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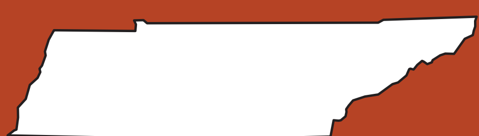
Tennessee's Forests, 2019



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Cover photo: Tree on a rocky ledge overlooking the gorge. (Courtesy photo by twenty20photos)

Following page photo: Sunset on Reelfoot Lake, TN. (Courtesy photo by twenty20photos)

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TENNESSEE'S FORESTS, 2019

Christopher M. Oswalt and Sonja N. Oswalt

FOREWORD

The U.S. Department of Agriculture, Forest Service, 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) (AREERA 1998) and updated in Title VIII of the 2014 U.S. Farm Bill (Agricultural Act of 2014).

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 are 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"* (USDA 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 from the "Data and Tools" section of the national FIA program website (USDA Forest Service 2025a). Additional information about the FIA Program can be obtained at the USDA Forest Service Research and Development website (USDA Forest Service 2025b).

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

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The following FIA field personnel 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.

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Mountain laurel (*Kalmia latifolia*). (U.S. Forest Service photo by Christopher Oswalt)

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HIGHLIGHTS

- In 2019, Tennessee had an estimated 13.8 million acres of forest which covered 51.3 percent of its total land area. The only real change in forest land occurred in the West survey unit where a 7.6-percent increase has been realized from 1999 to 2019 as some agricultural area was allowed to revert to forest.

- Based on a remeasurement of Tennessee's plots (measured at both time 1 and time 2), 199,100 acres of forest land were diverted to agricultural land use, while 189,200 acres of forest land were diverted to urban or developed land use.

- Forest land in Tennessee is owned primarily by nonindustrial private landowners, which comprises 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 in the State comprises 710,000 acres.

- In 2019, 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.

- There were 117 individual tree species identified in the 2019 inventory of Tennessee forests. A total population of 8.5 billion trees [diameter at breast height (d.b.h.) ≥1 inch] are estimated to be living and growing in forests of the State. Hardwood tree species are, of course, the most common.

- The trees with d.b.h. ≥5 inches hold over 37.1 billion cubic feet (bcf) of volume. While red maple had the greatest number of trees (9.5 percent of all trees), they only accounted for 5.6 percent of total wood volume in Tennessee's forests. There were greater volumes of wood in yellow-poplar (11.9 percent of total volume), white oak (9.5 percent of total volume), and chestnut oak trees (8.3 percent of total volume) than red maple.

- Four species groups (select white oak, other white oaks, select red oaks, and other red oaks) accounted for 33 percent of all aboveground biomass of live trees (≥1 inch d.b.h.).

- While very little hardwood volume exhibits clear evidence of artificial regeneration (i.e., planted), about one-third (32 percent) of softwood volume was planted. Loblolly and shortleaf pine volume are almost evenly split between stands that were naturally regenerated [1,170 million cubic feet (mmcf)] and those that were planted (1,140 mmcf).

- Based on estimates of net change (gross growth – mortality – removals), total volume increased each year (on average), over 622 mmcf of sound volume between 2015 and 2019. The annual positive net change amounts to an average 1.4-percent increase each year of the total standing live volume.

- In 2019, 76 percent of the total net annualized growth of 695 mmcf per year was on hardwood trees and 24 percent on softwoods. Similarly, 82 percent of total annualized removals was the result of hardwood removals and 18 percent was due to softwood removals.

- While harvest removals have declined slightly over time, current harvest removals accounted for about 312 mmcf of volume. Since harvest removals made up 81 percent of all removals, hardwood harvest removals accounted for 84 percent of all harvest removals in the State.

- While stable recently, average annual mortality has experienced a slight decrease between 2002 and 2019 with a current rate of 330 mcf per year.

- 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.

- Invasive plant presence was monitored on 4,669 plots. Invasive plants were detected on 43 percent of those plots (2,011 plots). The most common forest invasive plant monitored by FIA was Japanese honeysuckle (*Lonicera japonica*) impacting nearly 1.0 million acres of forest land across the State.

INTRODUCTION

This resource bulletin consolidates data from the ninth complete survey of Tennessee's forest resources which was conducted during the period 2013–19 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 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 1—Inventory Methods section for further information on data collection methodology). The inventory dates of 2019, 2014, 2009, and 2004 are repeated throughout this report. The inventory year of 2019 represents data that was collected from 2013 to 2019. The

Great Smoky Mountains National Park, Tennessee, USA in autumn.

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 2019 and 2014 are calculated using plots collected from 2010 to 2014 as compared to the same plots being remeasured from 2013 to 2019. The 2019 inventory accounted for a total of 4,758 plots where 2,911 were forested across the State. A total of 2,861 plots measured for the 2014 inventory were remeasured during the 2019 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 November of 2024. Publicly available data from the FIADB is regularly updated when data collection and 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.

History of Tennessee's Forest Inventory

Nine previous inventories have been completed in Tennessee. The inventories of 1950, 1961, 1971, 1980, 1989, 1999, 2004, 2009, and 2014 provide statistics for measuring changes and trends over the past 60 years (Oswalt et al. 2009, 2012, 2022; 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, wild-life habitat, species richness, and cultural benefits among others. The 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 9.3.00 of the National Information Management System (NIMS) in order to meet national FIA program standards. The 2004 Tennessee forest resources report (Oswalt et al. 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 while the 2014 report was processed with version 8.1 of NIMS. Changes in NIMS versions can include programmatic changes that at times alter standard definitions and 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 9.3.00). 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 2019 for many forest land attributes and for the period between 1980 and 2019 for many timberland attributes.

Updating Estimates of Volume and Biomass

In 2023, the Forest Inventory and Analysis (FIA) program adopted the National Scale Volume and Biomass Estimators (NSVB) (Westfall et al. 2024) delivering an updated national modeling framework for estimating cubic-foot volume, carbon, and biomass. As a result of collaborative research between Forest Service scientists and partners, the NSVB effort brings forth contemporary model building techniques and extensive new data that delivers a more consistent accounting of structural components of trees across the United States. NSVB biomass and carbon equations were developed from detailed tree measurements, allowing for direct and more accurate modeling of nonmerchantable components and more accurate quantification of model uncertainty. Rather than adhering to administrative boundaries, NSVB is constructed around ecological units, better reflecting environmental gradients that influence tree size, form, and growth. In addition, NSVB offers greater accuracy in carbon estimation, converting biomass to carbon by applying species-specific carbon fractions. Estimates shown in this report for prior years have been updated to reflect the new methodology so that comparison is possible.

The changes in estimates because of adapting the NSVB models vary by tree species and geographic area. At the national level, there are only minor differences in merchantable cubic-foot volume (1.6 percent increase), whereas there is a 15-percent increase in tree aboveground biomass and 12-percent increase in carbon, due to more accurate accounting of biomass in tree limbs and tops (Westfall et al. 2024).

AREA

Trends in Forest Land

In 2019, Tennessee occupied about 27.0 million acres in the Southern United States, with the Mississippi River delineating its western border (fig. 1). Forest land totaled 13.8 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 in Tennessee (55 years; table 2). The only real change in forest land has occurred in the West unit (fig. 2) where an 8-percent average increase has been realized from 1999 to 2019 as some agricultural area reverted to forest.

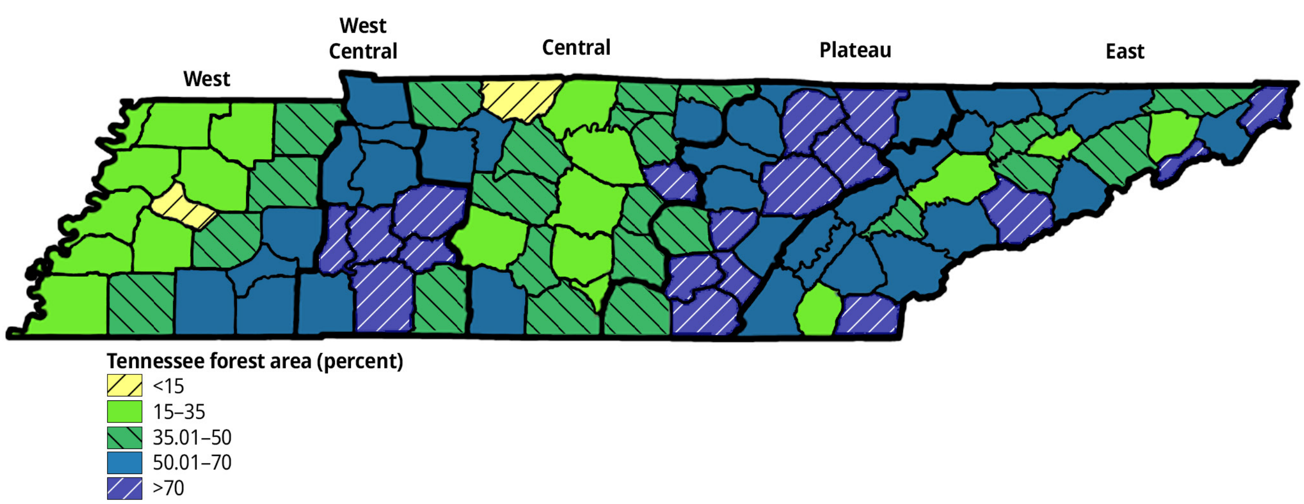

Figure 1—Forest survey units and county forest land area in Tennessee.

Table 1—Area by survey unit and land status, Tennessee, 2019

Unit	Total area	All forest	Unreserved			Reserved			Nonforest land	Census water
			Total	Timberland	Unproductive	Total	Productive	Unproductive		
	thousand acres									
West	6,100.0	2,294.3	2,236.3	2,234.7	1.6	58.0	58.0	0.0	3,656.2	149.5
West Central	3,395.7	2,255.6	2,228.2	2,219.4	8.8	27.5	27.5	0.0	1,029.0	111.0
Central	6,281.6	2,646.6	2,630.3	2,630.3	0.0	16.3	16.3	0.0	3,521.1	113.9
Plateau	4,454.0	2,943.8	2,810.7	2,810.7	0.0	133.1	133.1	0.0	1,463.0	47.2
East	6,740.7	3,691.6	3,357.0	3,346.9	10.1	334.6	334.1	0.5	2,799.0	250.0
All survey units	26,972.0	13,831.9	13,262.5	13,242.0	20.5	569.5	569.0	0.5	12,468.3	671.6

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—Area by land status, Tennessee, 1961–2019

Land class	1961	1971	1980	1989	1999	2004	2009	2014	2019
Timberland	13,432.4	12,819.8	12,879.0	13,265.2	13,305.2	13,254.5	13,547.2	13,301.20	13,242.00
Other/reserved	263.5	316.5	429.5	337.3	406.9	566.1	456.1	579.10	569.50
Total forest	13,695.9	13,136.3	13,308.5	13,602.5	13,712.2	13,820.6	14,003.3	13,880.30	13,831.90
Nonforestland	12,826.2	13,338.6	13,141.6	12,844.5	13,259.6	13,151.2	12,968.1	13,091.1	12,468.3
Total land area	26,522.1	26,474.9	26,450.1	26,447.0	26,971.8	26,971.8	26,971.4	26,971.4	26,972.0
Percent forested	51.6	49.6	50.3	51.4	50.8	51.2	51.9	51.5	51.3

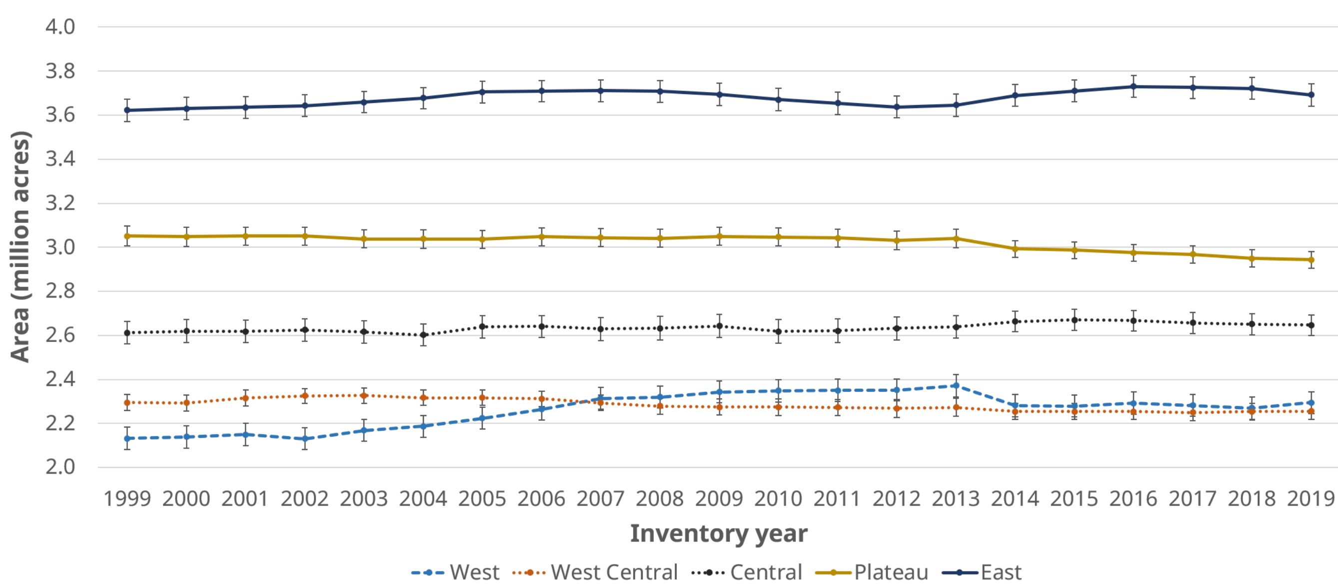

Figure 2—Forest land area by survey unit, Tennessee, 1999–2019.

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) (USDA Forest Service 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 et al. (2005) for the methods used to calculate these components of change]. Forest and nonforest conditions on forested plots are categorized by land use allowing 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 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 some regional changes. Forests are dynamic and transitions to and from other land uses are common. Most changes in forest land in the State can be attributed to both agriculture and development (fig. 3). Based on a remeasurement of Tennessee's plots (measured at both time 1 and time 2), 199,100 acres of forest land were diverted to agricultural land use, while 189,200 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. A total of 388,300 acres were recorded as diversions for the 2019 inventory. The largest diversions to agriculture occurred in the West survey unit (-68,500 acres), while the largest diversions to developed land (-69,200 acres) occurred in the East survey unit (table 3). Overall, however, the Plateau unit experienced the largest negative change with 41,900 acres of forest diverted to agriculture and development that were not offset by reversions from those land uses to forest.

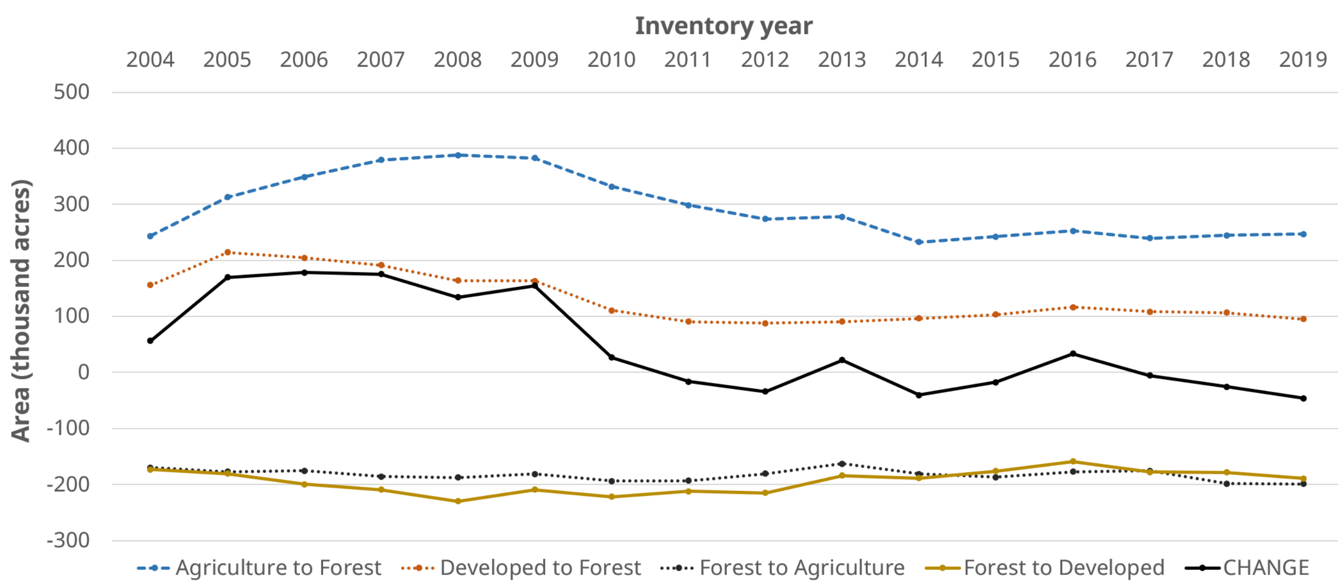

Figure 3—Forest reversions and diversions and net change for forest land in Tennessee, 2004–2019.

Table 3—Changes in forest land by survey unit, Tennessee, 2019

Unit	Change [1]	Additions: Total additions	Additions: Agriculture [2]	Additions: Developed [3]	Diversions: Total diversions	Diversions: Agriculture [2]	Diversions: Developed [3]
	thousand acres						
West	21.4	117.7	95.8	21.9	-96.3	-68.5	-27.8
West Central	3.6	51.5	40.5	11	-47.9	-33.6	-14.3
Central	-11.8	52.9	37.8	15.1	-64.7	-27.9	-36.8
Plateau	-41.9	49.3	26.4	22.9	-91.2	-50.1	-41.2
East	-17.3	70.9	46.5	24.4	-88.2	-19	-69.2
All survey units	-46	342.3	247.1	95.2	-388.3	-199.1	-189.2

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 Inventory Methods section in appendix 1).

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

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

[3] 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.

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

Ownership

Forest land in Tennessee is owned primarily by nonindustrial private landowners, which comprise 82 percent of the total area (fig. 4). Forest industry land comprises only 1 percent of forest land in the State. Forest land stewarded by the Forest Service in the State comprises about 710,400 acres. Forest land in private ownership is highest in the Central survey unit (92 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, Stand age and 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 in which oaks predominate are the most common across the State, with the oak-hickory (70.0 percent) and oak-pine (7.0 percent) comprising nearly 80 percent of the forest. Loblolly-shortleaf pine, a forest-type group very common across the South covered 8.4 percent of all forests and represented the largest softwood forest-type group in the State.

Stand age and 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 better able to 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 understanding of the successional status and potential future development of the forest and the populations of its inhabitants.

Table 4—Area of forest land by forest-type group and ownership group, Tennessee, 2019

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	83.3	32.6	3.1	3	0	44.6
	Loblolly-shortleaf pine	1,156.00	57.7	33.6	59.5	42.1	963.1
	Other eastern softwoods	271.1	0	12.2	4.6	2.3	252.1
	Total softwoods	1,510.40	90.3	48.8	67.1	44.4	1,259.80
Hardwood types	Oak-pine	965.60	84.1	58.5	31.8	22.7	768.6
	Oak-hickory	9,657.80	488.9	433.5	704.1	98.7	7,932.60
	Oak-gum-cypress	338.6	0	32.5	34.3	12.7	259.1
	Elm-ash-cottonwood	839.2	0	35.1	108.6	15.4	680.1
	Maple-beech-birch	349.1	40.1	45.6	15.1	0	248.2
	Other hardwoods	73.9	7	15	6.3	0	45.7
	Exotic hardwoods	64.5	0	5.9	5.9	0	52.7
	Total hardwoods	12,288.70	620.1	626.1	906	149.5	9,986.90
Nonstocked		33	0	0	1.5	0	31.5
All groups		13,832.00	710.4	674.9	974.6	193.9	11,278.20

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.

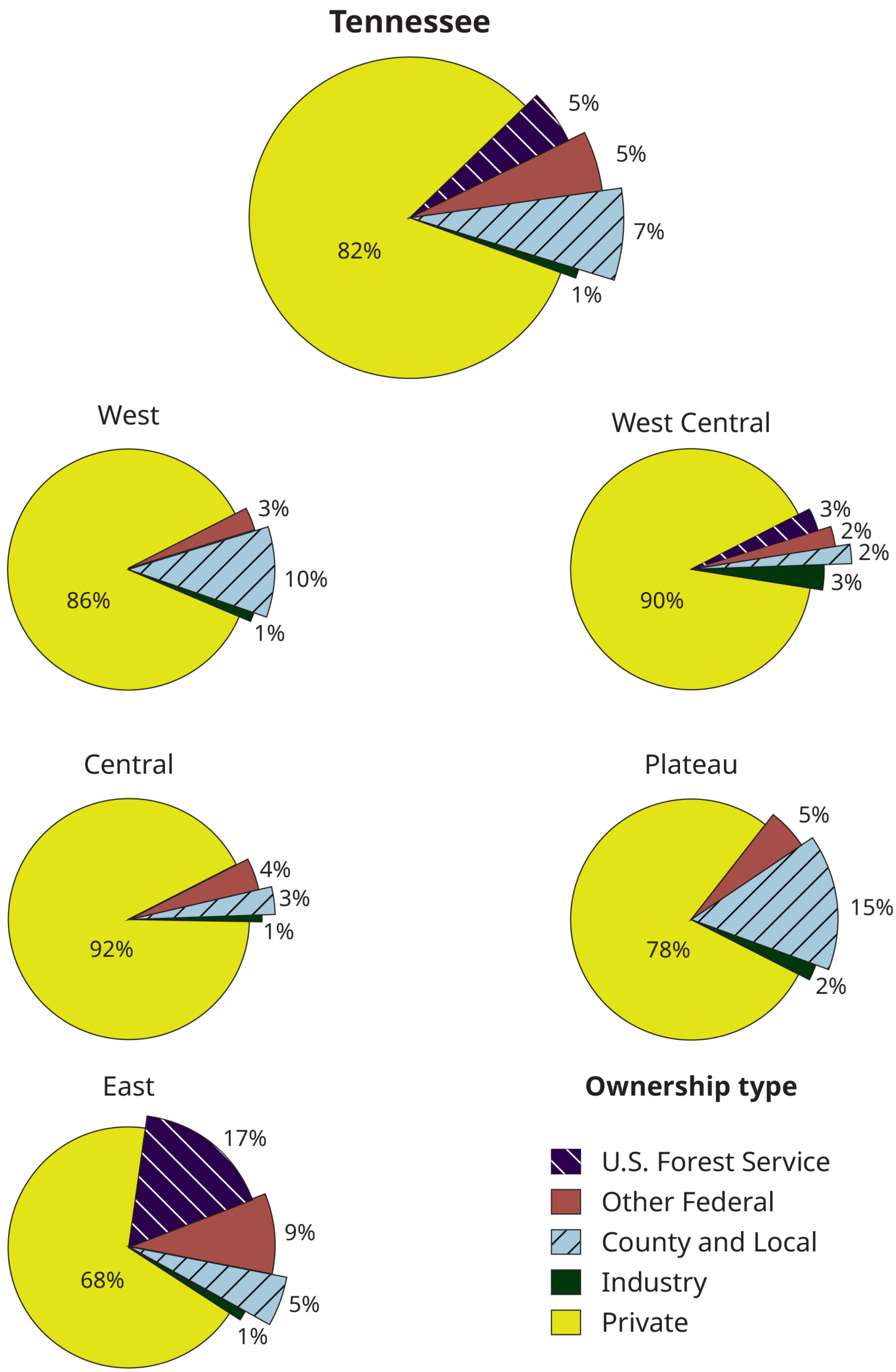

Figure 4—Forest land area by ownership group and survey unit in Tennessee, 2019.

The stand-size classes utilized by FIA are small, medium, and large diameter (formerly 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. 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. These are typically 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 2019, the majority of stands were in the large diameter size class (fig. 5). The area of forest land classified as large diameter has increased in recent years. In 2004, an estimated 63 percent of all forest land in Tennessee was in large diameter stands. In 2014, the percentage of large diameter stands had increased to 68 percent and by 2019 had increased to 73 percent. The largest declines occurred in the medium diameter size stands with a decline from 23 percent to 17 percent from 2004 to 2019, respectively. Stands classified as small diameter declined from 13 percent in 2004 to 10 percent in 2019. 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 50 years (1961 to 2019) (Oswalt et al. 2009) (fig. 5). In 1971, early-successional forests accounted for

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. (U.S. Forest Service photo by Christiopher Oswalt)

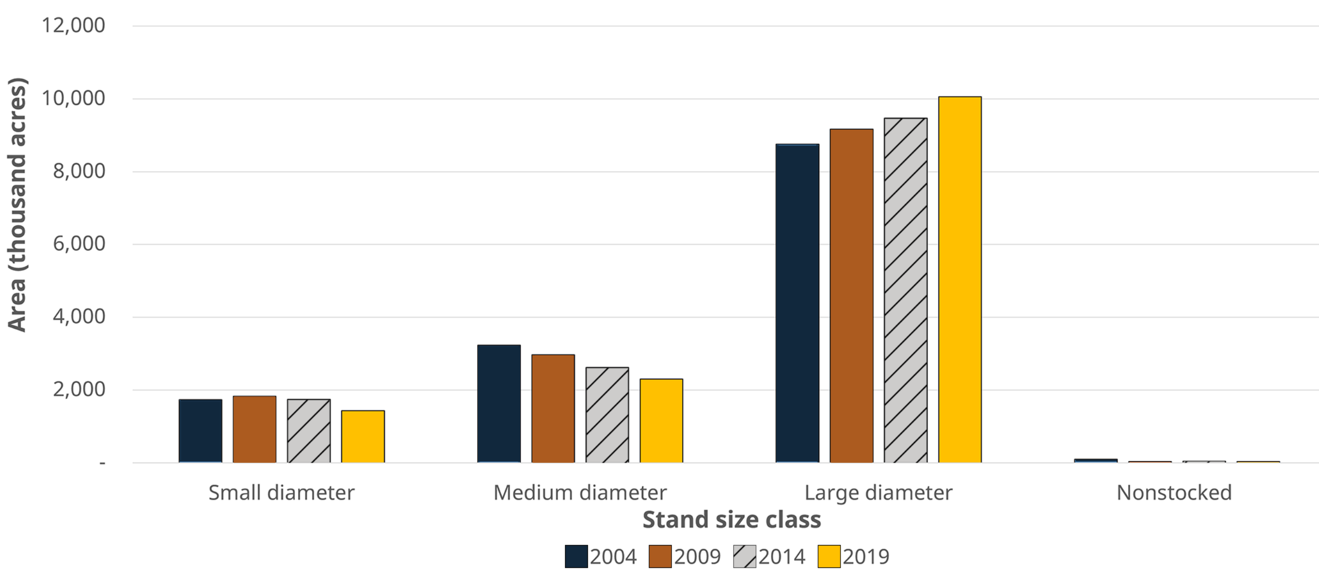

Figure 5—Forest land area by stand size class for total area, Tennessee, 2019.

about 35 percent of all forest land in the State. In 2019, early-successional forests accounted for only 10 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 is a larger increase in large diameter stands in mixed (pine-oak) forest types (fig. 6). Increases in large diameter stands occurred in hardwood and softwood forest types at a slightly lower pace. However, the mixed stands are not as common as softwood or hardwood stands across the State.

NUMBER OF TREES, VOLUME, AND BIOMASS

There were 121 individual tree species identified in the 2019 inventory of Tennessee forests. A total population of 8.5 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. 7). Red maple (*Acer rubrum*) was by far the most common hardwood species and eastern redcedar (*Juniperus virginiana*) was the most encountered softwood species (table 5).

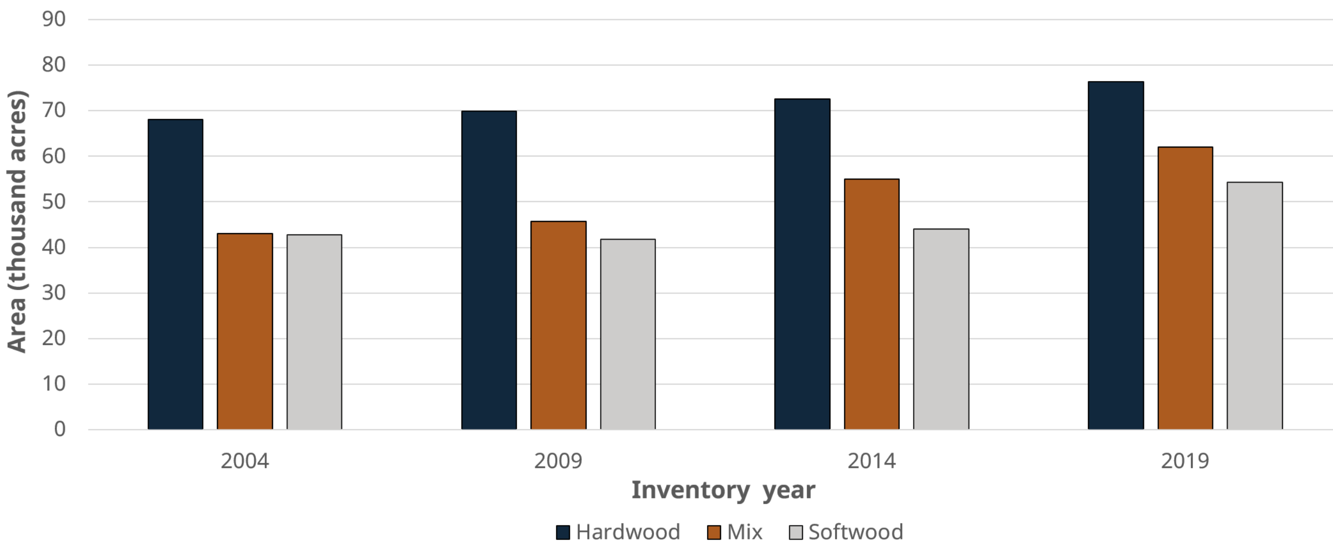

Figure 6—Forest land area by stand size class for area in hardwood, mixed, and softwood forests types for the periods 2004, 2009, 2014, and 2019.

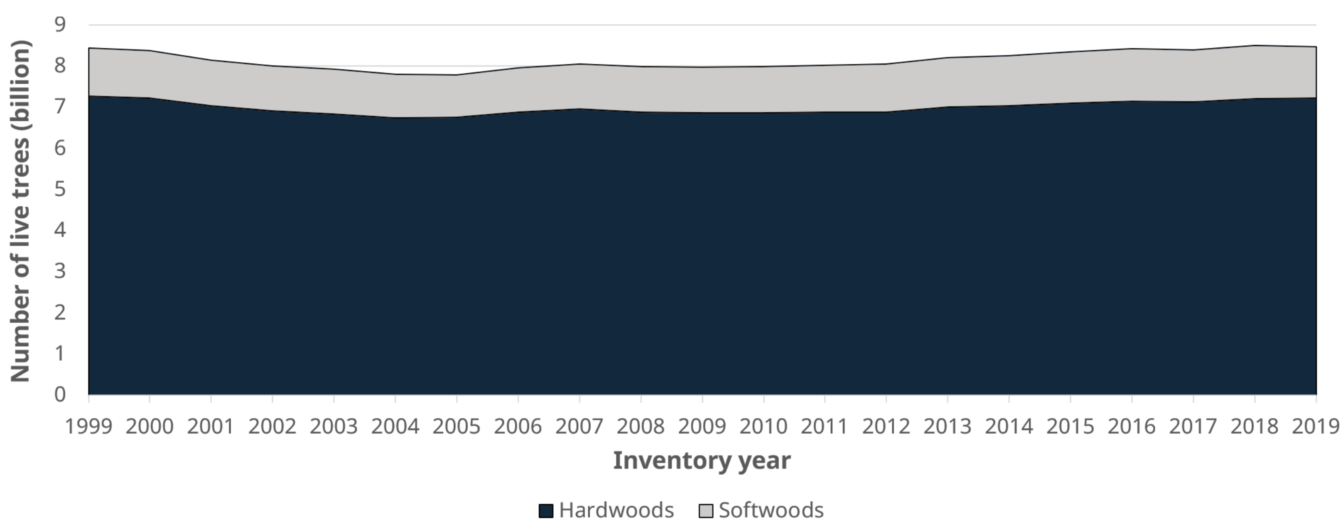

Figure 7—Number of live trees (≥1-inch d.b.h.) on forest land by major species group for the period of 1999 to 2019.

Table 5—Number of live trees by species (≥1 inch d.b.h.) and ratio of saplings to sawtimber by tree size class on forest land, Tennessee, 2019

Species	Total	Sawtimber-size	Poletimber-size	Sapling-size	Sap-saw-ratio
Red maple *(Acer rubrum)*	803,605,742	35,087,017	121,141,635	647,377,090	18.45
Yellow-poplar *(Liriodendron tulipifera)*	579,697,526	59,392,964	85,306,304	434,998,257	7.32
Sweetgum *(Liquidambar styraciflua)*	463,434,858	25,215,568	77,059,365	361,159,924	14.32
Blackgum *(Nyssa sylvatica)*	423,592,381	9,648,656	39,570,046	374,373,679	38.80
Sugar maple *(Acer saccharum)*	414,835,029	20,316,589	60,819,095	333,699,345	16.42
Eastern redcedar *(Juniperus virginiana)*	402,801,230	31,983,394	82,660,431	288,157,405	9.01
Sourwood *(Oxydendrum arboreum)*	379,082,058	3,464,710	73,519,493	302,097,854	87.19
Loblolly pine *(Pinus taeda)*	350,918,948	62,639,585	125,554,801	162,724,562	2.60
Winged elm *(Ulmus alata)*	335,246,360	3,717,911	33,030,982	298,497,468	80.29
White oak *(Quercus alba)*	282,401,272	60,908,880	75,901,840	145,590,552	2.39
American beech *(Fagus grandifolia)*	269,099,235	12,129,801	23,955,249	233,014,185	19.21
Eastern hophornbeam *(Ostrya virginiana)*	258,039,866	47,026	8,486,397	249,506,443	5,305.71
Virginia pine *(Pinus virginiana)*	243,515,943	22,830,778	42,592,595	178,092,571	7.80
Black cherry *(Prunus serotina)*	195,904,805	7,779,571	35,078,963	153,046,270	19.67
Flowering dogwood *(Cornus florida)*	165,168,816	36,810	8,884,096	156,247,909	4,244.71
Chestnut oak *(Quercus prinus)*	164,701,262	55,418,607	49,792,147	59,490,508	1.07
Pignut hickory *(Carya glabra)*	158,245,069	21,801,397	40,666,835	95,776,837	4.39
Green ash *(Fraxinus pennsylvanica)*	143,225,929	8,880,349	17,454,199	116,891,381	13.16
Eastern redbud *(Cercis canadensis)*	137,246,920	71,329	3,978,271	133,197,320	1,867.37
Sassafras *(Sassafras albidum)*	130,696,113	4,366,830	18,890,512	107,438,772	24.60

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

The trees with d.b.h. ≥5 inches held over 37.1 billion cubic feet (bcf) of volume (fig. 8). While red maple has the greatest number of trees (table 5; 9.5 percent of all trees), they only account for 5.6 percent of total wood volume in Tennessee's forests (table 6). There were greater volumes of wood in yellow-poplar (11.9 percent of total volume), white oak (9.5 percent of total volume), and chestnut oak trees (8.3 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.

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 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 for softwood species (fig. 9), to reach its current level of 30.2 bcf in hardwoods and 4.8 bcf in softwoods (programmatic changes in how volume is calculated is discussed in earlier sections. Additionally, comparisons between the historic and 2019 [NSVB] estimates are available

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

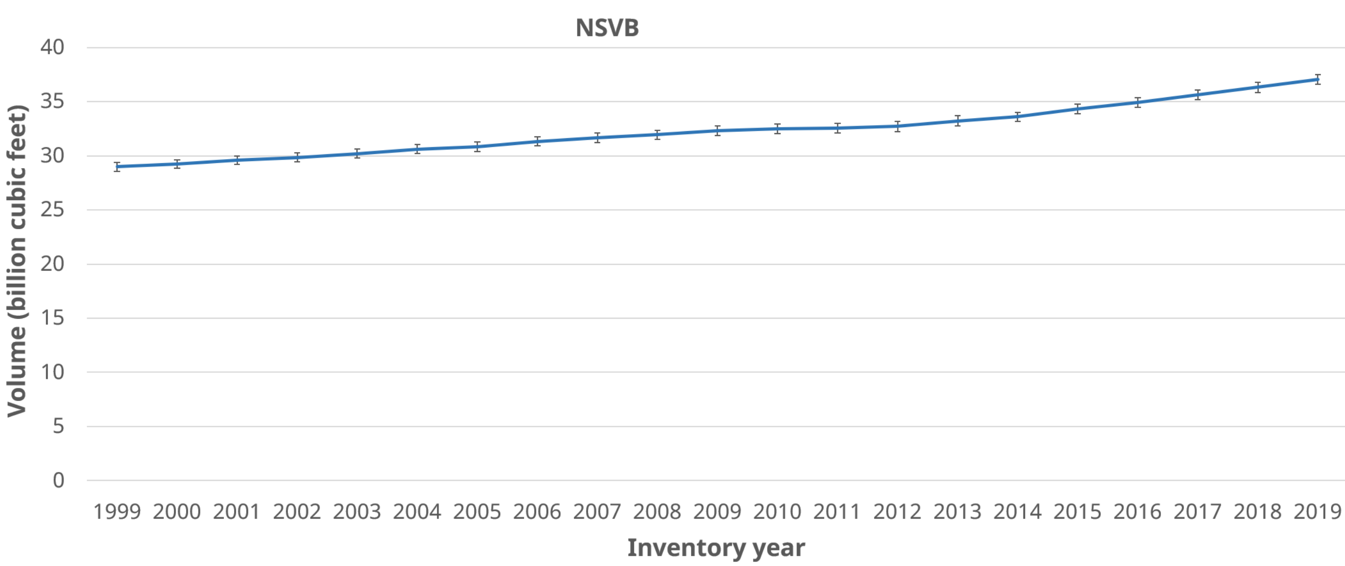

Figure 8—Net merchantable bole volume of live trees (≥5 inches d.b.h.), in cubic feet (new NSVB and historical regional estimates), on forest land for the period 1999 to 2019.

Table 6—Net merchantable bole volume of live trees by species (≥5 inches d.b.h.), in cubic feet, by major ownership group on forest land, Tennessee, 2019

Species	Total	Public	Private
Yellow-poplar *(Liriodendron tulipifera)*	4,401,066,722	1,041,225,142	3,359,841,580
White oak *(Quercus alba)*	3,534,094,043	607,421,596	2,926,672,447
Chestnut oak *(Quercus prinus)*	3,073,245,684	939,159,963	2,134,085,721
Red maple *(Acer rubrum)*	2,046,087,388	533,611,803	1,512,475,585
Loblolly pine *(Pinus taeda)*	1,870,508,565	180,400,054	1,690,108,512
Sweetgum *(Liquidambar styraciflua)*	1,459,756,552	187,184,980	1,272,571,572
Pignut hickory *(Carya glabra)*	1,381,700,984	154,945,373	1,226,755,611
Scarlet oak *(Quercus coccinea)*	1,309,654,896	384,303,211	925,351,685
Sugar maple *(Acer saccharum)*	1,272,830,211	148,982,377	1,123,847,834
Northern red oak *(Quercus rubra)*	1,022,498,701	309,589,088	712,909,613
Black oak *(Quercus velutina)*	971,981,722	227,325,201	744,656,520
Southern red oak *(Quercus falcata)*	966,832,771	161,487,681	805,345,090
American beech *(Fagus grandifolia)*	848,136,362	111,727,322	736,409,039
Mockernut hickory *(Carya alba)*	812,970,535	140,968,192	672,002,343
Eastern redcedar *(Juniperus virginiana)*	809,804,385	91,134,756	718,669,629
Virginia pine *(Pinus virginiana)*	804,992,128	187,928,191	617,063,937
Shagbark hickory *(Carya ovata)*	795,828,249	58,470,745	737,357,504
Eastern white pine *(Pinus strobus)*	596,302,666	320,935,556	275,367,110
Blackgum *(Nyssa sylvatica)*	528,552,253	111,617,879	416,934,374
Black cherry *(Prunus serotina)*	525,407,890	54,782,922	470,624,968

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

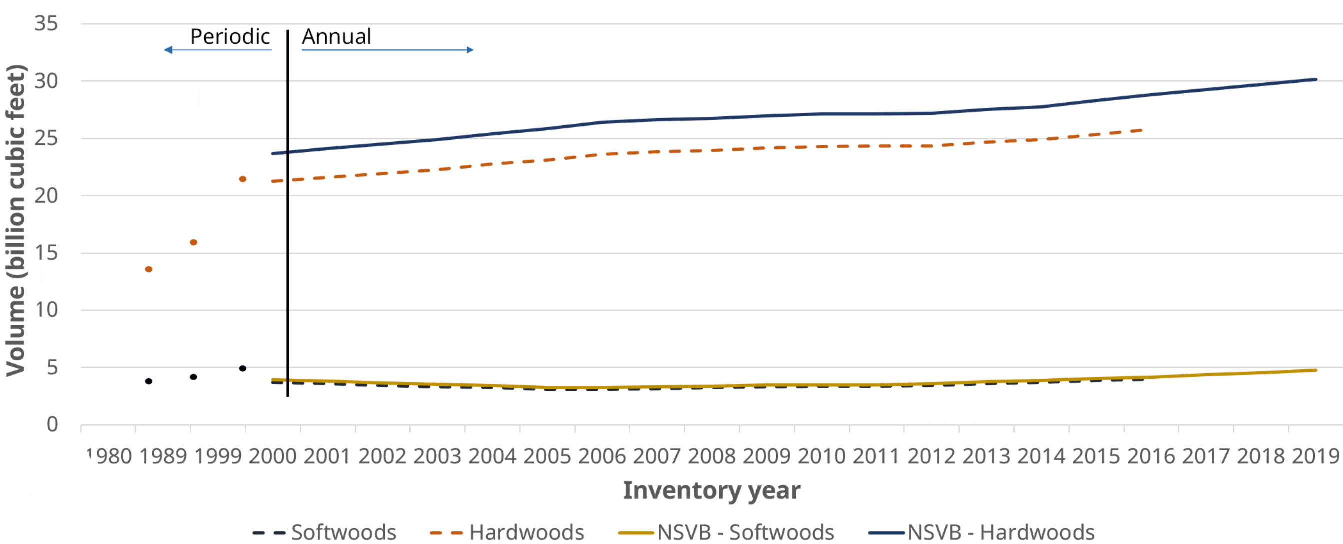

Figure 9—Net merchantable bole volume of live trees (≥5 inches d.b.h.), in cubic feet (new NSVB and historical regional estimates), by major species group on timberland for the period 1980 to 2019 (estimates from 1980 to 1999 is from the periodic inventory while 2000 to 2019 is from the annual inventory).

in figure 9). While very little hardwood volume exhibits clear evidence of artificial regeneration (i.e., planted), about one-third (32 percent) of softwood volume was planted (table 7). Loblolly and shortleaf pine volume are almost evenly split between stands that were naturally regenerated, 1.2 million cubic feet (mmcf), and those that were planted (1.1 mmcf). Hardwood volume is predominately in naturally regenerated stands and perhaps even 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.

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, 2019

		Stand origin		
Species group	Total	Natural stands	Clear evidence of artificial regeneration	Percent planted
Total	34,976,781,284	33,658,669,398	1,318,111,887	3.8
Loblolly and shortleaf pines	2,309,813,967	1,169,587,270	1,140,226,697	49.4
Other yellow pines	784,342,001	778,516,323	5,825,677	0.7
Eastern white and red pines	531,191,474	524,388,011	6,803,463	1.3
Eastern hemlock	246,839,713	246,839,713	–	0.0
Cypress	114,730,225	114,730,225	–	0.0
Other eastern softwoods	806,605,808	800,034,818	6,570,989	0.8
Select white oaks	3,789,982,894	3,771,168,389	18,814,506	0.5
Select red oaks	1,256,095,635	1,249,663,011	6,432,624	0.5
Other white oaks	3,341,988,832	3,336,094,060	5,894,773	0.2
Other red oaks	3,309,236,942	3,286,885,144	22,351,798	0.7
Hickory	3,291,013,299	3,288,428,949	2,584,349	0.1
Yellow birch	14,727,999	14,727,999	–	0.0
Hard maple	1,236,696,020	1,234,517,280	2,178,740	0.2
Soft maple	1,938,227,337	1,932,886,610	5,340,727	0.3
Beech	798,206,583	797,541,657	664,926	0.1
Sweetgum	1,393,015,421	1,368,754,603	24,260,818	1.7
Tupelo and blackgum	558,375,453	556,241,438	2,134,015	0.4
Ash	952,120,138	950,197,468	1,922,670	0.2
Cottonwood and aspen (East)	79,323,823	78,081,343	1,242,480	1.6
Basswood	171,687,628	171,687,628	–	0.0
Yellow-poplar	4,094,569,193	4,062,822,914	31,746,279	0.8
Black walnut	346,981,878	346,981,878	–	0.0
Other eastern soft hardwoods	2,562,857,094	2,534,481,527	28,375,567	1.1
Other eastern hard hardwoods	335,097,877	334,023,115	1,074,762	0.3
Eastern noncommercial hardwoods	711,964,690	708,298,664	3,666,026	0.5
Urban-specific hardwoods	1,089,361	1,089,361	–	0.0

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.

In an ownership pattern common across the Southern United States, the majority of the wood volume (84 percent) in 2019 was owned by nonindustrial private landowners (table 8). Eight percent of the volume was on lands stewarded by federal agencies such as the Forest Service (for example, National Forest lands), while the other 8 percent of the volume was growing on State and local public lands.

Sound bole volume and biomass are highly related; therefore similar to volume, the majority of tree biomass in Tennessee forests was accounted for by hardwood species (table 9).

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, 2019

		Ownership group			
Species group	Total	National Forest	Other Federal	State and local	Private
Total	34,976,781,284	2,160,655,132	896,956,591	2,618,610,082	29,300,559,479
Loblolly and shortleaf pines	2,309,813,967	55,846,426	74,072,154	107,913,710	2,071,981,677
Other yellow pines	784,342,001	110,636,548	3,752,764	36,956,738	632,995,951
Eastern white and red pines	531,191,474	219,813,219	–	36,011,145	275,367,110
Eastern hemlock	246,839,713	51,639,333	–	36,788,338	158,412,042
Cypress	114,730,225	–	–	39,020,778	75,709,447
Other eastern softwoods	806,605,808	18915338	41627438	27,393,402	718,669,629
Select white oaks	3,789,982,894	150,546,004	104,229,829	267,328,845	3,267,878,217
Select red oaks	1,256,095,635	125,921,750	26,540,598	79,305,712	1,024,327,574
Other white oaks	3,341,988,832	436,436,333	73,202,397	278,728,532	2,553,621,571
Other red oaks	3,309,236,942	143,559,973	126,554,821	388,289,254	2,650,832,895
Hickory	3,291,013,299	66,274,555	63,215,949	220,736,396	2,940,786,400
Yellow birch	14,727,999	13,602,418	–	–	1,125,581
Hard maple	1,236,696,020	21,625,642	34411656	55,628,982	1,125,029,740
Soft maple	1,938,227,337	219,215,027	35,032,510	141,595,866	1,542,383,934
Beech	798,206,583	10,349,942	4,292,436	47,155,166	736,409,039
Sweetgum	1,393,015,421	22,861,700	36,417,326	61,164,823	1,272,571,572
Tupelo and blackgum	558,375,453	36,822,115	19,731,993	44,668,127	457,153,218
Ash	952,120,138	11,269,338	24,886,289	62,902,512	853,061,999
Cottonwood and aspen (East)	79,323,823	–	1,117,939	7,259,402	70,946,483
Basswood	171,687,628	25542106	5,728,574	34,070,301	106,346,647
Yellow-poplar	4,094,569,193	241,961,309	125,337,781	367,428,523	3,359,841,580
Black walnut	346,981,878	2,984,753	13,762,298	23,304,313	306,930,514
Other eastern soft hardwoods	2,562,857,094	55,478,477	67,777,053	194,914,228	2,244,687,337
Other eastern hard hardwoods	335,097,877	58,505,278	3,936,083	20,375,336	252,281,181
Eastern noncommercial hardwoods	711,964,690	60,811,752	11,328,704	39,669,655	600,154,579
Urban-specific hardwoods	1,089,361	35,797	–	–	1,053,564

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.

Total aboveground biomass of live trees was over 62.5 million dry short tons (table 9). The loblolly and shortleaf pine species group accounted for about 3 percent of all aboveground live tree biomass. While most of the aboveground live tree biomass for species groups such as the oaks were found growing in trees located in a dominant or codominant crown class, for species like maples (particularly red maple), the aboveground live tree biomass was split more evenly between the dominant/codominant classes and the intermediate/overtopped classes (table 9).

Table 9—Aboveground biomass of live trees by species (≥1 inch d.b.h., in dry short tons, by species group and crown class on forest land, Tennessee, 2019

		Crown class				
Species group	Total	Open grown	Dominant	Codominant	Intermediate	Overtopped
Total	62,509,875	41,649	445,652	6,421,481	11,028,660	44,572,433
Loblolly and shortleaf pines	1,796,919	–	7,973	606,412	538,479	644,055
Other yellow pines	2,182,251	–	37,085	456,581	784,304	904,281
Eastern white and red pines	512,840	–	1,910	907	48,754	461,269
Spruce and balsam fir	4,603	–	–	–	–	4,603
Eastern hemlock	574,429	–	–	12,296	1,710	560,423
Cypress	25,585	–	–	3,729	16,988	4,868
Other eastern softwoods	3,173,256	–	4,406	353,132	941,482	1,874,236
Select white oaks	2,663,912	–	14,930	209,336	455,447	1,984,199
Select red oaks	627,990	–	12,078	92,521	157,572	365,820
Other white oaks	1,214,957	–	–	141,439	275,788	797,731
Other red oaks	1,559,264	1,246	12,188	344,959	336,653	864,217
Hickory	3,027,700	–	5,859	152,789	266,242	2,602,810
Yellow birch	63,230	–	–	13,066	14,785	35,379
Hard maple	3,669,092	–	31,196	44,261	385,204	3,208,430
Soft maple	7,913,473	–	87,164	533,718	930,743	6,361,848
Beech	1,506,071	288	12,735	31,747	84,254	1,377,047
Sweetgum	3,056,805	–	10,928	642,709	513,713	1,889,455
Tupelo and blackgum	2,795,011	–	5,864	78,637	246,200	2,464,310
Ash	2,071,536	–	52,332	194,082	412,166	1,412,955
Cottonwood and aspen (East)	70,954	–	9,661	25,070	26,980	9,242
Basswood	222,882	–	13,423	–	37,984	171,475
Yellow-poplar	3,543,013	24,973	48,714	800,779	947,338	1,721,210
Black walnut	246,669	–	2,012	9,969	140,227	94,462
Other eastern soft hardwoods	8,092,189	9,401	63,737	887,026	1,659,883	5,472,142
Other eastern hard hardwoods	3,337,885	704	1,211	348,759	593,953	2,393,257
Eastern noncommercial hardwoods	8,521,014	5,037	10,243	421,480	1,210,225	6,874,030
Tropical and subtropical hardwoods	819	–	–	–	819	–
Urban-specific hardwoods	35,526	–	–	16,077	768	18,681

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 11 to 25 inches while the smallest and largest diameter classes have remained relatively unchanged (fig. 10). In 2019, most volume was on private lands (fig. 11). Public forest land has a diameter distribution with a peak slightly larger than private forests lands. The peak of the distribution for publicly stewarded forest lands was the 15.0–16.9 inch diameter class while the peak is 13.0–14.9 for private forest lands (fig. 11).

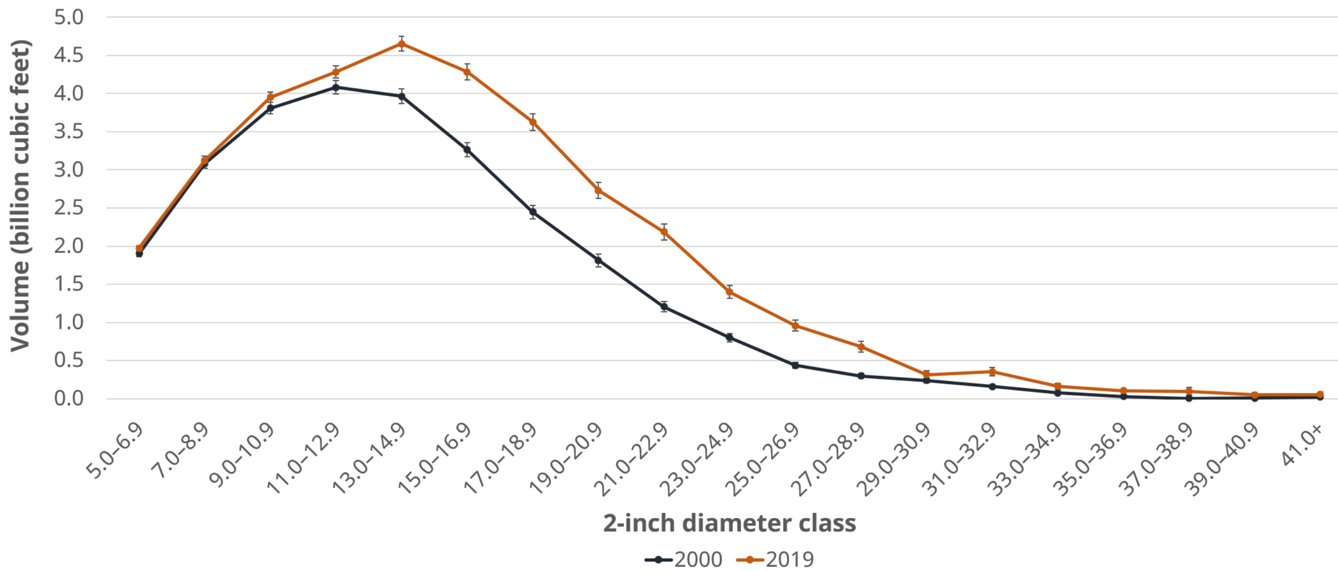

Figure 10—Net merchantable bole volume of live trees (≥5 inches d.b.h.), in cubic feet, by 2-inch diameter class on timberland for 2000 and 2019.

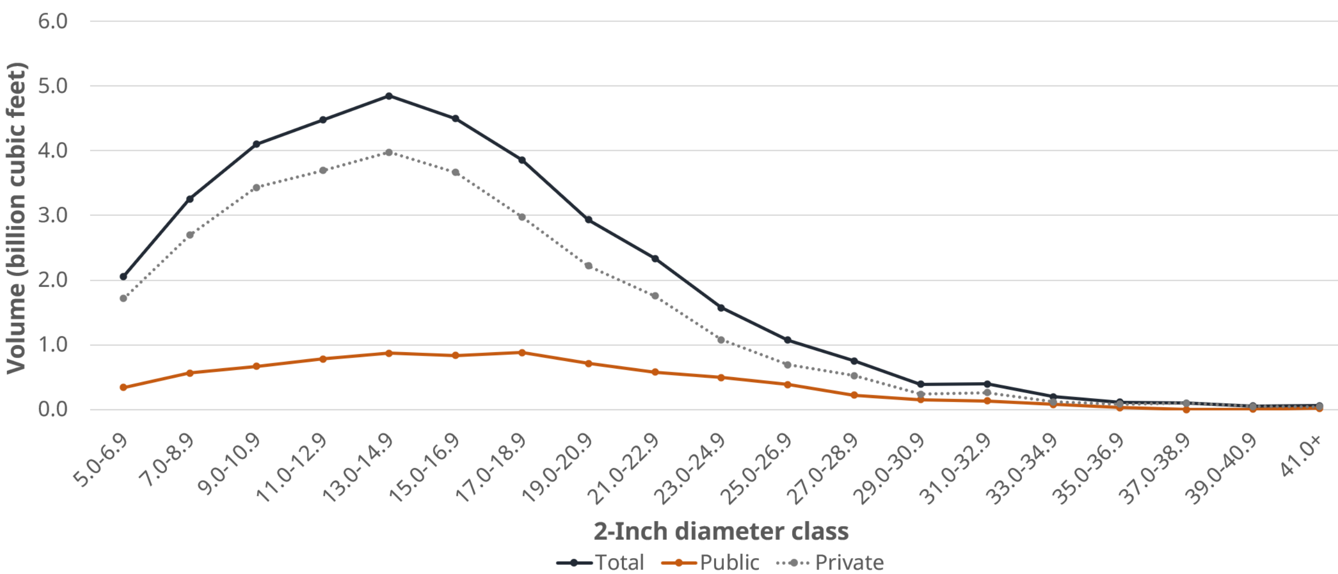

Figure 11—Net merchantable bole volume of live trees (≥5 inches d.b.h.), in cubic feet, by major ownership group on forest land, Tennessee, 2019.

GROWTH, REMOVALS, AND MORTALITY

Based on estimates of net change (gross growth – mortality – removals) from remeasured plots, total volume increased each year (on average), over 622 mmcf of sound volume between 2014 and 2019 (table 10). The annual positive net change amounts to an average 1.8 percent increase each year of the total standing live volume (table 8). 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

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, 2019

		Ownership group			
Species group	Total	National Forest	Other federal	State and local	Private
Total	622,350,063	27,336,833	24,431,745	50,237,770	585,396,544
Loblolly and shortleaf pines	125,470,453	1,522,978	3,706,294	3,134,897	120,609,993
Other yellow pines	13,399,121	2,028,302	209,991	1,024,411	14,433,574
Eastern white and red pines	4,269,850	1,996,424	-986,090	-2,093,995	6,817,419
Spruce and balsam fir	687,489	46,678	640,811	–	–
Eastern hemlock	-11,700,136	-6,247,038	-4,674,980	-317,722	-416,779
Cypress	1,742,640	–	727,798	1,136,835	1,623,678
Other eastern softwoods	21,318,345	418,367	1,457,924	622,364	20,314,258
Select white oaks	42,810,110	2,582,000	2,215,743	3,658,956	42,960,887
Select red oaks	16,113,505	1,667,082	-185,863	-865,988	16,808,334
Other white oaks	40,944,060	8,800,590	895,859	6,284,616	29,032,396
Other red oaks	29,322,180	817,484	3,495,655	8,959,366	23,180,200
Hickory	43,039,131	370,017	2,004,347	4,586,064	39,415,909
Yellow birch	1,436,407	217,912	1,182,021	-51,769	88,243
Hard maple	27,185,059	685,230	1,200,824	190,322	26,046,924
Soft maple	39,141,990	3,885,056	1,808,777	3,544,253	33,635,373
Beech	12,537,401	-33,952	1,024,160	1,109,466	11,238,134
Sweetgum	41,752,136	687,977	-36,587	2,342,827	41,522,870
Tupelo and blackgum	8,225,983	719,897	837,641	835,020	6,892,365
Ash	4,421,724	6,552	-144,134	40,389	5,062,022
Cottonwood and aspen (East)	5,024,282	–	55,379	785,150	4,183,753
Basswood	2,888,916	479,746	451,623	851,919	1,371,171
Yellow-poplar	82,214,960	3,782,929	5,774,351	7,544,341	71,169,042
Black walnut	7,233,608	211,612	469,549	655,921	6,332,663
Other eastern soft hardwoods	47,029,993	932,521	1,634,229	4,996,837	49,069,680
Other eastern hard hardwoods	1,144,221	734,822	293,796	216,414	688,299
Eastern noncommercial hardwoods	14,600,382	1,018,264	372,624	1,046,873	13,214,335
Tropical and subtropical hardwoods	0	–	–	–	0
Urban-specific hardwoods	96,257	5,382	–	–	101,800

D.b.h. = diameter at breast height.
– = No trees sampled in this category.

increase (125 mmcf per year) of any other single species group. When all four oak species groups are combined, average annual net change of all oak species was slightly larger than that of the loblolly and shortleaf pine group (129 mmcf).

In 2019, 76 percent of the total net annualized growth of 914 mmcf per year was on hardwood trees and 24 percent on softwoods (fig. 12). Similarly, 82 percent of total annualized removals was the result of hardwood removals and 18 percent was due to softwood removals (fig. 12). 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 was grown than was being removed though harvesting and/or land use changes. In fact, removals represent 1.1 and 1.3 percent of the total standing volume for softwoods and hardwoods, respectively (fig. 12).

Average annual removals (all) and harvest removals have been declining during the period from 2002 to 2019 (fig. 13). 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 7 years.

While harvest removals have declined slightly over time (fig. 13), 2019 harvest removals accounted for about 312 mmcf of volume. Since harvest removals in 2019 made up 81 percent of all removals, hardwood harvest removals accounted for 84 percent of all harvest removals in the State. Hardwood harvest removals are

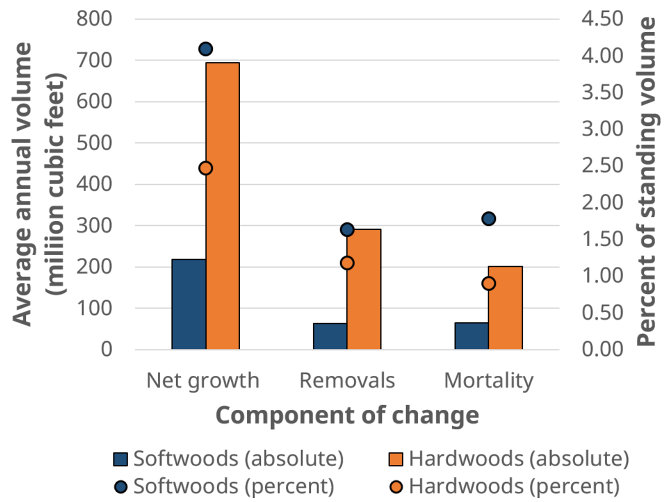

Figure 12—Average annual net growth, removals, and mortality of sound bole volume of trees (≥5 inches d.b.h.), as an absolute value (left axis) and as a percent of total standing stock (right axis) by major species group on forest land, 2019.

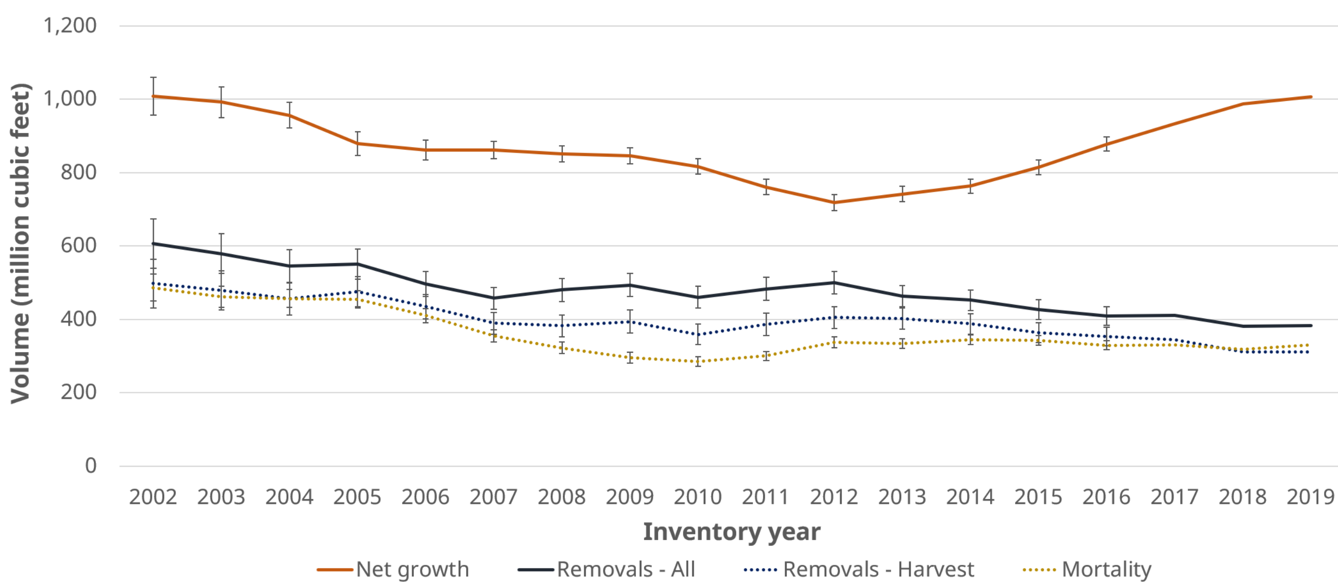

Figure 13—Average annual net growth, all removals, harvest removals, and mortality of sound bole volume of trees (≥5 inches d.b.h.) on forest land for the period 2002 to 2019.

Roan Mountain in East Tennessee. (Courtesy photo by twenty20 photos)

concentrated in the larger diameter stands (trees at least 11.0 inches diameter for hardwoods and at least 9.0 inches diameter for softwoods., corresponding to the greater use of hardwoods for sawn lumber rather than pulp products (fig. 14). Softwood 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 2002–2019 time period can still reflect the overall economic downturn experienced across the country. Harvesting activity across the Southern United States has shown declines during this time period as the demand for wood products decreased.

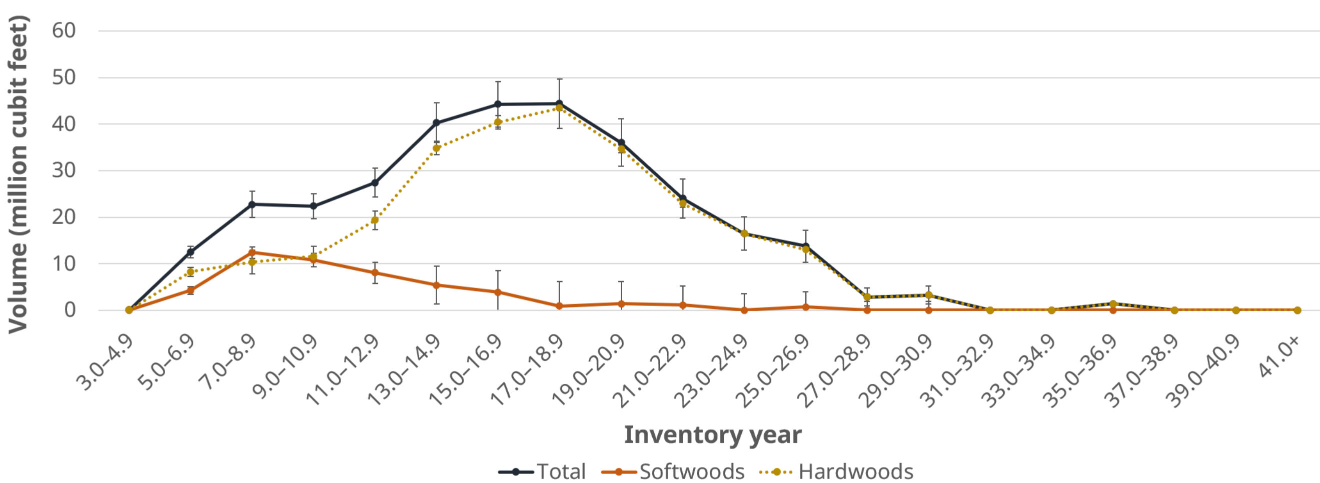

Figure 14—Average annual harvest removals of sound bole volume of trees (≥5 inches d.b.h.), across 2-inch diameter classes by major species group on forest land, Tennessee, 2019.

While stable recently, average annual mortality has experienced a slight decrease over the time period between 2002 and 2019 with a current rate of 330 mmcf per year. The peak in this time period was in 2002 with average annual mortality near 486 mmcf per year. Inventory data for the year 2002 was still exhibiting signs of the southern pine beetle epidemic that occurred in Tennessee forests during the period between 1999 and 2001 (Oswalt et al. 2012). This fact is extremely apparent when comparing average annual mortality for hardwoods to mortality in softwoods during the same period (fig. 15). Hardwood mortality was 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.

DISTURBANCE AND INVASIVE PLANTS

Disturbance is a natural and necessary part of forest health. In 2019, both insect and animal damage (e.g., grazing) was noted as the primary disturbance on more acres than any other disturbance, followed by severe weather events and fire (fig. 16). Disturbances during the period

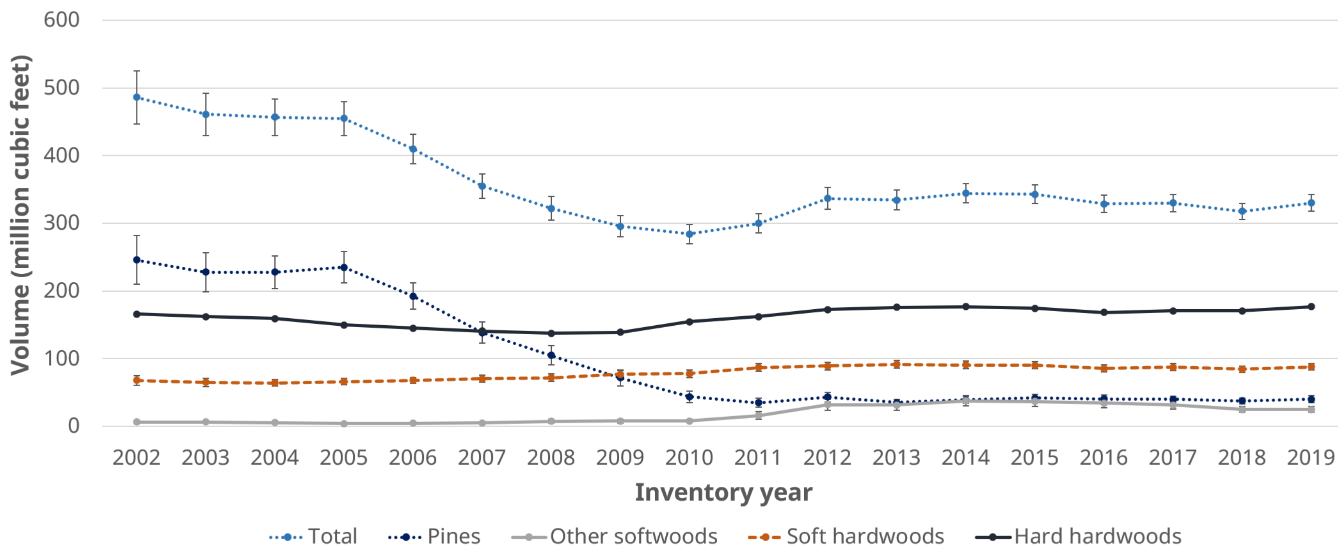

Figure 15—Average annual mortality of sound bole volume of trees (≥5 inches d.b.h.) by major species group on forest land for the period 2002 to 2019.

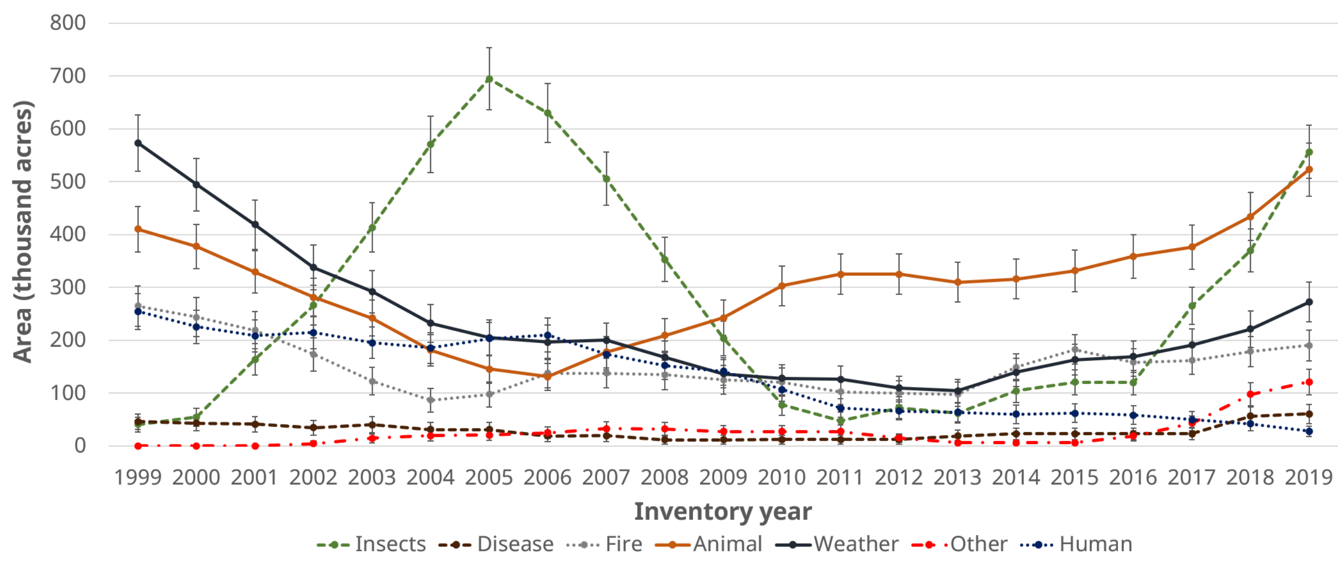

Figure 16—Area of forest land by primary disturbance for the period 1999 to 2019.

Microstegium vimineum, a nonnnative grass, blankets the forest floor impeding the regeneration of native plant species. (U.S. Forest Service photo by Christopher Oswalt)

between 2000 and 2019 have been considerably dynamic. The peak of insect disturbance in 2005 corresponds to the southern pine beetle epidemic that occurred in Tennessee forests between 1999 and 2001 (Oswalt et al. 2012). Considered across the overall forest landscape, disturbance rates have recently climbed back to levels experienced during the peak of the southern pine beetle epidemic (fig. 17). Recent increases (3–4 years) have occurred among all disturbance categories with the exception of human-mediated disturbances.

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 et al. 2017), support biodiversity (Jonsson et al. 2005), and establish important fungal and mycorrhizal communities (Norden and Paltto 2001).

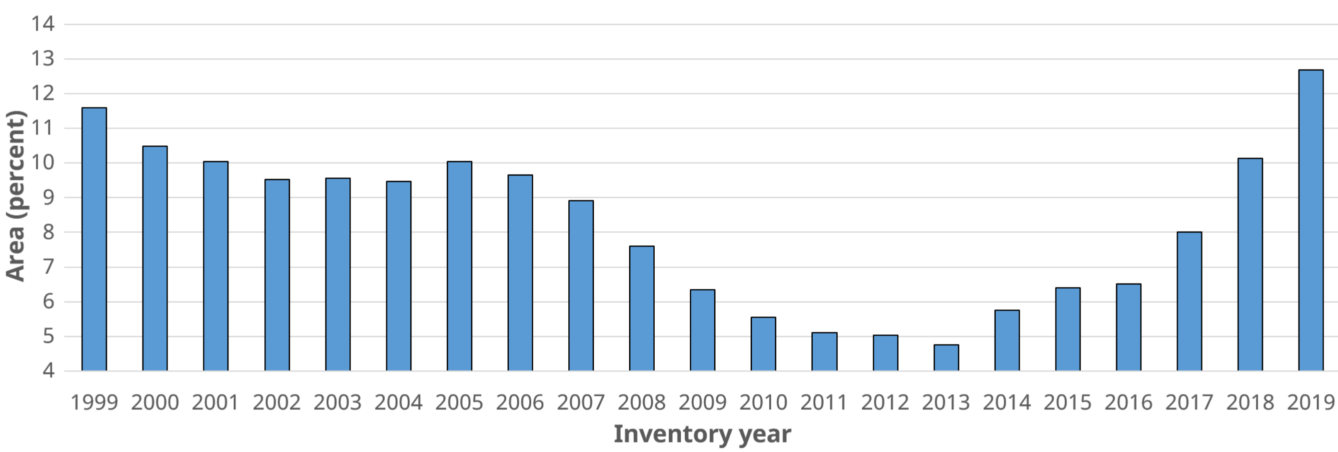

Figure 17—Forest land area (percent) with a recorded primary disturbance for the period 1999 to 2019.

In 2019, there was 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 158 million standing dead trees (table 11). Average standing dead trees per acre of forest land were highest in the East survey unit.

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. One, 10, 100, 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 woody debris, and piles) accounted for a total of 92 million dry short tons on forest land (table 12). While the vast majority of that DWM was found on forests with no immediate signs of recent disturbance, a considerable amount was found in forests disturbed by fire, insects, 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 100-hour fuels 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 11—Number of standing dead trees (≥5 inches d.b.h.) by ownership group on forest land, Tennessee, 2019

Ownership	Standing dead
National Forest	16,762,194
Other Federal	14,356,600
State and local	12,094,285
Private	115,189,424
Total	158,402,503

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

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 Oswalt 2007), replacing native ecosystems (Bruce et al. 1997), and potentially disrupting wildlife habitat (Pyšek et al. 2012). FIA monitors select invasive plant species on forests in Tennessee.

Invasive plant presence/absence was monitored on 4,669 plots (see appendix 1—Inventory Methods for plot design). Invasive plants were detected on 43 percent of those subplots (2,011 plots). The highest concentrations of monitored forest invasives are in the East survey unit (fig. 19, see fig. 1 for unit boundaries). The most common forest invasive plant monitored by FIA was Japanese honeysuckle (*Lonicera japonica*) impacting nearly 1.0 million acres of forest land

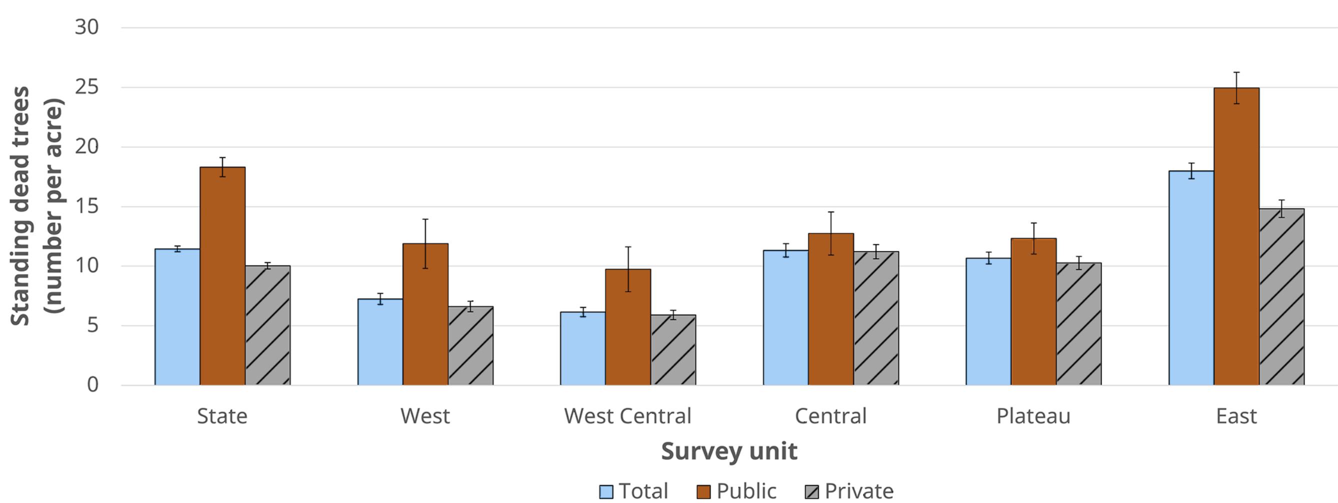

Figure 18—Number of standing dead trees (≥5 inches d.b.h.) by survey unit on forest land, Tennessee, 2019.

Table 12—Total weight of DWM (FWD, CWD and piles) in dry short tons, by primary disturbance and forest type group on forest land, Tennessee, 2019

Forest type group	Total	None	Primary disturbance						
			Insects	Disease	Fire	Animal	Weather	Other	Human
Total	91,555,931	71,366,986	10,469,241	330,936	1,775,232	2,657,729	4,879,360	20,550	55,897
White / red / jack pine group	277,310	148,430	108,596	–	20,284	–	–	–	–
Loblolly / shortleaf pine group	4,046,744	1,977,581	281,660	–	889,980	897,523	–	–	–
Other eastern softwoods group	223,811	223,811	–	–	–	–	–	–	–
Oak / pine group	6,629,705	5,572,743	169,609	–	53,392	833,961	–	–	–
Oak / hickory group	71,365,446	55,297,665	9,817,615	330,936	811,249	925,924	4,116,282	9,879	55,897
Oak / gum / cypress group	5,669	5,669	–	–	–	–	–	–	–
Elm / ash / cottonwood group	5,411,687	4,688,495	–	–	–	–	723,192	–	–
Maple / beech / birch group	2,766,685	2,662,042	57,200	–	–	–	39,887	7,557	–
Other hardwoods group	41,201	3,198	34,561	–	327	–	–	3115	–
Exotic hardwoods group	787,674	787,352	–	–	–	321	–	–	–

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, 2019

Forest-type group	Down and dead woody fuels				Slash	Forest floor fuels	
	1 hour	10 hours	100 hours	1,000+ hours		Duff	Litter
	tons per acre						
Elm-ash-cottonwood	0.02	0.34	1.30	0.94	4.12	4.86	3.97
Other eastern softwoods	0.05	0.25	0.13	0.58	0.00	1.88	3.29
Maple-beech-birch	0.05	0.41	2.46	4.96	0.00	11.85	5.36
Loblolly-shortleaf pine	0.03	0.40	0.94	1.99	0.00	8.02	7.95
White-red-jack pine	0.06	0.53	1.40	2.90	0.00	138.95	14.47
Other hardwoods	0.07	1.04	3.44	1.09	0.00	50.08	15.52
Oak-pine	0.04	0.37	0.95	1.68	4.67	13.18	7.38
Exotic hardwoods	0.05	0.48	1.01	7.42	0.00	4.24	2.62
Nonstocked	0.00	0.00	0.00	0.00	0.00	0.00	5.20
Oak-gum-cypress	0.19	1.18	0.00	0.00	0.00	16.30	0.00
Oak-hickory	0.04	0.49	1.74	3.56	1.24	10.55	8.12
All groups	0.59	5.49	13.37	25.13	10.02	259.91	73.87

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

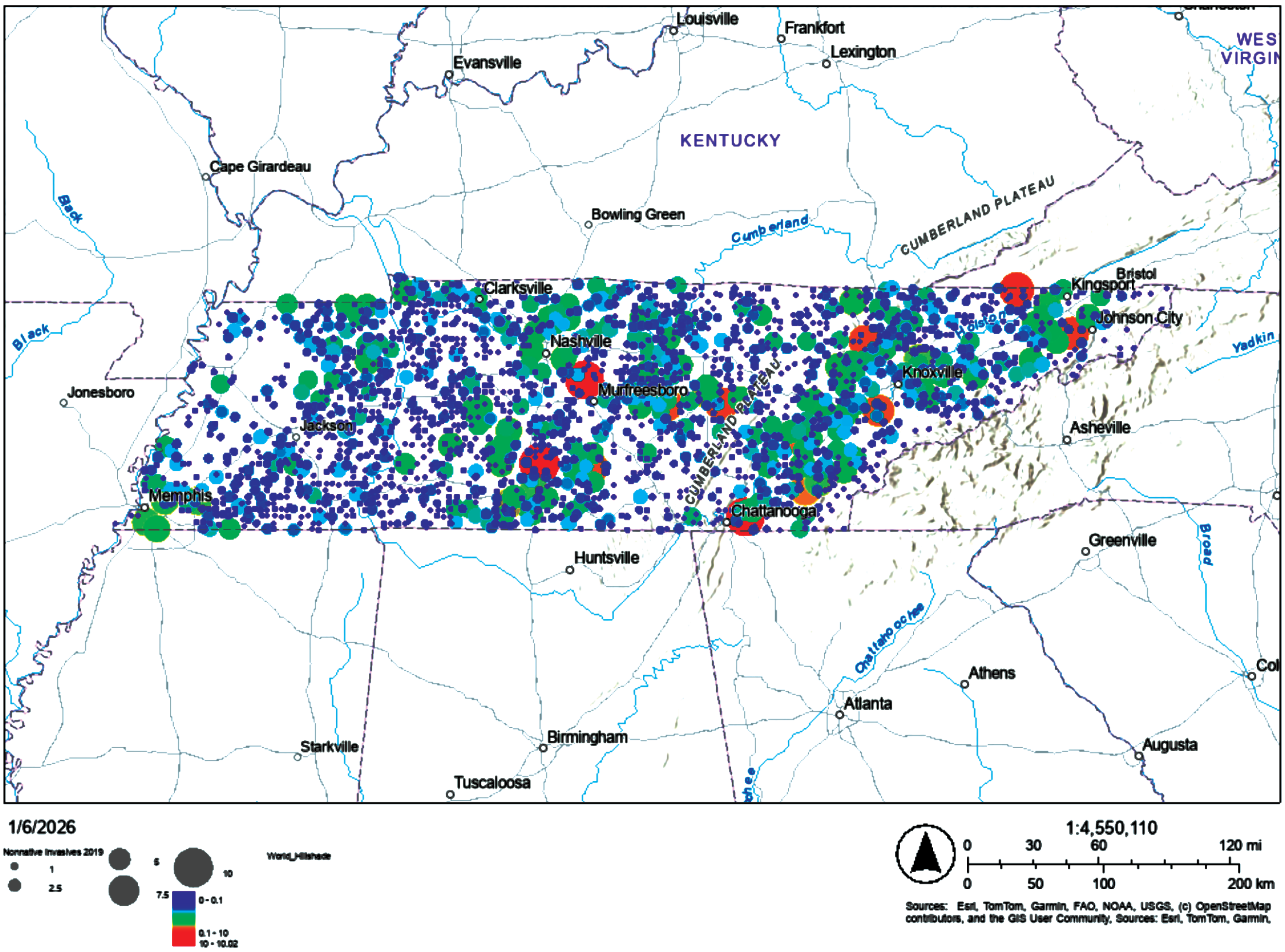

Figure 19—Distribution of monitored forest invasive plants in Tennessee, 2019.

across the State (table 14). Studies indicate that the presence of Japanese honeysuckle (*L. japonica*) in forests subject to disturbance can result in lower success of recolonization by tree species, lowering tree density and native plant richness (Dillenburg et al. 1993, Nickelson et al. 2015). The most common invasive tree in Tennessee was tree of heaven (*Ailanthus altissima*). Nepalese browntop (*Microstegium vimineum*) was the second most common found impacting an estimated 490,000 acres across the State.

While Kudzu (*Pueraria montana*) was a very visible and high-profile invasive vine on forest edges, it was observed on <1 percent of forested subplots surveyed. Kudzu (*P. montana*) can rapidly colonize disturbed sites, even those with poor soil, but is less persistent in the low light conditions of the forest understory (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, 2019

Invasive species	Area of forest land
	thousand acres
Japanese honeysuckle	956.26
Nepalese browntop	489.87
Privet	304.29
Rose	111.49
Tree of heaven	106.62
Honeysuckle	99.04
Japanese privet	80.70
Sericea lespedeza	42.54
Princesstree	26.31
Lespedeza	22.11
Periwinkle	21.56
Kudzu	19.61
Oleaster	19.15
Winter creeper	15.85
Silktree	14.47

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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 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. Some examples follow:

> *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 United States 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 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 1—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 FIA. 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. A1.1). 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 (USDA Forest Service 2014).

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.

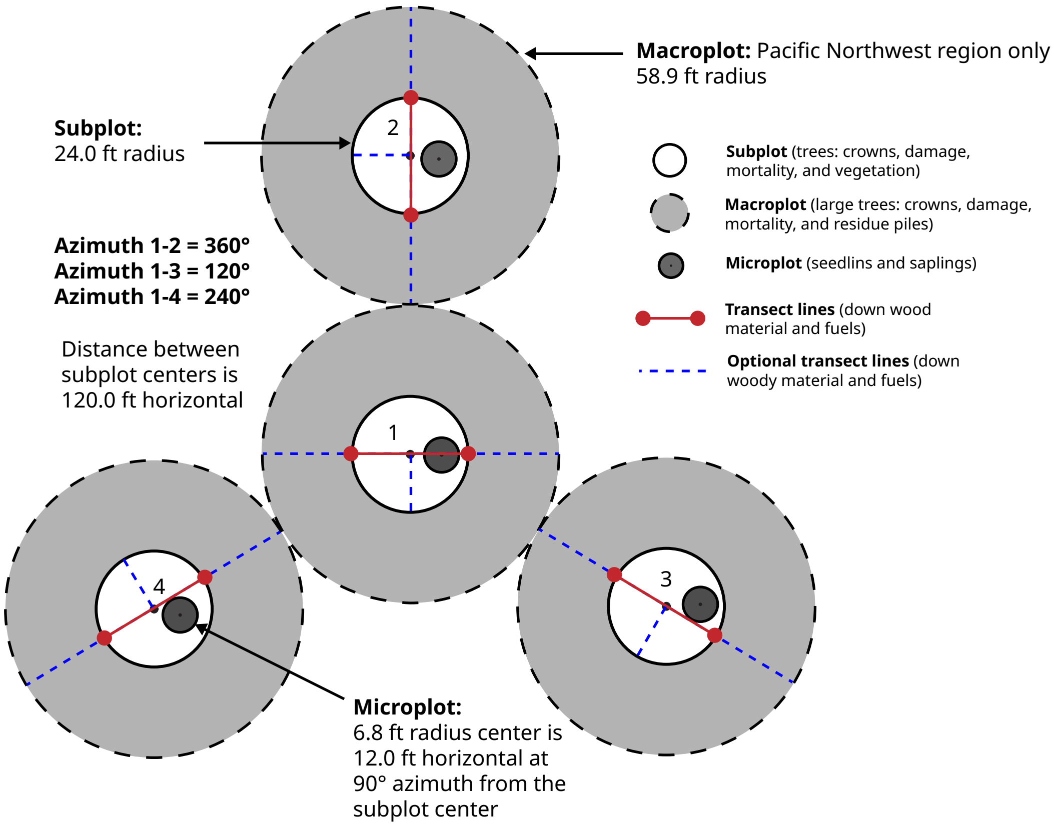

Figure A1.1—National and regional fixed-plot design, 2021.

Phase 2+

Data on forest health variables (P2+) are collected on about 1/16th 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.

Literature Cited

Bechtold, W.A.; Patterson, P.L., eds. 2005. The enhanced forest inventory and analysis program-national sampling design and estimation procedures. Gen. Tech. Rep. SRS–80. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 85 p. https://doi.org/10.2737/SRS-GTR-80.

U.S. Department of Agriculture Forest Service. 2014. Forest inventory and analysis national core field guide. Internal report. Volume 1: field data collection procedures for phase 2 plots. Version 6.11. Washington, DC: U.S. Department of Agriculture Forest Service. 305 p. On file with: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis, 201 14th Street, Washington, DC 20250.

APPENDIX 2—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 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 (USDA 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 (Pollard et al. 2006).

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:

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

Literature Cited

Pollard, J.E.; Westfall, J.A.; Patterson, P.L. [et al.]. 2006. Forest Inventory and Analysis National Data Quality Assessment Report for 2000 to 2003. Gen. Tech. Rep. RMRS-GTR-181. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 43 p.

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Oswalt, C.M.; Oswalt, S.N. 2026. Tennessee's Forests, 2019. Resour. Bull. SRS–252. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 43 p. https://doi.org/10.2737/SRS-RB-252.

This resource bulletin consolidates data from the ninth complete survey of Tennessee's forest resources which was conducted during the period 2015–2019 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 inventory, forest health monitoring, forest trends, Tennessee, timber volume.

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