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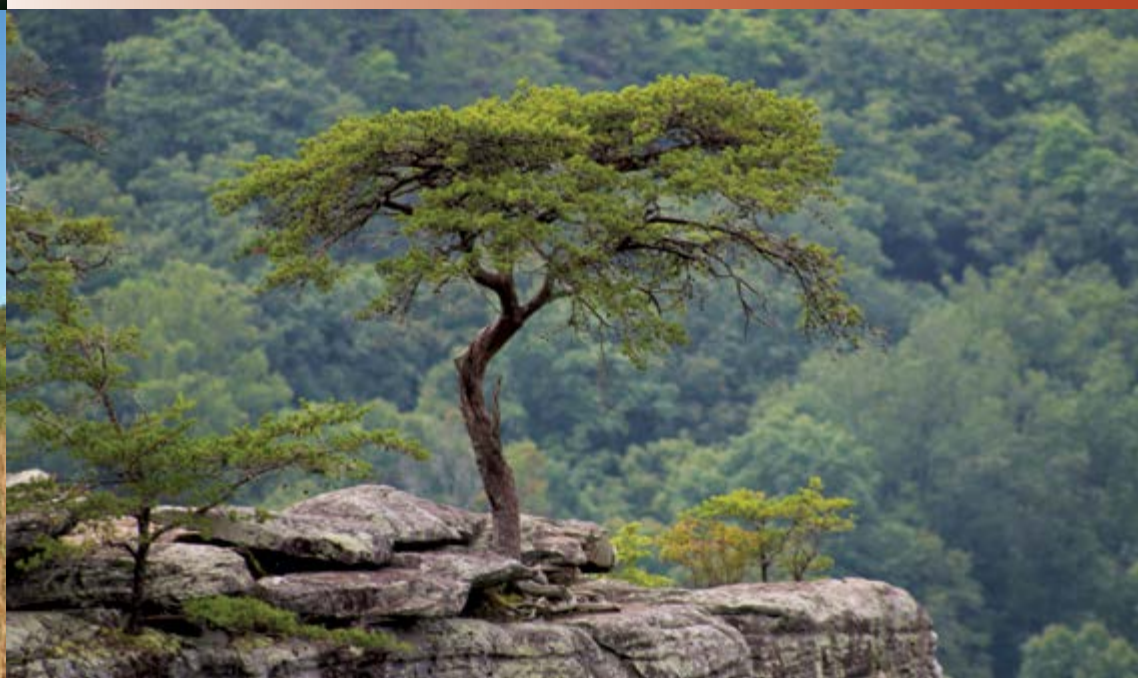
Tennessee's Forests, 2014
(with updates for 2016)

Christopher M. Oswalt,
Thomas J. Brandeis, and Sonja N. Oswalt



About the Authors

Christopher M. Oswalt is a Research Forester with the U.S. Department of Agriculture Forest Service, Southern Research Station, Forest Inventory and Analysis Research Work Unit, Knoxville, TN 37919.

Thomas J. Brandeis is a Supervisory Research Forester with the U.S. Department of Agriculture Forest Service, Southern Research Station, Forest Inventory and Analysis Research Work Unit, Knoxville, TN 37919.

Sonja N. Oswalt is a Forester with the U.S. Department of Agriculture Forest Service, Southern Research Station, Forest Inventory and Analysis Research Work Unit, Knoxville, TN 37919.

Cover Photos

Front cover: top left, the fall foliage of maples make for a fantastic display of color in many eastern forests (USDA Forest Service photo by Christopher M. Oswalt); top right, sunset on Reelfoot Lake, Tennessee (photo courtesy of Twenty20 Photos); center left, mountain laurel (*Kalmia latifolia*) (USDA Forest Service photo by Christopher M. Oswalt); bottom left, young pines that will make up the future forests of Tennessee (USDA Forest Service photo by Christopher M. Oswalt); bottom right, tree on a rocky ledge overlooking the gorge (photo courtesy of Twenty20 Photos). Back cover: top left, Great Smoky Mountains National Park, Tennessee, overlooking the Newfound Pass in autumn. Dead trees are very obvious from this overlook (photo courtesy of Sean Pavone Photography); top right, Laurel Fork Falls in East Tennessee (photo courtesy of Twenty20 Photos); center right, Roan Mountain in East Tennessee (photo courtesy of Twenty20 Photos); bottom left, a timber harvest that is barely visibile as part of a diverse landscape with numerous land uses (USDA Forest Service photo by Christopher M. Oswalt); bottom right, a regenerating stand of natural pine below older pine trees that succumbed to the southern pine beetle (*Dendroctonus frontalis*), a natural insect that can sometimes cause significant mortality among many pines species common in Tennessee (USDA Forest Service photo by Christopher M. Oswalt).

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Southern Research Station
200 W.T. Weaver Blvd.
Asheville, NC 28804

www.srs.fs.usda.gov

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Mountain laurel (*Kalmia latifolia*). (USDA Forest Service photo by Christopher M. Oswalt)

FOREWORD

The Forest Service, U.S. Department of Agriculture, Southern Research Station's (SRS) Forest Inventory and Analysis (FIA) research work unit and cooperating State forestry agencies conduct annual forest inventories of resources in the 13 Southern States (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia), the Commonwealth of Puerto Rico, and the U.S. Virgin Islands. To provide more frequent and nationally consistent information on America's forest resources, all research stations and their respective FIA work units conduct annual surveys with a common sample design. These surveys are mandated by law through the Agricultural Research Extension and Education Reform Act of 1998 (Farm Bill).

The primary objective in conducting these inventories is to gather the multi-resource information needed to formulate sound forest policies, provide information for economic development, develop forest programs, and provide a scientific basis to monitor forest ecosystems. These data are used to provide an overview of forest resources that may include, but is not limited to, forest area, forest ownership, forest type, stand structure, timber volume, growth, removals, mortality, management activity, down woody material, carbon storage and sequestration, and invasive species. The information presented is applicable at the State and survey unit level; although it provides the background for more intensive studies of critical situations, it is not designed to reflect resource conditions at small scales.

More information about Forest Service resource inventories is available in "Forest Resource Inventories: An Overview" (U.S. Department of Agriculture Forest Service 1992). More detailed information about sampling methodologies used in the annual FIA inventories can be found in "The Enhanced Forest Inventory and Analysis Program—National Sampling Design and Estimation Procedures" (Bechtold and Patterson 2005).

Data tables included in FIA reports are designed to provide an array of forest resource estimates, but additional tables can be obtained at https://www.fia.fs.fed.us/tools-data/index.php. Additional information about the FIA program can be obtained at https://www.fia.fs.fed.us/.

Additional information about any aspect of this or other FIA surveys may be obtained from:

U.S. Department of Agriculture
Forest Service
Southern Research Station
Forest Inventory and Analysis
Research Work Unit
4700 Old Kingston Pike
Knoxville, TN 37919
Telephone: 865-862-2000
Burl Carraway
Program Manager

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The following people made field measurements or checked the quality of the data collected for this most recent survey. SRS FIA appreciates their hard work and their consistent efforts to obtain high-quality data.

Tennessee Division of Forestry

Arnold, David
Campbell, Ray
Ferris, Cheryle
Ferris, John
Godbee, Douglas
Goodrich, Jenny
Hendrickson, Shawn
Holder, Michael
Lecher, Brent
Merrill, Eric
Meyer, Jamie
Miller, Eric
Mullins, John

FIA Staff

Allen, Brian
Ammons, Tyler
Barrett, Cody
Bingham, Ben
Camfield, Tyler
Chittom, Hilary
Combs, Sarah
Cooper, Jason
Davidson, Lyndell
Dooley, Kerry
Edwards, Andrew
Farrell, Barry
Frost, Jay
Grapstein, Elyna
Grayson, Jeremy
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Simpson, John
Smith, Greg
Stanley, Mike
Stratton, Dan
Stutts, Dustin
Swift, Hunter
Turner, Jeff
Wall, David
Wood, Marcus
Zimmerman, Lewis

CONTENTS

List of Figures

List of Tables

HIGHLIGHTS

• In 2016, Tennessee had an estimated 13.9 million acres of forest which covered 51.6 percent of its total land area. The only real change in forest land occurred in the West survey unit where a 7.5-percent increase has been realized from 1999 to 2016 as some agricultural area was allowed to revert to forest (see page 3).

• Based on a remeasurement of Tennessee's plots (measured at both time 1 and time 2), 176,900 acres of forest land was diverted to agricultural land use, while 158,700 acres of forest land were diverted to urban or developed land use (see page 5).

• Forest land in Tennessee is owned primarily by nonindustrial private landowners, which comprise 82 percent of the area. Forest industry land comprises only 1 percent of forest land in the State. Forest land stewarded by the Forest Service, U.S. Department of Agriculture in the State comprise 713,000 acres (see page 5).

• In 2016, the majority of stands were in the large diameter size class. A loss of small and medium diameter stands is a long-term occurrence in Tennessee. The State has seen a declining trend in early-successional or small diameter forests over nearly 50 years (see page 9).

• There were 117 individual tree species identified in the 2016 inventory of Tennessee forests. A total population of 8.4 billion trees [diameter at breast height (d.b.h.) ≥1 inch] are estimated to be growing in forests throughout the State. Hardwood tree species are, of course, the most common and have been for a long time (see page 10).

• The trees with d.b.h. ≥ 5 inches hold over 31.6 billion cubic feet (bcf) of volume. While red maple has the greatest number of trees (9.4 percent of all trees), they only account for 5.6 percent of total wood volume in Tennessee's forests. There were greater volumes of wood in yellow-poplar (11.5 percent of total volume), white oak (9.8 percent of total volume), and chestnut oak trees (8.6 percent of total volume) (see page 10) than red maple.

• Four species groups (select white oak, other white oaks, select red oaks, and other red oaks) account for 37 percent of all aboveground

The fall foliage of maples make for a fantastic display of color in many eastern forests. (USDA Forest Service photo by Christopher M. Oswalt)

biomass of live trees (≥ 1-inch d.b.h.). Total aboveground biomass of live trees is over 822 million dry short tons (see page 16).

• While very little hardwood volume exhibits clear evidence of artificial regeneration (i.e., planted), about one-third (29 percent) of softwood volume was planted. Loblolly and shortleaf pine volume are almost evenly split between stands that were naturally regenerated [816 million cubic feet (mcf)] and those that were planted (870 mcf) (see page 12).

• Based on estimates of net change (gross growth – mortality – removals) from remeasured plots, total sound bole volume increased (on average) more than 430 mcf annually between 2011 and 2016. The annual positive net change amounts to an average 1.4-percent increase each year of the total standing live volume (see page 18).

• In 2016, 80 percent of the total net annualized growth of 637 mcf per year was on hardwood trees and 20 percent on softwoods. Similarly, 82 percent of total annualized removals was the result of hardwood removals and 18 percent was due to softwood removals (see pages 18 and 19).

• While harvest removals have declined slightly over time, current harvest removals account for about 346 mcf of volume. Since harvest removals currently make up 94 percent of all removals, hardwood harvest removals account for 82 percent of all harvest removals in the State (see page 19).

• While stable recently, average annual mortality has experienced a slight decrease over the time period between 2002 and 2016 with a current rate of 303 mcf per year (see page 19).

• There is an average of 11 standing dead trees ≥ 5 inches d.b.h. per acre in Tennessee with slightly higher numbers on public land versus private land. Statewide, that amounts to approximately 157 million standing dead trees (see page 23).

• Invasive plant presence/absence was monitored on 11,292 subplots. Invasive plants were detected on 47 percent of those subplots (5,307 subplots). The highest concentrations of monitored forest invasives are in the East survey unit. The most common forest invasive plant monitored by FIA is Japanese honeysuckle (*Lonicera japonica*), impacting nearly 1.2 million acres of forest land across the State (see pages 25 and 26).

INTRODUCTION

This resource bulletin consolidates data from the ninth complete survey of Tennessee's forest resources conducted during the period 2010–2014 (with additional data up to 2016) by the U.S. Department of Agriculture (USDA) Forest Service, Forest Inventory and Analysis (FIA) program in cooperation with the Tennessee Department of Agriculture Division of Forestry (TDF). Data on the extent, condition, and classification of forest land and associated timber volumes, as well as growth, removals, and mortality rates, are described and interpreted. Data on forest health and forest landowner characteristics are also evaluated. Estimates of forest resources are reported at multiple scales. The two most common scales discussed in this report are State and unit. The State of Tennessee is divided into five FIA units (fig. 1) that approximate broad physiographical sections of the State. The five FIA units are labeled: (1) West, (2) West Central, (3) Central, (4) Plateau, and (5) East. In 1999, the Southern Research Station (SRS) FIA program and the TDF began implementing the new annual survey strategy in Tennessee. The strategy involves rotating measurements of five systematic samples (or panels), each of which represents about 20 percent of all plots in the State. A panel generally takes 1 year to complete and covers only one growing season. For Tennessee, data collection for all five panels was completed in 5 years. This analysis focuses primarily on changes and trends in recent years and their implications for Tennessee's forests, forest landowners, and citizens (see the appendix A—Inventory Methods section for further information on data collection methodology). The inventory dates of 2014, 2009, and 2004 are repeated throughout this report. The inventory year of 2014 represents data that was collected from 2010 to 2014. The inventory year 2009 represents data that was collected from 2005 to 2009. The inventory year 2004 represents data that were collected from 2000 to 2004. Estimates of components of change (i.e., growth, removals, and mortality) are calculated based on plot measurements collected at two points in time. For example, estimates of change for the period between 2009 and 2014 are calculated using plots collected from 2005 to 2009 as compared to the same plots being remeasured from 2010 to 2014. The 2014 inventory accounted for a total of 4,701 plots where 2,713 were forested across the State. There were 931, 558, 541, 429, and 477 plots measured in the East, Plateau, Central, West Central, and West units, respectively. A total of 2,721 plots measured for the 2009 inventory were remeasured during the 2014 inventory. The remeasured plots were used to calculate estimates of growth, removals, and mortality, commonly referred to as GRM. Note: This data was accessed and compiled from the FIA database (FIADB) in March, April, and May of 2019. Publicly available data from the FIADB is regularly updated when data collection and/or processing anomalies are found and corrected. Additionally, new data are added on a regular basis which may be reflected by small changes in the past or current estimates.

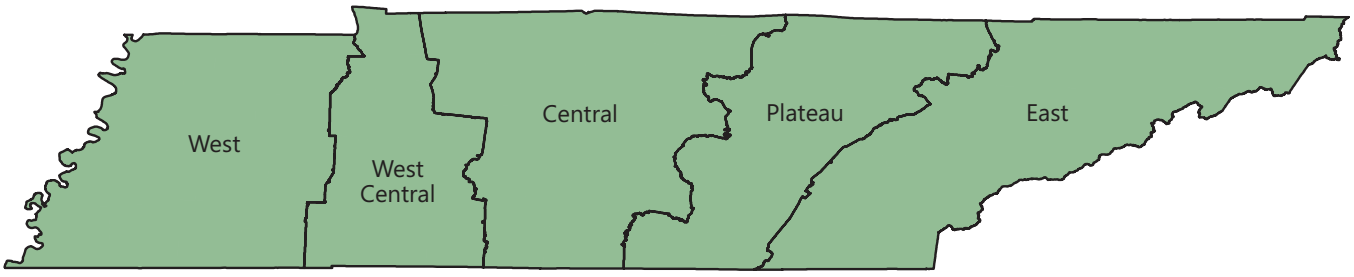


Figure 1—Forest Inventory and Analysis survey unit boundaries, Tennessee.

Additional Data Available

During the development of this report, additional data measured in Tennessee became available. Data for inventory years 2015 and 2016 have been included in this report. The 2015 and 2016 inventories accounted for a total of 4,698 plots (2,937 forested plots) and 4,700 plots (2,942 forested plots), respectively, across the State. While the 2014 inventory year represents the next complete 5-year cycle of data (and is used in the title of this report), the 2014 inventory is highlighted throughout this report along with estimates from the 2015 and 2016 inventories. The inventory year 2016 is consistently used as the nominal date for the presentation of the most current estimates.

History of Tennessee's Forest Inventory

Eight previous inventories have been completed in Tennessee. The inventories of 1950, 1961, 1971, 1980, 1989, 1999, 2004, and 2009 provide statistics for measuring changes and trends over the past 60 years (Oswalt and others 2009, Oswalt and others 2012, Schweitzer 2000). Traditionally, FIA reporting of forest resource statistics has been oriented toward sustaining timber resources to meet the demand for forest products. Over time the idea of "sustainability" has evolved from a concept driven by commodity production to one that is defined by a diversity of values including timber resources, wildlife habitat, species richness, and cultural benefits among others. The USDA Forest Service FIA program has evolved alongside the broader concept of sustainability. The FIA program now reports on a diverse set of variables and attempts to help answer numerous questions surrounding the forest resources of each State, including Tennessee.

Updates of Past Estimates

Currently, the FIA program's data is processed through version 8.1 of the National Information Management System (NIMS) in order to meet national FIA program standards. The 2004 Tennessee forest resources report (Oswalt and others 2009) was based on data processed through version 2.2 of the FIA NIMS and the 2009 report was based on data processed through version 4.0 of the FIA NIMS. Changes in NIMS versions can include programmatic changes that at times alter standard definitions and/or estimate derivation. For example, some forest types may have been retired or consolidated, while others might include changes to component tree species lists. To ensure the most valid comparisons possible across annual inventories, all data collected on the annual design (Bechtold and Patterson 2005) are reprocessed through a newer version of the FIA NIMS when significant changes are made. The data and estimates available to the public and the estimates presented in this report can reflect that reprocessing and therefore, some historical estimates may not match previously published reports. Estimates published in this report supersede estimates for the same period published in previous reports. The SRS FIA program has made available some historic data in electronic form in the FIADB (currently version 8.0). Historic data were converted to the current format of the FIADB. For Tennessee, electronic data are now available for all inventories from 1980 to present. Common comparisons in this report are made for the period between 1999 and 2016 for many forest land attributes and for the period between 1980 and 2016 for many timberland attributes.

AREA

Trends in Forest Land

Tennessee occupies about 27.0 million acres in the Southern United States, with the Mississippi River delineating its western border (fig. 2). Forest land totals 13.9 million acres, 96 percent of which is available for timber production (hereafter, timberland) (table 1). Across the State, forest land area has been stable at or near 50 percent of the land base for as long as FIA has been keeping records (55 years; table 2). The only real change in forest land has occurred in the West unit (fig. 3) where a 7.5-percent increase has been realized from 1999 to 2016 as some agricultural area was allowed to revert to forest.

The FIA program records land use on both nonforest and forest plots (see the Forest Inventory and Analysis national core field guide for details on land use categories and how they are delineated on FIA plots) (U.S. Department of Agriculture Forest Service 2012, 2014). We are then able to create a matrix of land use change using the remeasured plots that are also used to calculate tree level growth, removals, and mortality [see Scott and others (2005) for the methods used to calculate these components of change]. Forest and nonforest conditions on forested plots are categorized by land use which allows us to apply that condition's expansion factor to the land use and estimate area change.

For example, if a previously forested plot is found to have been cleared for development when remeasured, the approximate 6,000 acres that plot represented will be seen as changing from forest to developed land. If the elapsed time period between plot measurements

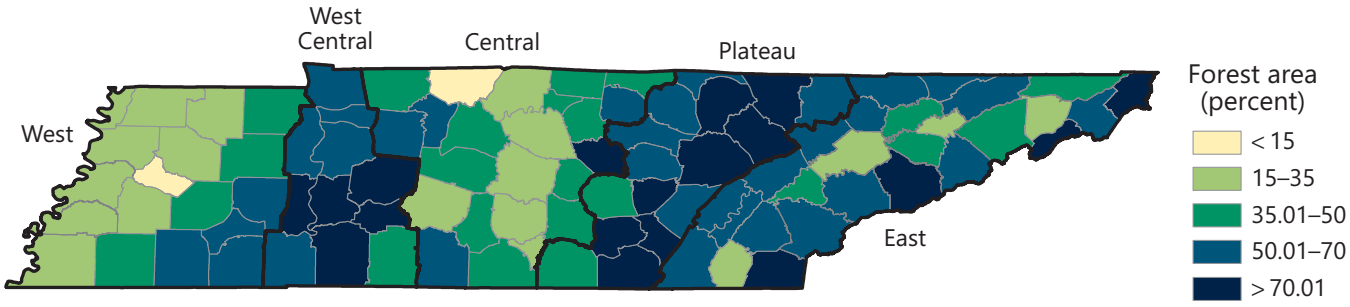


Figure 2—Forest land area as a percentage of total land area for counties, Tennessee, 2016.

Table 1—Area by survey unit and land status, Tennessee, 2016

Survey unit	Total area	All forest	Unreserved			Reserved			Nonforest land	Census water
			Total	Timberland	Unproductive	Total	Productive	Unproductive		
	thousand acres									
West	6,100.0	2,292.5	2,236.2	2,234.7	1.5	56.3	56.3	0.0	3,660.1	147.3
West Central	3,395.7	2,254.7	2,227.4	2,220.4	7.0	27.3	27.3	0.0	1,030.0	111.0
Central	6,281.6	2,666.5	2,650.2	2,650.2	0.0	16.3	16.3	0.0	3,501.1	114.0
Plateau	4,454.0	2,975.0	2,842.7	2,842.7	0.0	132.3	132.3	0.0	1,437.2	41.7
East	6,740.6	3,730.7	3,402.6	3,392.6	10.0	328.1	325.5	2.6	2,768.1	241.8
All survey units	26,971.8	13,919.5	13,359.2	13,340.7	18.5	560.3	557.7	2.6	12,396.6	655.8

Numbers in rows and columns may not sum to totals due to rounding.
0.0 = no sample for the cell or a value of > 0.0 but < 0.05.

Table 2—Forest land area and percent forest land for forest surveys, Tennessee, 2016

Year	Forest land area	Percent[a]
	thousand acres	
1959	11,497.00	44.5
1963	11,700.00	45.2
1975	11,900.00	46.0
1988	12,674.75	49.0
2004	12,283.43	47.5
2009	12,400.65	47.9
2014	12,442.48	48.0
2016	12,379.17	47.8

[a] Based on the current U.S. Census Bureau estimate of 27.0 million acres of land in Tennessee.

Great Smoky Mountains National Park, Tennessee, in autumn. (photo courtesy of Sean Pavone Photography)

was 5 years, then that plot would represent approximately 1,200 acres per year of forest land area that changed to a developed land use. If only half the plot was cleared for development, that change in condition would be mapped and the plot would represent approximately 3,000 acres changing land use and 3,000 acres staying in forest, with an annualized change of approximately 600 acres per year. All of the annually changed acres were then summed for statewide annual change totals.

While very little overall change in the total area of forest has occurred, there are changes that are occurring. Forests are dynamic and transitions to and from other land uses are

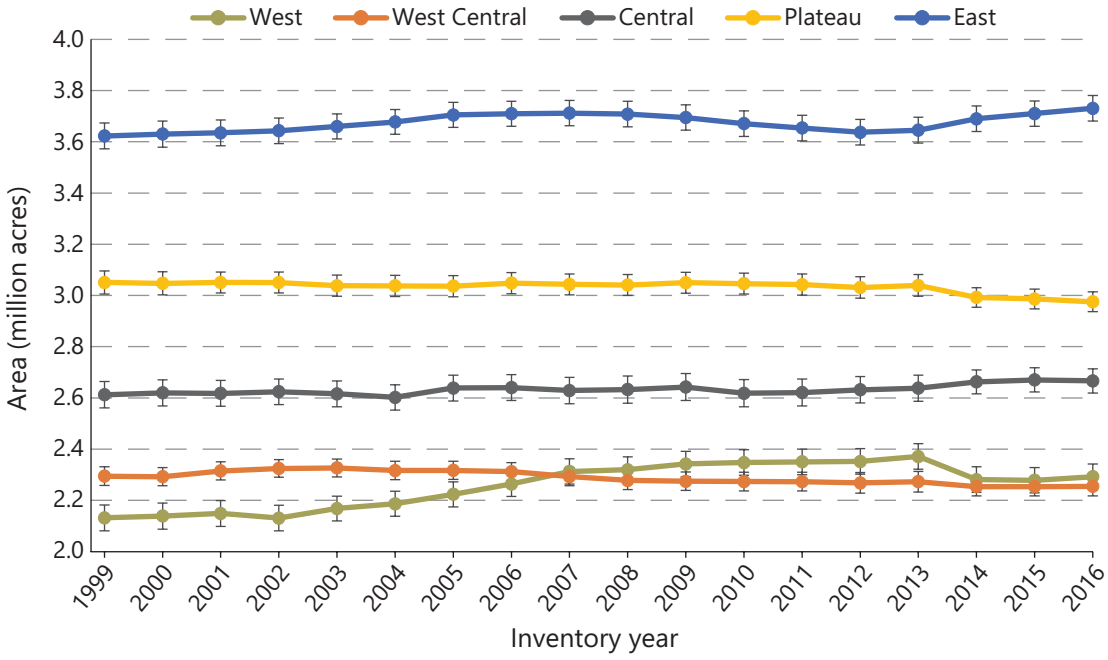


Figure 3—Forest land area by survey unit, Tennessee, 1999–2016.

common. Most changes in forest land in the State can be attributed to both agriculture and development (fig. 4). Based on a remeasurement of Tennessee's plots (measured at both time 1 and time 2), 176,900 acres of forest land were diverted to agricultural land use, while 158,700 acres of forest land were diverted to urban or developed land use (table 3). Once forest land has been converted to developed land, studies suggest that it is unlikely to ever return to a forested condition. In contrast, agricultural land does revert to forest land if economic conditions change. While a total of 335,800 acres were recorded as diversions for the 2016 inventory, more acres reverted back to forests. The largest diversions to agriculture occurred in the West survey unit, while the largest diversions to developed land occurred in the East unit (table 3). Overall, however, the Plateau unit experienced the largest negative change with 17,000 acres of forest diverted to agriculture and development that were not offset by reversions from those land uses to forest.

Ownership

Forest land in Tennessee is owned primarily by nonindustrial private landowners, which comprise 82 percent of the area (fig. 5). Forest industry land comprises only 1 percent of forest land in the State. Forest land stewarded by the Forest Service in the State comprises 713,000 acres. Forest land in private ownership is highest in the Central survey unit (93 percent) while lowest in the East (68 percent) survey unit. Concomitantly, Forest Service and other federally managed forest land is highest in the East survey unit.

Forest Types and Stand Size

Forest types—Even though Tennessee is known as a "hardwood State" as 90 percent of all forest land within the State is occupied by hardwood forest-type groups (table 4), there are many other forest types that occupy the remaining 10 percent. Forest-type groups

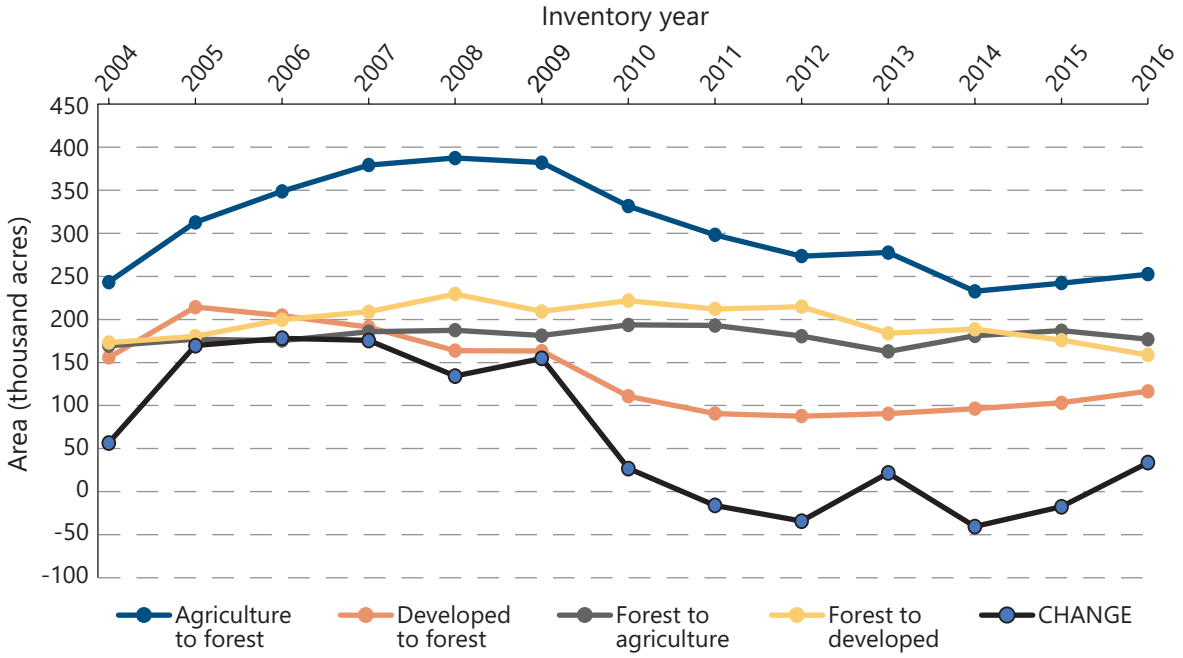


Figure 4—Forest reversions and diversions and net change for forest land in Tennessee, 2004–2016.

Table 3—Changes in forest land by survey unit, Tennessee, 2016

Survey unit	Change[a]	Additions			Diversions		
		Total additions	Agriculture[b]	Developed[c]	Total diversions	Agriculture[b]	Developed[c]
	thousand acres						
West	36.8	112.3	92.6	19.7	-75.6	-51.3	-24.2
West Central	-13.6	32.5	21.4	11.1	-46.1	-27.0	-19.2
Central	22.1	81.1	59.7	21.4	-59.0	-31.1	-27.9
Plateau	-17.0	55.7	30.0	25.7	-72.7	-42.5	-30.1
East	5.3	87.7	49.0	38.7	-82.4	-25.0	-57.3
All survey units	33.6	369.3	252.7	116.6	-335.8	-176.9	-158.7

Numbers in rows and columns may not sum to totals due to rounding.

The EXPCHNG evalid is 97.4 percent remeasured.

Note: The net changes from diversions and additions in this table do not equal the real change in forest land area between surveys because of an incomplete remeasure of all plots (see Appendix A—Inventory Methods).

[a] Change is the difference between diversions (a loss) and additions (a gain) of forest land.

[b] Agriculture includes cropland, pasture, idle farmland, orchards, Christmas tree plantations, maintained wildlife openings, and rangeland.

[c] Developed includes business; manufacturing; residential; rights-of-way (roads, railways, power/oil/gas lines, and canals); recreation areas (parks, skiing, golf courses, etc.); mining; and water.

in which oaks predominate are the most common across the State, with the oak-hickory (70.0 percent) and oak-pine (7.2 percent) comprising nearly 80 percent of the forest. Loblolly-shortleaf pine, a forest-type group very common across the South, covers almost 8 percent of all forests and represents the largest softwood forest-type group in the State.

Stand size—It is important to know the size of the trees that make up the forests in Tennessee. Armed with this knowledge, resource managers are able to better understand the structure of the forested stands and the habitat that exists on the landscape. In addition, trend analysis of stand size (a classification based on stocking and the diameter of the majority of the live trees in a stand) facilitates an understanding of the successional status and potential future development of the forest and the populations of its inhabitants.

The stand-size classes utilized by FIA are small, medium, and large diameter (formerly

Roan Mountain in east Tennessee. (photo courtesy of Twenty20 Photos)

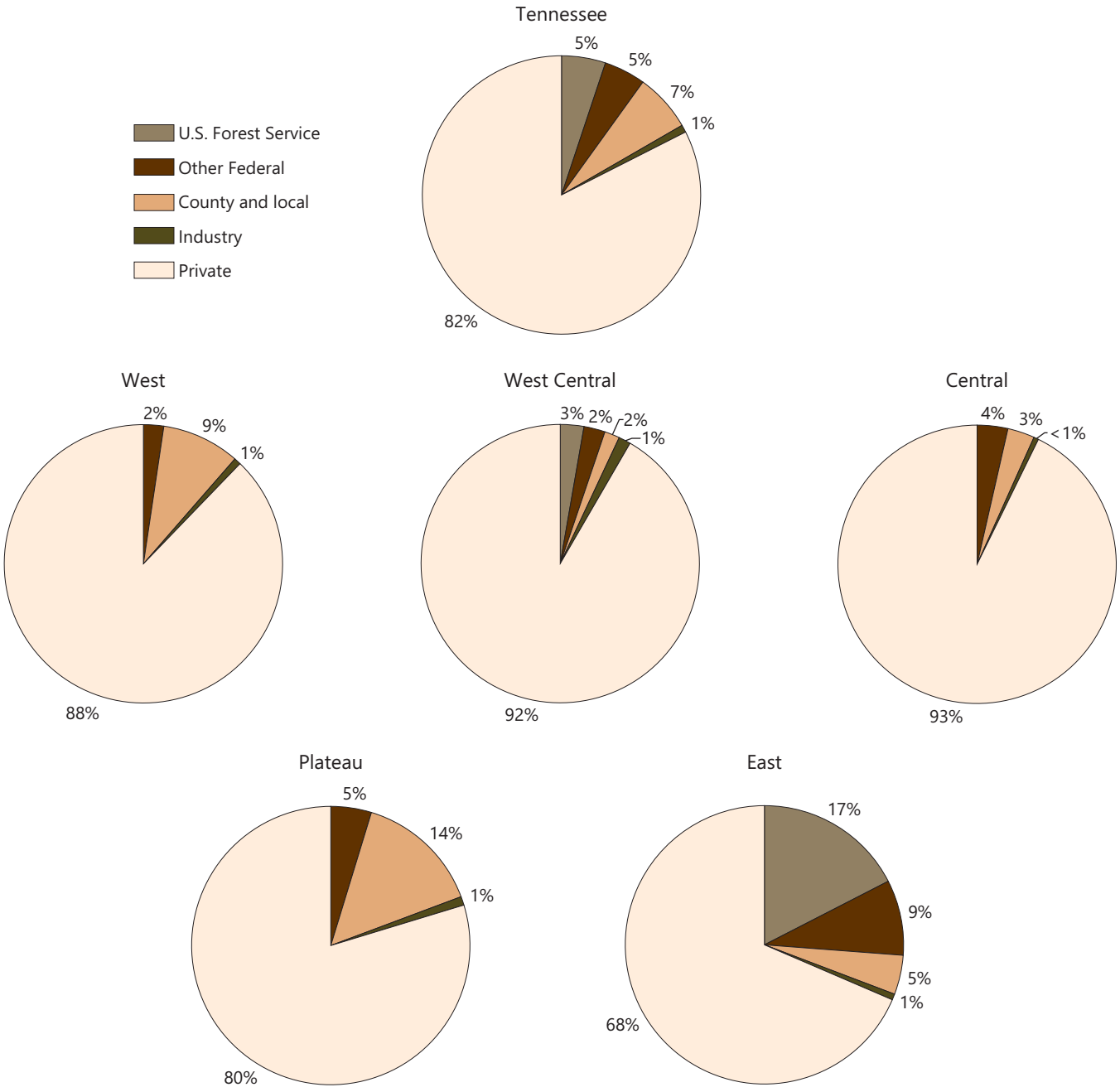


Figure 5—Forest land area by ownership group and survey unit in Tennessee, 2016.

sapling-seedling, poletimber, and sawtimber, respectively), as well as nonstocked. Small diameter stands are forested areas where the majority of the trees are < 5.0 inches d.b.h. Medium diameter stands are at least 5.0 inches d.b.h. but are not large enough to be considered large diameter. In order to be large diameter size, a softwood species must be ≥ 9.0 inches, while hardwood species must be ≥ 11.0 inches. Nonstocked means that although the land is considered forested, there are not enough trees on it to categorize it into a particular stand-size class. Generally, these are forested areas that have recently been harvested, but new tree growth has not regenerated to an adequate level of stocking at the time of the field inventory.

In 2016, the majority of stands were in the large diameter size class (fig. 6). The area of forest land classified as large diameter has

Table 4—Area of forest land by forest-type group and ownership group, Tennessee, 2016

Forest-type group	All ownerships	Ownership group				
		U.S. Forest Service	Other Federal	State and local government	Forest industry	Nonindustrial private
	thousand acres					
Softwood types						
White-red-jack pine	59.8	29.1	0.0	3.0	0.0	27.7
Loblolly-shortleaf pine	1,095.2	57.3	28.9	55.2	19.8	933.9
Other eastern softwoods	256.3	0.0	12.8	4.2	0.0	239.3
Total softwoods	1,411.3	86.4	41.7	62.4	19.8	1,201.0
Hardwood types						
Oak-pine	1,001.1	80.4	60.0	38.6	27.3	794.6
Oak-hickory	9,794.7	495.2	432.6	661.3	52.0	8,153.6
Oak-gum-cypress	363.1	0.0	31.7	50.9	12.2	268.3
Elm-ash-cottonwood	841.4	0.0	33.2	85.5	9.1	713.6
Maple-beech-birch	366.7	43.8	48.4	23.1	0.0	251.4
Other hardwoods	52.1	6.5	15.0	6.0	0.0	24.5
Exotic hardwoods	44.2	0.0	5.9	0.0	0.0	38.2
Total hardwoods	12,463.2	625.9	626.9	865.6	100.6	10,244.2
Nonstocked	45.0	0.5	3.0	7.4	0.0	34.1
All groups	13,919.5	712.8	671.6	935.3	120.4	11,479.4

Numbers in rows and columns may not sum to totals due to rounding.
0.0 = no sample for the cell or a value of > 0.0 but < 0.05.

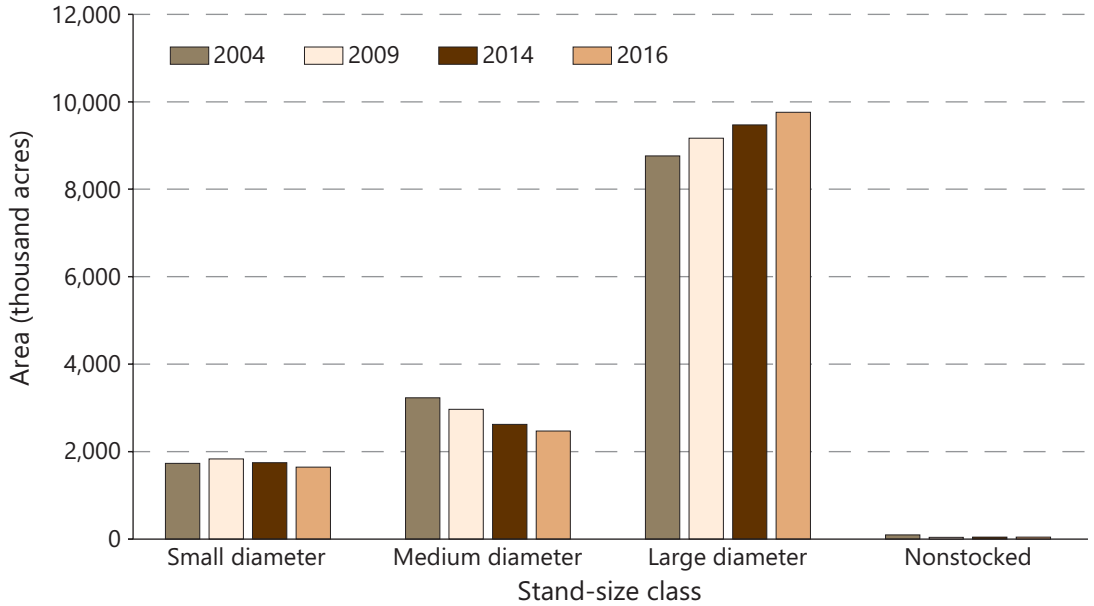


Figure 6—Forest land area by stand-size class for total area, Tennessee, 2004, 2009, 2014, 2016.

been increasing in recent years. In 2004, an estimated 63 percent of all forest land in Tennessee was in large-diameter stands. In 2014, the percent of large-diameter stands had increased to 68 percent and by 2016 had increased to 70 percent. The largest declines occurred in the medium-diameter size stands with a decline from 23 percent to 18 percent from 2004 to 2016, respectively. Stands classified as small-diameter declined from 13 percent in 2004 to 12 percent in 2016. A loss of small- and medium-diameter stands is a long-term occurrence in Tennessee. The State has seen a declining trend in early-successional or small-diameter forests over nearly 50 years (1961 to 2016) (Oswalt and others 2009) (fig. 6).

In 1971, early-successional forests accounted for about 35 percent of all forest land in the State. In 2016, early-successional forests accounted for only 12 percent of all forest land.

While relatively similar trends in stand-size class distribution exist among all forest types in Tennessee, small but important distinctions do exist. For example, there appears to be a larger increase in large-diameter stands in mixed (pine-oak) forest types (fig. 7). Increases in large-diameter stands appear to be occurring in hardwood and softwood forest types at a slightly lower pace. However, the mixed stands are not as common as softwood and/or hardwood stands across the State.

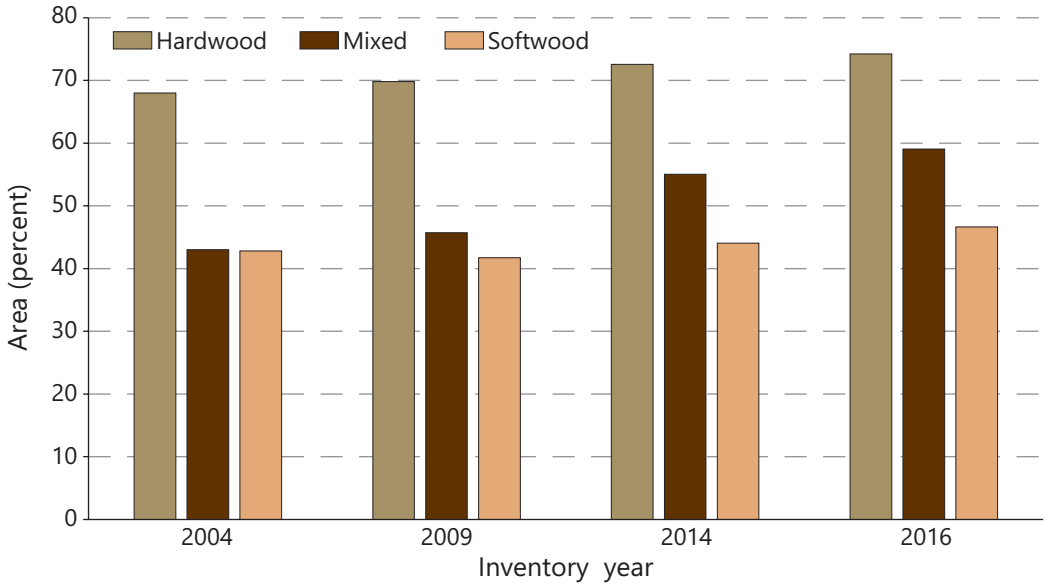
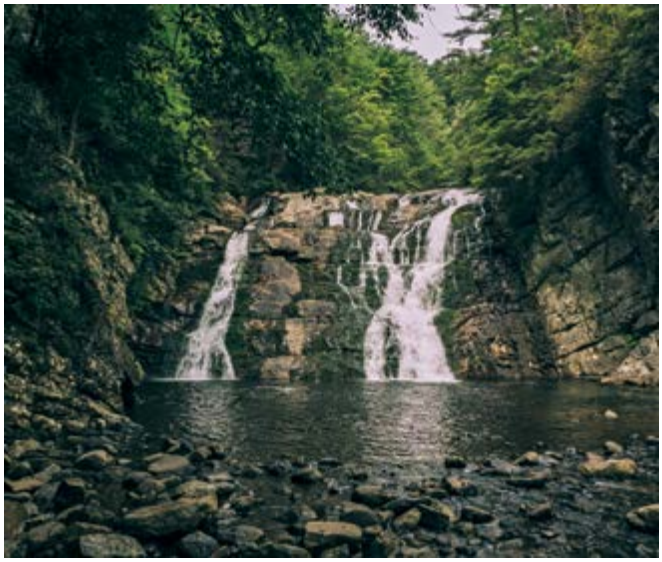


Figure 7—Forest land area for large-diameter stands, in hardwood, mixed, and softwood forest types, Tennessee, 2004, 2009, 2014, 2016.

NUMBER OF TREES, VOLUME, AND BIOMASS

There were 117 individual tree species identified in the 2016 inventory of Tennessee forests. A total population of 8.4 billion trees (d.b.h. ≥1 inch) are estimated to be growing in forests of the State. Hardwood tree species are, of course, the most common and have been for a long time (fig. 8). Red maple (*Acer rubrum*) is by far the most common hardwood species, and eastern redcedar (*Juniperus virginiana*) was the most encountered softwood species (table 5).

The trees with d.b.h. ≥ 5 inches hold over 31.6 billion cubic feet (bcf) of volume (fig. 9). While red maple has the greatest number of trees (9.4 percent of all trees), that species only accounts for 5.6 percent of total wood volume in Tennessee's forests (table 6). There were greater volumes of wood in yellow-poplar (11.5 percent of total volume), white oak (9.8 percent of total volume), and chestnut oak trees (8.6 percent of total volume) (table 6). While only two different oak species are accounted for in the top 20 most numerous tree species, 6 different oak species are among the top 20 most voluminous tree species. This suggests that many of the oak species are larger, older, and occupy more of a dominant canopy position.



Laurel Fork Falls in east Tennessee. (photo courtesy of Twenty20 Photos)

If we look at timberland, a subset of all forest land which excludes lands reserved from timber harvesting by statute, we can examine trends in

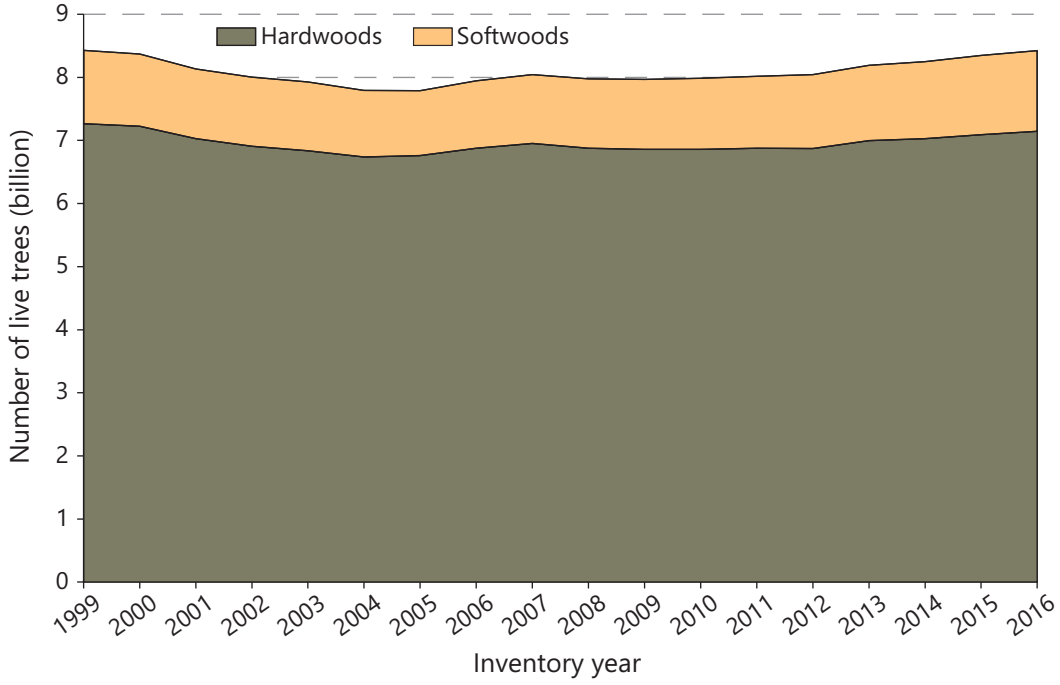


Figure 8—Number of live trees (≥1 inch d.b.h.) on forest land by major species group, Tennessee, 1999–2016.

Table 5—Number of live trees (≥ 1 inch d.b.h.) by species and ratio of saplings to sawtimber by tree size-class on forest land, Tennessee, 2016

Species	Total	Tree-size class			Sap-saw-ratio
		Sawtimber-size	Poletimber-size	Sapling-size	
Red maple	793,452,093	33,542,934	122,923,730	636,985,429	18.99
Yellow-poplar	527,546,082	57,063,948	79,946,049	390,536,085	6.84
Sweetgum	450,505,601	23,232,785	72,428,701	354,844,115	15.27
Sugar maple	431,317,106	19,444,767	60,571,906	351,300,432	18.07
Blackgum	430,527,305	9,449,138	39,758,587	381,319,580	40.35
Eastern redcedar	406,237,218	29,610,693	79,926,891	296,699,634	10.02
Sourwood	377,563,761	3,186,348	73,580,443	300,796,971	94.40
Loblolly pine	358,131,584	42,350,953	115,542,809	200,237,823	4.73
Winged elm	322,458,387	3,261,742	31,313,322	287,883,323	88.26
White oak	293,368,537	61,297,490	80,271,217	151,799,830	2.48
American beech	249,784,795	11,908,062	21,963,376	215,913,357	18.13
Virginia pine	249,687,533	22,464,780	40,203,842	187,018,911	8.32
Eastern hophornbeam	244,904,799	47,117	8,683,799	236,173,883	5,012.50
Black cherry	199,041,941	7,452,276	33,162,394	158,427,271	21.26
Flowering dogwood	192,808,510	–	9,761,083	183,047,427	N/R
Chestnut oak	169,168,734	55,262,528	52,856,805	61,049,401	1.10
Pignut hickory	166,712,567	21,642,384	42,720,291	102,349,892	4.73
Sassafras	137,692,067	4,530,779	18,950,998	114,210,291	25.21
Mockernut hickory	127,197,339	13,445,903	29,397,955	84,353,481	6.27
Green ash	123,869,277	8,761,713	18,555,423	96,552,141	11.02

D.b.h. = diameter at breast height.
– = no sample for the cell; N/R = no ratio.

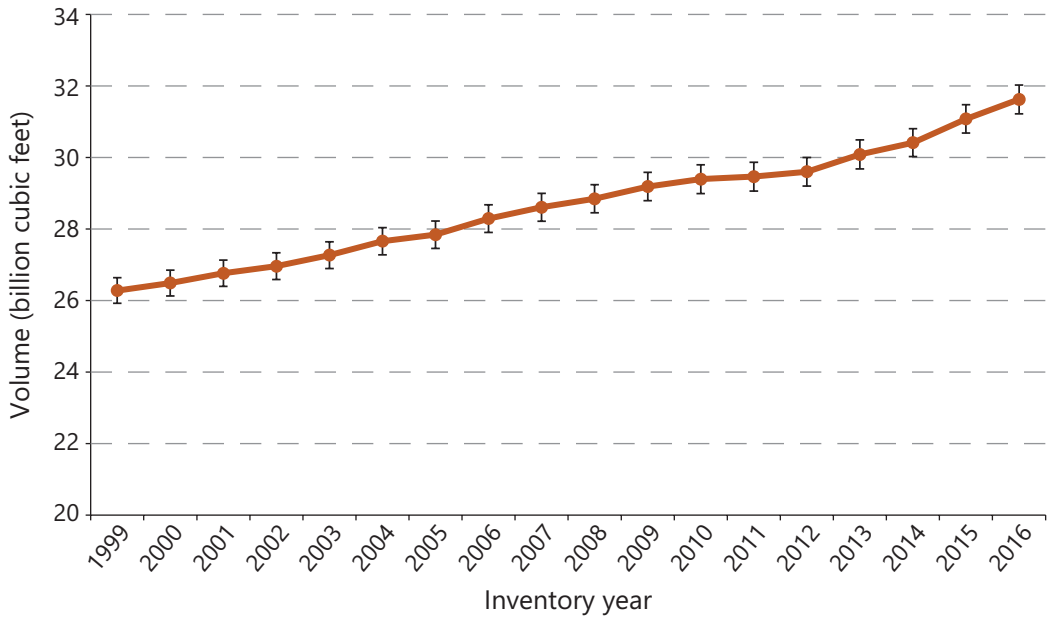


Figure 9—Net merchantable bole volume of live trees (≥ 5 inches d.b.h.) on forest land for the period 1999 to 2016.

Table 6—Net merchantable bole volume of live trees (≥5 inches d.b.h.) in cubic feet, by species and major ownership group on forest land, Tennessee, 2016

Species	Total	Major ownership group	
		Public	Private
	cubic feet		
Yellow-poplar	3,623,867,220	864,557,855	2,759,309,365
White oak	3,111,689,977	534,423,583	2,577,266,394
Chestnut oak	2,709,901,948	820,873,957	1,889,027,992
Red maple	1,785,118,476	471,472,229	1,313,646,247
Loblolly pine	1,328,098,429	153,065,214	1,175,033,215
Sweetgum	1,313,869,550	170,406,542	1,143,463,008
Scarlet oak	1,148,882,446	340,471,538	808,410,909
Pignut hickory	1,102,895,774	128,564,855	974,330,919
Sugar maple	1,035,024,283	129,029,050	905,995,233
Northern red oak	896,617,415	277,053,694	619,563,721
Southern red oak	855,948,653	136,310,987	719,637,665
Black oak	781,313,833	187,756,867	593,556,966
Eastern redcedar	713,619,984	84,976,733	628,643,251
Virginia pine	708,935,867	168,976,924	539,958,943
American beech	646,454,659	83,048,118	563,406,541
Shagbark hickory	583,978,210	42,121,878	541,856,332
Eastern white pine	556,657,174	304,912,623	251,744,551
Green ash	470,494,051	99,251,629	371,242,422
White ash	465,611,553	44,830,483	420,781,070

D.b.h. = diameter at breast height.

wood volume further back in time by including those forest inventories in Tennessee that were previously limited to timberland. Net volume has increased steadily for hardwood species, and to a lesser extent softwood species (fig. 10), to reach its current level of 25.8 bcf in hardwoods and 4.0 bcf in softwoods. While very little hardwood volume exhibits clear evidence of artificial regeneration (i.e., planted), about one-third (29 percent) of softwood volume was planted (table 7). Loblolly and shortleaf pine volume are almost evenly split between stands that naturally regenerated, 816 million cubic feet (mcf), and those that were planted (870 mcf). Hardwood volume is predominately in naturally regenerated stands. The relatively small percentage of hardwood volume in planted stands could be hardwood trees that regenerated naturally within softwood plantations rather than planted hardwood trees.

In an ownership pattern common across the Southern United States, the majority of wood volume (83 percent) is owned by nonindustrial private landowners (table 8). Nine percent of the volume is on lands stewarded by Federal agencies such as the Forest Service, while the other 7 percent of the volume is growing on State and local public lands.

Sound bole volume and biomass are highly related, so similar to volume, the majority of tree biomass in Tennessee forests is accounted

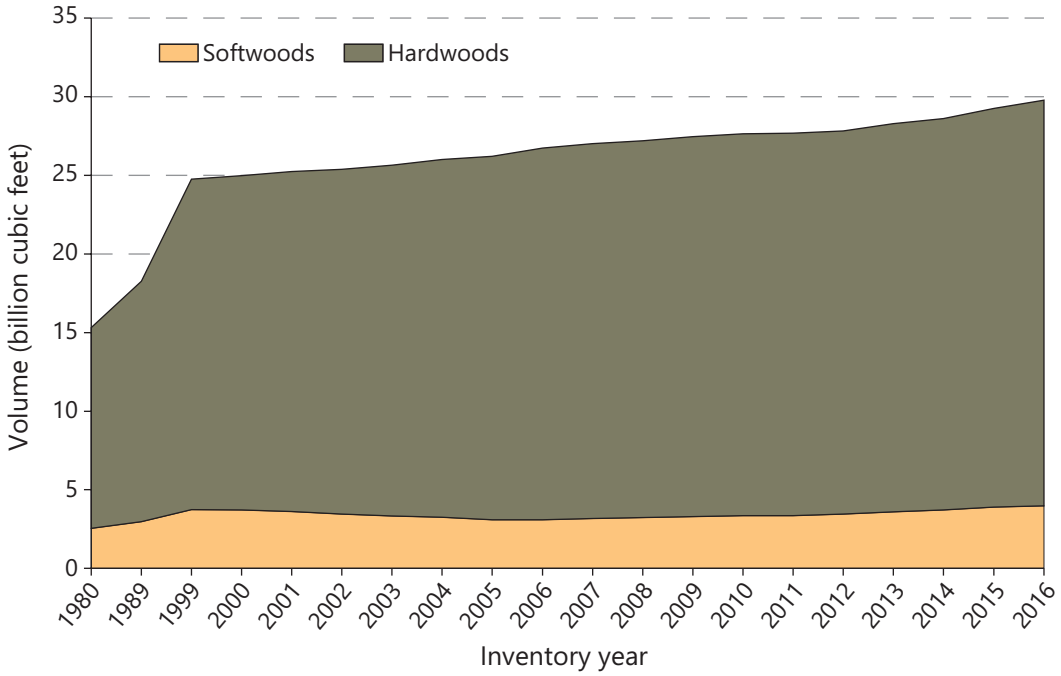


Figure 10—Net merchantable bole volume of live trees (≥ 5 inches d.b.h.) by major species group on timberland, Tennessee, 1980–2016.

Young pines that will make up the future forests of Tennessee. (USDA Forest Service photo by Christopher M. Oswalt)

Table 7—Net merchantable bole volume of live trees (≥ 5 inches d.b.h.) in cubic feet, by species group and stand origin on timberland, Tennessee, 1980–2016

Species group	Total	Stand origin		Percent planted
		Natural stands	Clear evidence of artificial regeneration	
	cubic feet			
Total	29,782,287,293	28,744,574,742	1,037,712,551	3.5
Loblolly and shortleaf pine	1,686,015,347	815,555,518	870,459,829	51.6
Other yellow pines	697,488,205	688,766,267	8,721,938	1.3
Eastern white and red pine	497,552,830	487,448,301	10,104,529	2
Eastern hemlock	248,508,091	248,508,091	–	0
Cypress	143,447,221	143,447,221	–	0
Other eastern softwoods	710,309,904	701,293,016	9,016,889	1.3
Select white oaks	3,327,218,000	3,307,688,031	19,529,969	0.6
Select red oaks	1,073,858,193	1,067,727,503	6,130,691	0.6
Other white oaks	2,922,369,047	2,916,927,260	5,441,787	0.2
Other red oaks	2,869,144,935	2,851,230,551	17,914,384	0.6
Hickory	2,575,785,779	2,573,249,846	2,535,933	0.1
Yellow birch	13,640,108	13,640,108	–	0
Hard maple	1,004,680,097	1,001,509,218	3,170,879	0.3
Soft maple	1,691,393,416	1,686,039,822	5,353,594	0.3
Beech	611,610,202	611,104,061	506,141	0.1
Sweetgum	1,254,248,909	1,225,667,319	28,581,590	2.3
Tupelo and blackgum	492,655,496	490,464,216	2,191,281	0.4
Ash	944,224,797	942,363,142	1,861,655	0.2
Cottonwood and aspen	66,238,594	65,534,103	704,491	1.1
Basswood	141,697,704	141,697,704	–	0
Yellow-poplar	3,343,923,215	3,322,746,674	21,176,541	0.6
Black walnut	263,323,261	263,323,261	–	0
Other eastern soft hardwoods	2,233,134,165	2,212,434,028	20,700,137	0.9
Other eastern hard hardwoods	327,846,975	326,097,259	1,749,716	0.5
Eastern noncommercial hardwoods	641,972,801	640,112,222	1,860,579	0.3

D.b.h. = diameter at breast height.

– = no sample for the cell.

Sampling error (SE) percent (confidence level 68 percent).

Note: For 95-percent confidence level, multiply SE percentage by 1.96.

Table 8—Net merchantable bole volume of live trees (≥ 5 inches d.b.h.) in cubic feet, by species group and ownership group on timberland, Tennessee, 1980–2016

Species group	Total	Ownership group			
		National Forest	Other Federal	State and local	Private
			cubic feet		
Total	29,782,287,293	1,984,158,320	772,008,281	2,161,390,739	24,864,729,953
Loblolly and shortleaf pine	1,686,015,347	50,938,301	60,603,445	68,346,001	1,506,127,600
Other yellow pines	697,488,205	105,857,890	3,097,475	32,554,814	555,978,026
Eastern white and red pine	497,552,830	209,119,226	–	36,689,053	251,744,551
Eastern hemlock	248,508,091	61,075,525	–	24,344,350	163,088,216
Cypress	143,447,221	–	–	64,788,324	78,658,896
Other eastern softwoods	710,309,904	19,202,036	37,911,258	24,553,359	628,643,251
Select white oaks	3,327,218,000	133,272,995	95,133,414	228,098,207	2,870,713,384
Select red oaks	1,073,858,193	118,851,403	21,390,419	61,148,329	872,468,042
Other white oaks	2,922,369,047	392,145,176	62,349,279	216,826,624	2,251,047,968
Other red oaks	2,869,144,935	134,851,106	114,409,955	328,431,759	2,291,452,116
Hickory	2,575,785,779	53,705,080	48,779,846	174,020,934	2,299,279,919
Yellow birch	13,640,108	12,138,422	–	193,031	1,308,655
Hard maple	1,004,680,097	19,740,492	29,450,295	49,178,630	906,310,681
Soft maple	1,691,393,416	198,721,828	28,448,578	124,221,452	1,340,001,558
Beech	611,610,202	10,366,379	3,257,144	34,580,138	563,406,541
Sweetgum	1,254,248,909	19,980,758	36,309,998	54,495,145	1,143,463,008
Tupelo and blackgum	492,655,496	35,070,587	15,685,286	37,622,188	404,277,436
Ash	944,224,797	9,972,142	24,949,866	80,225,502	829,077,287
Cottonwood and aspen	66,238,594	–	1,005,564	5,751,135	59,481,895
Basswood	141,697,704	20,662,190	4,406,920	27,345,370	89,283,224
Yellow-poplar	3,343,923,215	217,685,346	98,492,383	268,436,121	2,759,309,365
Black walnut	263,323,261	2,467,988	11,132,487	16,903,575	232,819,211
Other eastern soft hardwoods	2,233,134,165	48,672,633	60,543,246	152,463,165	1,971,455,120
Other eastern hard hardwoods	327,846,975	54,802,968	4,323,605	17,898,074	250,822,328
Eastern noncommercial hardwoods	641,972,801	54,857,850	10,327,818	32,275,458	544,511,675

D.b.h. = diameter at breast height.

– = no sample for the cell.

Sampling error (SE) percent (confidence level 68 percent).

Note: For 95-percent confidence level, multiply SE percentage by 1.96.

for by hardwood species (table 9). In fact, four species groups (select white oaks, other white oaks, select red oaks, and other red oaks) account for 37 percent of all aboveground biomass of live trees (≥1 inch d.b.h.). Total aboveground biomass of live trees is over 822 million dry short tons (table 9). The loblolly and shortleaf pine species group accounts for about 5 percent of all aboveground live tree biomass. While most of the aboveground live tree biomass for species groups such as oaks is found growing in trees located in a dominant or codominant crown class, for species like maples (particularly red maple), the aboveground live tree biomass is more evenly split between the dominant/codominant classes and the intermediate/overtopped classes (table 9).

Table 9—Aboveground biomass of live trees (≥ 1 inch d.b.h.) in dry short tons, by species group and crown class on forest land, Tennessee, 2016

Species group	Total	Crown class				
		Open grown	Dominant	Codominant	Intermediate	Overtopped
		dry short tons				
Total	822,131,973	837,602	37,419,907	552,173,914	110,095,673	121,604,876
Loblolly and shortleaf pine	36,916,892	108,360	1,145,358	31,224,662	3,004,910	1,433,601
Other yellow pines	16,871,213	20,214	353,388	12,672,749	2,258,934	1,565,928
Eastern white and red pine	9,169,743	3,637	887,228	6,311,824	467,246	1,499,809
Spruce and balsam fir	373,305	–	–	325,724	18,280	29,301
Eastern hemlock	5,236,052	–	32,650	2,651,003	591,091	1,961,308
Cypress	2,882,716	–	527,680	2,002,593	191,218	161,225
Other eastern softwoods	15,587,520	8,172	333,006	7,086,941	3,395,595	4,763,806
Select white oaks	97,980,558	239,295	4,229,127	73,948,717	10,569,102	8,994,317
Select red oaks	33,178,472	38,180	1,998,580	27,042,416	2,531,469	1,567,827
Other white oaks	89,150,096	39,973	2,283,316	70,252,873	10,416,662	6,157,273
Other red oaks	86,355,557	90,946	5,591,023	70,916,384	6,699,610	3,057,594
Hickory	83,409,203	38,436	4,468,308	56,499,404	11,593,716	10,809,339
Yellow birch	2,404,422	–	–	1,733,962	472,898	197,562
Hard maple	31,409,104	128,231	493,277	13,676,849	6,459,623	10,651,125
Soft maple	47,543,544	13,787	731,005	22,886,942	9,367,746	14,544,063
Beech	17,018,452	427	762,170	8,889,556	2,803,782	4,562,517
Sweetgum	30,903,926	20,400	1,696,302	20,857,564	3,874,120	4,455,539
Tupelo and blackgum	13,715,416	1,991	288,450	5,021,843	2,901,578	5,501,554
Ash	25,931,791	–	1,521,499	17,133,273	4,206,352	3,070,666
Cottonwood and aspen	1,222,992	–	439,256	696,263	34,774	52,699
Basswood	2,710,122	–	220,051	1,477,893	545,325	466,853
Yellow-poplar	70,683,521	49,380	5,837,701	53,668,339	6,525,129	4,602,972
Black walnut	6,251,758	–	431,393	4,208,170	1,184,930	427,265
Other eastern soft hardwoods	57,941,072	28,849	2,541,275	30,360,979	11,754,538	13,255,432
Other eastern hard hardwoods	13,524,483	2,231	395,804	5,606,492	2,853,897	4,666,060
Eastern noncommercial hardwoods	23,760,041	5,096	212,060	5,020,499	5,373,148	13,149,239

D.b.h. = diameter at breast height.
– = no sample for the cell.

The distribution of wood volume across tree diameter classes has important implications for forest management planning and the wood products industries. While total volume on timberland has increased over time, most of that increase has occurred in diameter classes between 10 to 25 inches while the smallest and largest diameter classes have remained relatively unchanged (fig. 11). Currently, most volume is on private lands (fig. 12). Public forest land has a diameter distribution with a peak slightly larger than private forest lands. The peak of the distribution for publicly stewarded forest lands is the 15.0–16.9 inch diameter class while the peak is 13.0–14.9 for private forest lands (fig. 12).

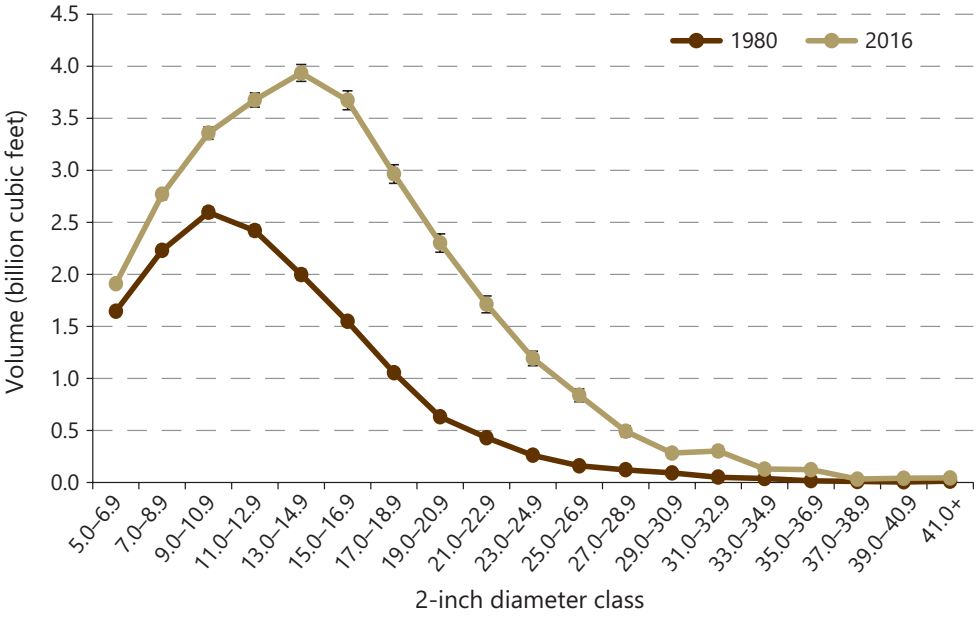


Figure 11—Net merchantable bole volume of live trees (≥5 inches d.b.h.) by 2-inch diameter class on timberland, Tennessee, 1980 and 2016.

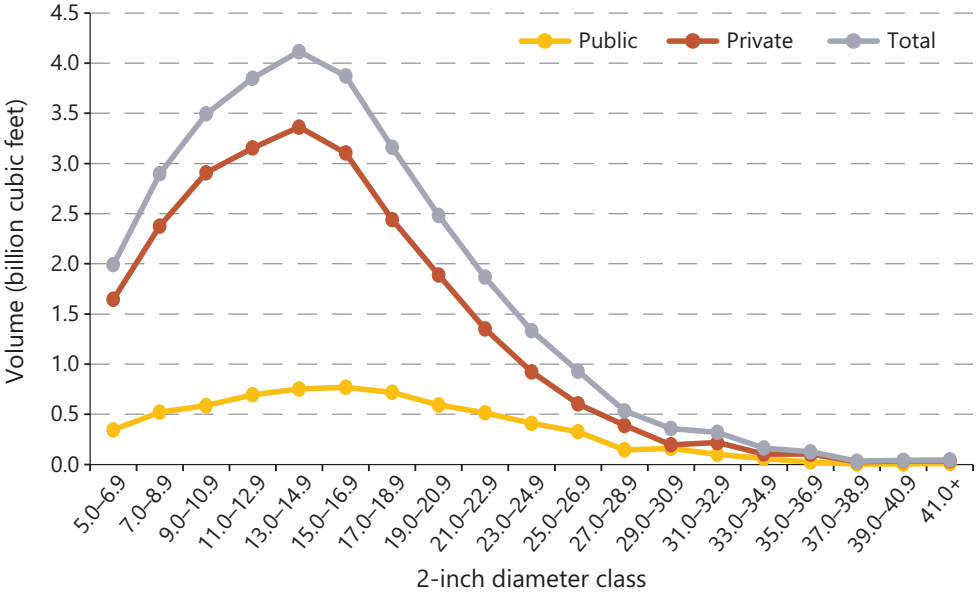


Figure 12—Net merchantable bole volume of live trees (≥5 inches d.b.h.) by major ownership group on forest land, Tennessee, 2016.

GROWTH, REMOVALS, AND MORTALITY

Based on estimates of net change (gross growth – mortality – removals) from remeasured plots, total sound bole volume increased (on average) more than 430 mcf annually between 2011 and 2016 (table 10). The annual positive net change amounts to an average 1.4-percent increase each year of the total standing live volume (table 10). Among all species groups, only eastern hemlock (*Tsuga Canadensis*) exhibited negative average annual net change. The loblolly and shortleaf pine species group experienced the largest average annual increase (83 mcf per year) of any other single species group. When all four oak species groups are combined, average annual net change of all oak species is still smaller than that of the loblolly and shortleaf pine group.

In 2016, 80 percent of the total net annualized growth of 637 mcf per year was on hardwood trees and 20 percent on softwoods (fig. 13).

Table 10—Average annual net change (net growth minus removals) of sound bole volume of trees (≥ 5 inches d.b.h.) in cubic feet, by species and ownership groups on forest land, Tennessee, 2016

Species group	Total	Ownership group			
		National Forest	Other Federal	State and local	Private
			cubic feet		
Total	430,172,060	20,254,091	17,116,493	41,311,987	351,489,490
Loblolly and shortleaf pine	83,089,912	2,495,058	2,294,344	4,580,021	73,720,490
Other yellow pines	9,776,435	1,625,761	548,215	680,256	6,922,202
Eastern white and red pine	3,911,194	2,110,057	-1,682,989	959,768	2,524,358
Spruce and balsam fir	272,232	42,088	230,144	0	0
Eastern hemlock	-20,040,717	-9,954,335	-9,698,291	95,353	-483,444
Cypress	1,960,120	0	24,762	1,186,556	748,802
Other eastern softwoods	19,116,500	448,958	1,531,498	607,317	16,528,727
Select white oaks	23,262,473	2,388,246	2,505,377	4,472,324	13,896,526
Select red oaks	13,845,669	2,013,733	958,231	-858,976	11,732,681
Other white oaks	29,737,198	6,576,704	3,532,990	4,309,653	15,317,850
Other red oaks	3,761,021	298,048	3,161,911	4,900,090	-4,599,028
Hickory	26,493,507	618,166	1,297,596	3,705,820	20,871,925
Yellow birch	1,321,736	-76,168	1,386,132	-86,965	98,737
Hard maple	19,353,701	625,280	1,094,980	-309,182	17,942,623
Soft maple	31,143,085	3,446,544	2,789,815	1,870,152	23,036,576
Beech	7,893,823	-96,708	-569,130	146,420	8,413,241
Sweetgum	35,204,206	670,738	23,507	1,311,600	33,198,361
Tupelo and blackgum	6,537,689	469,088	389,438	632,545	5,046,619
Ash	10,665,730	286,570	731,663	1,625,633	8,021,863
Cottonwood and aspen	4,846,536	0	51,007	645,632	4,149,897
Basswood	1,368,212	309,240	271,552	602,914	184,507
Yellow-poplar	62,827,730	3,651,890	5,274,451	3,980,786	49,920,602
Black walnut	3,881,254	205,321	360,490	567,723	2,747,720
Other eastern soft hardwoods	37,927,573	669,648	704,833	4,530,828	32,022,266
Other eastern hard hardwoods	12,789	348,688	-83,015	526,127	-779,012
Eastern noncommercial hardwoods	12,002,451	1,081,475	-13,020	629,595	10,304,401

D.b.h. = diameter at breast height.

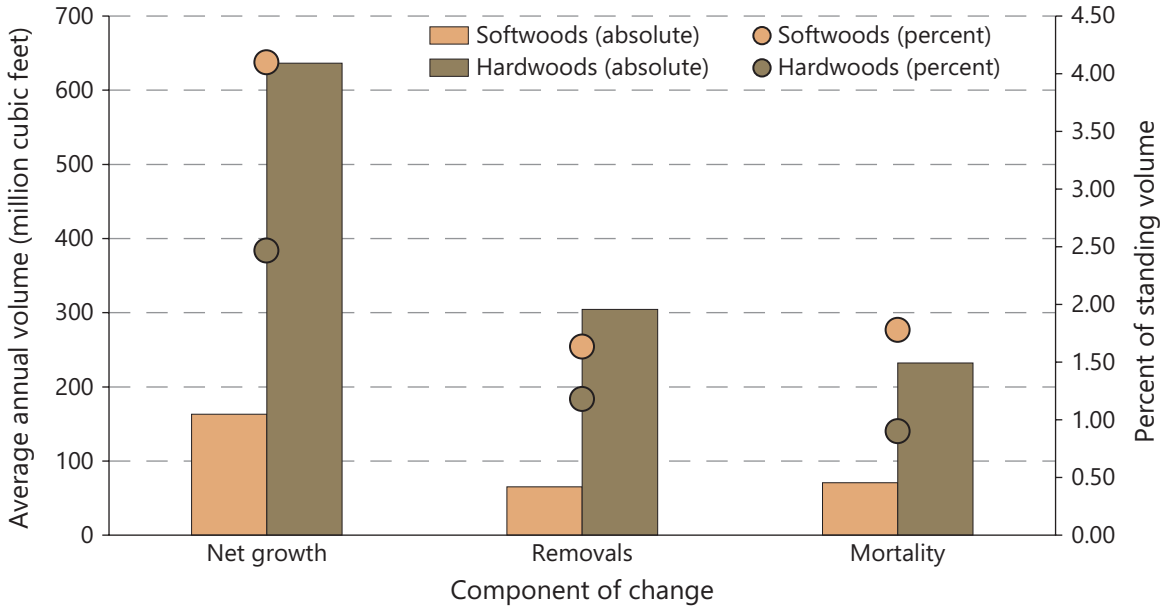


Figure 13—Average annual net growth, removals, and mortality of sound bole volume of trees (≥5 inches d.b.h.), as an absolute value (left axis) and as a percent of total standing stock (right axis) by major species group on forest land, Tennessee, 2016.

Similarly, 82 percent of total annualized removals was the result of hardwood removals and 18 percent was due to softwood removals (fig. 13). The ratio of net growth to removals, a valuable statistic to gauge the health of current populations looking forward, for both hardwood and softwood species as individual groups was above 2 to 1 for each. The ratio for both groups indicates that annually, on Tennessee forests, at least twice as much volume is grown than is being removed through harvesting and/or land use changes. In fact, removals represent 1.6 and 1.2 percent of the total standing volume for softwoods and hardwoods, respectively (fig. 13).

Average annual removals (all) and harvest removals have been declining during the period from 2002 to 2016 (fig. 14). While mortality and net growth have also declined overall during the same time period, average annual mortality appears to have stabilized and annual net growth has increased over the last 5 years.

While harvest removals have declined slightly over time (fig. 14), current harvest removals account for about 346 mcf of volume. Since harvest removals currently make up 94 percent of all removals, hardwood harvest removals account for 82 percent of all harvest removals in the State. Hardwood harvest removals are concentrated in the larger-diameter stands, corresponding to the greater use of hardwoods for sawn lumber rather than pulp products (fig 15). Softwoods harvest removals are concentrated in smaller diameter stands even though softwood trees are used for both sawn lumber and pulp products. Due to the nature of FIA plot collection, there is a time lag between some events being observed in inventory data summaries. As such, plots measured over the 2002–2016 time period can still reflect the overall economic downturn experienced across the country. Harvesting activity across the Southern United States shows declines during this time as the demand for wood products decreased.

While stable recently, average annual mortality has experienced a slight decrease over the time period between 2002 and 2016 with a current rate of 303 mcf per year. The peak in this

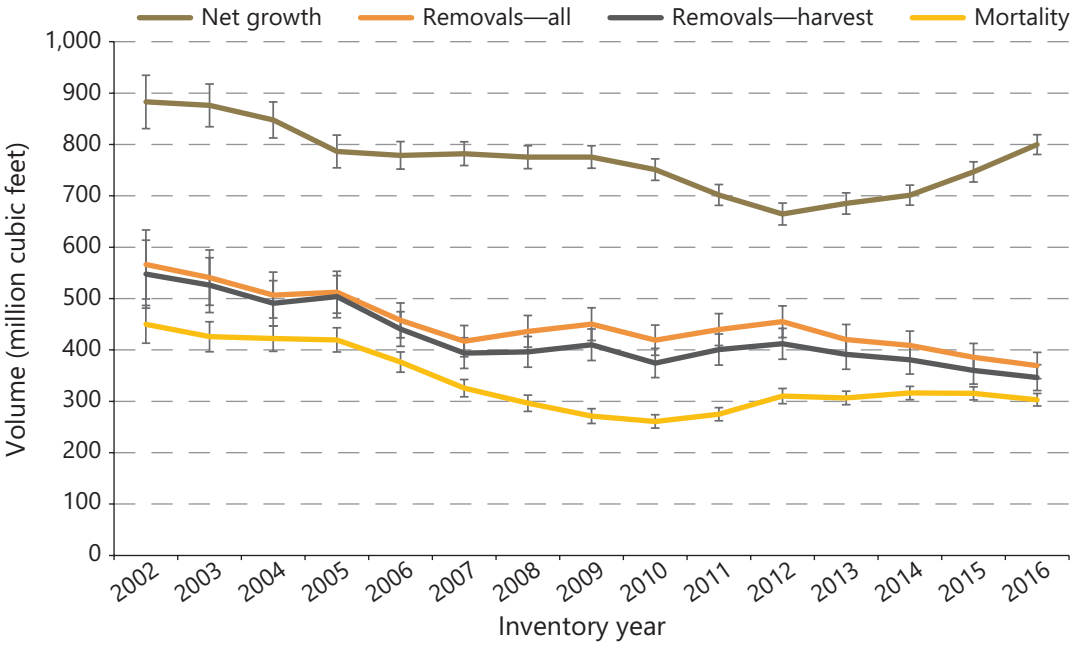


Figure 14—Average annual net growth, all removals, harvest removals, and mortality of sound bole volume of trees (≥ 5 inches d.b.h.) on forest land, Tennessee, 2002–2016.

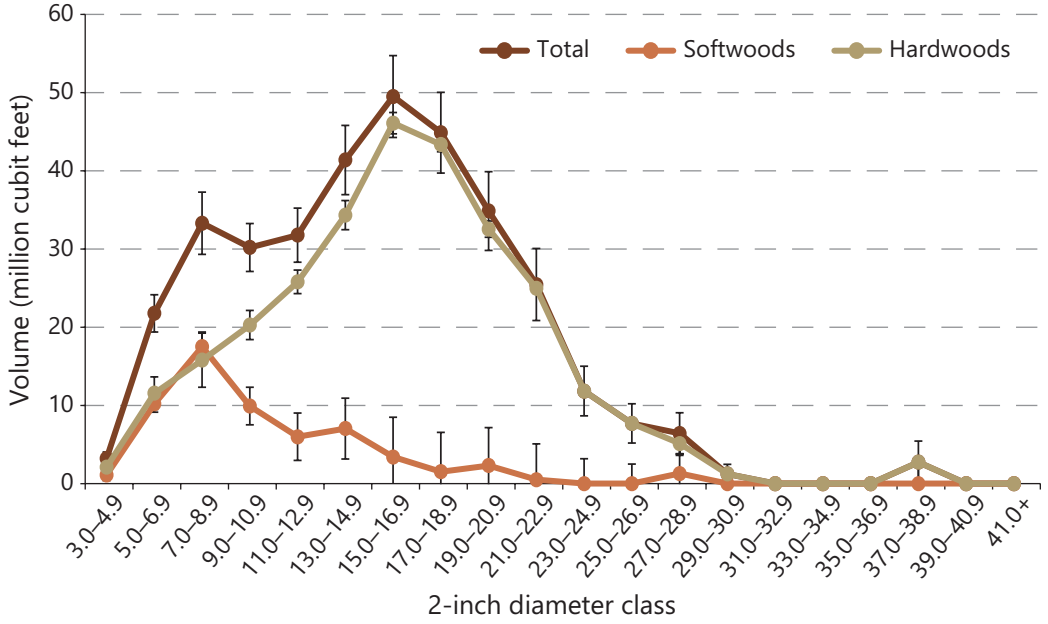


Figure 15—Average annual harvest removals of sound bole volume of trees (≥ 5 inches d.b.h.) across 2-inch diameter classes by major species group on forest land, Tennessee, 2016.

A regenerating stand of natural pine below older pine trees that succumbed to the southern pine beetle (*Dendroctonus frontalis*), a natural insect that can sometimes cause significant mortality among many pines species common in Tennessee. (USDA Forest Service photo by Christopher M. Oswalt)

time period was in 2002 with average annual mortality near 450 mcf per year (fig. 16). Inventory data for the year 2002 was still exhibiting signs of the southern pine beetle epidemic that occurred in Tennessee forests between 1999 and 2001 (Oswalt and others 2012). This fact is extremely apparent when you compare average annual mortality for hardwoods to mortality in softwoods during the same period (fig. 16). Hardwood mortality is relatively stable across time. Softwood mortality was high during 2002 through 2005 and then significantly declined during the period from 2006 to 2010. Softwood annual mortality has been relatively stable since 2010, near 71 mcf annually.

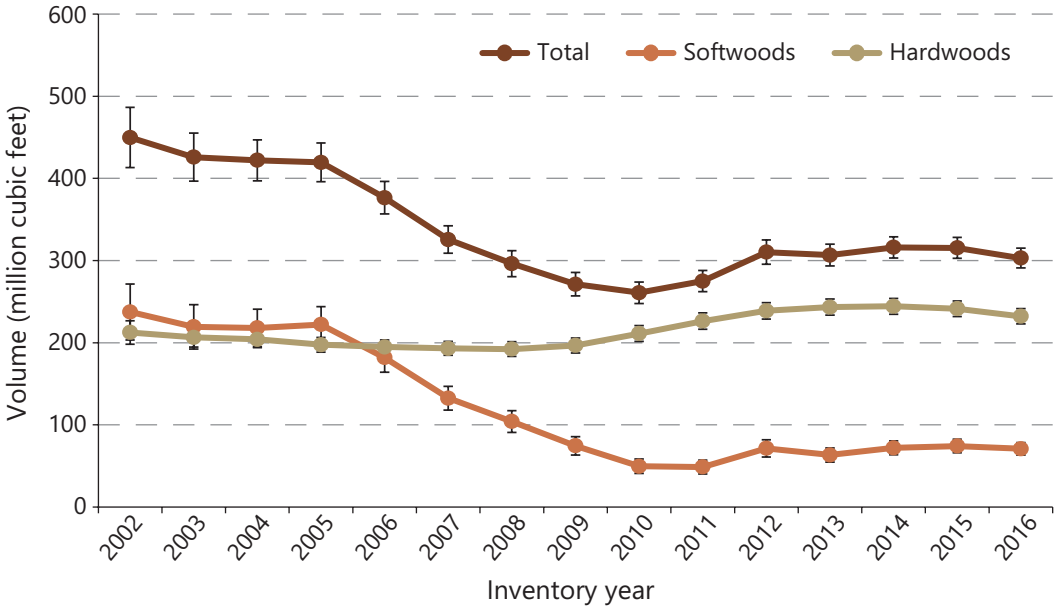


Figure 16—Average annual mortality of sound bole volume of trees (≥ 5 inches d.b.h.) by major species group on forest land, Tennessee, 2002–2016.

A timber harvest that is barely visibile as part of a diverse landscape with numerous land uses. (USDA Forest Service photo by Christopher M. Oswalt)

DISTURBANCE AND INVASIVE PLANTS

Disturbance is a natural and necessary part of forest health. As of 2016, animal damage (e.g., grazing) is noted as the primary disturbance on more acres than any other disturbance, followed by severe weather events and fire (fig. 17). For the most part, most visible disturbance types have been consistent since about 2010. However, disturbances during the period between 2000 and 2010 were considerably more dynamic. The peak of insect disturbance in 2005 corresponds to the southern pine beetle epidemic that occurred in the Tennessee forests between 1999 and 2001 (Oswalt and others 2012). Disturbance rates considered across the overall forest landscape are relatively low; currently, only 6.5 percent of forest land had disturbances severe enough for crew members to record (discrete acres disturbed, not summing acres disturbed by more than one event).

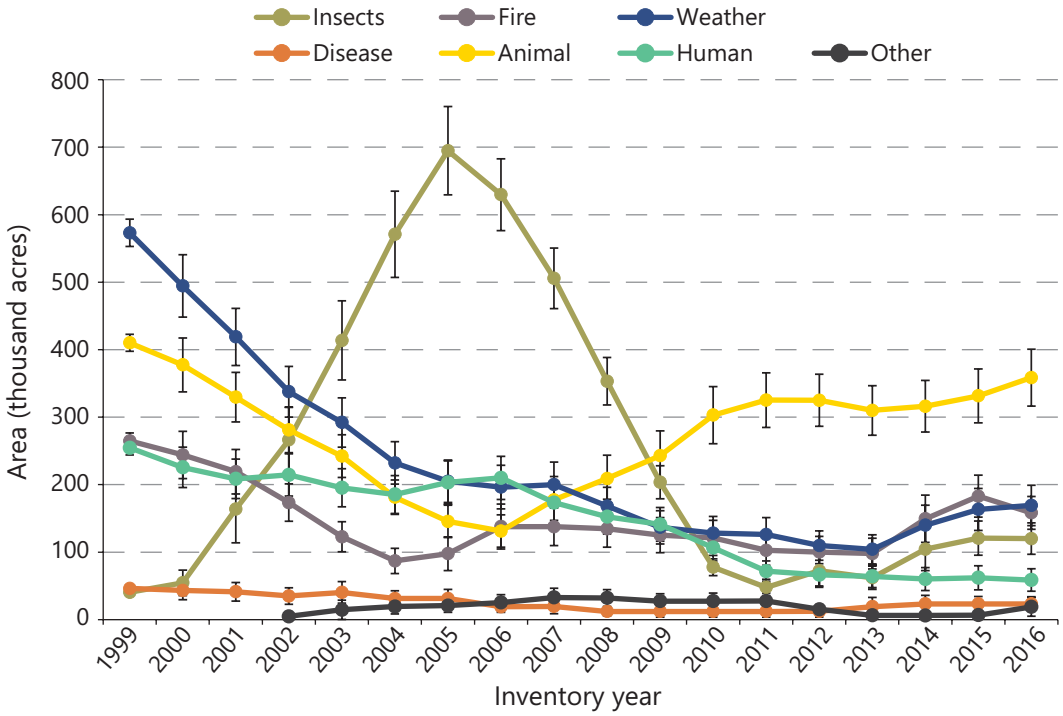


Figure 17—Area of forest land by primary disturbance, Tennessee, 1999–2016.

Standing Dead Trees and Down Woody Material

Dead wood performs many functions within a forest ecosystem. While too much accumulated dead wood can become a fire hazard, dead wood is necessary to replenish soil nutrients (Polit and Brown 1996), provide wildlife food sources and habitat (Ketzler and others 2017), support biodiversity (Jonsson and others 2005), and establish important fungal and mycorrhizal communities (Norden and Paltto 2001).

There is an average of 11 standing dead trees ≥ 5 inches d.b.h. per acre in Tennessee, with slightly higher numbers on public land versus private land (fig. 18). Statewide, that amounts to approximately 157 million standing dead trees (table 11). Average standing dead trees per acre of forest land were highest in the East and Central survey units.

Eventually, standing dead trees fall and become part of the forest floor microcosm. Down woody material (DWM) can be divided into size classes based on fuel time-lag classes: 1-hour, 10-hour, 100-hour, and 1,000-hour fuel classes indicate the amount of time it would take for two-thirds of a single piece of DWM in that size class to dry to the ambient air moisture. All downed dead wood (fine woody debris, coarse

Microstegium vimineum, a nonnnative grass, blankets the forest floor, impeding the regeneration of native plant species. (USDA photo by Christopher M. Oswalt)

Table 11—Number of standing dead trees (≥ 5 inches d.b.h.) by ownership group on forest land, Tennessee, 2016

Ownership group	Standing dead trees
National forest	16,396,749
Other Federal	14,224,910
State and local	9,461,442
Private	116,750,274
Total	156,833,375

D.b.h. = diameter at breast height.

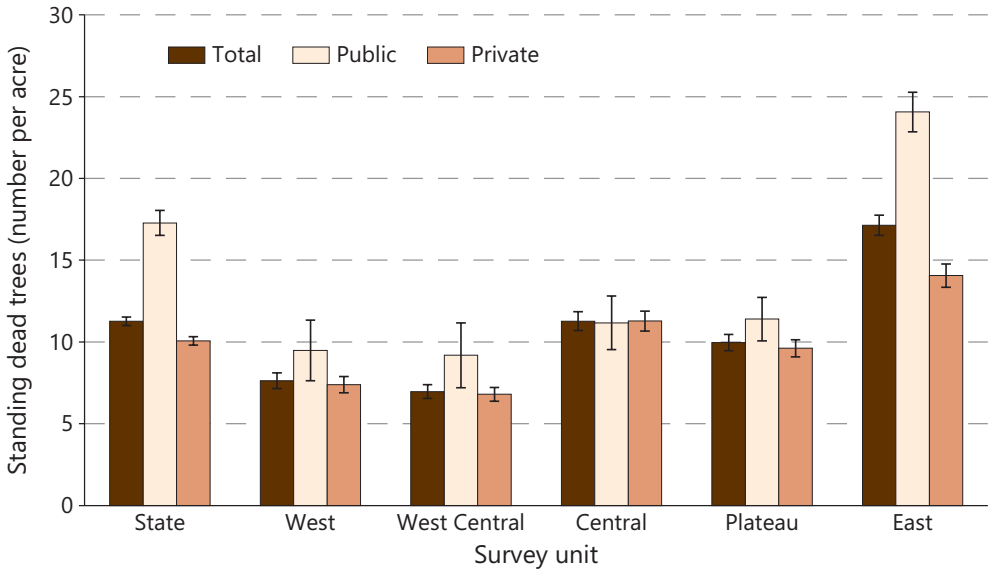


Figure 18—Number of standing dead trees (≥ 5 inches d.b.h.) by survey unit on forest land, Tennessee, 2016.

Great Smoky Mountains National Park, Tennessee, overlooking the Newfound Pass in autumn. Dead trees are very obvious from this overlook. (photo courtesy of Sean Pavone Photography)

woody debris, and piles) accounts for a total of 85.6 million dry short tons on forest land (table 12). While the vast majority of DWM is found on forests with no immediate signs of recent disturbance, a considerable amount is found in forests disturbed by fire, animals, and weather (table 12). Accounting for the area of forests that the DWM is distributed across, the 1,000+-hour fuel class has the highest per acre DWM loading, and the 100-hour fuel class in the oak-gum-cypress forest-type group has the highest loading of all forest-type group and fuel class combinations (table 13). Duff, litter, and slash all contribute more tons per acre of potential fuel individually than all fine woody material combined (table 13).

Table 12—Total weight of DWM (FWD, CWD, and piles) in dry short tons, by forest-type group and primary disturbance on forest land, Tennessee, 2016

Forest-type group	Total	None	Primary disturbance						
			Insects	Disease	Fire	Animal	Weather	Other	Human
			dry short tons						
Total	85,595,565	77,875,141	226,797	206,331	2,269,484	2,539,640	2,423,340	2,485	52,347
White-red-jack pine	248,210	248,210	–	–	–	–	–	–	–
Loblolly-shortleaf pine	3,906,496	1,678,969	–	–	1,267,755	959,772	–	–	–
Other eastern softwoods	297,910	297,910	–	–	–	–	–	–	–
Oak-pine	2,884,612	1,980,729	–	–	45,732	858,151	–	–	–
Oak-hickory	70,479,618	65,958,476	178,391	206,331	939,015	721,717	2,423,340	–	52,347
Oak-gum-cypress	167,836	167,836	–	–	–	–	–	–	–
Elm-ash-cottonwood	4,550,202	4,550,202	–	–	–	–	–	–	–
Maple-beech-birch	2,040,001	1,983,734	36,801	–	16,982	–	–	2,485	–
Other hardwoods	26,408	14,802	11,606	–	–	–	–	–	–
Exotic hardwoods	974,900	974,900	–	–	–	–	–	–	–
Nonstocked	19,371	19,371	–	–	–	–	–	–	–

DWM = Down woody material; FWD= Fine woody debris; CWD= Coarse woody debris.
– = no sample for the cell.

Table 13—Mean fuel loading on forest land by forest-type group and fuel class, Tennessee, 2016

Forest-type group	Fuel class						
				Slash	Forest floor fuels		
	1-hour	10-hour	100-hour	1,000+-hour	Slash	Duff	Litter
	tons per acre						
White-red-jack pine	0.1	0.6	1.4	2.2	0.0	144.7	15.8
Oak-hickory	0.0	0.5	1.5	4.1	0.5	9.3	9.5
Exotic hardwoods	0.1	1.7	5.5	14.1	0.0	5.1	12.0
Maple-beech-birch	0.0	0.5	1.7	7.3	0.0	19.3	6.2
Oak-gum-cypress	0.1	13.0	23.2	0.0	0.0	5.2	66.9
Other eastern softwoods	0.0	0.3	0.4	0.5	0.0	1.9	3.7
Oak-pine	0.0	0.4	0.8	2.2	0.0	11.9	9.2
Elm-ash-cottonwood	0.0	0.3	1.0	1.0	6.7	2.4	4.9
Nonstocked	0.0	0.0	0.0	0.4	0.0	0.0	6.8
Other hardwoods	0.0	0.4	1.1	1.4	0.0	71.7	18.9
Loblolly-shortleaf pine	0.0	0.3	0.7	2.6	0.0	12.0	10.5
All groups	0.0354	0.4521	1.3474	3.7624	0.6559	10.0271	9.2994

Numbers in columns do not sum to totals.
0.0 = no sample for the cell or a value of > 0.0 but < 0.05.

Invasive Plant Species

Invasive plants in southern forests can disrupt ecosystem functions by altering soil chemistry (Rudgers and Orr 2009), changing forest development trajectories (Oswalt and others 2007), replacing native ecosystems (Bruce and others 1997), and potentially disrupting wildlife habitat (Pyšek and others 2012). The FIA program monitors select invasive plant species on forests in Tennessee.

Invasive plant presence/absence was monitored on 11,292 subplots (see appendix A—Inventory Methods for plot design). Invasive plants were detected on 47 percent of those subplots (5,307 subplots). The highest concentrations of monitored forest invasives is in the East survey unit (fig. 19). The most common forest invasive plant monitored by FIA is Japanese honeysuckle (*Lonicera japonica*), impacting nearly 1.2 million acres of forest land across

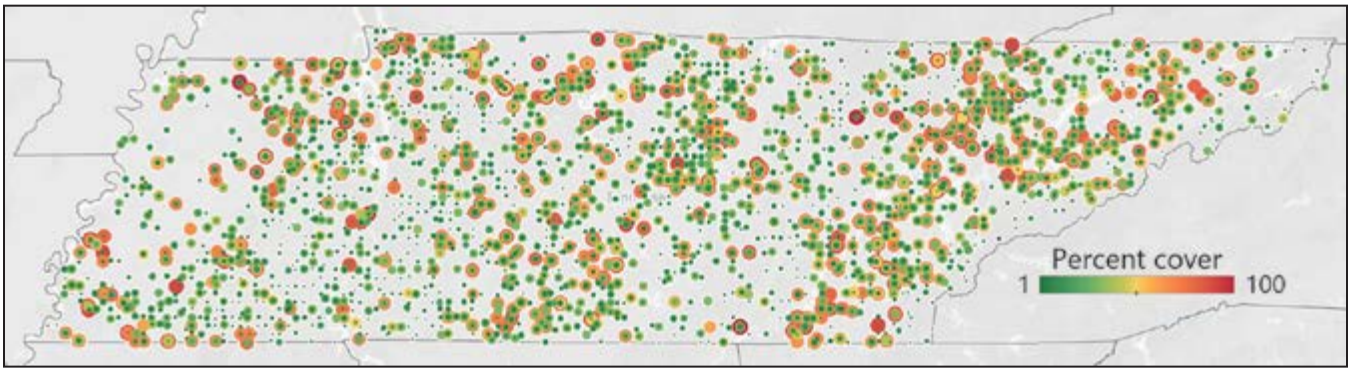


Figure 19—Distribution of monitored forest invasive plants in Tennessee, 2016.

the State (table 14). Studies indicate that the presence of Japanese honeysuckle in forests subject to disturbance can result in lower success of recolonization by tree species, lowering tree density and native plant richness (Dillenburg and others 1993, Nickelson and others 2015). The most common invasive tree in Tennessee is princesstree (*Paulownia tomentosa*). Nepalese browntop (*Microstegium vimineum*) is the second most common invasive plant impacting an estimated 416,000 acres across the State.

While Kudzu (*Pueraria montana*) is a very visible and high-profile invasive vine on forest edges, it was observed on <1 percent of forested subplots surveyed. Kudzu can rapidly colonize disturbed sites, even those with poor soil, but is less persistent in the low-light conditions of the forest canopy (Forseth and Innis 2004). Nevertheless, the ability of the plant to alter species composition and light environments at the forest edge remain reasons for continued monitoring and control efforts, particularly as urban expansion continues.

Table 14—Area of forest land impacted by the 15 most common monitored forest invasive plants in Tennessee, 2016

Invasive species	Area of forest land
	thousand acres
Japanese honeysuckle	1,173.82
Nepalese browntop	416.12
Privet	269.82
Rose	111.62
Tree of heaven	100.43
Honeysuckle	90.16
Japanese privet	74.87
Sericea lespedeza	49.33
Tall fescue	29.82
Lespedeza	26.86
Periwinkle	26.21
Princesstree	20.78
Kudzu	16.21
Oleaster	12.17
Silktree	11.21

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GLOSSARY

All-live tree—All living trees. All size classes, all tree classes, and both saw-log and nonsaw-log species are included. See: FIA tree species list in the field manual.

Average annual mortality—Average annual volume of trees ≥ 5.0 inches d.b.h. that died from human and natural causes during the intersurvey period, excluding those removed by harvesting, cultural operations, land clearing or changes in land use.

Average annual removals—Average annual volume of trees ≥ 5.0 inches d.b.h. removed from the inventory by harvesting, cultural operations (such as timber-stand improvement), land clearing, or changes in land use during the intersurvey period.

Average net annual growth—Average annual net change in volume of trees ≥ 5.0 inches d.b.h./d.r.c. without taking into account losses from cutting (gross growth minus mortality) during the intersurvey period.

Biomass—For the southern region, total aboveground biomass is estimated using allometric equations and is defined as the aboveground weight of wood and bark in live trees ≥ 1.0 inch d.b.h./d.r.c. from the ground to the tip of the tree, excluding all foliage (leaves, needles, buds, fruit, and limbs < 0.5 inch in diameter). Biomass is expressed as oven-dry weight and the units are tons.

Note: the weight of wood and bark in limbs < 0.5 inch in diameter is included in the biomass of small-diameter trees.

Additionally, biomass in the merchantable stem is estimated regionally, where the main and merchantable stems are defined as follows.

Main stem—The central portion of the tree extending from the ground level to the tip for timber species. Woodland species includes from ground level to the tips of all branches of qualifying stems. For timber species trees that fork, the main stem refers to the fork that would yield the most merchantable volume.

Merchantable stem—That portion of the main stem of a timber species tree from a 1-foot stump to a minimum 4-inch top diameter inside or outside bark depending on species. That portion of a woodland species tree from the d.r.c. measurements to the 1.5-inch diameters of all the qualifying stems.

Nationally aboveground and belowground biomass is estimated from each tree's sound volume using a Component Ratio Method that is consistently applied in all FIA regions.

Gross aboveground biomass—Total tree biomass excluding foliage and roots with no deductions made for rotten, missing, or broken-top cubic-foot cull.

Net aboveground biomass—Gross aboveground biomass minus deductions for missing cull, broken-top, and a reduction for a proportion of rotten cull for live or standing dead trees ≥ 5.0 inches d.b.h (Rotten cull will have a factor to reduce specific gravity separately from sound wood). Live and standing dead trees 1.0 to 4.9 inches only have deductions for broken-top cull. Additional deductions are made for dead trees ≥ 1.0 inch using decay class.

Belowground biomass—Coarse roots only.

Further, the total net aboveground biomass estimated using the Component Ratio Method is divided into the following components:

Top—That portion of the main stem of a timber species tree above the 4-inch top diameter. For woodland species, this component of the biomass is included with branches.

Branches—All the branches of a timber species tree excluding the main stem. That portion of all the branches of qualifying stems of woodland species above the 1.5-inch diameter ends.

Bole—See: Merchantable stem.

Stump—That portion of timber species below 1-foot to ground level. That portion of woodland species from all the d.r.c. measurements to ground level.

Blind check—A reinstallation done by a qualified inspection crew without production crew data on hand; at least two full subplots are completely remeasured along with all the plot level information. The two datasets are maintained separately. Discrepancies between the two sets of data are not reconciled. See: Quality assurance and quality control.

Bole—Trunk or main stem of a tree. (See: Main stem.)

Census water—See: Land use.

Coarse woody debris (CWD)—Downed, dead tree and shrub boles, large limbs, and other woody pieces with a minimum small-end diameter of ≥ 3 inches and a length of ≥ 3 feet not attached to a living or standing dead source.

Cold check—An inspection done either as part of the training process, or as part of the ongoing quality control program. Normally the installation crew is not present at the time of inspection. The inspector has the completed data in-hand at the time of inspection. The inspection can include the whole plot or a subset of the plot. Data errors are corrected. See: Quality assurance and quality control.

Components of change—Volume increment and decrement values that explain the change in inventory between two points in time. Components of change are usually expressed in terms of growing-stock or all-live merchantable volume. These components can be expressed as average annual values by dividing the component by the number of years in the measurement cycle. FIA inventories are designed to measure net change over time, as well as the individual components of change that constitute net change (e.g., growth, removals, mortality). Change estimates are computed for two sequential measurements of each inventory panel. Upon remeasurement, a new initial inventory is established for remeasurement at the next scheduled inventory. As such, computation of change components is not intended to span more than one inventory cycle. Rather, the change estimation process is repeated cycle by cycle. This simplifies field protocols and ensures that change estimation is based on short and relatively constant time intervals (e.g., 5 years). Change estimates for individual panels are combined across multiple panels in the same manner as panels are combined to obtain current inventory parameters such as total standing volume. FIA recognizes the following components of change as prescribed core variables; they usually are expressed in terms of growing-stock or all-live volume, where t is the initial inventory of a measurement cycle, and $t + 1$ is the terminal inventory:

Cut—The volume of trees cut between time t and time $t + 1$. The estimate is based on tree size at the midpoint of the measurement interval (includes cut growth). Tree size at the midpoint is modeled from tree size at time t. Trees felled or killed in conjunction with a harvest or silvicultural operation (whether they are utilized or not) are included, but trees on land diverted from forest to nonforest (diversions) are excluded.

Cut growth—The growth of cut trees between time t and the midpoint of the measurement interval. Tree size at the midpoint is modeled from tree size at time t. This term also includes the subsequent growth on ingrowth trees that achieve the minimum diameter threshold prior to being cut.

Diversion—The volume of trees on land diverted from forest to nonforest (or, for some analyses, this may also include land diverted to reserved forest land and other forest land), whether utilized or not, between time *t* and time *t* + 1. The estimate is based on tree size at the midpoint of the measurement interval (includes diversion growth). Tree size at the midpoint is modeled from tree size at time *t*.

Diversion growth—The growth of diversion trees from time *t* to the midpoint of the measurement interval. Tree size at the midpoint is modeled from tree size at time *t*. This term also includes the subsequent growth on ingrowth trees that achieve the minimum diameter threshold prior to diversion.

Growth on ingrowth—The growth on trees between the time they grow across the minimum d.b.h./d.r.c. threshold and time *t* + 1.

Ingrowth—The volume of trees at the time that they grow across the minimum d.b.h./d.r.c. threshold between time *t* and time *t* + 1. The estimate is based on the size of trees at the d.b.h./d.r.c. threshold which is 1.0 inch for all-live trees and 5.0 inches for growing-stock trees. This term also includes trees that subsequently die (i.e., ingrowth mortality), are cut (i.e., ingrowth, cut), or diverted to nonforest (i.e., ingrowth diversion); as well as trees that achieve the minimum threshold after an area reverts to a forest land use (i.e., reversion ingrowth).

Mortality—The volume of trees that die from human or natural causes between time t and time *t* + 1. The estimate is based on tree size at the midpoint of the measurement interval (includes mortality growth). Tree size at the midpoint is modeled from tree size at time *t*.

Mortality growth—The growth of trees that died from human or natural causes between time *t* and the midpoint of the measurement interval. Tree size at the midpoint is modeled from tree size at time *t*. This term also includes the subsequent growth on ingrowth trees that achieve the minimum diameter threshold prior to mortality.

Reversion—The volume of trees on land that reverts from a nonforest land use to a forest land use (or, for some analyses, land that reverts from any source to timberland) between time *t* and time *t* + 1. The estimate is based on tree size at the midpoint of the measurement interval. Tree size at the midpoint is modeled from tree size at time *t* + 1.

Reversion growth—The growth of reversion trees from the midpoint of the measurement interval to time *t* + 1. Tree size at the midpoint is modeled from tree size at time *t* + 1. This term also includes the subsequent growth on ingrowth trees that achieve the minimum diameter threshold after reversion.

Survivor growth—The growth on trees tallied at time *t* that survive until time *t* + 1.

The following components of change may be used to further quantify changes in growing-stock (but not all-live) volume:

Cull decrement—The net gain in growing-stock volume due to reclassification of cull trees to growing-stock trees between two surveys. Cull decrement is the volume of trees that were cull at time *t*, but growing stock at time *t* + 1. The estimate is based on tree size at the midpoint of the measurement interval. Tree size at the midpoint can be modeled from tree at time *t*, time *t* + 1, or both.

Cull decrement growth—The growth from the midpoint of the measurement interval to time *t* + 1 on trees that were cull at time *t*, but growing stock at time *t* + 1. Tree size at the midpoint can be modeled from tree size at time *t*, time *t* + 1, or both.

Cull increment—The net reduction in growing-stock volume due to reclassification of growing stock trees to cull trees between two surveys. Cull increment is the volume of trees

that were growing stock at time *t*, but cull at time *t* + 1. The estimate is based on tree size at the midpoint of the measurement interval (includes cull increment growth). Tree size at the midpoint can be modeled from tree size at time *t*, time *t* + 1, or both.

Cull increment growth—The growth to the midpoint of the measurement interval between time *t* and *t* + 1 of trees that were growing stock at time t, but cull trees at time *t* + 1. Tree size at the midpoint can be modeled from tree size at time *t*, time *t* + 1, or both.

Condition class—The combination of discrete landscape and forest attributes that identify, define, and stratify the area associated with a plot. Examples of such attributes include condition status, forest type, stand origin, stand size, owner group, reserve status and stand density.

Cull—Portions of a tree that are unusable for industrial wood products because of rot, form, or other defect. Cull is further categorized as the following:

Broken-top cubic-foot cull—The broken-top proportion of a timber species tree's merchantable portion from the break to the actual or projected 4-inch top diameter outside bark, or to where the central stem forks, where all forks are <4.0 inches diameter. For trees 1.0 to 4.9 inches diameter this is the proportion of the main stem missing due to a broken-top.

Form board-foot cull—The part of the tree's saw-log portion that is sound but not usable for sawn wood products due to sweep, crook, forking, or other physical culls.

Missing cubic-foot cull—The proportion of a tree's merchantable portion that is missing or absent. Does not include any cull deductions above actual length for broken-top timber trees. Does include cull deductions above actual length for broken-top woodland species. Trees with d.b.h./d.r.c. < 5.0 inches have a null value in this field.

Percent board-foot cull—Percentage of sound and unsound board-foot volume, to the nearest 1 percent.

Rotten cubic-foot cull—The proportion of a tree's merchantable portion that is in a decayed state. Does not include any cull deductions above actual length for broken-top timber trees. Does include cull deductions above actual length for broken-top woodland species. Trees < 5.0 inches d.b.h. have a null value in this field.

Rotten/missing cull—The part of the tree's merchantable portion that is decayed and/or absent due to other factors.

Total board-foot cull—The proportion of a timber species tree's saw-log portion that is rotten, missing, or sound but not useable for sawn wood products due to sweep, crook, forking, or other physical defects (form board-foot cull). Nonsaw-log species and softwoods < 9.0 inches d.b.h. and hardwoods < 11.0 inches d.b.h. have a null value in this field.

Cull tree—Live trees that are unsuitable for the production of some roundwood products, now or prospectively. Cull trees can include those with decay (rotten cull) or poor form, limbiness, or splits (rough cull). Rough cull is suitable for pulpwood and other fiber products.

Cycle—One sequential and complete set of panels.

Diameter at breast height (d.b.h.)—The diameter for tree stem, located at 4.5 feet above the ground (breast height) on the uphill side of a tree. The point of diameter measurement may vary on abnormally formed trees.

Diameter class—A classification of trees based on diameter outside bark, measured at breast height (d.b.h.) above the ground or at root collar (d.r.c.). Note: Diameter classes are commonly in 2-inch increments, beginning with 2-inches. Each class provides a range of values with the class name being the approximate midpoint. For example, the 6-inch class includes trees 5.0 through 6.9 inches d.b.h.

Disturbance—Natural or human-caused disruption that is ≥ 1.0 acre in size and results in mortality and/or damage to 25 percent of all trees in a stand or 50 percent of an individual species' count or, in the case when the disturbance does not initially affect tree growth or health (e.g., grazing, browsing, flooding, etc.), affects 25 percent of the soil surface or understory vegetation. For initial forest plot establishment the disturbance must be within the last 5 years. For remeasured plots only those disturbances that have occurred since the previous inventory are recognized.

Diversion—See: Components of change.

Down woody material (DWM)—DWM is dead material on the ground in various stages of decay. It includes coarse and fine woody material. Previously named down woody debris (DWD). The depth of duff layer, litter layer, and overall fuelbed; fuel loading on the microplot; and residue piles are also measured as part of the DWM indicator for FIA.

Dry weight—The oven-dry weight of biomass.

Federal land—An ownership class of public lands owned by the U.S. Government. See: Ownership.

Fine woody debris (FWD)—Downed, dead branches, twigs, and small tree or shrub boles < 3 inches in diameter not attached to a living or standing dead source.

Fixed-radius plot—A circular sampled area with a specified radius in which all trees of a given size, shrubs, or other items are tallied.

Forest floor—The entire thickness of organic material overlying the mineral soil, consisting of the litter and the duff (humus).

Forest industry land—See: Ownership.

Forest land—Land that is at least 10 percent stocked by forest trees of any size, or land formerly having such tree cover, and is not currently developed for a nonforest use. The minimum area for classification as forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must be at least 120 feet wide to qualify as forest land. Unimproved roads and trails, streams and other bodies of water, or natural clearings in forested areas shall be classified as forest, if < 120 feet in width or 1.0 acre in size. Forest land is divided into timberland, reserved forest land, and other forest land (such as woodland).

Forest type—A classification of forest land based upon and named for the tree species that forms the plurality of live-tree stocking. A forest-type classification for a field location indicates the predominant live-tree species cover for the field location; hardwoods and softwoods are first grouped to determine predominant group, and forest type is selected from the predominant group.

Forest-type group—A combination of forest types that share closely associated species or site requirements.

Elm-ash-cottonwood—Forests in which elm, ash, or cottonwood, singly or in combination, constitute a plurality of the stocking. (Common associates include willow, sycamore, beech, and maple.)

Loblolly-shortleaf pine—Forests in which loblolly pine, shortleaf pine, or other

southern yellow pines, except longleaf or slash pine, singly or in combination, constitute a plurality of the stocking. (Common associates include oak, hickory, and gum.)

Maple-beech-birch—Forests in which maple, beech, or yellow birch, singly or in combination, constitute a plurality of the stocking. (Common associates include hemlock, elm, basswood, and white pine.)

Oak-gum-cypress—Bottomland forests in which tupelo, blackgum, sweetgum, oaks, or southern cypress, singly or in combination, constitute a plurality of the stocking, except where pines account for 25 to 50 percent of stocking, in which case the stand is classified as oak-pine. (Common associates include cottonwood, willow, ash, elm, hackberry, and maple.)

Oak-hickory—Forests in which upland oaks or hickory, singly or in combination, constitute a plurality of the stocking, except where pines account for 25 to 50 percent, in which case the stand is classified oak-pine. (Common associates include yellow-poplar, elm, maple, and black walnut.)

Oak-pine—Forests in which hardwoods (usually upland oaks) constitute a plurality of the stocking but in which pines account for 25 to 50 percent of the stocking. (Common associates include gum, hickory, and yellow-poplar.)

Growing-stock trees—Live large-diameter timber species (excludes nonsaw-log species) trees with one-third or more of the gross board-foot volume in the entire saw-log portion meeting grade, soundness, and size requirements or the potential to do so for medium-diameter and small-diameter trees. A growing-stock tree must have one 12-foot log or two noncontiguous 8-foot merchantable logs, now (large diameter) or prospectively (medium diameter and small diameter), to qualify as growing stock.

Hardwoods—Tree species belonging to the botanical divisions Magnoliophyta, Ginkgophyta, Cycadophyta, or Pteridophyta, usually angiospermic, dicotyledonous, broad-leaved and deciduous.

Soft hardwoods—Hardwood species with an average specific gravity of ≤ 0.50, such as gums, yellow-poplar, cottonwoods, red maple, basswoods, and willows.

Hard hardwoods—Hardwood species with an average specific gravity > 0.50, such as oaks, hard maples, hickories, and beech.

Hot check—An inspection normally done as part of the training process. The inspector is present on the plot with the trainee and provides immediate feedback regarding data quality. Data errors are corrected. Hot checks can be done on training plots or production plots. See: Quality assurance and quality control.

Land—The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river flood plains.

Land cover—The dominant vegetation or other kind of material that covers the land surface. A given land cover may have many land uses.

Land use—The purpose of human activity on the land; it is usually, but not always, related to land cover.

Southern regional present land use categories are as follows:

Accessible timberland—Land that is within the population of interest, is accessible, is on a subplot that can be occupied at subplot center, can safely be visited, and meets the criteria for forest land (see: forest land).

Accessible other forest land—Land that meets the definition of accessible forest land, but is incapable of producing 20 cubic feet per acre per year of industrial wood under natural

conditions because of adverse site conditions. Adverse conditions include sterile soils, dry climate, poor drainage, high elevation, steepness and soil rockiness.

Agricultural land—Land managed for crops, pasture, or other agricultural use. The area must be at least 1.0 acre in size and 120 feet wide (with the exception of windbreak/shelterbelt, which has no minimum width). This land use includes cropland, pasture (improved through cultural practices), idle farmland, orchard, Christmas tree plantation, maintained wildlife opening, and windbreak/shelterbelt.

Rangeland—Land primarily composed of grasses, forbs, or shrubs. This includes lands vegetated naturally or artificially to provide a plant cover managed like native vegetation and does not meet the definition of pasture. The area must be at least ≥ 1.0 acre in size and ≤ 120 feet wide.

Developed—Land used primarily by humans for purposes other than forestry or agriculture. This land use includes cultural (business, industrial/commercial, residential, and other places of intense human activity), rights-of-way (improved roads, railway, power lines, maintained canal), recreation (parks, skiing, golf courses), and mining.

Other—Land parcels ≥ 1.0 acre in size and ≥ 120 feet wide, which do not fall into one of the uses described above. Examples include undeveloped beaches, barren land (rock, sand), marshes, bogs, ice, and snow. This land use includes nonvegetated, wetland, beach, and nonforest-chaparral.

Census water—Rivers and streams that are >200 feet wide and bodies of water >4.5 acres in size.

Noncensus water—Rivers, streams and other bodies of water that do not meet the requirements for census water.

Nonsampled—Not sampled due to denied access, hazardous conditions, being outside the U.S. or other reasons.

Large-diameter trees—Softwoods ≥ 9.0 inches d.b.h. and hardwoods ≥ 11.0 inches d.b.h. These trees were called sawtimber-sized trees in prior surveys. See: Stand-size class.

Litter—Undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.).

Main stem—The central portion of the tree extending from the ground level to the tip for timber species. For woodland species the main stem extends from the ground level to the tips of all branches of qualifying stems. For timber species trees that fork, the main stem follows the fork that would yield the most merchantable volume.

Measurement quality objective (MQO)—A data user's estimate of the precision, bias, and completeness of data necessary to satisfy a prescribed application (e.g., Resource Planning Act, assessments by State foresters, forest planning, forest health analyses). Describes the acceptable tolerance for each data element. MQOs consist of two parts: a statement of the tolerance and a percentage of time when the collected data are required to be within tolerance. MQOs can only be assigned where standard methods of sampling or field measurements exist, or where experience has established upper or lower bounds on precision or bias. MQOs can be set for measured data elements, observed data elements, and derived data elements.

Medium-diameter tree—Softwood timber species 5.0 to 8.9 inches d.b.h. and hardwood timber species 5.0 to 10.9 inches d.b.h. These trees were called poletimber-sized trees in prior surveys. See: Stand-size class.

Microplot—A circular, fixed-radius plot with a radius of 6.8 feet (0.003 acre) that is used to sample trees < 5.0 inches d.b.h./d.r.c., as well as other vegetation. Point center is 90 degrees and 12 feet offset from point center of each subplot.

Mortality—See: Components of change.

National forest land—See: Ownership.

Noncensus water—See: Land use.

Nonforest land—Land that does not support or has never supported, forests, and lands formerly forested where use for timber management is precluded by development for other uses. Includes areas used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining rights-of-way, power line clearings of any width, and noncensus water. If intermingled in forest areas, unimproved roads and nonforest strips must be ≥120 feet wide, and clearings, etc., ≥1.0 acre in size, to qualify as nonforest land.

Nonindustrial private forest land—See: Ownership.

Other forest land—Forest land other than timberland and reserved forest land. It includes available and reserved forest land that is incapable of producing 20 cubic feet per acre per year of wood under natural conditions because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness.

Other public land—See: Ownership.

Other removals—The volume of trees removed from the inventory by cultural operations such as timber stand improvement, land clearing, and other changes in land use, resulting in the removal of the trees from timberland.

Ownership—A legal entity having control of a parcel or group of parcels of land. An ownership may be an individual; a combination of persons; a legal entity such as corporation, partnership, club, or trust; or a public agency.

National forest land—Federal land that has been legally designated as national forests or purchase units, and other land under the administration of the Forest Service, including experimental areas and Bankhead-Jones Title III land.

Forest industry land—An ownership class of private lands owned by a company or an individual(s) operating a primary wood-processing plant.

Nonindustrial private forest (NIPF) land—Privately owned land excluding forest industry land.

Corporate—Owned by corporations, including incorporated farm ownerships.

Individual—All lands owned by individuals, including farm operators.

Other public—An ownership class that includes all public lands except national forests.

Miscellaneous Federal land—Federal land other than national forests.

State, county, and municipal land—Land owned by States, counties, and local public agencies or municipalities, or land leased to these governmental units for 50 years or more.

Phase 1 (P1)—FIA activities related to remote sensing, the primary purpose of which is to label plots and obtain stratum weights for population estimates.

Phase 2 (P2)—FIA activities conducted on the network of ground plots. The primary purpose is to obtain field data that enable classification and summarization of area, tree, and other attributes associated with forest land uses.

Phase 2+ (Phase 3 [P3])—A subset of Phase 2 plots where additional attributes related to forest health are measured.

Plantation—Stands that currently show evidence of being planted or artificially seeded.

Poletimber-sized tree—Softwood timber species 5.0 to 8.9 inches d.b.h. and hardwood timber species 5.0 to 10.9 inches d.b.h. Now referred to as medium-diameter trees.

Private land—See: Ownership.

Productivity class—A classification of forest land in terms of potential annual cubic-foot volume growth per acre at culmination of mean annual increment (MAI) in fully stocked natural stands.

Quality assurance (QA)—The total integrated program for ensuring that the uncertainties inherent in FIA data are known and do not exceed acceptable magnitudes, within a stated level of confidence. Quality assurance encompasses the plans, specifications, and policies affecting the collection, processing, and reporting of data. It is the system of activities designed to provide program managers and project leaders with independent assurance that total system quality control is being effectively implemented.

Quality control (QC)—The routine application of prescribed field and laboratory procedures (e.g., random check cruising, periodic calibration, instrument maintenance, use of certified standards, etc.) in order to reduce random and systematic errors and ensure that data are generated within known and acceptable performance limits. Quality control also ensures the use of qualified personnel; reliable equipment and supplies; training of personnel; good field and laboratory practices; and strict adherence to standard operating procedures.

Reserved forest land—Forest land where management for the production of wood products is prohibited through statute or administrative designation. Examples include national forest wilderness areas and national parks and monuments.

Reversion—Land that reverts from a nonforest land use to a forest land use. See: Components of change.

Sapling—Live trees 1.0 to 4.9 inches d.b.h./d.r.c.

Seedling—Live trees < 1.0 inch d.b.h./d.r.c. that are ≥ 6.0 inches in height for softwoods and ≥ 12.0 inches in height for hardwoods and > 0.5-inch d.b.h./d.r.c. at ground level for longleaf pine.

Small-diameter trees—Trees 1.0 to 4.9 inches in d.b.h./d.r.c. These were called sapling-seedling sized trees in prior surveys. See: Stand-size class.

Softwoods—Tree species belonging to the botanical division Coniferophyta, usually evergreen having needles or scale-like leaves.

Species group—A collection of species used for reporting purposes.

Stand—Vegetation or a group of plants occupying a specific area and sufficiently uniform in species composition, age arrangement, structure, and condition as to be distinguished from the vegetation on adjoining areas.

Stand age—A stand descriptor that indicates the average age of the live dominant and codominant trees in the predominant stand-size class of a condition.

Standing dead tree—A dead tree ≥ 5.0 inches d.b.h. that has a bole which has an unbroken actual length of at least 4.5 feet, and lean < 45 degrees from vertical as measured from the base of the tree to 4.5 feet.

Stand origin—A classification of forest stands describing their means of origin.

Planted—Planted or artificially seeded.

Natural—No evidence of artificial regeneration.

Stand-size class—A classification of forest land based on the diameter-class distribution of live trees in the stand. See definitions of large-, medium-, and small-diameter trees.

Large-diameter stands—Stands at least 10 percent stocked with live trees, with one-half or more of total stocking in large- and medium-diameter trees, and with large-

diameter tree stocking at least equal to medium-diameter tree stocking.

Medium-diameter stands—Stands at least 10 percent stocked with live trees, with one-half or more of total stocking in medium- and large-diameter trees, and with medium-diameter tree stocking exceeding large-diameter tree stocking.

Small-diameter stands—Stands at least 10 percent stocked with live trees, in which small-diameter trees account for more than one-half of total stocking.

Nonstocked stands—Stands < 10 percent stocked with live trees.

Stand structure—The predominant canopy structure for the condition, only considering the vertical position of the dominant and codominant trees in the stand and not considering trees that are intermediate or overtopped. As a general rule, a different story should comprise 25 percent of the stand.

Nonstocked—The condition is < 10 percent stocked.

Single-storied—Most of the dominant/codominant tree crowns form a single canopy (i.e., most of the trees are approximately the same height).

Multistoried—Two or more recognizable levels characterize the crown canopy. Dominant/codominant trees of many sizes (diameters and heights) for a multilevel canopy.

State, county, and municipal land—See: Ownership.

Stocking—(1) At the tree level, stocking is the density value assigned to a sampled tree (usually in terms of numbers of trees or basal area per acre), expressed as a percent of the total tree density required to fully utilize the growth potential of the land. (2) At the stand level, stocking refers to the sum of the stocking values of all trees sampled.

Subplot—A circular area with a fixed horizontal radius of 24.0 feet (1/24 acre), primarily used to sample trees ≥ 5.0 inches at d.b.h./d.r.c.

Survivor tree—A sample tree alive at both the current and previous inventories.

Timberland—Forest land that is producing or capable of producing 20 cubic feet per acre or more per year of wood at culmination of MAI. Timberland excludes reserved forest lands.

Treatment—Forestry treatments are a form of human disturbance. The term treatment further implies that a silvicultural application has been prescribed. This does not include occasional stumps of unknown origin or sparse removals for firewood, Christmas trees, or other miscellaneous purposes. The area affected by any treatment must be at least 1.0 acre in size.

None—No observable treatment.

Cutting—The removal of one or more trees from a stand. SRS FIA categories are the following:

Clearcut harvest—The removal of the majority of the merchantable trees in a stand; residual stand stocking is under 50 percent.

Partial harvest—Removal primarily consisting of highest quality trees. Residual consists of lower quality trees because of high grading or selection harvest (e.g. uneven aged, group selection, high grading, species selection).

Seed-tree/shelterwood harvest—Crop trees are harvested leaving seed source trees either in a shelterwood or seed tree. Also includes the final harvest of the seed trees.

Commercial thinning—The removal of trees (usually of medium-diameter) from medium-diameter stands leaving sufficient stocking of growing-stock trees to feature

in future stand development. Also included are thinning in large-diameter stands where medium-diameter trees have been removed to improve quality of those trees featured in a final harvest.

Timber stand improvement (cut trees only)—The cleaning, release, or other stand improvement involving noncommercial cutting applied to an immature stand that leaves sufficient stocking.

Salvage cutting—The harvesting of dead or damaged trees or of trees in danger of being killed by insects, disease, flooding, or other factors in order to save their economic value.

Site preparation—Clearing, slash burning, chopping, disking, bedding, or other practices clearly intended to prepare a site for either natural or artificial regeneration.

Artificial regeneration—Following a disturbance or treatment (usually cutting), a new stand where at least 50 percent of the live trees present resulted from planting or direct seeding.

Natural regeneration—Following a disturbance or treatment (usually cutting), a new stand where at least 50 percent of the live trees present (of any size) were established through the growth of existing trees and/or natural seeding or sprouting.

Other silvicultural treatment—The use of fertilizers, herbicides, girdling, pruning, or other activities designed to improve the commercial value of the residual stand, or chaining, which is a practice used on woodlands to encourage wildlife forage.

Tree—A woody perennial plant, typically large, with a single well-defined stem carrying a more or less definite crown; sometimes defined as attaining a minimum diameter of 3 inches and a minimum height of 15 feet at maturity. For FIA, any plant on the tree list in the current field manual is measured as a tree.

Volume—A measure of the solid content of the tree stem used to measure wood quantity.

Gross board-foot volume—Total board-foot volume of wood inside bark without deductions for total board-foot cull.

Gross cubic-foot volume—Total cubic-foot volume of wood inside bark without deductions for rotten, missing, or broken-top cull.

Net board-foot volume—Gross board-foot volume minus deductions for total board-foot cull.

Net cubic-foot volume—Gross cubic-foot volume minus deductions for rotten, missing, and broken-top cull.

APPENDIX A—INVENTORY METHODS

The Tennessee 2014 inventory was a three-phase, fixed-plot design conducted on an annual basis. Phase 1 (P1) provides the area estimates for the inventory. Phase 2 (P2) involves on-the-ground measurements of sample plots by field personnel. Phase 2+ (P2+, formerly identified as Phase 3 [P3]) is a subset of the P2 plot system, where additional measurements are made by field personnel to aid in the assessment of forest health. The three phases of the sampling method are based on a hexagonal grid design, with successive phases being sampled with less intensity. There are 16 P2 hexagons for every P2+ hexagon. P2 and P2+ hexagons represent about 6,000 and 96,000 acres, respectively.

Under the annual inventory system, 20 percent (1 panel) of the total number of plots in a State are measured every year over a 5-year period (1 cycle). Each panel of plots is selected on a sub-grid that is slightly offset from the previous panel so that each panel covers essentially the same sample area (both spatially and in intensity) as the prior panel. In the sixth year, the plots that were measured in the first panel are remeasured. This marks the beginning of the next cycle of data collection. After field measurements are completed, a cycle of data is available for the 5-year report.

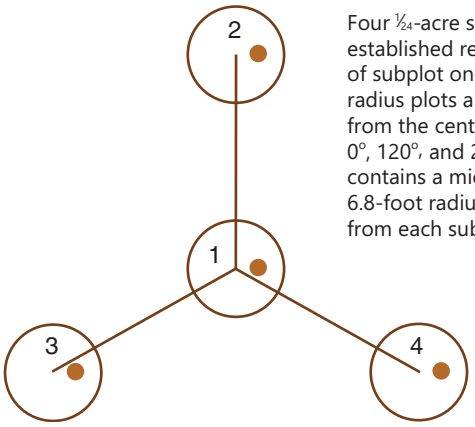
The 2014 inventory accounted for a total of 4,701 plots where 2,713 were forested across the State. There were 931, 558, 541, 429, and 477 plots measured in the East, Plateau, Central, West Central, and West units, respectively. A total of 2,721 plots measured for the 2009 inventory were remeasured during the 2014 inventory. The remeasured plots were used to calculate estimates of growth, removals, and mortality, commonly referred to as GRM. Note: This data was accessed and compiled from the FIA database (FIADB) in March, April, and May of 2019. Publicly available data from the FIADB is regularly updated when data collection and/or processing anomalies are found and corrected. Additionally, new data are added on a regular basis which may be reflected by small changes in the past or current estimates.

Phase 1

For the 2016 inventory of Tennessee, the P1 forest area estimate was based on classifying National Land Cover Database points collected in 2011. Stratification of forest and nonforest was performed at the unit level. Area estimation of all lands and ownerships was based on the probability of selection of P2 plot locations. As a result, the known forest land area (for specific ownerships) does not always agree with area estimates based on probability of selection. For example, the acreage of national forests, published by the National Forest System, will not agree exactly with the statistical estimate of national forest land derived by Forest Inventory and Analysis. These numbers could differ substantially for very small areas.

Phase 2

Bechtold and Patterson (2005) describe P2 and P3 ground plots and explain their use. These plots are clusters of four points arranged so that one point is central and the other three lie 120 feet from it at azimuths of 0, 120, and 240 degrees (fig. A.1). Each point is the center of a circular subplot with a fixed 24-foot radius. Trees ≥ 5.0 inches diameter at breast height (d.b.h.) are measured in these subplots. Each subplot in turn contains a circular microplot with a fixed 6.8-foot radius. Trees 1.0–4.9 inches d.b.h. and seedlings (<1.0 inch d.b.h.) are measured in these microplots (U.S. Department of Agriculture Forest Service 2014).



Four 1/24-acre subplots are established relative to the center of subplot one. The 24-foot radius plots are located 120 feet from the center of subplot one at 0°, 120°, and 240°. Each subplot contains a microplot with a 6.8-foot radius, 12 feet (at 90°) from each subplot center.

Figure A.1—Layout of annual fixed-radius plot design.

Sometimes, a plot cluster straddles two or more land use or forest condition classes (Bechtold and Patterson 2005). There are seven condition-class variables that require mapping of a unique condition on a plot: (1) land use, (2) forest type, (3) stand size, (4) ownership, (5) stand density, (6) regeneration status, and (7) reserved status. A new condition is defined and mapped each time one of these variables changes during plot measurement.

Phase 2+

Data on forest health variables (P2+) are collected on about $1/16^{th}$ of the P2 sample plots. P2+ data are coarse descriptions and are meant to be used as general indicators of overall forest health over large geographic areas. P2+ data collection has included variables pertaining to tree crown health, down woody material, and foliar ozone injury in the past. In recent years, however, the forest health monitoring data collection has evolved with some of the protocols changing and others being put on hiatus pending renovation. Down woody materials data were collected for the past cycle of Tennessee forest health monitoring. That data collection took place under a more simplified set of field protocols that can be implemented on a greater number of plots to improve the sample size. This and other forest health monitoring data collection will continue to evolve as these protocols are refined.

Summary

Users wishing to make rigorous comparisons of data between surveys should be aware of any changes in methodologies between measurements and the evolving nature of the FIA program. The most valuable and powerful trend information is obtained when the same plots are revisited from one survey to the next and measured in the same way. Determining the strength of a trend or determining the level of confidence associated with a trend, is difficult or impossible when sampling methods change over time.

APPENDIX B—DATA RELIABILITY

A relative standard of accuracy has been incorporated into the forest inventory. This standard satisfies user demands, minimizes human and instrumental sources of error, and keeps costs within prescribed limits. The two primary types of error are measurement error and sampling error.

Measurement Error

There are three elements of measurement error: (1) biased error, caused by instruments that are not properly calibrated; (2) compensating error, caused by instruments of moderate precision; and (3) accidental error, caused by human error in measuring and compiling. All of these are held to a minimum by the Forest Inventory and Analysis (FIA) quality assurance (QA) program. The goal of the QA program is to provide a framework of quality control procedures to assure the production of complete, accurate, and unbiased forest assessments for given standards. These methods include the use of nationally standardized field manuals, the use of portable data recorders, thorough entry-level training, periodic review training, supervision, the use of check plots, editing checks, and an emphasis on careful work. Additionally, data quality is assessed and documented using performance measurements and post-survey assessments. These assessments are then used to identify areas of the data collection process that need improvement or refinement in order to meet the program's quality objectives.

Each variable collected by FIA is assigned a measurement quality objective (MQO) and a measurement tolerance level. The MQOs are documented in the FIA National Field Manual (U.S. Department of Agriculture Forest Service 2014). In some instances, the MQOs are a "best guess" of what experienced field crews should be able to consistently achieve. Tolerances are somewhat arbitrary and are based on the ability of crews to make repeatable measurements or observations within the assigned MQO. For more information see the FIA National Data Quality Assessment Report (https://doi.org/10.2737/RMRS-GTR-181).

Sunset on Reelfoot Lake, Tennessee. (photo courtesy of Twenty20 Photos)

Sampling Error

Sampling error is associated with the natural and expected deviation of the sample from the true population mean. This deviation is susceptible to a mathematical evaluation of the probability of error. Sampling errors for State totals are based on one standard deviation. That is, there is a 68.27 percent probability that the confidence interval given for each sample estimate will cover the true population mean.

The size of the sampling error generally increases as the size of the area examined decreases. In addition, as area or volume totals are stratified by forest type, species, diameter class, ownership, or other subunits, the sampling error may increase and be greatest for the smallest divisions. However, there may be instances where a smaller component does not have a proportionately larger sampling error. This can happen when the post-defined strata are more homogeneous than the larger strata, thereby having a smaller variance. For specific post-defined strata, the sampling error can be calculated using the following formula. Sampling errors obtained by this method are only approximations of reliability because this process assumes constant variance across all subdivisions of totals.

$$SE_s = SE_t \frac{\sqrt{X_t}}{\sqrt{X_s}}$$

where

SE_s = sampling error for subdivision of survey unit or State total

SE_t = sampling error for survey unit or State total

X_s = sum of values for the variable of interest (area or volume) for subdivision of survey unit or State

X_t = total area or volume for survey unit or State

For example, the approximation of sampling error for forest land area in the Plateau survey unit is computed as:

$$SE_s = 0.70 \left[\frac{\sqrt{13{,}919{,}509}}{\sqrt{2{,}975{,}046}} \right] = 1.51\%$$

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This resource bulletin consolidates data from the ninth complete survey of Tennessee's forest resources, which was conducted during the period 2010–2014 (with additional data up to 2016) by the U.S. Department of Agriculture (USDA) Forest Service, Forest Inventory and Analysis (FIA) program in cooperation with the Tennessee Department of Agriculture Division of Forestry (TDF). Data on the extent, condition, and classification of forest land and associated timber volumes, as well as growth, removals, and mortality rates, are described and interpreted. Data on forest health and forest landowner characteristics are also evaluated. Estimates of forest resources are reported at multiple scales.

Keywords: Carbon, disturbance, FIA, forest health monitoring, forest inventory, forest trends, Tennessee, timber volume.

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Southern Research Station
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