders (Taylor & Kuo 2009), as well as promote physical activity, reducing obesity and related morbidity (Maas 2009). Being around trees, even just having views of trees, can result in reduction of employee sick days (Kaplan 1993), surgery recovery times (Ulrich 1984) and crime and aggression (Kuo and Sullivan 2001). In addition, the amount of neighborhood tree cover has been shown to have an impact on cardiovascular and respiratory mortality (Donovan et al 2013) as well as birthweight (Abelt and McLafferty 2017 Donovan et al 2011). In short, a healthy, abundant, accessible community tree canopy is a crucial component of public health strategies.

As more people move to cities and urban areas, there is greater impetus to understand and apply the interrelationship between urban and community forests and human health. Nature-based community health strategies are becoming more common, yet across the literature, estimations of the public health benefits provided by urban forest ecosystems have been limited. This section estimates the economic value of select human health benefits provided by urban and community forests in Texas.

METHODS

Health Care Savings

An extensive review of peer-reviewed journal articles identified several public health outcomes that had direct economic benefits from the community forest. Three of these have published quantifiable metrics which can be applied to the urban tree canopy data layer in Texas for spatial analysis. The three indicators used to quantify and value human health benefits provided by urban and community forests were cost-savings from the reduction in medical expenses associated with obesity (expenses/person/year), the reduction in hospitalizations due to stroke (cases/year), and the reduction in cases of depression (cases/year).

Model input data were obtained from the National Land Cover Database (NLCD), Texas Department of State Health Services (percent of Texas population considered obese, rate of hospitalization due to stroke, excess annual medical costs associated with obesity, daily cost of hospitalization due to stroke), Substance Abuse and Mental Health Services Administration (cases of depression per Texas resident), and scholarly papers on the cost of depression (Greenburg et al 2015) and estimated effect of nearby tree canopy on these health metrics (Brown et al 2021, Lovasi et al 2013, Ellaway et al 2005).

Annual avoided health care cost estimates from obesity and stroke were standardized per square meter of tree cover for every community in Texas using state and national data. For spatial quantification, the avoided health care estimates were applied only to the top 25 percentile of urban tree canopy (highest UTC quartile) on a by-county basis and each pixel multiplied by percent tree canopy. Annual health cost savings were then applied to the U.S. Census Block Group population figures for the spatial area.

To calculate the reduction in medical expenses associated with obesity, the model applied the rate of obesity in Texas (30% of Texans considered obese), the excess annual medical costs of an obese person compared to a person of average weight ($1,900/year), and the estimated reduction in risk of obesity for people living in neighborhoods of higher tree cover (40%), to NLCD development classes within the highest UTC quartile of each county.

To calculate the cost savings due to the reduction in hospitalizations from stroke, the model applied the rate of hospitalization (2.2% of Texans hospitalized due to stroke), the cost of an average hospital stay from stroke ($209,880/stay), and the estimated reduction in number of stroke hospitalization cases associated with higher relative tree canopy (20%), to areas (pixels) of the highest quartile of tree cover within the development classes of the NLCD.

To calculate the cost savings from the reduction in the number of cases of depression, the model applied the rate of depression (14.14 cases/1,000 Texans), the annual medical cost of depression ($7,126/person), and the reduction in cases of depression in people living near a biologically diverse ecosystem (5%), to the top 10% of the EPA's Regional Ecological Assessment Protocol (REAP) composite layer, considered to be biological "hotspots", that were found within the NLCD Development Classes. Annual cost savings were multiplied by the total number of residents living within 250 meters of one of these biodiversity hotspots. This population estimate was derived from the number of building footprints within 250 meters of a hotspot multiplied by the median number of people per household (2.84).

Avoided Health Costs from Air Pollution Removal

Trees remove gaseous air pollution and fine particulates through uptake and interception by leaves. The USDA Forest Service estimated the value of urban tree canopy in removal of six air pollutants (CO, NO_2, O_3, $PM_{2.5}$ and SO_2) and particulate matter across the United States. Removal estimates are based on modeling of gas exchange and particulate matter interception. Valuation for CO is calculated based on the median externality value and producer price index. Valuation for NO_2, O_3, $PM_{2.5}$ and SO_2 is calculated using US EPA's BenMAP (US EPA 2015a). The Texas estimate ranged from 0 to $\$65.34/m^2$ of canopy depending on factors such as local leaf area index, wind speed, precipitation and existing air quality. This value was averaged across counties and applied to urban tree canopy in NLCD Development Classes at $\$26.60/m^2$.

RESULTS

The geospatial overlay analysis estimated the highest quartile of tree cover represents 10.% of all urban and community lands in Texas. The highest quartile of tree cover varied significantly across communities, from the lowest minimum top quartile value of 0.00225% tree cover (City of Pecos, Pecos County) to the highest minimum top quartile value of 65.6% tree cover (City of Pine Forest, Orange County). Approximately 2.9 million people across the state live within this area of highest quartile. Applying the estimated rates of reduction in hospital stays due to stroke and cases of obesity to people living in these top UTC quartiles, Texas urban and community forests save $3.3 billion dollars, annually, in medical expenses related to these conditions. Additionally, 23.7% of the biologically diverse REAP hotspot sites within urban and community lands were found in the NLCD development classes. An estimated 685 thousand people live within 250 meters of these hotspots. Applying the reduction in the rate of depression, these residential biodiversity hotspots contribute an additional $3.5 million dollars, annually, in medical cost savings. Regionally, $2.5 billion dollars in annual medical cost savings comes from cities in the Central Texas region, $748.6 million from East Texas and $119.8 million from West Texas (Figure 12). An additional $63.4 million in healthcare savings occurs from the reduction in air pollution across the state. Combining these values, avoided health costs from the 1.2 million acres of urban and community forests in Texas is estimated at $3.4 billion dollars a year (Table 11).

Table 11. Estimated values of human health services (Million $/year) provided by urban tree canopy in Texas.

	CENTRAL	EAST	WEST	STATEWIDE
Air Pollution	33,150,782	29,111,852	1,206,841	63,469,475
Obesity & Stroke	2,459,416,275	748,666,946	119,836,857	3,327,920,078
Health Biodiversity	2,824,950	541,260	85,686	3,451,896
Total	***2,495,392,006***	***77,320,058***	***121,129,385***	***3,394,841,449***

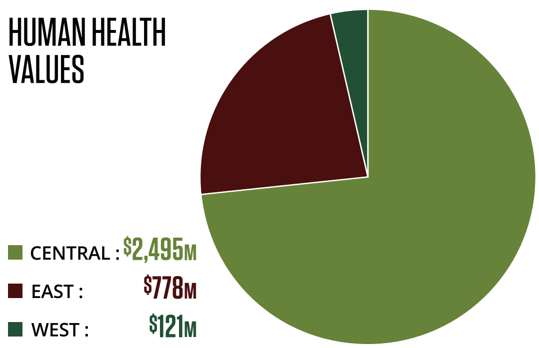


Figure 12. Regional contribution to annual state-wide value of human health services provided by trees and forests in urban and community areas

DISCUSSION

This assessment was conducted as a broad-brush evaluation of the impacts of community trees on human health. Health impacts from nature are difficult to quantify as there can be many confounding factors, such as age of neighborhood, building materials, income, family size, compounded health issues and so on, that can introduce bias and skew results. As such, per acre health benefits in this assessment were limited to those health metrics with consistent documentation in discrete costs and connection with trees and forests (obesity, stroke hospitalization, and depression). Some of the other health benefits from community trees not included in this assessment are reduction in pre-term births and increased birthweights, lower incidences of heart disease, reduction in heat-related illness anddeaths, faster recovery times and better self-reported mental health.

While a single tree in a neighborhood of any percent tree cover can impact health in a positive way, the literature demonstrates that significant, measurable health benefits are typically associated with higher relative tree cover, as opposed to absolute tree cover. People living in the eastern United States where tree cover routinely exceeds forty percent are not reportedly happier and healthier than people living in the west where urban tree canopy may never reach twenty percent. Thus, considering the diversity of Texas ecoregions, this assessment looked at each county individually and applied the benefit value to the highest quartile of each community. As some health benefits are also realized in mid and low tree cover quartiles and other possible health metrics were not assessed at all, it is likely that the actual health benefit from community forests exceeds the annual estimated $3.4 billion dollars.

Value of Urban Forest Watershed Services

Over one-half of the nation's freshwater resources originate from forests that cover about one-third of the United States. Healthy forests are critically important to protecting water resources, providing the cleanest water of any land use. They also absorb rainfall, recharge groundwater aquifers, slow and filter stormwater runoff, reduce floods, 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 and providing frontline pollution filtration services.

Numerous studies have documented the benefits of urban trees in reducing the amount and concentration of stormwater that enters waterways following rain events. Tree canopies intercept and hold rain droplets, reducing the volume and impact of precipitation falling to the ground. Rooting space occupied by trees increases infiltration rates and the water-holding capacity of the soil. Transpiration moves water from the soil back to the atmosphere, creating additional room for water storage in the soil. Lastly, tree roots and soil microbes filter nutrients and chemicals from subsurface flows through the soil, providing a valuable buffer to nearby streams. All of these processes work together to reduce stormwater runoff and erosion in what is referred to as the forest–water relationship.

Increasing population, water demand, and the frequency and intensity of natural disasters have the potential to disrupt these critical watershed functions. This section estimates the economic values of watershed services provided by urban and community forests in Texas.

AVOIDED RUNOFF

Any time precipitation falls on the ground, it has the potential to pick up debris, chemicals, sediment, and other pollutants and deliver them to a municipal stormwater system or directly to a stream, lake, or river. This is particularly true with impervious surfaces as essentially all precipitation is converted to runoff. Since many waterways are often sources of public drinking water supplies, increases in impervious cover can have substantial impacts on human health, water quality, and aquatic ecosystems.

Annual avoided runoff was the primary watershed function that was used to quantify and value watershed services provided by urban and community forests. This function refers to the ability of trees and vegetation to store, utilize, and return precipitation to the atmosphere, thereby reducing the amount and intensity of stormwater runoff that can result in flooding and/or nonpoint source water pollution. Avoided runoff relates most closely to the water regulation / disturbance prevention function used in the *Texas Statewide Assessment of Forest Ecosystem Services, 2013*.

METHODS

County-based hydrologic estimates produced by i-Tree Eco (Hirabayashi 2015) were used to assess watershed services provided by urban and community forests in Texas. This open-source, peer-reviewed model integrates local weather, tree canopy, impervious cover, and leaf area index data to generate hourly estimates of hydrologic variables (*potential evaporation, potential evapotranspiration, evaporation, transpiration, precipitation interception,* and *avoided runoff*). Model input data were obtained from the National Climatic Data Center, National Land Cover Dataset, and NASA's MODIS satellite sensor.

These hourly estimates were summed throughout the year and multiplied by the area of urban land in each county to derive an annual total volume for each hydrologic variable (cubic meters/year). Urban

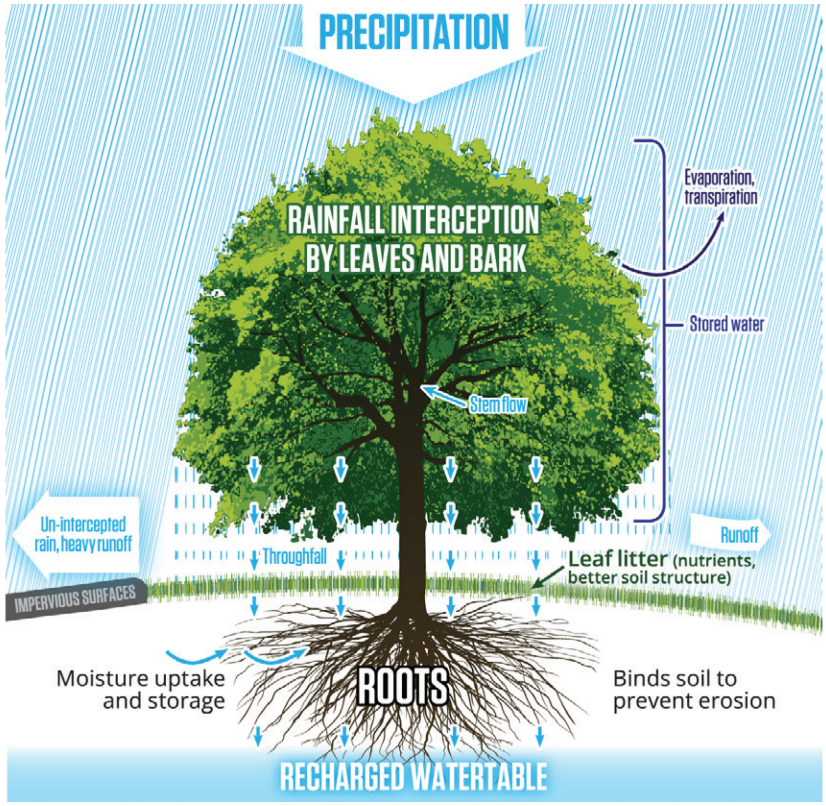


Figure 13: Graphic showing urban forests' ability to manage stormwater runoff

areas were delimited using 2010 Census data. Results were then standardized per square meter of tree cover based on 2010 local weather data and county specific tree and impervious cover data, percent evergreen cover, and leaf area index values, and averaged to generate a statewide value. Standardizing the county-based, annual hydrologic estimates by tree cover enabled spatial quantification in ArcGIS.

To calculate annual avoided runoff, i-Tree Eco simulated stormwater runoff for two scenarios, 1) with current tree cover and 2) with no tree cover, for every county in Texas. The difference in surface runoff between the two simulations represented the effect of trees and vegetation on reducing surface runoff. Estimates were averaged to create a statewide value (0.009406 meters/year) and multiplied by tree canopy within urban areas and places. The US national average dollar value for avoided runoff, ($0.008936/gallon) was then applied to these avoided runoff estimates. This rate is based on 16 studies of costs of stormwater control (USDA Forest Service's Tree Guide). Community results were summed to calculate statewide and regional values.

RESULTS

Annually, Texas urban and community forests mitigate over 11.9 billion gallons of stormwater runoff. The total value of watershed services provided by Texas urban and community forests was $106.3 million (Table 12).

Table 12. Estimated amount and value of avoided runoff provided by urban tree canopy in Texas

	CENTRAL	EAST	WEST	STATEWIDE
	Gallons H_2O/Year			
Avoided Runoff	6,668,028,462	4,983,183,953	243,555,676	11,894,768,091
	Dollars/Year			
Value	59,585,502	44,529,732	2,176,414	106,291,648

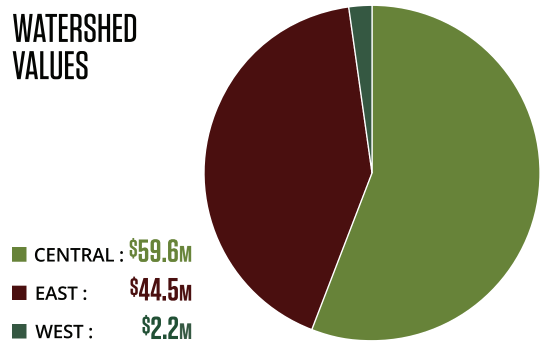


Figure 14. Regional contribution to annual avoided runoff value

DISCUSSION

This assessment was conducted as a broad, statewide evaluation of urban and community forests in Texas. As such, values were not differentiated among species group, forest condition, or forest cover type. Unlike the previous assessment, value was assessed primarily based on tree canopy stocking level instead of proximity to water, where riparian and wetland forests were highly valued. Future valuation efforts may look to increase the resolution of the economic estimates to better account for the differences in forestland across the state.

While urban and community forests play a critical role in other watershed regulating services, such as water capture and water filtration, they were not specifically quantified and valued in this assessment. All of these services are inter-related and inter-dependent, though the strongest documented connection in the literature was avoided runoff.

Soil stabilization provided by trees is a critical ecosystem service, preventing erosion from polluting water bodies, securing stream banks and flood plains, and maintaining soil productivity. Additionally, riparian trees provide stream thermal protection, aquatic habitat of submerged tree roots, and detritus/organic material food sources, which also support biodiversity. These functions were not specifically assessed, however it can be assumed that some value derived from these services is included in the biodiversity valuation.

The i-Tree Eco model includes several assumptions. For simplicity, the model assumes that all precipitation falling on pervious cover infiltrates into the ground and all precipitation that lands on impervious cover will run off. This has the potential to over-estimate avoided runoff since some precipitation events will be intense enough to generate runoff from pervious surfaces. However, since the model only factors in tree leaves in the rainfall interception calculation, and not branches, twigs, and bark, the potential for over-estimation may be offset.

The amount of leaf area is far more influential than the total number of trees in the avoided runoff calculations. For instance, a few scattered large, mature trees with high leaf surface areas will likely produce greater estimates of avoided runoff than many smaller sized trees with sparse canopies.

Other Considerations of Urban Forest Services in Texas

MANAGEMENT

Urban and community forests are often characterized by their structure (horizontal and vertical distribution of vegetation) and composition (species, age, and health). These elements are determinants of ecosystem function, which itself is a means of mitigating environmental quality issues associated with the built environment (Nowak et al 2006). Therefore, by altering the structure and composition of the urban forest — managing the urban forest — we can enhance ecosystem functions that maximize human well-being in cities.

Urban and community forest management encompasses activities associated with maintenance as well as planning and implementation. A well-managed urban forest is more resilient, leading to less tree damage and associated loss of ecosystem services following storms and weather events. Large, mature trees have higher ecosystem services relative to small, young trees, and proven success in their environment. However, it is important that the urban forest have a broad age-class distribution to ensure the next generation of trees and a consistent supply of services. In the same way, species diversity is critical for sustainability. As exotic pests and diseases make their way across the globe, a community forest that lacks diversity may be decimated in a single season with a single pest. Applying strategic management principles and regular maintenance, not only decreases risk of harm to people and property from neglected trees, but enhances quality of life for residents.

URBAN FOREST DISSERVICES

Urban forests can also incur costs due to maintenance and management requirements, contribute to the perceived risk of crime, and produce pollen and other allergens. Since these could have a negative effect on human well-being, these functions are referred to as disservices and are common to human influenced ecosystems.

While planting, pruning, and general maintenance of community trees can be expected as part of management of a city's green infrastructure in the same way as maintenance of the gray infrastructure components such as sewers, streets and utility lines, the cost of such activities does partially offset the value of the benefits. However, peer-reviewed research consistently reports the annual return on investment of a single tree is fivefold. Sometimes trees interfere with the built environment, such as root lift of sidewalks or curb and gutters, resulting in necessary repair or replacement. Infrastructure repair costs are themselves a result of improper placement or species selection and can be reduced through community forest master planning.

Other disservices are less quantifiable. Trees release a certain amount of chemical emissions called volatile organic compounds (VOCs). Trees use VOCs to attract pollinators and repel harmful insects and animals. They also produce VOCs in response to stress. VOCs bind with other chemicals in the atmosphere to contribute to air pollution. Some species, such as poplar and willow, are known to emit a higher quantity of VOCs. Species also influences allergens. About seven percent of the nation's population suffer from seasonal allergies due to trees, grasses, weeds and other plants (Asthma and Allergy Foundation of America, 2018). In Texas, pollen from Ashe juniper and oak are known contributors in winter and spring, respectively. Selecting the "right tree for the right place" can help reduce disservices of the urban forest ecosystem.

Risk, perception of risk, and other disservices can be reduced through techniques like pruning to lift canopy that improves visibility, ensuring adequate space and soil volume, and selecting appropriate species. Inventories and management plans identify gaps or needs in the community forest relative to public health, safety and well-being and outline steps for optimization. Understanding the resource and targeted planning to sustain it can enhance the value provided by the community forest ecosystem.

Summation of Urban Forest Services in Texas

Texas urban and community forests provide numerous ecosystem services that are essential to the survival and well-being of all residents. These forests cover 1.2 million acres in urban areas, and collectively are valued at $6.1 billion annually (Table 13).

Table 13. Value of ecosystem services provided by Texas urban and community forests

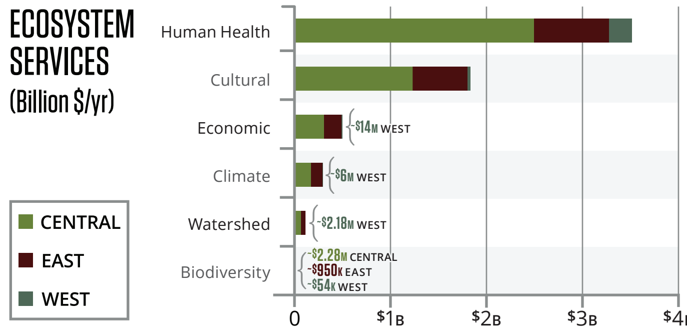
	CENTRAL	EAST	WEST	STATEWIDE
Tree Canopy	Acres			
	663,114	495,561	24,221	1,182,896
Biodiversity	Dollars/Year			
	2,278,228	949,498	53,993	3,281,719
Climate				
Carbon Storage	70,741,597	52,866,960	2,583,900	126,192,457
Carbon Growth	37,269,656	27,852,544	1,361,307	66,483,507
Avoided Emissions	55,548,970	41,513,131	2,028,976	99,091,077
Total	*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				
Property Value	166,320,294	82,889,934	9,415,427	258,625,654
Energy Savings	136,323,078	101,877,635	4,979,322	243,180,035
Total	*302,643,372*	*184,767,569*	*14,394,749*	*501,805,689*
Human Health				
Air Pollution	33,150,782	29,111,852	1,206,841	63,469,475
Obesity & Stroke	2,459,416,275	748,666,946	119,836,857	3,327,920,078
Health Biodiversity	2,824,950	541,260	85,686	3,451,896
Total	*2,495,392,006*	*778,320,058*	*121,129,385*	*3,394,841,449*
Watershed				
Avoided Runoff	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*

At 55%, human health services, by far, made the greatest contribution to the total urban and community forest ecosystem service value in Texas (Figure 15). Reduction in medical costs associated with reduced risk of obesity and stroke was the largest contributor to this service.

BIODIVERSITY SERVICES

Biological diversity is a valuable resource because it underpins all ecosystem functioning and associated services essential in supporting human existence. Understandably, most urban and community lands are low in biodiversity. Texas has 63,415 acres of urban and community tree canopy that are considered significantly biologically diverse, providing an annual ecosystem service value of $3.3 million/year. Recognizing the ecological importance of biodiverse "hotspots" provides resource managers and policy makers the appropriate data to prioritize opportunities for avoiding potential impacts on these higher-value areas before loss occurs.

Figure 15. Value (Billion $) of ecosystem services for Texas urban and community forests, by region



CLIMATE SERVICES

With carbon an ever-growing part of the public conversation, it is important to understand the associated benefits related to climate ecosystem services that come from trees. The total economic value of climate services in Texas urban and community forests is valued at $292 million/year. This value includes all pillars of carbon assessment: carbon stocks, carbon accumulation, and avoided emissions through energy savings.

CULTURAL SERVICES

Texans are 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 tree crown cover, translating to a total cultural value of Texas urban and community forests to the residents of Texas of approximately $1.8 billion/year. However, this is just one component of cultural value from urban and community forests. Trees help define the sense of place of a community, which is often an underlying factor of why people move to an area and why they stay. This, in turn, contributes to feelings of connectedness, which can lead to reduced crime and increased desire to engage in volunteer activities. These have intrinsic value that directly and indirectly lead to economic value related to reduction in labor and infrastructure costs, neither of which are evaluated and quantified in this assessment.

ECONOMIC SERVICES

The economic value of urban and community forests is evident in the correlation between the presence of urban tree cover and the corresponding increase of property value and decrease in energy usage. Community trees save urban Texas residents $243 million/year in energy costs while simultaneously adding $259 million/annually to property value. Always important in the hot Texas climate, this is more critical than ever as volatile weather events become the norm and energy prices rise.

HUMAN HEALTH SERVICES

The estimated value of human health services from Texas' urban forests is $3.4 billion annually. Per acre health benefits in this assessment were limited to those health metrics with consistent documentation in discrete costs and connection with trees and forests (obesity, stroke hospitalization and depression) and healthcare savings occurring from the reduction in air pollution; there are many more health benefits realized from having access to trees. These benefits accrue from nearby trees and, with strategic planning, planting and policy, can be a nature-based solution to the issues of socioeconomic disparities in health and environmental inequity.

WATERSHED SERVICES

Watershed services provided by Texas urban and community forests are valued at more than $106 million annually. While this amount is substantial, it is constantly at risk, given the fact that urban forests are threatened by land conversion, insects and disease, and natural disasters. Forest conversion and tree mortality, regardless of the cause, can result in substantial changes in watershed function and hydrology. Often, this leads to an increase in impervious cover, reducing water infiltration and aquifer recharge, while increasing stormwater runoff and flooding. The complex interactions among natural hydrologic and ecological processes, land use, and water management underscore the need for sustainable urban forest management programs.

USES, LIMITATIONS, AND FUTURE STEPS

The goal of this assessment was to assess the conservative economic value of urban and community forest ecosystem services in Texas, a complicated task, given a state as diverse as Texas. Recognizing these values is paramount to smart land use planning and the long-term sustainability and resiliency of Texas community forests. Expanding the land-use cost-benefit analysis to incorporate the economic impact of these ecosystem services will enable a more realistic and clearer assessment of the full costs and benefits of both the landscape itself, as well as any future landscape changes.

The results of this assessment can be accessed through www.texasforestinfo.com (Figure 16). This interactive website provides a wealth of information about the state's tree and forest resources, as well as the benefits they provide. The "Forest Ecosystem Values" application links to the geospatial data used in this assessment and enables users to view maps, obtain ecosystem service values and print reports for customized areas of the state.

This assessment quantifies and values only specific ecosystem services provided by Texas urban and community forests. Other lands, such as agricultural, prairie, and rangelands within the project scope, were not included in this assessment. While these results can be used to assess the effects of forest conversion, the total change in ecosystem service value is largely dependent upon the new land use.

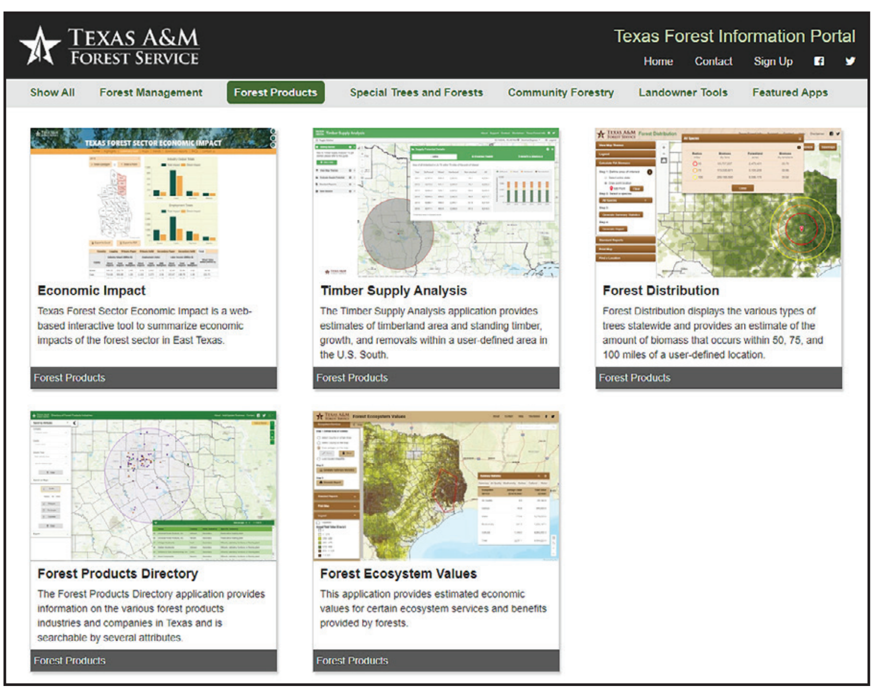


Figure 16. The Texas Forest Information Portal contains numerous tools for assessing forest resources in Texas

Additionally, this assessment was conducted as a broad, regional evaluation of urban and community forests in Texas. As such, per acre ecosystem service values were not differentiated between species group or forest condition. Regional ecosystem service values were largely based on the number of acres covered by tree canopy within the respective area, regardless of their composition or health

While there have been many attempts to value ecosystem services across the world, these assessments are still in their infancy and constantly evolving. As these services continue to gain notoriety, additional studies will undoubtedly be conducted, leading to improved economic estimates of urban and community forest-based ecosystem services in Texas. Future valuation efforts will look to incorporate the most recent economic estimates, identify methodologies that account for the differences in forestland composition, stocking, and health and utilize updated, higher resolution geospatial data.

Currently, a great deal of effort is ongoing to improve and develop new models (primarily process models) that more accurately assess and predict any number of ecosystem services. Soon, robust models will be available to map, assess, and predict the various ecosystem services to finer detail, thus allowing future efforts to more accurately estimate economic values of ecosystem services provided by forests and woodlands in Texas. Researchers with USDA Forest Service and Davey Resource Group are constantly working to improve the accuracy and functionality of the i-Tree suite of tools. As new models become available, Texas A&M Forest Service will consider them for applicability in valuing urban and community forest ecosystem services in Texas.

References

Abelt, K.A., S. McLafferty. (2017). Green streets: Urban green and birth outcomes. *International Journal Environmental Research and Public Health.* 14(7):771.

Ando, A., J. Camm et al. (1998). Species Distributions, Land Values, and Efficient Conservation. *Science.* 279(5359), 2126.

Brahic, E., J. Terreaux. (2010). Problems and methods of forest-biodiversity economic valuation. Sciences Eaux & Territoires, no. 03bis, 16-19.

Bridges, L.E., S.C. Grado, J.S. Gordon, D.L. Grebner, J.D. Kushla. (2020). The influence of canopy cover on property values in a small southern U.S. city. *Arboriculture & Urban Forestry.* 46(4): 262-275.

Brouwer, R. (2000). Environmental value transfer: state of the art and future prospects. *Ecological Economics.* 32(1), 137-152.

Brown, S.C., W. Aitken, J. Lombard, K. Wang, T. Rundek, C. Dong, C.M. Guitierrez, M.M. Bryne, M. Toro, M. Nardi, J. Kardys, A.K. Parrish, J. Szapocznik. (2021). Abstract P631: The Relationship of Neighborhood Greenness to Stroke/ Transient Ischemic Attack in 249,405 US Medicare Beneficiaries. *Stroke.* 52:AP631. www.ahajournals.org/doi/10.1161/str.52.suppl_1.P631.

Chan, K., T. Satterfield, J. Goldstein. (2012). Rethinking ecosystem services to better address and navigate cultural values. Ecological Economics. 74: 8-18.

Christie M, N. Hanley, J. Warren, K. Murphy, R.Wright, T. Hyde. (2006) Valuing the diversity of biodiversity. *Ecological Economics.* 58:304–317

Czajkowski, J. R. (2009). Modeling Shifts in Willingness to Pay from a Bayesian Updating Perspective. *Land Economics.* 85(2):308–328.

Convention on Biological Diversity. (2010). Case Study for Australia - Ecosystem Approach to Sustainable Forest Management Practices – Regional Forest Agreements.

Costanza, R., R. d'Arge., R. de Groot., S. Farber., M Grasso., B. Hannon., K. Limburg., S. Naeem., R. O'Neill., J. Paruelo., R. Raskin., P Sutton., M. Belt. (1997). The value of the world's ecosystem services and natural capital. *Nature.* 387:253-260.

Cox, D.T.C., D.F. Shanahan, H.L. Hudson, R.A. Fuller, K. Anderson, S. Hancock, K.J. Gaston. (2017). Doses of nearby nature simultaneously associated with multiple health benefits. *Journal of Environmental Research & Public Health.* 14(2):172.

Daily, C. (1997). Nature's Services. *Societal Dependence on Natural Ecosystems*. Washington, D. C.: Island Press, p. 392.

de Groot, R. S., M. A. Wilson, R. M. J. Boumans. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics.* 41:393-408.

Dillman, D.A., J.A. Smyth, and L. L. Christian. (2009). *Mail and internet surveys: The tailored design method*. 3rd ed. John Wiley & Sons, New York, NY. 499 p.

Dimke, K.C., T.D. Sydnor, D.S. Gardner. (2013). The effect of landscape trees on residential property values of six communities in Cincinnati, Ohio. *Arboriculture & Urban Forestry*. 39(2):49-55.

Donovan, G.H., D.T. Butry. (2009). Trees in the city: Valuing street trees in Portland, OR. *Landscape and Urban Planning*. 94:77-83.

Donovan, G.H., D.T. Butry, Y.L. Michael, J.P. Prestemon, A.M. Liebhold, D. Gatziolis, M.Y. Mao. (2013). The relationship between trees and human health evidence from the spread of the emerald ash borer. *American Journal of Preventative Medicine*. 44:139–145.

Donovan, G.H., Y.L. Michael, D.T. Butry, A.D. Sullivan, J.M. Chase. (2011). Urban trees and the risk of poor birth outcomes. *Health Place.* 17:390-393.

Ellaway, A., S. Macintyre, X. Bonnefoy. (2005). Graffiti, greenery, and obesity in adults: secondary analysis of European cross sectional survey. *BMJ*, 331(7517): 611–612.

Gonzalez-Benecke, C.A., T.A. Martin, E.J. Jokela, R. De La Torre. (2011). A flexible hybrid model of life cycle carbon balance for loblolly pine (Pinus taeda L.) management systems. *Forests*, 2(3),749-776.

Greenberg, P.E., A.A. Fournier, T. Sisitsky, C.T. Pike, R.C. Kessler. (2015). The economic burden of adults with major depressive disorder in the United States (2005 and 2010). *Journal of Clinical Psychiatry*. 76(2):155-62.

Hirabayashi, S. (2015). i-Tree Eco Precipitation Interception Model Descriptions. http://www.itreetools.org/eco/resources/iTree_Eco_Precipitation_Interception_Model_Descriptions.pdf

Hirabayashi, S., D.J. Nowak. (2015). i-Tree Eco United States County Based Hydrologic Estimates and Estimates of Species Differentiation.

Holmes, P.T., W.L. Adamowicz. (2003). Attribute-based methods. P. 171-219 in *A primer on nonmarket valuation.*, A.P. Champ, J.K. Boyle, and C.T. Brown, (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands.

Hooper, D.U., F.S. Chapin III, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, D. M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setälä, A. J. Symstad, J. Vandermeer, and D. A. Wardle. (2005). Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs.* 75(1):3–35.

Huang, C. H., G.D. Kronrad. (2001). The cost of sequestering carbon on private forest lands. *Forest Policy and Economics*. 2(2):133-142.

i-Tree Users Manual v6. Retrieved December 10, 2021 from https://www.itreetools.org/documents/275/EcoV6_UsersManual.2021.09.22.pdf

Jackson, C.R., G. Sun, D.M. Amatya. (2004). Fifty years of forest hydrology in the Southeast . In: Ice, G.G; Stednick, J.D., eds. A century of forest and wildland watershed lessons. Bethesda, MD: Society of American Foresters. 33–112.

Kaplan, S. (1995). The Restorative Benefits of Nature: Toward an Integrative Framework. *Journal of Environmental Psychology*. 15:169-182.

Kaplan, R. (1993). The Role of Nature in the Context of the Workplace. *Landscape and Urban Planning*. 26:193-201.

Kroeger, T., S. Johnson, J. Horn. (2012). Species conservation value of non-industrial private forestlands. In: Stewardship Ecosystem Services Survey Project. . Eds: F. Escobedo and N Timilsina. Univ. of Florida.

Kuo, F.E., W.C. Sullivan. (2001). Environment and crime in the inner city: Does vegetation reduce crime? *Environment and Behavior.* 33:343-367.

Liu, S., R. Costanza, A. Troy, J. D'Agostino, W. Mates. (2010). Valuing New Jersey's ecosystem services and natural capital: a spatially explicit benefit transfer approach. *Environmental Management*. 45:1271-1285.

Loomis, J., E. Ekstrand. (1998). Alternative approaches for incorporating respondent uncertainty when estimating willingness to pay: the case of the Mexican spotted owl. *Ecological Economics*. 27(1):29-41.

Lovasi, G.S., O. Schwartz-Soicher, J.W. Quinn, D.K. Berger, K. Neckerman, R. Jaslow, K.K. Lee, A. Rundell. (2013). Neighborhood safety and green space as predictors of obesity among preschool children from low-income families in New York City. *Preventive Medicine*. 57(3):189–193.

Maas, J., R.A. Verheij, S. de Vries, P. Spreeuwenberg, F.G. Schellevis, P.P. Groenewegen. (2009) Morbidity is related to a green living environment. *Journal of Epidemiology and Community Health*. 63(12):967-973.

McPherson, E.G., Simpson, J.R., Peper, P.J., Gardner, S.L., Vargas, K.E., Maco, S.E., Xiao, Q. (2006). *Coastal Plain Community Tree Guide: benefits, costs, and strategic planning.* General Technical Report PSW-GTR-201. Albany, CA. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 105p.

REFERENCES

Mendoza-González, G., M.L. Martínez, D. Lithgow, O. Pérez-Maqueo, P. Simonin. (2012). Land use change and its effects on the value of ecosystem services along the coast of the Gulf of Mexico. *Ecological Economics.* 82:23–32.

Milcu, A. Ioana, J. Hanspach, D. Abson, J. Fischer. (2013). Cultural ecosystem services: a literature review and prospects for future research. *Ecology and Society*. 18(3):44.

Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: synthesis. Washington, D. C.: Island Press.

Mullan K., A. Kontoleon. (2008). Benefits and costs of forest biodiversity: economic theory and case study evidence. United Kingdom: University of Cambridge.

Multi-Resolution Land Characteristics Consortium (MRLC), 2015. National Land Cover Database (NLCD) 2011. http://www.mrlc.gov/nlcd11_data.php [accessed Dec. 2021].

Moore, R., T. Williams., E. Rodriguez., J. Hepinstall-Cymmerman. (2011). *Quantifying the value of non-timber ecosystem services from Georgia's private forests.* Georgia Forestry Foundation.

National Climatic Data Center (NCDC), 2013. Climate data online: text & map search. http://www.ncdc.noaa.gov/cdo-web/. [accessed 11 February 2013].

Ning, Liu; P. Caldwell; G. R. Dobbs, C. Miniat, P. Bolstad, S Nelson. G. Sun (2021). Environmental Research Letter. 16 084008.

Nowak, D.J. (2018). Quantifying and valuing the role of trees and nature on environmental quality and human health. In: van den Bosch, M.; Bird, W., eds. *Nature and Public Health. Oxford textbook of nature and public health*. Oxford, UK: Oxford University Press: 312-316. Chapter 10.4.

Nowak, D. J., N. Appleton, A. Ellis, E. Greenfield. (2017). Residential building energy conservation and avoided power plant emissions by urban and community trees in the United States. *Urban Forestry & Urban Greening*. 21:158-165.

Nowak, D.J., E.J. Greenfield. (2010). *Urban and community forests of the South Central West region.* Newtown Square, PA: USDA Forest Service, Northern Research Station.

Nowak, D. J., E.J. Greenfield, R. E. Hoehn, E. Lapoint. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental pollution*, 178, 229-236.

Nowak, D. J., S.M. Stein, P.B. Randler, E.J. Greenfield, S.J. Comas, M.A. Carr, R.J. Alig. (2010). *Sustaining America's urban trees and forests: a Forests on the Edge report*. Newtown Square, PA: USDA Forest Service, Northern Research Station.

Nowak, D. J., J.T. Walton. (2005). Projected urban growth (2000–2050) and its estimated impact on the US forest resource. *Journal of Forestry*. 103(8), 383-389.

Osowski, S.L., J. Danielson, S. Schwelling, D. German, S. Gilbert, D. Lueckenhoff, D. Parrish, A. K. Ludeke, J. Bergan. (2005). *Texas Environmental Resource Stewards (TERS): Texas Ecological Assessment Protocol (TEAP) Results Pilot Project*. U. S. Environmental Protection Agency Region 6, Texas Parks and Wildlife Department, and The Nature Conservancy.

Osowski, S.L., J. Danielson, D. Parrish. (2011). *Regional Ecological Assessment Protocol (REAP) Project Report*. Report Number EPA-906-R-11-001. Dallas, TX: U.S. Environmental Protection Agency Region 6.

Plummer, M. L. (2009). Assessing benefit transfer for the valuation of ecosystem services. *Frontiers in Ecology and the Environment.* 7(1):38-45.

Polasky, S., E. Nelson, E. Lonsdorf, P. Fackler, A. Starfield. (2005). Conserving species in a working landscape: land use with biological and economic-objectives. *Ecological Applications.* 15:2209-2209.

Sachs, J.D., J.M. Baillie, W.J. Sutherland, P.R. Armsworth, N. Ash, J. Beddington, T.M. Blackburn, B. Collen, B. Gardiner, K.J. Gaston, H.J. Godfray, R.E. Green, P.H. Harvey, B. House, S. Knapp, N.F. Kumpel, D. W. Macdonald, G.M. Mace, J. Mallet, A. Matthews, R.M. May, O. Petchey, A. Purvis, D. Roe, K. Safi, K. Turner, M. Walpole, R. Watson, K.E. Jones, (2009). Biodiversity conservation and the millennium development goals. *Science.* 325:1502–1503.

Salles, J. (2011). Valuing biodiversity and ecosystem services: Why put economic values on nature? *Comtes Rendus Biologies.* 334:469–482.

Sander, H., S. Polasky, R. Haight. (2010). The value of urban tree cover: A hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics*. 69:1646-1656.

Sarukhán, J., A. Whyte, editors. (2005). *Ecosystems and human well-being: Synthesis (Millennium Ecosystem Assessment)*. Island Press, World Resources Institute, Washington, D.C., USA.

Sedjo, R., J. Wisniewski, A. Sample, J. Kinsman. (1995). The economics of managing carbon via forestry: assessment of existing studies. *Environmental and Resource Economics*, 6:139-165.

Sun, G., M. Riedel, R. Jackson, R. Kolka, D. Amatya, and J. Shepard. (2004). Book Chapter 3: Influences of management of Southern forests on water quantity and quality. In: H.M. Rauscher and K. Johnsen (Eds.) *Southern Forest Sciences: Past, Current, and Future.* Gen. Tech. Rep/ SRS-75. Ashville, NC U.S. Department of Agriculture, Forest Service, Southern Research Station. 394 p.

Sundquist, E.T., R.C. Burruss, S.P. Faulkner, R.A. Gleason, J.W. Harden, Y.K. Kharaka, L.L. Tieszen, M.P. Waldrop. (2008). Carbon Sequestration to Mitigate Climate Change: U.S. Geological Survey, Fact Sheet 2008–3097, 4p.

Taylor, A.F., F.E. Kuo. (2009). Children with attention deficits concentrate better after a walk in the park. *Journal of Attention Disorders.* 12:402-409.

Texas A&M Forest Service. (2013). *Texas Statewide Assessment of Forest Ecosystem Services*. https://texasforestinfo.tamu.edu/forestecosystemvalues/assets/static/Texas-Forest-Ecosystem-Services-Report.pdf

Texas Department of State Health Services. (2020). *Texas Stroke System of Care Report.* www.dshs.texas.gov/heart/pdf/2020_Stroke_Report-(FINAL).pdf

Tilman, D., R.M. May, S. Polasky, C. L. Lehman. (2005). Diversity, productivity and temporal stability in the economies of humans and nature. *Journal of Environmental Economics and Management*. 49:405–426.

Torres, L.B., W. Miller, W. Yan. (2022). *Texas Housing Insite*. Texas Real Estate Research Center. www.recenter.tamu.edu/data/housing-activity/#!/activity/State/Texas.

Turner R. K., J. Paavola, P. Cooper, S. Farber, V. Jessamy, S. Georgiou. (2003). Valuing nature: lessons learned and future research directions. *Ecological Economics.* 46:492–510.

Ulrich, R.S. (1984). View through a window may influence recovery from surgery. *Science*. 224:420-421.

United States Census Bureau. (2010). Urban%age of the population for states, Historical Decennial Census 1900-2010. United States Census Bureau.

van Dijk, A.I.J.M., Bruijnzeel, L.A. 2001. Modeling Rainfall Interception by Vegetation of Variable Density Using and Adapted Analytical Model. Part 1. *Journal of Hydrology* 247: 230-238.

Wang, J., Endreny, T.A., Nowak, D.J. 2008. Mechanistic simulation of tree effects in an urban water balance model. *Journal of the American Water Resources Association* 44(1): 75-85.

Wolf, K.L. (2008). City Trees, Nature, and Physical Activity: A Research Review. *Arborist News*. 17(1):22-24.

APPENDIX A: Methods for Urban Ecosystem Services Analysis

AREA OF INTEREST

Urban Areas and Communities

The area of interest (AOI) for this Urban and Community Forest ecosystem services analysis was produced from two sets of data from the Census TIGER files: Urban Areas and Places.

U.S. Census Urban Areas identifies two types of urban areas:

- Urbanized Areas (UAs) of 50,000 or more people.
- Urban Clusters (UCs) of at least 2,500 and less than 50,000 people.

Because the U.S. Census delineates these areas only once every 10 years following a census, the most recent data for this analysis was from the 2010 Census.

Census Places are geographies defined by the U.S. Census Bureau, which include both Incorporated Places and Census Designated Places (CDPs).

Incorporated Places are legally bounded entities established by the government in each state and requirements for such designation vary by state. The most common types of incorporated places are cities, towns, villages, and boroughs, with exceptions by state.

Census Designated Places are statistical entities that represent and are geographically defined to provide data for areas with settled population centers and may include urban areas and/or commercial or industrial types of land use. These areas usually have identifying names but are not legally incorporated. These CDPs were excluded in our analysis.

Census Places are updated annually, and for this analysis 2019 data were used.

The Area of Interest developed for this analysis was produced by combining (Union) Urban Areas and Places into one layer.

Tree Canopy

Tree canopy was derived from the National Land Cover Dataset (NLCD) 2016 Tree Canopy Cover data product generated by the USDA Forest Service. The NLCD tree canopy product consists of a 30-meter resolution raster containing% tree canopy estimates ranging from 0 to 100%, as a continuous variable, for each pixel across all land covers and types in the coterminous United States. Each individual value represents the proportion of that 30-meter cell covered by tree canopy, derived from multi-spectral Landsat imagery and other available ground and ancillary information. The product is then filtered and masked to eliminate obvious non-tree areas and to create a more cartographically useful product. For this analysis, the NLCD tree canopy product was clipped to the urban areas described above.

WATERSHED ECOSYSTEM SERVICE

Avoided Runoff

An ecosystem service value for avoided runoff provided by trees was calculated using the following formula.

$$Avoided\ runoff\left(\frac{\$}{yr}\right) = 0.009406\frac{m}{yr} \times \frac{pct\ tree\ canopy}{100} \times 900\frac{m^2}{pixel} \times 264.172\frac{gal}{m^3} \times \frac{\$0.008936}{gal}$$

This calculation provided values in units of dollars/year for each 30-meter pixel.

BIODIVERSITY ECOSYSTEM SERVICE

Biodiversity

An ecosystem service value for Biodiversity was calculated for $51.75 per acre of tree canopy occurring within "ecologically important hotspots" per year. Ecological important hotspots are defined here from EPA's Regional Ecological Assessment Protocol (REAP) Composite information that scores areas based on eighteen individual measures divided into three main sub-layers: diversity, rarity, and sustainability. A hotspot in this analysis was identified as an area having a composite score of within the top 10% of all scores within the six-state EPA Region 6.

The following formula was used in the geospatial analysis.

$$Biodiversity\left(\frac{\$}{yr}\right) = \frac{\$51.75}{ac \cdot yr} \times \frac{pct\ tree\ canopy\ in\ hotspots}{100} \times 0.2223948\frac{ac}{pixel}$$

This produced biodiversity values in units of dollars/year for each 30-meter pixel.

CLIMATE ECOSYSTEM SERVICE

Carbon Sequestration

The value of climate regulation through carbon sequestration was determined using data supplied by David Nowak of the USDA Forest Service. Nowak determined that, on average, urban trees store 7.69 kg C/m^2 of tree canopy and annually accumulate (net) 0.272 kg C/m^2 of tree canopy. In this study, these values were combined with the social cost of carbon ($51/ton C) for all tree canopy within the urban and community area to produce the value of carbon sequestration. The value of carbon storage, which is a snapshot of carbon stocks, was amortized over 20 years at a 3% discount rate to produce an annual value. The following formulas were used to compute values of carbon storage and carbon accumulation in units of dollars/year for each 30-meter pixel; the total carbon sequestration value is the sum of the two.

$$Carbon\ storage\left(\frac{\$}{yr}\right) = \frac{pct\ tree\ canopy}{100} \times \frac{900m^2}{pixel} \times 7.69\frac{kg\ C}{m^2} \times \frac{1\ ton}{1{,}000\ kg} \times \frac{\$51}{ton} \times \frac{0.067216}{yr}$$

$$Carbon\ accumulation\left(\frac{\$}{yr}\right) = \frac{pct\ tree\ canopy}{100} \times \frac{900m^2}{pixel} \times 7.69\frac{kg\ C}{m^2 \cdot yr} \times \frac{1\ ton}{1{,}000\ kg} \times \frac{\$51}{ton}$$

Avoided Emissions

The value of avoided emissions due to reduced residential energy usage was produced using a value of $207/ha of tree canopy per year as provided by David Nowak of the USDA Forest Service. This gave a maximum potential value of $18.63/year per 900 m^2 pixel (900 m^2 ÷ 10,000 m^2/ha × $207/ha/yr). This maximum potential value was then multiplied by the percent tree canopy to determine the final value for this service in units of dollars/year for each 30-meter pixel.

CULTURAL ECOSYSTEM SERVICE

Cultural

A cultural ecosystem services value was developed by applying a Willingness-to-Pay (WTP) value to the number of households and average tree canopy occurring within a U.S. Census block group. A Willingness-to-Pay value of $2.09/month/household/percentage point of tree canopy cover was used as determined by a choice experiment. Number of households per block group was obtained from the U.S. Census Bureau's 2014 American Community Survey data.

To produce the layer, the number of households within a block group was multiplied by the WTP value and this total value was distributed equally among all the pixels within the block group. This per-pixel value was then multiplied by the average percent tree canopy for that block group. This provided a value for WTP in dollars/year for each 30-meter pixel.

HUMAN HEALTH ECOSYSTEM SERVICE

Air Pollution Removal

An air pollution removal ecosystem service value was produced utilizing a county value determined from data provided by David Nowak of the USDA Forest Service. This data represented the value of urban tree canopy in removing air pollution in dollars per square meter of canopy. County values ranged from 0 up to $65.34/m^2 of canopy and averaged $26.60/m^2. These values were applied only to tree canopy that occurs within developed areas (including all four development intensity classes of NLCD 2016). Of the 254 counties in Texas, 58 exhibited values of $0/m^2.

Obesity and Stroke Reduction

A value for reduction in medical costs was developed based on two benefits from tree canopy: 1) reduction in obesity and associated costs and 2) reduction in hospitalizations due to stroke. Values from these two benefits were combined into one Obesity and Stroke Reduction ecosystem service. These values were applied to only areas (pixels) that were part of the top 25 percentile of urban tree canopy on a by-county basis.

To determine the benefit that tree canopy has for reducing risk of obesity, the following information was used. Records show that 30% of the population is obese, and that obese people spend an additional $1,900 in medical expenses. Research shows that living near trees lowers risk of being obese by 40%. U.S. Census population figures for block groups were used to determine the number of people living near significant tree cover. Total population within a block group was spread evenly across the block group area (in 900-m^2 pixels), and this population density value was multiplied by the lowered risk (40%) of paying the additional $1,900 in medical expenses for obese people and applied to the 30% of people who are obese. Again, these values were only applied for areas coinciding with areas included in the top 25 percentile of tree canopy for a county

$$Obesity\ reduction\left(\frac{\$}{yr}\right) = \frac{population}{pixel} \times 0.30 \times \frac{\$1{,}900}{yr} \times 0.40$$

The other benefit included in the Obesity and Stroke Reduction ecosystem service—reduction in hospitalizations due to stroke—was determined from the following information. The average daily cost of a stroke is $22,000 and an average stay in the hospital due to a stroke is 9 days. This results in an average hospitalization cost of $198,000 ($22,000/days × 9 days). The current rate of having a stroke in the general population is 2.2%. When compared to people residing in areas with little or no tree canopy, those living in the areas with the more tree canopy had a 20-percent reduction in risk for having a stroke. The calculated value was then adjusted for inflation to bring the 2017 values up to 2020 using a multiplier of 1.06. The following equation was used to calculate this value.

$$Stroke\ reduction\left(\frac{\$}{yr}\right) = \frac{population}{pixel} \times 0.022 \times \frac{\$198{,}000}{yr} \times 0.20 \times 1.06$$

These values were then combined and were applied only to those areas coinciding with the top 25 percentile for tree canopy for each county.

Biodiversity Health

A third health benefit resulting from increased biodiversity was produced since it is known that being near areas of high biodiversity can result in fewer cases of depression. More specifically, assuming scalability of research findings, there are 5% fewer cases of depression in people living within 250 meters of biodiverse greenspace, i.e. nearby nature (Cox et al 2017, Carrus et al 2015).

Texas 2018 Uniform Reporting System Mental Health Data Results report that there were 14.14 cases of depression per 1000 population.

According to the U.S. Census, 2.84 is the median family size. To get population per lot, it was assumed that 2.84 people live in a house. House locations were approximated by taking the centroid of a building footprint layer developed by Microsoft (https://github.com/Microsoft/USBuildingFootprints) for Bing Maps. In addition, it has been estimated that medical costs per case of depression was $7,125.58 in 2020.

Therefore, the ecosystem service (as healthcare savings) provided by biodiversity (ESBio) is estimated here to be

$$Depression\ reduction\left(\frac{\$}{yr}\right) = \frac{population\ near\ hotspots}{pixel} \times \frac{14.14}{1{,}000} \times \frac{\$7{,}125.58}{yr} \times 0.05$$

Where the population near hotspots is number of people living (as defined by number of centroids of building footprints multiplied by the median number of people per household) within 250 meters of biodiversity hotspots, where biodiversity hotspots are defined as areas of tree canopy (>10%) that coincide with the top ten ranked composite REAP composite scores as described under the biodiversity section.

ECONOMIC ECOSYSTEM SERVICE

Property Value

A value for the property value ecosystem service that trees provide was developed based on the following estimates. Median home value as provided by the Texas Real Estate Center with Texas A&M University was $275,800 for 2020. A conservative estimate of the increase in property value when one mature tree is present within 100 meters is 3%. This value applied to the median home price is $8,033 per real estate lot ($275,800 – $275,800 / 1.03 = $8,033/lot). Two NLCD development classes are composed primarily of single-family homes: low intensity and medium intensity. Statistics show that median lot size in low intensity development class is 1.0 acre and that median lot size for medium-intensity development class is 8,100 ft^2 or 0.186 acres (8,100 ft^2/43,560 ft^2/ac).

Using these estimates, value for a 900-m^2 area (30-m resolution pixel = 0.2223948 ac) calculated for low intensity development areas is $1,786. Value for medium intensity development area is $9,607. To annualize the values, the potential value was multiplied by the%age of single-family homes sold annually (4.88%).

To determine ecosystem service value that trees add to property value, these values were applied in the respective development classes where the tree canopy percentage was 10% or greater, producing a value in units of dollars/year for each 30-meter pixel.

Energy Savings

A value for ecosystem services provided through residential energy savings was produced using a value of $508/ha of tree canopy in urban and community lands as provided by David Nowak of the USDA Forest Service. This gave a maximum potential value of $45.72/year per 900 m^2 pixel (900 m^2 ÷ 10,000 m^2/ha × $508/ha/yr). This potential value was multiplied by the percent tree canopy to determine the final value for this service in units of dollars/year for each 30-meter pixel.

APPENDIX B: Survey Instrument

HOW DO YOU VALUE URBAN FORESTS?

The term urban forest might be unfamiliar, but odds are you live or work somewhere in Texas' 1.2 million urban forest acres. Urban forests grow within urban and suburban areas and include street trees, residential trees, parks, green space, and public right-of-ways. Your opinions in this survey will help us assess the economic and social importance of urban forests.

YOUR VIEWS MATTER!

As you work through the short survey, please read each question and any instructions carefully and record your initial response. Please do not leave any answers blank. As you move through the survey, you may learn more about the subject at hand, but your initial responses to the questions are most helpful. Please don't feel like you need to change your answers on previous questions as you move through the survey.

If you have any questions about this survey, please contact

TEXAS A&M FOREST SERVICE
200 Technology Way, Suite 1281 College Station, TX 77845
Phone: 979-458-6630

SECTION A: YOUR ASSESSMENT OF URBAN FORESTS IN TEXAS

S-1. Is your primary residence (your home) in a highly populated, urban or suburban area?

☐ Yes ☐ No ☐ I don't know

S-2. What is your age? ☐ < 21 ☐ 21 - 30 ☐ 31-40 ☐ 41 - 50
☐ 51-60 ☐ 61 - 70 ☐ 71-80 ☐ 81 - 90 ☐ > 91

A-1. Please indicate your level of understanding about the social, economic, and environmental benefits of urban forests?

☐ None ☐ Slight ☐ Some ☐ Moderate ☐ Great Deal

A-2. Please rate the importance of the following benefits provided by urban forests.

1 = Not Important 5 = Most Important

	1	2	3	4	5
Provide an opportunity for outdoor recreation	☐	☐	☐	☐	☐
Provide an opportunity for children to play	☐	☐	☐	☐	☐
Provide peaceful places and social well-being	☐	☐	☐	☐	☐
Enhance health and personal well-being	☐	☐	☐	☐	☐
Build a sense of community	☐	☐	☐	☐	☐

A-3. Please rate the importance of the <u>economic</u> benefits provided by urban forests.

1 = Not Important 5 = Most Important

	1	2	3	4	5
Reduce cooling and heating costs	☐	☐	☐	☐	☐
Increase in property value and desirability	☐	☐	☐	☐	☐
Attract people, businesses or visitors	☐	☐	☐	☐	☐
Improve shopping experience	☐	☐	☐	☐	☐

A-4. Please rate the importance of the following environmental benefits provided by urban forests.

	1 = Not Important 1	2	3	5 = Most Important 4	5
Wildlife habitat	☐	☐	☐	☐	☐
Temperature moderation	☐	☐	☐	☐	☐
Air quality improvement	☐	☐	☐	☐	☐
Reduction of carbon emission	☐	☐	☐	☐	☐
Water quality protection	☐	☐	☐	☐	☐
Moderate storm water runoff and flooding	☐	☐	☐	☐	☐
Reduce the effect of climate change	☐	☐	☐	☐	☐

A-5. Please rate the importance of the following health benefits provided by urban forests.

	1 = Not Important 1	2	3	5 = Most Important 4	5
Improved attention and mental alertness	☐	☐	☐	☐	☐
Improved physical health, decrease obesity	☐	☐	☐	☐	☐
Reduced hospital days	☐	☐	☐	☐	☐
Protection from harmful sunlight	☐	☐	☐	☐	☐
Decreased asthma	☐	☐	☐	☐	☐

A-6. What is yoour assessment of the urban forest in your city?

	1 = Not Important 1	2	3	5 = Most Important 4	5
Quantity of street and residential trees	☐	☐	☐	☐	☐
Quantity of parks, walking paths	☐	☐	☐	☐	☐
Quantity of greenspaces, green buffers	☐	☐	☐	☐	☐
Quality of maintenance	☐	☐	☐	☐	☐
Accessibility of parks, green spaces, paths	☐	☐	☐	☐	☐

A-7. Which of the following benefits from urban forests do you personally receive? *(Check all that apply)*

- ☐ A. Being able to see trees
- ☐ B. Noticeably improved health
- ☐ C. Wildlife and diverse plants/landscape
- ☐ D. Increased property value
- ☐ E. Recreational activities
- ☐ F. Peacefulness and noise reduction
- ☐ G. Cleaner air
- ☐ H. Heating and cooling cost savings
- ☐ I. Flood control
- ☐ J. Other *(Please explain)* ____________________________

A-8. Who should be responsible for establishing and maintaining urban forest on non-residential property in your city? *(Please check all that apply)*

☐ A. Local government ☐ B. State/Federal government ☐ C. Private citizens

A-9. Which of the following negative aspects from urban forests impacts you directly? *(Please check all that apply)*

- ☐ A. Damage from sidewalks, building, cars, other property
- ☐ B. Allergies, sensitivities and other health issues
- ☐ C. Wildlife nuisance
- ☐ D. human hazards
- ☐ E. unnecessary maintenance cost
- ☐ F. excessive tax
- ☐ G. wildfire risk
- ☐ H. Other *(Please explain)* ____________

A-10. Would you be willing to pay a fee to expand programs that promote additional urban forests acres, improve maintenance of urban forests, and improve access to community urban forest areas?

☐ A.Yes ☐ B. Maybe ☐ C. No

A-11. Please rate the importance of following considerations.

	1 = Not Important			5 = Most Important	
	1	2	3	4	5
Presence of trees on property, when selecting a residence	☐	☐	☐	☐	☐
Trees in neighborhood, when selecting a residence	☐	☐	☐	☐	☐
Support for effective, local ordinances to improve or maintain urban forest health	☐	☐	☐	☐	☐
Maintenance cost of urban forests	☐	☐	☐	☐	☐

SECTION B: THE IMPORTANCE OF URBAN FORESTS IN SELECTING A PLACE TO LIVE

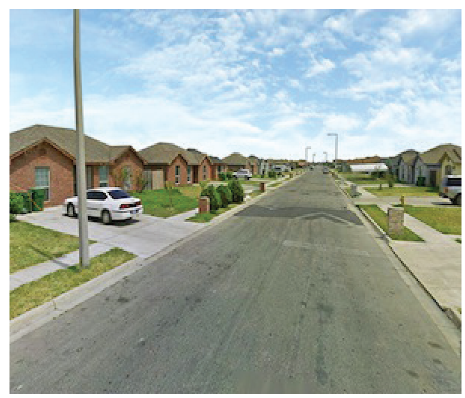
Imagine you are considering a move from your existing, hypothetical residence into one of two neighborhoods: Neighborhood A or Neighborhood B. For the next three questions, you will be asked to choose a new,hypothetical neighborhood or stay at your current residence based upon the urban forest amenities of each.

Please assume that each neighborhood is acceptable and equal in terms of housing, quality of schools, transportation, nearby friends, city services, etc.

Your current, hypothetical residence looks similar to the images here; has no public playgrounds, paths or natural trails; and no access to public greenspace.

Aerial View

Street View



Before you continue, please review the following examples of possible neighborhood features.

Tree Cover: Think of this as the number of, or density of trees in the neighborhood and surrounding areas especially when viewed from above. Choices include:

SPARSE TREE COVER
Open ground with only the occasional tree present,

Sparse Aerial View

Sparce Street View

MODERATE TREE COVER
Scattered trees and small grouping of trees scattered about the landscape, or

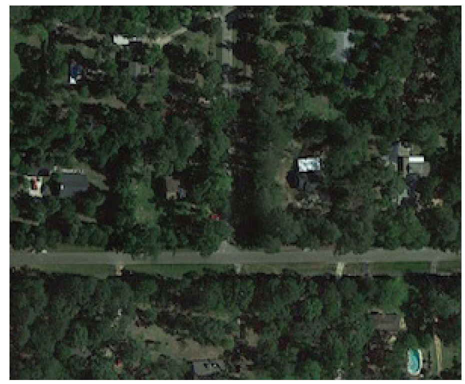
Moderate Aerial View

Moderate Street View

DENSE TREE COVER
Woodland with many trees and large grouping of trees.

Dense Aerial View

Dense Street View



Facilities: available facilities for recreational activities and enjoyment. Options include:

- No playground and very few walking paths,
- Small playground with some walking paths and outdoor seating, or
- Big playground (or multiple playgrounds) with plenty of walking paths, seating. Also includes bicycle trails and nature trails.

Environmental Health Concerns: this feature refers to the allergy, hay fever, and other health concerns that some may experience when living in the neighborhood. Options include:

- Minimal concerns,
- Moderate concerns, or
- High concerns for individuals with a history of environmental health concerns.

Distance to Public Green Space: the distance from the new home that you are considering to the closest, public green space. Green space is an area of grass, trees, or other vegetation set apart for recreational or aesthetic purposes in an otherwise urban environment. Options include:

- 5 minute walk from the home,
- 20 minute walk from the home, or
- 40 minute walk from the home to the public green space.

Additional Cost: this is the additional monthly cost that you would be required to pay to live in the neighborhood. Options include:

- $40 per month,
- $60 per month, or
- $80 per month.

The following questions were not displayed to the respondent.

Subsection Ba: 3 Questions

Ba-1. Neighborhood Consideration (1of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Dense Tree Cover** Wooded, many trees, large grouping of trees	**Sparse Tree Cover** Open ground, Occasional trees	—
Facilities	No playground	Big playground, plenty surface paths, cycle & natural trails	—
Environmental Health Concern	Moderate	Minimal	—
Distance to Public Green Space	20 minute walk	40 minute walk	—
Additional Cost	$40/mo	$60/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Ba-2. Neighborhood Consideration (2 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Moderate Tree Cover** Scattered trees or small grouping of trees	**Sparse Tree Cover** Open ground, Occasional trees	—
Facilities	Small playground, some paths and seating	No playground	—
Environmental Health Concern	Minimal	Minimal	—
Distance to Public Green Space	20 minute walk	20 minute walk	—
Additional Cost	$80/mo	$60/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Ba-3. Neighborhood Consideration (3 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Dense Tree Cover** Wooded, many trees, large grouping of trees	**Sparse Tree Cover** Open ground, Occasional trees	—
Facilities	Small playground, some paths and seating	No playground	—
Environmental Health Concern	High	Minimal	—
Distance to Public Green Space	5 minute walk	40 minute walk	—
Additional Cost	$40/mo	$60/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Subsection Bb: 3 Questions

Bb-1. Neighborhood Consideration (1 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Moderate Tree Cover** Scattered trees or small grouping of trees	**Dense Tree Cover** Wooded, many trees, large grouping of trees	—
Facilities	Small playground, some paths and seating	Big playground, plenty surface paths, cycle & natural trails	—
Environmental Health Concern	Moderate	High	—
Distance to Public Green Space	5 minute walk	20 minute walk	—
Additional Cost	$60/mo	$40/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Bb-2. Neighborhood Consideration (2 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Moderate Tree Cover** Scattered trees or small grouping of trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	No playground	—
Environmental Health Concern	Minimal	Moderate	—
Distance to Public Green Space	40 minute walk	5 minute walk	—
Additional Cost	$40/mo	$80/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Bb-3. Neighborhood Consideration (3 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Dense Tree Cover** Wooded, many trees, large grouping of trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	Small playground, some paths and seating	—
Environmental Health Concern	Minimal	Moderate	—
Distance to Public Green Space	5 minute walk	20 minute walk	—
Additional Cost	$80/mo	$40/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Subsection Bc: 3 Questions

Bc-1. Neighborhood Consideration (1 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Moderate Tree Cover** Scattered trees or small grouping of trees	**Dense Tree Cover** Wooded, many trees, large grouping of trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	No playground	—
Environmental Health Concern	Minimal	High	—
Distance to Public Green Space	5 minute walk	20 minute walk	—
Additional Cost	$40/mo	$80/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Bc-2. Neighborhood Consideration (2 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Moderate Tree Cover** Scattered trees or small grouping of trees	—
Facilities	Small playground, some paths and seating	Big playground, plenty surface paths, cycle & natural trails	—
Environmental Health Concern	Minimal	Moderate	—
Distance to Public Green Space	5 minute walk	40 minute walk	—
Additional Cost	$80/mo	$40/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Bc-3. Neighborhood Consideration (3 of 3)	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Moderate Tree Cover** Scattered trees or small grouping of trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	Small playground, some paths and seating	—
Environmental Health Concern	Moderate	High	—
Distance to Public Green Space	5 minute walk	40 minute walk	—
Additional Cost	$40/mo	$60/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Subsection Bd: 3 Questions

Bd-1. Neighborhood Consideration (1 of 3)	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Moderate Tree Cover** Scattered trees or small grouping of trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	Small playground, some paths and seating	—
Environmental Health Concern	Moderate	Moderate	—
Distance to Public Green Space	5 minute walk	20 minute walk	—
Additional Cost	$80/mo	$60/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Bd-2. Neighborhood Consideration (2 of 3)	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Moderate Tree Cover** Scattered trees or small grouping of trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	No playground, few paths	—
Environmental Health Concern	Minimal	Minimal	—
Distance to Public Green Space	20 minute walk	40 minute walk	—
Additional Cost	$60/mo	$40/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Bd-3. Neighborhood Consideration (3 of 3)	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Dense Tree Cover** Wooded, many trees, large grouping of trees	**Moderate Tree Cover** Scattered trees or small grouping of trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	No playground, few paths	—
Environmental Health Concern	Minimal	High	—
Distance to Public Green Space	40 minute walk	20 minute walk	—
Additional Cost	$60/mo	$40/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Subsection Be: 3 Questions

Be-1. Neighborhood Consideration (1 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Moderate Tree Cover** Scattered trees or small grouping of trees	**Dense Tree Cover** Wooded, many trees, large grouping of trees	—
Facilities	No playground, few paths	Big playground, plenty surface paths, cycle & natural trails	—
Environmental Health Concern	Minimal	High	—
Distance to Public Green Space	40 minute walk	5 minute walk	—
Additional Cost	$40/mo	$60/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Be-2. Neighborhood Consideration 2 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Dense Tree Cover** Wooded, many trees, large grouping of trees	**Sparse Tree Cover** Open ground, Occasional trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	No playground, few paths	—
Environmental Health Concern	Moderate	High	—
Distance to Public Green Space	40 minute walk	20 minute walk	—
Additional Cost	$40/mo	$80/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Be-3. Neighborhood Consideration (3 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Moderate Tree Cover** Scattered trees or small grouping of trees	**Sparse Tree Cover** Open ground, Occasional trees	—
Facilities	Big playground, plenty surface paths, cycle & natural trails	Small playground, some paths and seating	—
Environmental Health Concern	Minimal	Moderate	—
Distance to Public Green Space	5 minute walk	40 minute walk	—
Additional Cost	$60/mo	$40/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Subsection Bf: 3 Questions

Bf-1. Neighborhood Consideration (1 of 3)

	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Dense Tree Cover** Wooded, many trees, large grouping of trees	—
Facilities	Small playground, some paths and seating	Big playground, plenty surface paths, cycle & natural trails	—
Environmental Health Concern	Minimal	Minimal	—
Distance to Public Green Space	5 minute walk	40 minute walk	—
Additional Cost	$40/mo	$80/mo	—
Given these choices, I choose....	☐ A	☐ B	☐ No Move

Bf-2. Neighborhood Consideration (2 of 3)	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Sparse Tree Cover** Open ground, Occasional trees	**Moderate Tree Cover** Scattered trees or small grouping of trees	—
Facilities	Small playground, some paths and seating	No playground, few paths	—
Environmental Health Concern	Minimal	Moderate	—
Distance to Public Green Space	40 minute walk	20 minute walk	—
Additional Cost	$80/mo	$40/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

Bf-3. Neighborhood Consideration (3 of 3)	NEIGHBORHOOD A	NEIGHBORHOOD B	CURRENT
Tree Cover	**Moderate Tree Cover** Scattered trees or small grouping of trees	**Dense Tree Cover** Wooded, many trees, large grouping of trees	—
Facilities	Small playground, some paths and seating	No playground, few paths	—
Environmental Health Concern	Minimal	Minimal	—
Distance to Public Green Space	20 minute walk	40 minute walk	—
Additional Cost	$60/mo	$80/mo	—
Given these choices, I choose....	☐ **A**	☐ **B**	☐ **No Move**

SECTION C: TELL US ABOUT YOU

All Answers are confidential.

C-1. Please specify the number of trees on your residence. [Sliding scale from 0 to 20]
Please select 0 if you live in an apartment building. ______________ Number of trees

C-2. Which best describe the urban forest attribute around (4 block radius) your primary residence

☐ No observable urban forest ☐ Moderate urban forest
☐ Some urban ☐ Dense urban forests

C-3. What is your gender?

☐ Male ☐ Female

C-4. Do you have children?

☐ No ☐ Yes. *If yes, how many children currently live in your home?* ___________

C-5. What is your workforce status?

☐ Full time employee ☐ Self-employed ☐ Not in workforce
☐ Part time employee ☐ Retired and do not work ☐ Other *(please specify)*______________

C-6. What is your level of education? *(Please check the most appropriate response)* ☐ Grade School

☐ Some High School ☐ Some College ☐ Associate Degree ☐ Graduate Degree
☐ High School/GED ☐ Vocational Degree ☐ Undergraduate Degree ☐ Other *(please specify)*

____

C-7. Which best describes your primary residence?

☐ Own a home ☐ Rent a home ☐ Rent apartment ☐ Other *(please specify)* ______________

C-8. If you own 25 acres or more, other than your homestead residence, what type of land is it?
(Please check all that apply.)

☐ Forestland ☐ Range Land ☐ Mix: Woods & Agricultural ☐ Industrialized property: no forests
☐ Agricultural Land ☐ Woodlands ☐ Mix: Woods & Range ☐ Industrialized property: some forests

C-9. Please provide any additional comments you may have regarding this survey.

C-10. Thank you for taking time to fill out our questionnaire. Your cooperation is greatly appreciated. We invite you to learn more about htis survey, Texas A&M Forest Service and other important forestry-related issues at http://texasforestservice.tamu.edu

APRIL 2022