

Executive Summary

Introduction

The value of traditional goods, such as timber, from Texas' forests has long been recognized to be of economic importance to society. This value is relatively easy to assign. However, there is far greater worth to Texas' abundant forests and woodlands than realized by the value of wood fiber, wildlife and recreation. Texas forests provide numerous ecosystem services that are essential to the survival and well-being of all citizens in Texas. Yet, because no markets exist in which to buy and sell these services, they are not appropriately valued. This assessment estimates the economic value (2011 USD) that forest-based ecosystem services provide to society. The scope of this effort covers all forests in Texas, as identified by the USDA Forest Service Forest Inventory and Analysis (FIA) Program, and focuses on the following ecosystem services:

1. climate regulation: the effect forests have on regional and local climates by absorbing greenhouse gases such as carbon dioxide, and then storing them long-term in forest biomass and long-lived forest products;
2. watershed regulation: the ability of forests to provide a continuous, stable supply of clean drinking water through hydrological processes including water capture (water supply), water filtration (water quality), and water regulation/disturbance prevention (flood control and storm protection);
3. biological diversity regulation: the capacity of forests to promote essential biological diversity that drive most other services, as well as provide a sustainable habitat for wild plants and animals, soil formation/conservation, and pollination;
4. cultural values: the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, and aesthetic experience.

Values are reported for the state, by region (*East Texas* – 43 counties, *Central/West Texas* – 211 counties), and for seven ecoregions (*Pine Woodlands*, *Coastal Woodlands*, *Post Oak*, *Hackberry – Oak*, *Mesquite – Juniper*, *High Plains*, and *Mountain*) as shown in Figure 1. The value of timber and currently marketable recreational activities (e.g. hunting, fishing, camping, and bird watching) is not reported in this document because the economic contribution of these goods and services is currently documented in other available reports.



Figure 1. Map of the Texas regions (A = East Texas, B = Central/West Texas) and ecoregions (1 = *Pine Woodlands*, 2 = *Coastal Woodlands*, 3 = *Post Oak*, 4 = *Hackberry - Oak*, 5 = *Mesquite - Juniper*, 6 = *High Plains*, 7 = *Mountain*) used in this assessment. Forest cover is shown in green.

Watershed Regulating Services

Forests play an integral role in maintaining a continuous, stable supply of clean drinking water for millions of people throughout the state. To assess the economic contribution forests provide, watershed services were categorized into three primary functions (water capture, water filtration, and water regulation/disturbance

prevention) and assessed over six forest cover types (non-riparian forests, riparian forests, and wetland forests in both rural and urban settings). Watershed values, based on the forest cover type, were assigned to each primary function, applied to their representative area across the State as denoted by FIA data, and totaled for an overall watershed ecosystem service value.

The water capture function (water supply) was assessed based on the value of water for instream and offstream uses in each water resource region (WRR) in Texas. The amount of water originating annually on Texas forestlands was estimated to be 20.0 million acre-feet. After accounting for the impact of woody plant encroachment (-\$71.5 million/year), the total water capture value was \$489.7 million/year, the majority of which was derived from *East Texas* (74%), the *Pine Woodlands* ecoregion (63%), and rural non-riparian forests (67%) throughout the State.

The water filtration function (water quality) was assessed based on the ability of forests to purify water and reduce water treatment costs. The total value of this function was \$4.2 billion/year, with rural wetland forests accounting for 68% of this value. *East Texas* represented 59% of the value. The *Pine Woodlands* ecoregion (47%) provided the highest water filtration value, while the *High Plains* ecoregion (0.5%) provided the lowest.

The water regulation/disturbance prevention function (flood control) was assessed based on the ability of forests to control the timing and delivery of streamflow, effectively managing stormwater runoff. The total value of this function was \$8.5 billion/year, 65% of which came from *East Texas*. Rural wetland forests accounted for 82% of the total value.

The total Watershed Regulating Service value provided by Texas forests was \$13.2 billion/year, with 64% of this value made up by the water regulation function, followed by water filtration (32%) and water capture (4%). Rural wetland forests accounted for 75% of the total value, followed by rural riparian forests (15%). *East Texas* and the *Pine Woodlands* ecoregion represented 64% and 51% of the total value, respectively.

Climate Regulating Services through Carbon Sequestration

The valuation of carbon as an ecosystem service in climate regulation is key to determining the total value forests provide society. Forest carbon was assessed by stocks (current reserve of carbon held by forest biomass) and accumulation (the rate at which carbon is removed from the atmosphere and fixed into forest plant biomass). Since carbon is highly dependent upon the species composition and makeup of the forest, nine broad forest types, grouped based on similarities in growth habits and site characteristics, were identified. FIA data were used to estimate carbon stocks by five project-specific carbon pools. A conservative value of \$22 per metric ton of carbon (tC) was used as the value of carbon stocks and accumulation. The economic value of carbon stocks was amortized over 20 years to get an annualized carbon stock value.

The total carbon stock estimated for all Texas forests was 2.1 billion metric tons (*East Texas* = 38%; *Central/West Texas* = 62%) across 62.4 million forested acres. Total annual economic value of this stock was \$3.1 billion/year (*East Texas* = \$808.1 million; *Central/West Texas* = \$2.3 billion). In the *East Texas* region, the *Pine* forest type contributed, by far, the greatest total annual value at \$374.5 million, which is more than twice that of the next highest forest type. In the *Central/West Texas* region, *Mesquite* forest type stocks were 758.8 million tC, twice as large as the next largest forest type, and valued at \$1.1 billion annually. Unlike the *East Texas* region, which had equal *live tree above ground* and *soil organic* carbon pools, all forest types in *Central/West Texas* region had up to 80% of the carbon stock in the *soil organic* pool and relatively little carbon in the *live tree above ground* pool. This suggests that management efforts that reduce, but not eliminate, tree cover on these acres could restore the more historic ecosystems without significantly impacting carbon stocks.

The total carbon accumulation rate by all above ground, live vegetation across Texas forests was 52.8 million tC/year (*East Texas* = 12.2 million tC/year; *Central/West Texas* = 40.6 million tC/year), providing an annual

economic value of approximately \$1.2 billion (*East Texas* = \$269.2 million/year; *Central/West Texas* = \$893.1 million/year). Together, the total economic value of carbon stocks and carbon accumulation potential of Texas forestland equaled \$4.3 billion/year (*East Texas* = \$1.1 billion/year; *Central/West Texas* = \$3.2 billion/year). The annual economic value of carbon stock and carbon accumulation across the project-defined ecoregions was: *Pine Woodlands* = \$899.5 million; *Coastal Woodlands* = \$162.9 million; *Post Oak* = \$463.1 million; *Hackberry-Oak* = \$1,027.9 million; *Mesquite-Juniper* = \$1,359.8 million; *High-Plains* = \$150.1 million; and *Mountain* = \$207.2 million.

The averaged, per acre estimates of total carbon stocks for all forests was 33.7 tC/acre (*East Texas* = 45.0 tC/acre; *Central/West Texas* = 30.9 tC/acre). The amortized, average annual economic value of current carbon stocks was \$49.8/acre/year (*East Texas* = \$66.6/acre/year; *Central/West Texas* = \$45.7/acre/year). The annual economic value of carbon accumulation averaged across all forest types and weighted by total acres per forest type was \$18.6/acre/year (*East Texas* = \$22.2/acre/year; *Central/West Texas* = \$17.8/acre/year). Together, the total economic value of carbon stocks and carbon accumulation potential for all Texas forests averaged \$68.4/acre/year (*East Texas* = \$88.8/acre/year; *Central/West Texas* = \$63.5/acre/year).

Biological Diversity Regulating Services

Biological diversity (biodiversity) is a source of value in forests. Biodiversity may be 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, a two-tier process was used. First, a base economic value was determined for each acre, representing the conservation cost of forgoing alternative land uses. A conservative value of 1% of Texas' Gross State Product was used as the base value to provide the necessary biodiversity needed for human well-being. Thus, each acre was valued at approximately \$232.0 for its contribution towards biological systems, which is comparable to the value used by other ecosystem assessments in the southern U.S. The base economic value from biodiversity services, across all FIA-defined forests in Texas, was \$14.5 billion/year. The forests in the 43 *East Texas* counties provided \$2.8 billion/year, while the remaining counties in *Central/West Texas* contributed more than \$11.7 billion/year.

Secondly, additional value was assigned to acres identified as "hotspots" of ecological importance using the Regional Ecological Assessment Protocol (REAP) provided by U. S. Environmental Protection Agency (EPA) Region 6. 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. Texas had 6.3 million acres that fell within this category (i.e., "hotspots") for the region, providing an additional annual ecosystem service value of \$326.1 million/year. The *East Texas* region had 974.8 thousand "hotspot" acres valued at \$50.4 million/year. The *Central/West Texas* region had 5.4 million "hotspot" acres valued at \$275.6 million/year. Stacking the base biodiversity value and ecologically important value together, biodiversity services on FIA-defined forests provided a total annual economic value to Texas of \$14.8 billion/year (\$237.2/acre/year). The *East Texas* region and *Central/West Texas* region were valued at \$2.9 and \$11.9 billion annually, respectively.

Cultural Services

People enjoy the opportunities that Texas' 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 which are the focus of this section.

To capture the cultural values associated with Texas forests, a survey was distributed to randomly selected Texas residents to determine their preferences and opinions about Texas forests. Survey results, using the stated choice modeling approach, were used to estimate the economic values attached to these cultural

services. A total of 683 questionnaires were collected including mail and web-based surveys. The results for respondents' perceptions and experiences with forest ecosystem services were:

- 75% of respondents indicated they have at least some level of understanding of forest ecosystem services.
- 91% indicated that they intend to visit Texas forests in the future.
- 50% of respondents acknowledged that forests provide environmental benefits (air, water, carbon storage, wildlife habitats, and scenic view).
- 70% thought public rural forests should be primarily managed to provide recreational opportunities.
- 68% thought private rural forests should be primarily managed to provide fiber and other forest products.
- 60% of the respondents strongly agreed or agreed that forest landowners should be compensated for economic loss due to harvest restrictions for environmental benefits.
- 43% of the general public trusted forest owners in Texas to maintain healthy forests.
- 91% of the respondents strongly agreed or agreed that improved forest health and resilience benefits all citizens.

Data from the stated choice questions were analyzed using a logistic regression model to estimate the annual willingness to pay. An average household in Texas was willing to pay between \$0.54 - \$2.22/year for a 1,000-acre increase in forest area, depending on the type of forest. The estimated cultural values for rural forests and woodlands ranged from \$140 – \$3,275/acre/year depending upon region, forest type and ownership. Publicly owned rural forestlands in the *Post Oak* region ranked the highest at \$3,275/acre/year. The estimated cultural values for urban forests ranged from \$480 – \$4,300/acre/year, with public urban forestland in the *Post Oak* region ranking the highest. The total cultural value of Texas forests to the residents of Texas is approximately \$60.4 billion/year, including \$59.2 billion/year for 61.8 million acres of rural forests and \$1.2 billion/year for 581.4 thousand acres of forests in urban areas of the State.

Value for Texas

The annual contribution of the assessed cultural and regulating ecosystem services to the citizens of Texas is an estimated \$92.9 billion each year across all forested acres. Rural forests were valued at more than \$90.6 billion annually (Table 1). If represented on a per acre basis, Texas' rural forests provide \$1,464.54 worth of ecosystem services annually. The *East Texas* region contributed 27.5% (\$25.4 billion/year) and the *Central/West Texas* region provided 72.5% (\$66.9 billion/year).

Forests in urban areas were valued at approximately \$2.3 billion annually (Table 2). If represented on a per acre basis, Texas' urban forests provide \$3,106.25 worth of ecosystem services annually. Urban forests in the *East Texas* region contributed 35.3% (\$755.2 million/year) and the *Central/West Texas* region provided 64.7% (\$1.4 billion/year).

Table 1. Ecosystem service value of FIA-defined forests within rural areas by region. Values may reflect slight discrepancies due to rounding.

Ecosystem Service	Unit Value (\$/ac/yr)	Value (million \$/yr)
Watershed		
Texas	202.05	12,495.17
East Texas	683.44	8,096.27
Central/West Texas	87.98	4,398.89
Carbon		
Texas	68.41	4,230.85
East Texas	89.13	1,055.81
Central/West Texas	63.44	3,171.82
Biodiversity		
Texas	237.25	14,672.04
East Texas	236.23	2,798.46
Central/West Texas	237.49	11,873.58
Cultural		
Texas	956.83	59,173.19
East Texas	1,137.20	13,471.73
Central/West Texas	899.81	44,987.14
Totals		
Texas	1,464.54	90,571.24
East Texas	2,146.00	25,422.27
Central/West Texas	1,288.72	64,431.44

Table 2. Ecosystem service value of FIA-defined forests in urban areas by region.

Ecosystem Service	Value (\$/ac/yr)	Value (million \$/yr)
Watershed		
Texas	1,246.25	724.60
East Texas	1,508.51	343.12
Central/West Texas	1,077.72	381.48
Carbon		
Texas	40.68	23.65
East Texas	48.59	11.05
Central/West Texas	35.59	12.60
Biodiversity		
Texas	234.72	136.47
East Texas	233.51	53.11
Central/West Texas	235.50	83.36
Cultural		
Texas	2,068.18	1,202.50
East Texas	1,477.24	336.01
Central/West Texas	2,447.91	866.49
Air Quality		
Texas	327.28	190.29
East Texas	195.10	74.44
Central/West Texas	136.42	115.85
Totals		
Texas	3,917.10	2,277.52
East Texas	3,595.13	817.75
Central/West Texas	4,124.00	1,459.77