United States Department of Agriculture

Missouri's Forests, 2013:
Statistics and Quality Assurance

Forest Service

Northern Research Station

This document supplements Resource Bulletin NRS-108

FOREST INVENTORY METHODS

Strategic Model

The Forest Inventory and Analysis program of the Northern Research Station (NRS-FIA) is part of the national enhanced FIA program that focuses on a set of six strategic objectives (McRoberts 2005):

- A standard set of variables with nationally consistent meanings and measurements.
- Field inventories of all forested lands.
- Nationally consistent estimation.
- Adherence to national precision standards.
- Consistent reporting and data distribution.
- Credibility with users and stakeholders.

To ensure that these six objectives are achieved, 10 strategic approaches have been prescribed:

- A national set of prescribed core variables with a national field manual that describes measurement procedures and protocols for each variable
- A national plot configuration
- A nationally consistent sampling design
- Estimation using standardized formulas for sample-based estimators
- A national database of FIA data with core standards and user-friendly public access
- A national information management system
- A nationally consistent set of tables with estimates of prescribed core variables
- Publication of statewide tables with estimates of prescribed core variables at 5-year intervals
- Documentation of the technical aspects of the FIA program including procedures, protocols, and techniques
- Peer review and publication of the technical documentation for general access

The result of the strategic objectives and approaches is an inventory program with identifiably new features and a nationally consistent plot configuration, a nationally consistent sampling design for all lands, annual measurement of a proportion of plots in each state, nationally consistent estimation techniques and algorithms, and integration of the ground-sampling components of the FIA inventory and detection monitoring by the U.S. Forest Service's Forest Health Monitoring (FHM) program.

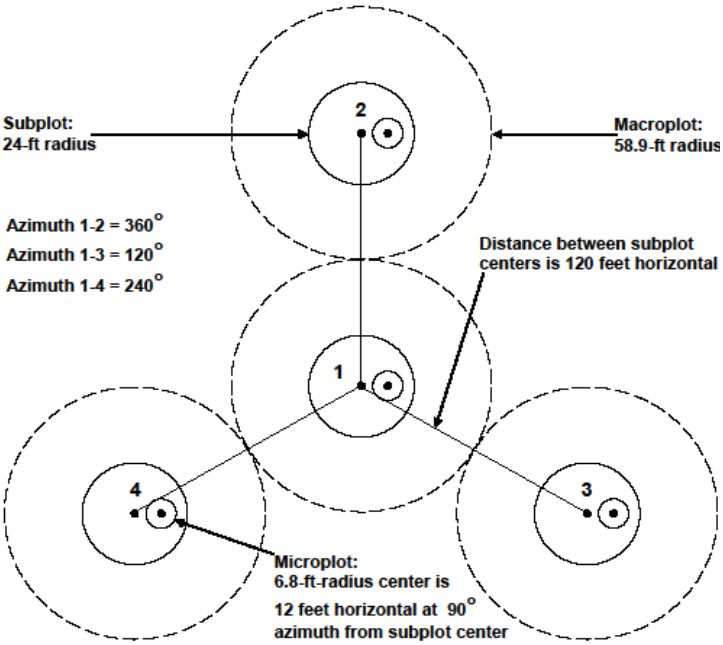

Figure 79.—National FIA plot design (adapted from Bechtold and Patterson 2005).

Plot Configuration

The national FIA plot design (Fig. 79) consists of four 24-ft-radius subplots configured as a central subplot and three peripheral subplots. Centers of the peripheral subplots are located 120 ft. from the central subplot and at azimuths of 360, 120, and 240o from the center of the central subplot. Each tree with diameter at breast height (d.b.h.) 5 inches or greater is measured on these subplots. Each subplot contains a 6.8-ft-radius microplot with center located 12 feet east of the subplot center on which each tree with d.b.h. between 1 and 5 inches is measured. Forest conditions that occur on any of the four subplots are identified and recorded; if the area of the condition is 1 acre or greater, the condition is mapped on the subplot. Factors that differentiate forest conditions include forest type, stand-size class, stand origin, land use, ownership, and density. Macroplots are not used by the Northern Research Station. They have a radius of 58.9 feet and are used for sampling intensification or sampling relatively rare events. Rocky Mountain and Pacific Northwest Research Stations use these larger sample areas in some cases.

Sample Design

Historic sampling errors indicate that a sampling intensity of about one plot per 6,000 acres is required to satisfy national FIA precision guidelines. Therefore, FIA divided the area of the United States into nonoverlapping, 5,937-acre hexagons and established a plot in each hexagon as follows: (1) if an existing FHM plot was located in a hexagon, it was selected; (2) if there was no FHM plot in the hexagon, the existing FIA plot from the previous periodic inventory nearest the hexagon center was selected; and (3) if neither an FHM nor an FIA plot was located in the hexagon, a new FIA plot was established at a random location in the hexagon (Brand et al. 2000, McRoberts 1999). This array of field plots is designated the Federal base sample and is considered an equal probability sample; its measurement is funded by the Federal government.

The Federal base sample was divided into five interpenetrating, nonoverlapping panels or subsamples, each of which provides complete, systematic coverage of a state. Each year, plots in a single panel are measured and panels are selected on a 5-year, rotating basis (McRoberts 1999). For estimation purposes, the measurement of each panel of plots is considered an independent, equal probability sample of all lands in a state.

Multi-phase Inventory

FIA conducts inventories in multiple phases. Phase 1 (P1) uses remotely sensed data to obtain initial plot land-cover observations and to stratify land area in the population of interest increasing the precision of estimates. In Phase 2 (P2), field crews visit the physical locations of permanent field plots to measure traditional inventory variables such as tree species, diameter, and height. All trees measured in the previous measurement of the plot are remeasured or otherwise accounted for and any new trees that have grown onto the plot are measured. In Phase 3 (P3), field crews visit a subset of P2 plots to obtain measurements for an additional suite of variables associated with forest and ecosystem health. P3 has been replaced by Phase 2+ (P2+), in which less data are collected per plot but there are more plots. Otherwise, P2+ and P3 follow the same paradigm focusing on forest and ecosystem health. Normally, the P2 and P3 or P2+ variables are acquired in the same visit. The three phases of the enhanced FIA program as implemented in this inventory are discussed in greater detail in the sections that follow.

Phase 1

Aerial photographs, digital orthoquads (DOQs: digitally scanned aerial photograph), and satellite imagery are used for initial plot measurement via remotely sensed data and stratification. P1 plot measurement consists of observations of conditions at the plot locations using aerial photographs or DOQs. Analysts determine a digitized geographic location for each field plot and a human interpreter assigns the plot a land cover/use with primary focus on identifying forest land. All plot locations that could possibly contain forest land, plus any additional plots that contained forest land at the previous measurement, are selected for further measurement via field crew visits in P2.

The combination of natural variability among plots and budgetary constraints prohibits measurement of a sufficient number of plots to satisfy national precision standards for most inventory variables unless the estimation process is enhanced using ancillary data. Thus, the land area is stratified by using remotely sensed data to facilitate stratified estimation.

NRS-FIA uses canopy density classes to derive strata. Canopy density information was obtained from the 2001 National Land Cover Database (NLCD 2001) (Homer et al. 2007). The NLCD 2001 canopy density layer for the United States was produced through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.mrlc.gov/). The layer characterizes subtle variations of forest canopy density as a percentage estimate of forest canopy cover (0 to100) within every 30 meter pixel over the United States. The method employed to map canopy density for NLCD 2001 is described in detail in Huang et al. (2001).

Strata categorizations were optimized for the entire NRS-FIA region. Using plot location information (center of the center subplot), a percent canopy density value was assigned to each plot. Plots were then aggregated into one of the five strata based on the center of the

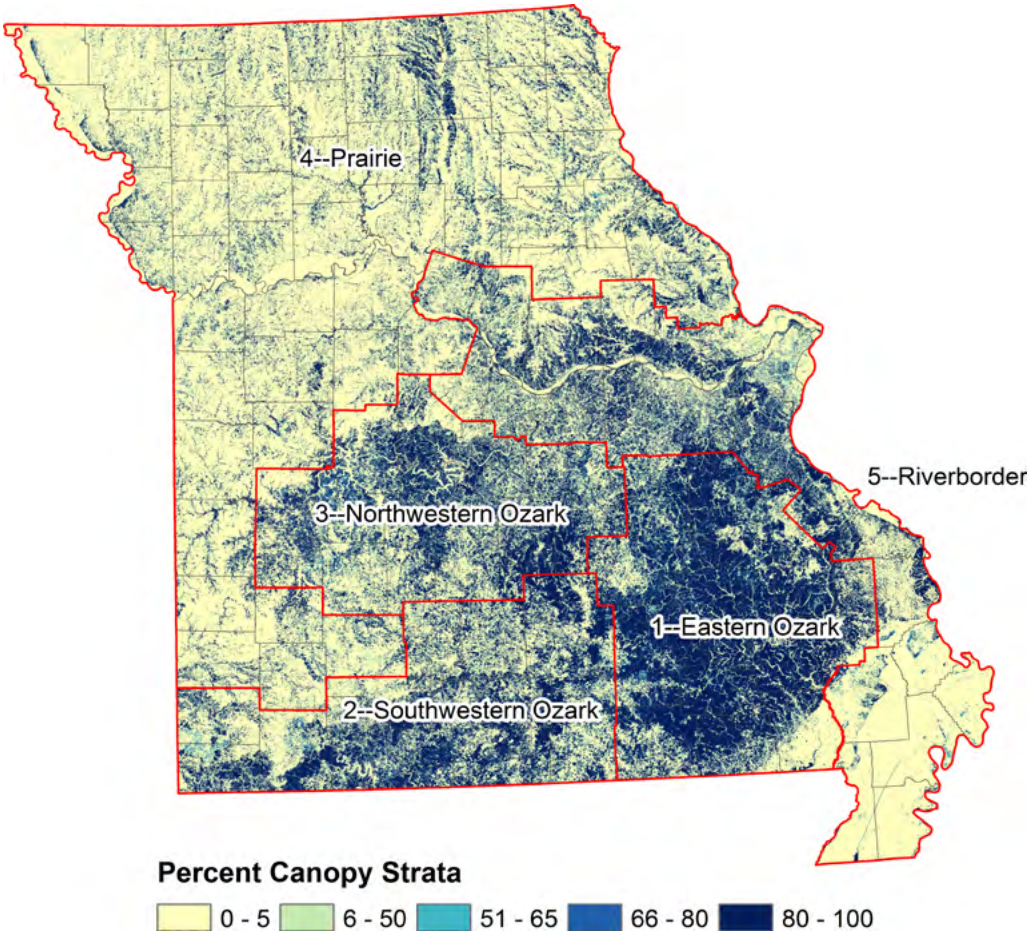

Figure 80.—Missouri percent canopy strata groupings.

center subplot. The percent canopy cover stratification scheme consists of five groupings: (1) 0-5 percent, (2) 6-50 percent, (3) 51-65 percent, (4) 66-80 percent, and (5) 81-100 percent. These groupings were based on observed natural clumping of pixel values and are presented in Figure 80.

If there were not enough plots in each of these classes to create strata, then collapsing rules were used to combine classes until sufficient sample sizes were obtained.

In addition to the classification of every pixel into one of the five canopy strata, every pixel was also assigned to an ownership stratum in order to reduce the effects of nonresponse bias that typically varies by owner. In Missouri, ownership layers derived from the Missouri Department of Natural Resources Lands, Parks, and Historic Sites, Missouri Department of Natural Resources, Division of State Parks, Planning and Development Program, the Conservation Biology Institutes Protected Areas Database Conservation Biology Institute 2010), Mark Twain National Forest ownership data, and 2000 U.S. Census TIGER data (U.S. Census Bureau 2000) for Missouri were used to classify pixels into, four ownership classes: (1) other public; (2) private; (3) inland census water; and (4) Mark Twain National Forest (Fig. 81). The largest ownership class, based on pixel counts, was private ownership at 41 million acres (Table MO-1). Every pixel was also assigned to a county based on the location of the pixel center.

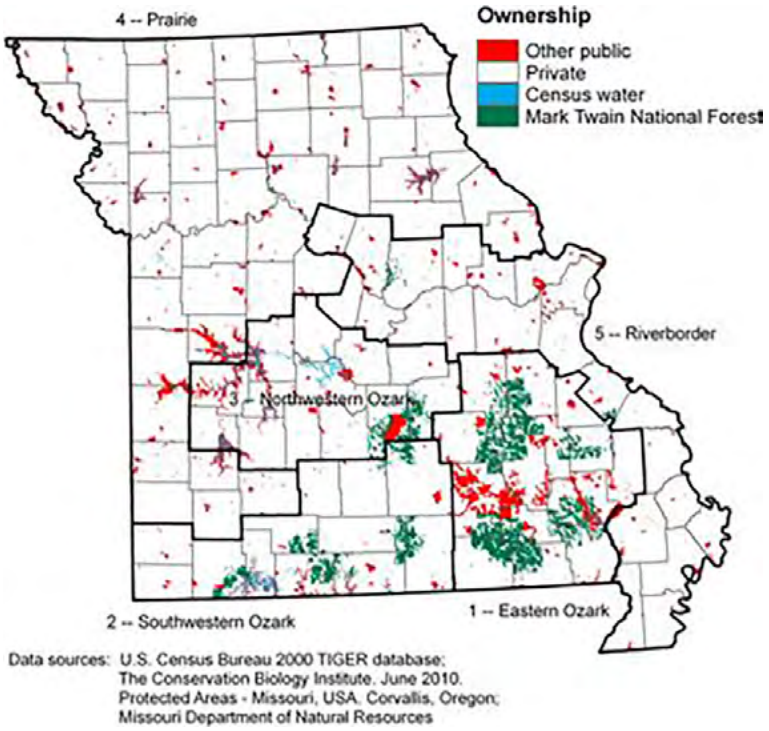

Figure 81.—Missouri forest ownership.

If there were enough plots in each of these classes to create strata, then the strata were defined by the class boundaries. If there were insufficient numbers of plots for some classes, collapsing rules were used to combine classes until sufficient sample sizes were obtained. NRS-FIA requires a minimum of 10 plots per stratum. There are two exemptions from the 10 plots per stratum rule. Any stand-alone estimation unit, such as a National Forest, will not be collapsed with another estimation unit regardless of the plot count. Also, the inland census water estimation units use an alternative minimum of two plots per stratum.

Table 1.—Ownership class acreages based on pixel counts

Ownership class	Acres
Private	41,080,776
Mark Twain National Forest	1,502,647
Other public	1,504,669
Inland census water	522,766

Stratified estimation requires that two tasks be accomplished. First, each plot must be assigned to a single stratum. Next, the proportion of each detailed stratum must be calculated (TM land-cover classification, ownership, and county group delineation). The first task is accomplished by assigning each plot to the stratum assigned for the pixel containing the center of the center subplot. The second task is accomplished by calculating the proportion of pixels in each stratum. The population estimate for a variable is calculated as the sum across all strata of the product of each stratum's observed proportion (from P1) and the variable's estimated mean per unit area for the stratum (from P2). Details of the stratum assignments used in Missouri are presented in the estimation section of this report.

Phase 2

In P2, field crews record a variety of data for plot locations determined in P1 to include accessible forest land. Before visiting plot locations, field crews consult county land records to determine the ownership of plots and then seek permission from private landowners to measure plots on their lands. At the plot, field crews determine the location of the geographic center of the center subplot using global positioning system receivers, maps, and notes from previous visits if available. Crews delineate a condition as a unique combination of reserved status, owner group, forest type, stand-size class, stand origin, and tree density. For every condition (at least 1 acre in size) on the plot, they record the delineating attributes and others such as land cover, stand age, site-productivity class, history of forest disturbance, and land use. The crews also record information on condition boundaries when multiple conditions are found on a plot. For each tree, field crews record a variety of observations and measurements, including condition, species, live/dead status, lean, diameter, height, crown ratio (percent of tree height represented by crown), crown class (dominant, codominant, suppressed), damage, and decay status. All trees measured in the previous measurement of the plot are remeasured or otherwise accounted for and any new trees that have grown onto the plot are measured. Office staff use statistical models based on field-crew measurements to calculate values for additional variables, including individual-tree volume, per unit area estimates of number of trees and volume, and biomass by plot, condition, species group, and live/dead status. The remeasurement of every tree enables the calculation of components of change including growth, mortality, and removals. U.S. Forest Service (2012) covers P2 data collection procedures and O'Connell et al. (2014) describe the P2 database.

Phase 3 (1999-2010)

The third phase of the enhanced FIA program focuses on forest health. P3 is administered cooperatively by the FIA program, other Forest Service programs including the Forest Health Monitoring (FHM) program, other Federal agencies, state natural resource agencies and universities. The FHM program consists of four interrelated and complementary activities: detection, evaluation and intensive site-ecosystem monitoring, and research on monitoring techniques. Detection monitoring consists of systematic aerial and ground surveys designed to collect baseline information on the current condition of forest ecosystems and to detect changes from those baselines over time. Evaluation monitoring studies examine the extent, severity, and probable causes of changes in forest health identified through the detection monitoring surveys. Intensive site-ecosystem monitoring studies regionally specific ecological processes at a network of sites located in representative forested ecosystems. Research on monitoring techniques focuses on developing and refining indicator measurements to improve the efficiency and reliability of data collection and analysis at all levels of the program.

The ground-survey portion of the detection monitoring program was integrated into the FIA program as P3 in 1999. The P3 sample consists of a 1:16 subset of the P2 plots with one P3 plot for about every 95,000 acres. P3 measurements are obtained by field crews during the growing season and include an extended suite of ecological data for Missouri. Data collected include:

1) Lichen diversity and abundance (data collected in inventory years 2002 through 2005),
2) Soil quality (erosion, compaction, and chemistry; data collected 2000 through 2005),
3) Vegetation diversity and structure (data collected in inventory years 2001 through 2003 and 2007 through 2010)

4) Down woody material (data collected in inventory years 2001 through 2010)

5) The Incidence and severity of ozone injury (data collected in inventory years 1999 through 2010) for selected bioindicator species, monitored as part of an associated sampling scheme

6) Crown indicators (data collected in inventory years 2000 through 2010)

All P2 measurements are collected on each P3 plot at the same time as the P3 measurements (U.S. For. Service 2007). Additional information on the collection procedures used in P3 is available at http://www.nrs.fs.fed.us/fia/topics/. Woodall et al. (2010) describe the P3 database.

P3 variables were selected to address specific criteria outlined by the Montreal Process Working Group for the conservation and sustainable management of temperate and boreal forests (Montreal Process Working Group 2009) and are based on the concept of indicator variables. Observations of an indicator variable represent an index of ecosystem functions that can be monitored over time to assess trends. Indicator variables are used in conjunction with each other, P2 data, data from FHM evaluation monitoring studies, and ancillary data to address ecological issues such as vegetation diversity, fuel loading, regional air-quality gradients, and carbon storage. The P2 and P3 data of the enhanced FIA program are a primary source of reporting data for the Montreal Process.

Phase 2+

For most forest health indicators, P2+ is a more refined and powerful version of P3, collecting only the more important attributes and sampling a greater number of plots. The P3 sample included approximately 6.3 percent of the P2 plots. Since 2012, P2+ protocols have been completed on approximately 12.5 percent of the P2 plots (including the historical P3 plots) and may be completed on up to approximately 25 percent of the plots depending upon future funding. The soils indicator is the one exception which will remain with the 6.3 percent sample intensity using the historical P3 plots and sampling protocol. The field guide for collecting attributes on P2+ plots (U.S. Forest Service 2014b) includes details on sampling sapling length, advance tree seedling regeneration (ATSR), vegetation profiles, invasive plants, down woody materials, soils, and tree crowns, as described below.

Advance Tree Seedling Regeneration. The tree seedling sample is designed to inventory and monitor the forest's regenerative capacity. Tree seedling counts are used along with the sapling tally to estimate advance tree seedling regeneration (ATSR). Information on ATSR, specifically lengths, is required for estimating regeneration success. ATSR data are used with estimates of competing vegetation derived from the vegetation profile and data on the abundance and character of invasive plants. These three components form the basis for analysis of regeneration adequacy and hence, the ability of native forests to regenerate and an indication of the expected future forest composition.

Vegetation Profile. Vegetation data are collected to describe vegetation structure for vascular plants. The data collected provide a horizontal and vertical estimation of vegetation located within the sample area. Information on the abundance and structure of understory plant communities has many uses. It can be used to assess wildlife habitat, biomass, forage availability, grazing potential, vegetation competition with tree growth, fuel loadings from understory vegetation, and potential site productivity.

Invasive Plants. The invasive plants protocol documents abundance and monitors change in abundance of selected species over time. Combined with other plot data and other datasets, these data can be used to predict the future spread of selected species. Invasive plant species are having tremendous economic and ecological impacts on our nation's forests, and the impacts are increasing over time. Providing accurate, statistically valid estimates of the distribution and abundance of some of the most damaging species will give managers and policy-makers a better understanding of the problem. Each FIA unit, in collaboration with vegetation experts, has developed lists of the most important invasive species to monitor on forested lands. The invasive plants protocol was implemented on approximately 20 percent of plots from 2009 through 2011 but changed to the P2+ sample (12.5 percent) in 2012.

Down Woody Materials. Down wood materials (DWM) are important components of forest ecosystems across the country. DWM are dead material on the ground in various stages of decay. Down wood materials and fuels estimated by the FIA program are coarse wood, slash, fine wood, and litter and duff depth. DWM help describe the following:

- Quality and status of wildlife habitats
- Structural diversity within a forest
- Fuel loading and fire behavior
- Carbon sequestration (amount of carbon tied up in dead wood)
- Storage and cycling of nutrients and water (important for site productivity)

Soils. The soils indicator is used to assess forest ecosystem health in terms of the physical and chemical properties of the soils. The soil resource is a primary component of all terrestrial ecosystems, and any environmental stressor that alters the natural function of the soil has the potential to influence the vitality, species composition, and hydrology of forest ecosystems. Specifically, soils data are collected to assess the following:

- Potential for erosion of nutrient-rich top soils and forest floors
- Factors relating to the storage and cycling of nutrients and water
- Availability of nutrients and water to plants (dependent upon soil structure and texture)
- Carbon sequestration (the amount of carbon tied up in soil organic matter)
- Deposition of toxic metals from pollution
- Acidification of the soil from deposition of pollutants

Crowns. The condition of tree crowns is an important indicator of tree and forest health. The crowns indicator is used to assess the health and vigor of trees based on two metrics, crown dieback and uncompacted live crown ratio. Crown dieback is recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. Uncompacted live crown ratio is the percentage of live crown length divided by the total tree length.

Trees with vigorous, healthy crowns tend to have higher growth rates. By contrast, trees with damaged or degraded crowns have a reduced capacity for photosynthesis and slower growth rates. Many stressors have been correlated with crown degradation including insects, disease, weather events, senescence, competition, and atmospheric deposition. Additionally, trees with unhealthy crowns are more susceptible to mortality.

Estimation

Most of the estimates and analysis of forest resources presented in this report, including all of the estimates in Tables MO-1 through MO-61 are based on data observed on the 7,800 Phase 2 plots across Missouri. The analysis of forest health issues that relate to down woody materials, soils, ozone damage, and crown condition are based on data observed on the 424 Phase 3 plots and 363 phase 2+ plots.

Integration with Previous Inventories

The first four inventories of Missouri were completed in 1947, 1959, 1972, and 1989 (U.S. Forest Service 1948, Gansner 1965, Spencer and Essex 1976, Spencer et al. 1992, respectively). Missouri's fifth inventory (the first conducted under the annual inventory system) was completed in 2003 and consisted of data collected in five panels over 5 years (1999, 2000, 2001, 2002 and 2003) (Moser et al. 2007). The sixth inventory (the first complete remeasurement of an annual inventory) was completed in 2008 (Raeker et al. 2011) and consisted of data collected in 2004, 2005, 2006, 2007 and 2008. The seventh inventory (the second complete remeasurement of an annual inventory) was completed in 2013 (this report: Piva et al. 2016). This seventh inventory includes the five panels of data collected in 2009, 2010, 2011, 2012 and 2013.

Data from new inventories often are compared with data from earlier inventories to determine trends in forest resources. However, for the comparisons to be valid, the procedures used in the two inventories must be similar. Identical classification procedures were used for the 2003, 2008, and 2013 inventories therefore comparisons made between these inventories are relatively uncomplicated.

Comparisons with the earlier inventories (1989, 1972, 1959, and 1947) are more problematic as there were major changes in plot design between the periodic inventories conducted prior to 1998 and annual inventories conducted after 1998.

For the sake of consistency, a new, national plot design was implemented by all five regional FIA units in 1999. This current design uses fixed-radius subplots exclusively. Prior to this new plot design, fixed and variable-radius subplots were used in the 1989 and 1972 inventories. Both designs have strong points but they often produce different classifications for individual plot characteristics. Procedures for assigning condition attributes such as forest type, stand-age, and stocking, for example, changed significantly with the introduction of the new annual plot design. Unpublished FIA research comparing these plot designs, however, showed no noticeable difference in volume and tree-count estimates.

For additional information on the sample protocols and estimation procedures for the first two phases of the FIA program, see Bechtold and Patterson (2005). For additional information on Phase 3 indicator sampling protocols, see U.S. Forest Service (2007) and Woodall and Monleon (2008).

Reserved Status Changes

In an effort to increase consistency among states and across inventory years, a refined set of procedures determining reserve status have been implemented with version 6.0 of the FIA field manual (U.S. Forest Service 2012), which took effect with the 2013 inventory year

(began October 2012). Furthermore, all previously collected annual inventory data (1999 to present) have been updated using the new standardized interpretation.

Starting with this report, timberland estimates generated for earlier annual inventories will differ from previously published estimates. The 2012 inventory was the last inventory in which all data were available under the previous and improved implementations. Small but significant changes are associated with timberland acreage (-2 percent), number of trees (-2 percent), volume (-2 percent), and biomass (-2 percent). The impact on harvest removals was quite small (-0.2 percent) but the impact on the estimate of annual other removals of growing-stock trees on timberland was very large (-69 percent). This large decrease in other removals is the result of improved consistency in reserved status determination.

The improved implementation of the reserve status definition increases the spatial and temporal precision of timberland estimates allowing for higher quality trend analyses and potentially better forest management decisions.

Forest typing and stand-size algorithms have been altered. These algorithms were implemented nationally by FIA to provide consistency from state to state. All previously collected annual inventory data (1999 to present) have been updated using the new algorithms.

COMMON SOURCES OF ERROR

Two general types of error—random variability (precision) and estimation bias (accuracy)—are of general interest to all users. Random variability refers to the precision of the estimate, which would occur if the entire sampling and estimation process were to be repeated many times. Estimation bias refers to the difference between the estimate and the "true value" in the absence of this random variability and refers to the overestimation or underestimation inherent in the entire estimation process.

Errors in the estimates presented in this report (both random variability and estimation bias) are affected by various sources. The four primary sources of error common to all sample-based estimates are sampling, measurement, prediction, and nonresponse error. A section is devoted to each of these sources of error. Included in each section is a definition of the source of error in the context of the FIA inventory as well as a discussion of methods used to quantify and/or reduce that source of error. Measures of sampling, measurement, and prediction errors associated with various attributes are presented. Issues of possible bias related to nonresponse also are addressed.

Sampling Error

The process of sampling (selecting a random subset of a population and calculating estimates from this subset) causes estimates to contain error they would not have if every member of the population (e.g., every tree in the State) had been observed and included in the sample. The 2013 inventory of Missouri is based on a sample of 7,800 plots located randomly across the State (total area of 44.6 million acres), or a sampling rate of about one plot for every 5,719 acres.

The procedures for statistical estimation outlined in the previous section and described in detail in Bechtold and Patterson (2005) provide the estimates of the population totals and means presented in this report. Along with every estimate is an associated sampling error

that is typically expressed as a percentage of the estimated value (the estimated value plus or minus the sampling error). This sampling error is the primary measure of the reliability of an estimate. This report utilizes a sampling error based on one standard error which means the chances are two in three that had a 100-percent inventory been taken using these methods, the results would have been within the limits indicated.

The sampling errors for state-level estimates of the major attributes presented in this report are presented in Table B. Table MO-65[1] presents sampling errors for these estimates at the county level.

Estimates for classifications smaller than the State totals in Table B will have larger sampling errors. For example, Table MO-65 shows the sampling error for timberland area in any county is higher than that for total timberland area in the State. To compute an approximate sampling error for an estimate that is smaller than a State total, use the following formula:

$$E = \frac{(SE)\sqrt{(\text{State total estimate})}}{\sqrt{(\text{Smaller estimate})}} \qquad (1)$$

where:

E = approximate sampling error for smaller estimate

SE = sampling error for State total estimate (percent)

For example, to compute the error on the area of forest land in the oak/pine forest-type group for the State, proceed as follows:

The total area of the oak/pine group in the State from Table MO-3 is 886.6 acres.

The total area of all forest land in the State from Table MO-3 is 15,452.5 acres.

The State total error for forest land area from Table MO-65 is 0.71 percent.

Using formula (1):

Sampling error = $E = \frac{(0.71)\sqrt{(15{,}452.5)}}{\sqrt{(886.6)}}$ = 2.96 percent.

This approximation works well for estimates of area, volume, number of trees, and biomass. It is less effective for estimates of growth, removals, or mortality. Individuals seeking more accurate sampling errors should use the estimation tools available at http://www.fia.fs.fed.us/tools-data/default.asp.

The estimators used by FIA are unbiased under the assumptions that the sample plots are a random sample of the total population and the observed value for any plot is the true value for that plot. Deviations from these basic assumptions are not reflected in the computation of sampling errors. The following sections on measurement, prediction, and nonresponse error address possible departures from these basic assumptions.

[1] Tables labeled with the State abbreviation (MO) followed by a number (e.g., Table MO-1) are located in a supplementary file titled "Missouri forest inventory summary tables" located at https://doi.org/10.2737/NRS-RB-108. Tables labeled with letters (e.g., Table A) are located on pages 28-38.

Measurement Error

Errors associated with the methods and instruments used to observe and record the sample attributes are called measurement errors. On FIA plots, attributes such as the diameter and height of a tree are measured with instruments, and other attributes such as species and crown class are observed without the aid of an instrument. On a typical FIA plot, 15 to 50 trees are observed with 15 to 20 attributes recorded on each tree. Also, many attributes that describe the plot and conditions on the plot are observed. Errors in any of these observations affect the quality of the estimates. If a measurement is biased (such as tree diameter consistently taken at an incorrect place on the tree), the estimates that use this observation (such as volume) will reflect this bias. Even if measurements are unbiased, high levels of random error in the measurements will add to the total random error of the estimation process.

To ensure that all FIA observations are made to the highest standards possible, a regular program of quality control and quality assurance is an integral part of all FIA data collection efforts. This program begins with the documentation of protocols and procedures used in the inventory followed by extensive crew training. To assess the quality of the data collected by these trained crews, a random sample of at least 4 percent of all plots is measured independently by a different qualified crew. These independent measurements are referred to as blind checks, the purpose of which is to assess the quality of field measurements. A second measurement on blind-check plots is made by a quality assurance (QA) crew. QA crews have as much or more experience and training in FIA field measurements as that of standard FIA crews.

The quality of field measurements is assessed nationally through a set of measurement quality objectives (MQOs) that are set for every data item collected. Each MQO consists of two parts: a tolerance or acceptable level of measurement error and an objective in terms of the percent of measurements within tolerance. Blind-check measurements are used to observe how often individual field crews are meeting these objectives and to assess the overall compliance among all crews. Table C shows the compliance rates for various measurements used to compute the estimates included in this report and in other NRS-FIA reports. Columns labeled "Missouri" are based on blind-check measurements of plots used in this report. The columns labeled "All NRS States" come from all measurements made by NRS-FIA crews within the entire 24-state area (Connecticut, Delaware, Illinois, Indiana, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, West Virginia, and Wisconsin). Training and supervision of crews is a regional effort and crews often work in more than one state. Regional data quality observations reflect the overall measurement quality of all data collected by NRS-FIA in NRS-FIA States.

In Missouri, many variables, such as diameter at breast height, have a low tolerance (± 0.1 in.) and a high percentage of data within the tolerance (95.5 percent). Measurements for determining tree size class are precise. In contrast, a few variables such as stand age have a larger tolerance (± 10 years) and less data within the tolerance (85.7 percent). The estimate of stand age is based on the composition of all age classes within a stand. Often, stands are heterogeneous by age but a single value must be assigned to them. Sometimes this confounds analysis of stand age over time.

In addition to percent compliance to MQOs, the blind-check observations were used to test for relative bias in the field crew measurements. Relative bias is defined here as a tendency for standard field crew measurements to be higher or lower than measurements taken by the QA crews. The estimated relative bias and limits of 95 percent confidence intervals (based on parametric bootstrap estimates) for the relative bias are presented in Table D.

Blind-check measurements do not provide direct observations of true bias in field measurements (average difference between field measurements and true values) because they are paired observations of two field measurements. The QA crew in these blind checks typically has more training and experience with FIA field measurements than the first crew, but both crews use the same methods and instruments to obtain measurements. These methods have been identified as the best available and selected for nationwide use by FIA; they are commonly used by similar natural-resource inventories. A basic assumption is that when applied correctly these methods provide unbiased observations of the attribute they are designed to measure. Under this assumption, relative bias observations in Table D provide observations of bias due to the difference in experience and training between the field and QA crews. In most cases, there is no significant bias.

Nearly 98 percent of the remeasured trees were given the same species codes by the field crews in both the current and previous inventories. Thirty-eight percent of the species codes that did not match between the current and previous inventories were oaks that were coded as other oak species and 34 percent were hickories that were coded as other hickory species.

Prediction Error

Errors associated with mathematical models (such as volume models) aimed at providing observations of the attributes of interest based on sample attributes are called prediction errors. The area, number of trees, volume, biomass, growth, removals, and mortality are the primary attributes of interest presented in this report. Estimates of area and number of trees are based on direct observation and do not rely on prediction models. Models are used to predict volume and biomass estimates of individual tree volumes. Change estimates such as growth, mortality, and removals are based on these model-based predictions of volume from both the current plot measurements and the measurements taken in the previous inventory.

Estimates of prediction errors associated with the volume models in this report were presented by Hahn and Hansen (1991) along with model forms, methods used in model development, and model-parameter estimates. The estimated prediction errors are based on observations of 10,453 trees measured in the 1989 Missouri inventory. For gross cubic-foot volume in live trees, there was an overall overprediction of 2.5 percent across all species, with an underprediction of 4.3 percent in trees less than 10 inches d.b.h., and an overprediction of 7.1 percent in trees 20 inches d.b.h. and larger Similar prediction errors were observed in the board-foot estimates.

In comparing FIA estimates to other data sources, users need to be aware of the prediction models used in both estimates. If both estimates are based on the same prediction models with matching fitted parameter values, the prediction bias of one estimate should cancel out that of the other estimate. If the estimates are based on different prediction models, the prediction error of both models must be considered

Nonresponse Error

Nonresponse error occurs when crews are unable to measure a plot (or a portion of a plot) at a selected location. Nonresponse falls into the following three classes:

- Denied access—Entire plots or portions of plots where the field crew is unable to obtain permission from the landowner to measure trees on the plot.
- Hazardous/inaccessible—Entire plots or portions of plots where conditions prevent a crew from safely accessing the plot or measuring trees on the plot.
- Other—Plots where the field crew is unable to obtain a valid measurement for reasons other than those stated.

Nonresponse has two effects on the sample. First, it reduces the sample size. The reduced sample size is reflected in the sampling errors. Second, nonresponse can bias the estimates if the portion of the population not being sampled differs from the portion being sampled.

In FIA, nonresponse rates are relatively low. In the 2013 Missouri inventory, 7,800 sample plots were selected for observation. Ninety-six percent of these are included in the sample used to estimate current resources. On 282 plots, crews were unable to obtain owner permission to measure the plot or part of the plot; hazardous conditions on two plots prevented the crew from measuring all or part of the plot. Even an overall nonresponse rate of 1 percent can cause considerable bias if not properly accounted for. The major source of nonresponse is denied access to plots, which occurs primarily on lands in private ownership. Also, observations for plots on nonforest and water land classes rarely require crews to physically enter the land, nor is permission needed because the observation can be obtained from aerial photos or other sources of remotely sensed information.

The stratified estimation process used by NRS-FIA with strata defined by ownership classes and canopy cover class reduces the possible effects of bias caused by nonresponse. Under the stratified estimation process used by NRS-FIA, nonresponses are removed from the sample, and stratum estimates (means, totals, and sampling errors) are obtained only from plots with valid observations. The net effect in the estimates of means and totals is that the average of the observed plots within the stratum (ownership-canopy-cover class) becomes the estimate for all nonresponses within that stratum. The nonresponse rate in one stratum does not affect the estimate in other strata. The response rate within each stratum is presented in Table E for the Missouri 2013 inventory.

In Table MO-1 of this report, we acknowledge denied access and hazardous as two land classes in Missouri within which we are unable to provide estimates on variables such as forest area and timber volume. However, we do report the total estimated area in each of these classes. In all other tables of this report, we do not acknowledge either of these classes, and in the estimation process we treat the sample where we do have observations as a random sample of the entire State.

The nonresponse plots in this inventory were not permanently removed from the FIA system of plots. In future inventories we will again attempt to measure these plots. At that time we may be able to obtain permission to access these plots, hazardous conditions may have changed, and other circumstances that caused us to drop plots from a specific inventory cycle may well be different.

GLOSSARY

Average annual mortality: The average annual change in mortality of trees during the period between inventories. This estimate can be provided in cubic feet for live and growing-stock trees that died or in board feet for sawtimber trees that died.

Average annual net growth: The average annual change in the volume of trees during the period between inventories. Components include the change in volume of trees that have met the minimum size requirements over the inventory period, plus the volume of trees reaching the minimum size during the period (ingrowth), minus the volume of trees that died during the period, minus the volume of cull during the period. Mortality removals (trees killed in the harvesting process and left on site) and diversion removals (trees removed from the forest land base due to a change from forest to nonforest land) are not included (see average annual removals). This estimate can be provided in cubic feet for live and growing-stock trees or in board feet for sawtimber trees.

Average annual removals: The average annual change in removals of trees during the period between inventories. The estimate includes harvest removals, mortality removals (trees killed in the harvesting process and left on site), and diversion removals (trees removed from the forest land base due to a change from forest to nonforest land). This estimate can be provided in cubic feet for live and growing-stock trees or in board feet for sawtimber trees.

Basal area: Tree area in square feet of the cross section at breast height of a single tree. When the basal areas of all trees in a stand are summed, the result usually is expressed as square feet of basal area per acre.

Bioindicator species: A tree, woody shrub, or herb species that responds to ambient levels of ozone pollution with distinct visible foliar symptoms that are easy to diagnose.

Biomass: The aboveground volume of live trees (including bark but excluding foliage) reported in dry tons (dry weight). Biomass has four components:

> **Bole:** Biomass of a tree from 1 foot above the ground to a 4 inch top outside bark or to a point where the central stem breaks into limbs.
>
> **Tops and limbs:** Total biomass of a tree from a 1 foot stump minus the bole.
>
> **1 to 5 inch trees:** Total aboveground biomass of a tree from 1 to 5 inches in d.b.h.
>
> **Stump:** Biomass of a tree 5 inches d.b.h. and larger from the ground to a height of 1 foot.

Bulk density: The mass of soil per unit volume. A measure of the ratio of pore space to solid materials in a given soil. It is expressed in units of grams per cubic centimeter of oven dry soil.

Coarse woody debris (CWD): Dead branches, twigs, and wood splinters 3.0 inches in diameter and larger measured at the smallest end.

Commercial species: Tree species suitable for industrial wood products.

Compacted live crown ratio: The percent of the total length of the tree that supports a full, live crown. To determine compacted live crown ratio for trees that have uneven length crowns, lower branches are visually transferred to fill holes in the upper portions of the crown, until a full, even crown is created.

Corporate: An ownership class of private lands owned by corporations.

County and municipal: An ownership class of public lands owned by counties or local public agencies, or lands leased by these governmental units for more than 50 years. Also known as local government.

Cropland: Land under cultivation within the last 24 months, including cropland harvested, crop failures, cultivated summer fallow, idle cropland used only for pasture, orchards, active Christmas tree plantations indicated by annual shearing, nurseries, and land in soil improvement crops but excluding land cultivated in developing improved pasture.

Crown: The part of a tree or woody plant bearing live branches or foliage.

Crown dieback: Recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. Dieback is considered only when it occurs in the upper and outer portions of the tree. When whole branches are dead in the upper crown, without obvious signs of damage such as breaks or animal injury, it is assumed the branches died from the terminal portion of the branch. Dead branches in the lower portion of the live crown are assumed to have died from competition and shading.

Cull tree: A live tree, 5.0 inches in d.b.h. or larger, that is unmerchantable for saw logs now or prospectively because of rot, roughness, or species. (See definitions for rotten and rough trees.)

Decay class: Qualitative assessment of stage of decay (five classes) of coarse woody debris based on visual assessments of color of wood, presence/absence of twigs and branches, texture of rotten portions, and structural integrity.

Diameter class: A classification of trees based on diameter outside bark measured at breast height (4.5 feet above ground). D.b.h. is the common abbreviation for "diameter at breast height." With 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches d.b.h. A "diameter at root collar", or d.r.c., measurement is acquired for multi-stemmed woodland species (e.g., Rocky Mountain juniper).

Down woody material (DWM): Woody pieces of trees and shrubs that have been uprooted (no longer supporting growth) or severed from their root system, not self-supporting, and lying on the ground.

Duff: A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) no longer can be identified.

Effective cation exchange capacity (ECEC): The sum of cations that a soil can adsorb in its natural pH. It is expressed in units of centimoles of positive charge per kilogram of soil.

Federal: An ownership class of public lands owned by the U.S. Government.

Fiber products: Products derived from wood and bark residues, such as pulp, composition board products, and wood chips.

Fine materials: Wood residues not suitable for chipping, such as planer shavings and sawdust.

Fine woody debris (FWD): Dead branches, twigs, and wood splinters 0.1 to 2.9 inches in diameter.

Forest land: Land that has at least 10 percent crown cover by live tally trees of any size or has had at least 10 percent canopy cover of live tally species in the past, based on the presence of stumps, snags, or other evidence. To qualify, the area must be at least 1.0 acre in size and 120.0 feet wide. Forest land includes transition zones, such as areas between forest and nonforest lands that meet the minimal tree stocking/cover and forest areas adjacent to urban and built-up lands. Roadside, streamside, and shelterbelt strips of trees must have a width of at least 120 feet and continuous length of at least 363 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if they are less than 120 feet wide or less than an acre in size. Tree-covered areas in agricultural production settings, such as fruit orchards, or tree-covered areas in urban settings, such as city parks, are not considered forest land.

Forest type: A classification of forest land based on the species presently forming a plurality of the live-tree stocking. If softwoods predominate (50 percent or more), then the forest type will be one of the softwood types and vice versa for hardwoods. For the eastern United States, there are mixed hardwood-pine forest types when the pine and/or redcedar (either eastern or southern) component is between 25 and 49 percent of the stocking. If the pine/redcedar component is less than 25 percent of the stocking, then one of the hardwood forest types is assigned.

Forest-type group: Combinations of forest types that share closely associated species or site requirements and are generally combined for brevity of reporting. See forest type for examples of forest-type group members.

Missouri forest-type groups and associated forest types:

WHITE/RED/JACK PINE GROUP

In these pure pine forest types, stocking of the pine component needs to be at least 50 percent.

> **Eastern white pine:** Associates—pitch pine, gray birch, aspen, red maple, pin cherry, white oak, paper birch, sweet birch, yellow birch, black cherry, white ash, northern red oak, sugar maple, basswood, hemlock, northern white-cedar, yellow-poplar, white oak, chestnut oak, scarlet oak, and shortleaf pine. Sites—wide variety, but best development on well drained sands and sandy loams.

LOBLOLLY/SHORTLEAF PINE GROUP

Shortleaf pine: Associates—white oak, southern red oak, scarlet oak, black oak, hickory, post oak, blackjack oak, blackgum, red maple, pitch pine, and Virginia pine. Sites—low, well drained ridges to rocky, dry, south slopes and the better drained spur ridges on north slopes and also on old fields.

OTHER EASTERN SOFTWOODS GROUP

Eastern redcedar (includes southern redcedar): Associates—gray birch, red maple, sweet birch, Virginia Pine, shortleaf pine, oak. Sites—usually dry uplands and abandoned fields on limestone outcrops and other shallow soils but can grow well on good sites.

OAK/PINE GROUP

In these oak/pine forest types, stocking of the pine component needs to be 25-49 percent.

Eastern white pine/northern red oak/white ash: Associates—red maple, basswood, yellow birch, bigtooth aspen, sugar maple, beech, paper birch, black cherry, hemlock, and sweet birch. Sites—deep, fertile, well-drained soil.

Eastern redcedar/hardwood: Associates—oak, hickory, walnut, ash, locust, dogwood, blackgum, hackberry, winged elm, shortleaf pine, and Virginia pine. Sites—usually dry uplands and abandoned fields.

Shortleaf pine/oak: Associates— oaks(generally including white, scarlet, blackjack, black, post, and southern red) hickory, blackgum, sweetgum, Virginia pine, and pitch pine. Sites—generally in dry, low ridges, flats, and south slopes.

OAK/HICKORY GROUP

Post oak/blackjack oak (includes dwarf post oak): Associates—black oak, hickory, southern red oak, white oak, scarlet oak, shingle oak, live oak, shortleaf pine, Virginia pine, blackgum, sourwood, red maple, winged elm, hackberry, chinkapin oak, shumard oak, dogwood, and eastern redcedar. Sites—dry uplands and ridges.

Chestnut oak: Associates—scarlet oak, white oak, black oak, post oak, pitch pine, blackgum, sweetgum, red maple, red oak, shortleaf pine, Virginia pine. Sites—rocky outcrops with thin soil, ridge tops.

White oak/red oak/hickory (includes all hickories except water and shellbark hickory): Associates—pin oak, northern pin oak, chinkapin oak, black oak, dwarf chinkapin oak, American elm, scarlet oak, bur oak, white ash, sugar maple, red maple, walnut, basswood, locust, beech, sweetgum, blackgum, yellow-poplar, and dogwood. Sites—wide variety of well-drained upland soils.

White oak: Associates—black oak, northern red oak, bur oak, hickory, white ash, yellow-poplar. Sites—scattered patches on upland, loamy soils but on drier sites than type White oak/red oak/hickory.

Northern red oak: Associates—black oak, scarlet oak, chestnut oak, and yellow-poplar. Sites —spotty distribution on ridge crests and north slopes in mountains but also found on rolling land, slopes, and benches on loamy soil.

Sassafras/persimmon: Associates—elm, eastern redcedar, hickory, ash, sugar maple, yellow-poplar, Texas sophora, and oaks. Sites—abandoned farmlands and old fields.

Sweetgum/yellow-poplar: Associates—red maple, white ash, green ash, and other moist site hardwoods. Sites—generally occupies moist, lower slopes.

Bur oak: Associates—northern pin oak, black oak, chinkapin oak, and eastern redcedar in northern and dry upland sites; shagbark hickory, black walnut, eastern cottonwood, white ash, American elm, swamp white oak, honey locust, and American basswood in southern and lowland sites. Sites—drier uplands to moist bottomlands with the drier uplands more common in the northern part of the range and the moist bottomlands more common in the southern part of the range.

Scarlet oak: Associates—black oak, southern red oak, chestnut oak, white oak, post oak, hickory, pitch pine, blackgum, sweetgum, black locust, sourwood, dogwood, shortleaf pine, and Virginia pine. Sites—dry ridges, south- or west-facing slopes and flats but often moister situations probably as a result of logging or fire.

Yellow-poplar: Associates—black locust, red maple, sweet birch, cucumbertree, and other moist-site hardwoods (except sweetgum) and white oak and northern red oak. Sites—lower slopes, northerly slopes, moist coves, flats, and old fields.

Black walnut: Associates—yellow-poplar, white ash, black cherry, basswood, beech, sugar maple, oaks, and hickory. Sites—coves and well-drained bottoms.

Black locust: Associates—many species of hardwoods and hard pines may occur with it in mixture, either having been planted or from natural seeding. Sites—may occur on any well-drained soil but best on dry sites, often in old fields.

Chestnut oak/black oak/scarlet oak: Associates—northern and southern red oaks, post oak, white oak, sourwood, shagbark hickory, pignut hickory, yellow-poplar, blackgum, sweetgum, red maple, eastern white pine, pitch pine, Table Mountain pine, shortleaf pine, and Virginia pine. Sites—dry upland sites on thin-soiled rocky outcrops on dry ridges and slopes.

Cherry/white ash/yellow-poplar: Associates—sugar maple, American beech, northern red oak, white oak, blackgum, hickory, cucumbertree, and yellow birch. Sites—fertile, moist, well-drained sites.

Elm/ash/black locust: Associates—Black locust, silver maple, boxelder, blackbead ebony, American elm, slippery elm, rock elm, red maple, green ash predominate; found in the Midwest, unknown in the Northeast. Sites—upland.

Red maple/oak: Associates—dominated by red maple along with upland oaks, hickories, yellow-poplar, black locust, sassafras, Virginia pine, and shortleaf pine. Sites—uplands.

Mixed upland hardwoods: Includes Ohio buckeye, yellow buckeye, Texas buckeye, red buckeye, painted buckeye, American hornbeam, American chestnut, eastern redbud, flowering dogwood, hawthorn spp., cockspur hawthorn, downy hawthorn, Washington hawthorn, fleshy hawthorn, dwarf hawthorn, honeylocust, Kentucky coffeetree, Osage orange, all mulberries, blackgum, sourwood, southern red oak, shingle oak, laurel oak, water oak, live oak, willow oak, black locust, blackbead ebony, anacahuita, and September elm. Associates—any mixture of hardwoods of species typical of the upland central hardwood region, and should include at least some oak. Sites—wide variety of upland sites.

OAK/GUM/CYPRESS GROUP

Swamp chestnut oak/cherrybark oak: Associates—shumard oak, delta post oak, white ash, hickory, white oak, blackgum, sweetgum, southern red oak, post oak, American elm, winged elm, yellow-poplar, and beech. Sites—within alluvial flood plains of major rivers, on all ridges in the terraces, and on the best fine sandy loam soils on the highest first bottom ridges.

Sweetgum/Nuttall oak/willow oak: Associates—American holly, green ash, American elm, pecan, cottonwood, red maple, honeylocust, persimmon, anacahuita. Sites—very wet.

Overcup oak/water hickory (includes shellbark hickory): Associates—pin oak, willow oak, American elm, green ash, hackberry, persimmon, and red maple. Sites—in South within alluvial flood plains in low, poorly drained flats with clay soils; also in sloughs and lowest backwater basins and low ridges with heavy soils that are subject to late spring inundation.

Baldcypress/water tupelo: 25 to 50 percent stocking of baldcypress (either baldcypress or Montezuma baldcypress). Associates—blackgum, willow, red maple, American elm, persimmon, overcup oak, and sweetgum. Sites—very low, poorly drained flats, deep sloughs, and swamps; wet most all the year; also, floodplains and stream margins.

ELM/ASH/COTTONWOOD GROUP

Black ash/American elm/red maple (includes slippery and rock elm): Associates—swamp white oak, silver maple, sycamore, pin oak, blackgum, white ash, and cottonwood. Sites—moist to wet areas, swamps, gullies, and poorly drained flats.

River birch/sycamore: Associates—red maple, black willow, and other moist-site hardwoods. Sites—moist soils at edges of creeks and rivers.

Cottonwood: Associates—willow, white ash, green ash, and sycamore. Sites—streambanks where bare, moist soil is available.

Willow (includes peachleaf and black willow): Associates—cottonwood, green ash, sycamore, pecan, American elm, red maple, and boxelder. Sites—streambanks where bare, moist soil is available.

Sycamore/pecan/American elm (includes slippery and rock elm): Associates—sweetgum, green ash, hackberry, silver maple, cottonwood, willow, boxelder, and river birch. Sites—bottomlands, alluvial flood plains of major rivers.

Sugarberry/hackberry/elm/green ash (includes American, winged, cedar, slippery and rock elm): Associates—boxelder, pecan, blackgum, persimmon, honeylocust, red maple, hackberry, and boxelder. Sites—low ridges and flats in flood plains.

Silver maple/American elm: Silver maple and American elm are the majority species in this type. Associates—chalk maple, sweetgum, pin oak, swamp white oak, eastern cottonwood, sycamore, green ash, and other moist-site hardwoods, according to the region. Sites—primarily on well-drained moist sites along river bottoms and floodplains, and beside lakes and larger streams.

Red maple/lowland: Red maple comprises a majority of the stocking. Because this type grows on a wide variety of sites over an extensive range, associates are diverse. Associates—yellow-poplar, blackgum, sweetgum, and loblolly pine. Sites—generally restricted to very moist to wet sites with poorly drained soils, and on swamp borders.

Cottonwood/willow (includes peachleaf, black, and Bebb willow): Associates—white ash, green ash, sycamore, American elm, red maple and boxelder. Sites—stream banks where bare, moist soil is available.

MAPLE/BEECH/BIRCH GROUP

Sugar maple/beech/yellow birch: Associates—butternut, basswood, red maple, hemlock, northern red oak, white ash, white pine, black cherry, sweet birch, American elm, rock elm, and eastern hophornbeam. Sites—fertile, moist, well-drained sites.

Hard maple/basswood (includes American, Carolina, and white basswood): Associates—black maple, white ash, northern red oak, eastern hophornbeam, American elm, red maple, eastern white pine, eastern hemlock. Sugar maple and basswood occur in different proportions but together comprise the majority of the stocking. Sites—fertile, moist, well-drained sites.

OTHER HARDWOODS GROUP

Other hardwoods: A "catch-all" group for hardwood species identified only to the genus level, with the exception of the following species (Note: this code primarily applies to a mapped subplot where only one or two "uncommon" tree species are tallied): hackberry spp., hawthorn spp., eucalyptus spp., persimmon spp., magnolia spp., mulberry spp., mesquite spp., citrus spp., royal palm spp., willow spp., saltcedar spp., striped maple, mountain maple, California buckeye, Arizona alder, serviceberry, Arizona madrone, pawpaw, sweet birch, Virginia roundleaf birch, Allegany chinkapin, Ozark chinkapin, southern catalpa, northern catalpa, yellowwood, Pacific dogwood, pumpkin ash, blue ash, velvet ash, Carolina ash, Texas ash, all silverbells, California black walnut, southern California black walnut, Texas walnut, Arizona walnut, all apple species, eastern hophornbeam, California sycamore, Arizona sycamore, chokecherry, peach, Canada plum, wild plum, bitter cherry, Allegheny plum, Chickasaw plum, sweet cherry, sour cherry, European plum, Mahaleb plum,

western soapberry, American mountain-ash, northern mountain-ash, Joshua tree, smoketree, great leucaena, and berlandier ash.

EXOTIC HARDWOODS GROUP

Other exotic hardwoods: Includes any of the following species: Norway maple, ailanthus, mimosa, European alder, Chinese chestnut, ginkgo, Lombardy poplar, European mountain-ash, West Indian mahogany, Siberian elm, saltcedar spp., chinaberry, Chinese tallowtree, tung-oil-tree, Russian olive, and avocado.

Growing stock: A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Rough and rotten cull trees are excluded. When associated with volume, this includes only trees 5.0 inches d.b.h. and larger.

Hardwood: A dicotyledonous tree, usually broad-leaved and deciduous.

Soft hardwoods: A category of hardwood species with wood generally of low specific gravity (less than 0.5). Notable examples include red maple, paper birch, quaking aspen, and American elm.

Hard hardwoods: A category of hardwood species with wood generally of high specific gravity (greater than 0.5). Notable examples include sugar maple, yellow birch, black walnut, and oaks.

Industrial wood: All commercial roundwood products except fuelwood.

Land area: The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river flood plains; streams, sloughs, estuaries, and canals less than 200 feet wide; and lakes, reservoirs, and ponds less than 4.5 acres in area.

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

Live cull: A classification that includes live, cull trees. When associated with volume, it is the net volume in live, cull trees that are 5.0 inches d.b.h. and larger.

Local government: An ownership class of public lands owned by counties or local public agencies, or lands leased by these governmental units for more than 50 years. Also known as county and municipal.

Logging residues: The unused portions of growing-stock and nongrowing-stock trees cut or killed by logging and left in the woods.

Merchantable: Refers to a pulpwood or saw log section that meets pulpwood or saw log specifications, respectively.

National Forest: An ownership class of Federal lands, designated by executive order or statute as National Forests or purchase units, and other lands under the administration of the Forest Service, including experimental areas.

Net volume in cubic feet: The gross volume in cubic feet less deductions for rot, roughness, and poor form. Volume is computed for the central stem from a 1-foot stump to a minimum 4.0-inch top diameter outside bark, or to the point where the central stem breaks into limbs.

Noncommercial species: Tree species of typically small size, poor form, or inferior quality, which normally do not develop into trees suitable for industrial wood products.

Noncorporate private: Nongovernmental conservation and natural resource organizations; unincorporated local partnerships, associations, and clubs; and Native American communities.

Nonforest land: Land that has never supported forests and lands formerly forested where use of timber management is precluded by development for other uses. (Note: Includes area used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining clearings, powerline clearings of any width, and 1- to 4.5-acre areas of water classified by the U.S. Census Bureau as land. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., must be more than 1 acre in area to qualify as nonforest land.)

Nonstocked areas: Timberland less than 10-percent stocked with live trees.

Other red oaks: A group of species in the genus *Quercus* that includes scarlet oak, northern pin oak, southern red oak, bear oak, shingle oak, laurel oak, blackjack oak, water oak, pin oak, willow oak, and black oak.

Other white oaks: A group of species in the genus *Quercus* that includes overcup oak, chestnut oak, and post oak.

Ownership: The property owned by one ownership unit.

Ownership unit: A classification of ownership encompassing all types of legal entities having an ownership interest in land, regardless of the number of people involved. A unit may be an individual, a combination of persons; a legal entity such as a corporation, partnership, club, or trust, or a public agency. An ownership unit has control of a parcel or group of parcels of land.

Ozone: A regional, gaseous air pollutant produced primarily through sunlight-driven chemical reactions of nitrogen dioxide and hydrocarbons in the atmosphere and causing foliar injury to deciduous trees, conifers, shrubs, and herbaceous species.

Ozone bioindicator site: An open area used for ozone injury evaluations on ozone-sensitive species. The area must meet certain site selection guidelines on size, condition, and plant counts to be used for ozone injury evaluations in FIA.

Physiographic class: A measure of soil and water conditions that affect tree growth on a site. The physiographic classes are as follows:

> **Xeric:** Very dry soils where excessive drainage seriously limits both growth and species occurrence. These sites are usually on upland and upper half slopes.

Xeromesic: Moderately dry soils where excessive drainage limits growth and species occurrence to some extent. These sites are usually on the lower half slopes.

Mesic: Deep, well-drained soils. Growth and species occurrence are limited only by climate. These include all cove sites (small sheltered bays) and bottomlands (low land) along intermittent streams.

Hydromesic: Moderately wet soils where insufficient drainage or infrequent flooding limits growth and species occurrence to some extent.

Hydric: Very wet sites where excess water seriously limits both growth and species occurrence.

Poletimber trees: Live trees at least 5.0 inches in d.b.h. but smaller than sawtimber trees.

Primary wood-using mill: A mill that converts roundwood products into other wood products. Common examples are sawmills that convert saw logs into lumber and pulpmills that convert pulpwood into wood pulp.

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

Pulpwood: Roundwood, whole-tree chips, or wood residues used for the production of wood pulp.

Reserved forest land: Forest land withdrawn from timber utilization through statute, administrative regulation, or designation without regard to productive status.

Residues: Bark and woody materials that are generated in primary wood-using mills when roundwood products are converted to other products. Examples include slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and pulp screenings. Includes bark residues and wood residues (both coarse and fine materials) but excludes logging residues.

Rotten tree: A live tree of commercial species that does not contain a saw log now or prospectively primarily because of rot (that is, when rot accounts for more than 50 percent of the total cull volume).

Rough tree: (a) A live tree of commercial species that does not contain a saw log now or prospectively primarily because of roughness (that is, when sound cull due to such factors as poor form, splits, or cracks accounts for more than 50 percent of the total cull volume) or (b) a live tree of noncommercial species.

Roundwood products: Logs, bolts, and other round timber generated from harvesting trees for industrial or consumer use.

Salvable dead tree: A downed or standing dead tree considered currently or potentially merchantable by regional standards.

Saplings: Live trees 1.0 inch through 4.9 inches d.b.h.

Saw log: A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards.

Sawtimber tree: A live tree of commercial species containing at least a 12 foot saw log or two noncontiguous saw logs 8 feet or longer, and meeting regional specifications for freedom from defect. Softwoods must be at least 9.0 inches d.b.h. Hardwoods must be at least 11.0 inches d.b.h.

Sawtimber volume: Net volume of the saw-log portion of live sawtimber in board feet, International 1/4-inch rule (unless specified otherwise), from stump to a minimum 7.0 inches top d.o.b. for softwoods and a minimum 9.0 inches top d.o.b. for hardwoods.

Seedlings: Live trees less than 1.0 inch d.b.h. and at least 1 foot in height.

Select red oaks: A group of species in the genus *Quercus* that includes cherrybark oak, northern red oak, and Shumard oak.

Select white oaks: A group of species in the genus *Quercus* that includes white oak, swamp white oak, bur oak, swamp chestnut oak, and chinkapin oak.

Site index: An expression of forest site quality based on the height of a free-growing dominant or codominant tree of a representative species in the forest type at age 50.

Snag: A standing dead tree. In the current inventory, a snag must be 5.0 inches d.b.h./d.r.c. and 4.5 feet tall, and have a lean angle less than 45 degrees from vertical. A snag may be either self-supported by its roots, or supported by another tree or snag.

Softwood: A coniferous tree, usually evergreen, having needles or scale-like leaves.

Soil Order: The broadest category or class of soil based largely on the processes that formed the soil as indicated by the presence or absence of diagnostic horizons or layers. Several dominant soil orders in Missouris are as follows:

> **Alfisols:** Moist mineral soils that form mostly in cool to hot humid areas. These soils usually form under deciduous forests and are usually quite productive. These soils are more weathered than Inceptisols but less than Spodosols.
>
> **Entisols:** Mineral soils with no horizons or only the beginning of horizons. These soils are basically unaltered from their parent material. Soils of this order vary widely in productivity.
>
> **Inceptisols:** Soils with few diagnostic features that have formed quickly from the parent material. They form under a wide variety of climates. These soils are more advanced than Entisols but less than other orders. They vary widely in productivity.
>
> **Mollisols:** Organic soils that form in semiarid to semi-humid areas mostly under prairie vegetation. These are some of the most productive soils.

Ultisols: an ochric epipedon and an argillic or kandic horizon (a horizon that contains an appreciable amount of translocated silicate clay) that has few bases and commonly is calcium deficient. Most of these soils supported mixed coniferous and hardwood forest vegetation at the time of settlement. Some are now used as cropland or pasture.

Vertisols: clayey soils that have deep, wide cracks for some time during the year. They shrink as they dry and swell as they become moist. The natural vegetation is predominantly grass, savanna, open forest, or desert shrub. Most Vertisols are well suited to mechanized farming if there is plenty of rainfall or irrigation water. Vertisols are well-known among engineers because their unique properties limit engineering uses.

Sound dead: The net volume in salvable dead trees.

Stand: A group of trees on a minimum of 1 acre of forest land that is stocked by forest trees of any size.

Stand-size class: A classification of forest land based on the size class of live trees in the area. The classes are as follows:

Nonstocked: Forest land stocked with less than 10 percent of full stocking with live trees. Examples are recently cutover areas or recently reverted agricultural fields.

Seedling-sapling: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in seedlings or saplings or both.

Poletimber: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of poletimber exceeds that of sawtimber.

Sawtimber: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of sawtimber is at least equal to that of poletimber.

State: An ownership class of public lands owned by states or lands leased by states for more than 50 years. Also a general reference to one of the political and geographic subdivisions of the United States.

Stocking: The degree of occupancy of land by trees, measured by basal area or number of trees by size and spacing, or both, compared to a stocking standard; that is, the basal area or number of trees, or both, required to fully utilize the growth potential of the land.

Timberland: Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

Timber products output: All timber products cut from roundwood and byproducts of wood manufacturing plants. Roundwood products include logs, bolts, or other round sections cut from growing-stock trees, cull trees, salvable dead trees, trees on nonforest land, noncommercial species, sapling-size trees, and limbwood. Byproducts from primary manufacturing plants include slabs, edging, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and screenings of pulpmills that are used as pulpwood chips or other products.

Tree: A woody plant usually having one or more erect perennial stems, a stem diameter at breast height of at least 3.0 inches, a more or less definitely formed crown of foliage, and a height of at least 15 feet at maturity.

Tree size class: A classification of trees based on diameter at breast height, including sawtimber trees, poletimber trees, saplings, and seedlings.

Tops: The wood of a tree above the merchantable height (or above the point on the stem 4.0 inches diameter outside bark (d.o.b.) or to the point where the central stem breaks into limbs). It includes the usable material in the uppermost stem.

Urban forest land: Land that would otherwise meet the criteria for timberland but is in an urban-suburban area surrounded by commercial, industrial, or residential development and not likely to be managed for the production of industrial wood products on a continuing basis. Wood removed would be for land clearing, fuelwood, or esthetic purposes. Such forest land may be associated with industrial, commercial, residential subdivision, industrial parks, golf course perimeters, airport buffer strips, and public urban parks that qualify as forest land.

Unreserved forest land: Forest land not withdrawn from harvest by statute or administrative regulation. This includes forest lands that are not capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands.

Veneer log: A roundwood product from which veneer is sliced or sawn and that usually meets certain standards of minimum diameter and length and maximum defect.

Weight: The weight of wood and bark, oven-dry basis (approximately 12 percent moisture content).

TABLES

Tables labeled with the State abbreviation followed by a number (e.g., Table MO-1) report estimates of forest characteristics collected during this inventory period, including estimates of forested area, number of trees, and volume growth. These tables can be found in a supplemental file labeled "Missouri forest inventory summary tables" at https://doi.org/10.2737/NRS-RB-108.

Tables A through E referenced in this report are published in this document on subsequent pages. These tables report data related to sampling, measurement variables, and measurement quality objectives.

Table A.—Area and number of plots in each stratum, Missouri, 2013

Table B.—State-level estimates of major forest resource attributes and their sampling errors, Missouri, 2013

Table C. —Compliance to measurement quality objectives (MQO) tolerances of variables based on blind check plots, Missouri, 2013

Table D. —Observed relative bias values (Average [field crew - QA crew]) for measurement variables based on blind check plots, Missouri, 2013

Table E.—FIA nonresponse by ownership and strata, Missouri, 2013

Table A.—Area and number of plots in each stratum, Missouri, 2013

Strata			Plots							
Forest Inventory Unit[a] and Ownership layer[b]	Canopy cover class[c]	Acres[d]	Selected[e]	Nonforest office[f]	Field check[g]	Field check measured[h]	Forest measured[i]	Measured for change[j]	Field measured for change[k]	Not measured[l]
Eastern Ozark										
Mark Twain National Forest										
	0 - 65	46,023	13	1	12	12	12	13	12	0
	66 - 80	68,129	23	0	23	23	23	23	23	0
	81 - 100	823,240	271	0	271	271	271	265	265	0
	Total	937,392	307	1	306	306	306	301	300	0
Other public										
	0 - 80	92,761	16	4	12	12	12	16	12	0
	81 - 100	397,246	67	0	67	67	67	67	67	0
	Total	490,007	83	4	79	79	79	83	79	0
Private										
	0 - 5	1,301,521	224	185	39	29	29	211	26	10
	6 - 50	367,288	66	20	46	39	35	52	32	7
	51 - 65	246,847	35	2	33	31	30	31	29	2
	66 - 80	336,284	49	3	46	39	39	44	41	7
	81 - 100	2,418,930	439	3	436	381	379	365	362	55
	Total	4,670,870	813	213	600	519	512	703	490	81
Inland Census Water										
	0 - 100	20,340	2	2	0	0	0	2	0	0
Eastern Ozark total		6,118,609	1,205	220	985	904	897	1,089	869	81
Southwestern Ozark										
Mark Twain National Forest										
	0 - 65	17,701	5	0	5	5	5	4	4	0
	66 - 80	26,659	9	0	9	9	9	8	8	0
	81 - 100	346,308	114	0	114	114	114	108	108	0
	Total	390,668	128	0	128	128	128	120	120	0
Other public										
	0 - 100	120,330	23	1	22	22	22	23	22	0
Private										
	0 - 5	2,180,341	375	302	73	70	58	372	70	3
	6 - 50	400,735	67	24	43	40	38	64	40	3
	51 - 65	261,667	41	6	35	32	30	39	33	3
	66 - 80	352,446	59	6	53	50	48	57	51	3
	81 - 100	1,779,188	294	1	293	281	279	275	274	12
	Total	4,974,377	836	339	497	473	453	807	468	24
Inland Census Water										
	0 - 100	61,242	8	7	1	1	1	7	1	0
Southwestern Ozark total		5,546,617	995	347	648	624	604	957	611	24
Northwestern Ozark										
Mark Twain National Forest										
	0 - 65	3,540	1	0	1	1	1	1	1	0
	66 - 80	2,962	1	0	1	1	1	1	1	0
	81 - 100	130,625	43	0	43	43	43	41	41	0
	Total	137,127	45	0	45	45	45	43	43	0
Other public										
	0 - 80	99,903	17	7	10	10	9	17	10	0
	81 - 100	109,390	18	0	18	18	18	18	18	0
	Total	209,293	35	7	28	28	27	35	28	0

continued

Table A.—continued

Strata			Plots							
Forest Inventory Unit[a] and Ownership layer[b]	Canopy cover class[c]	Acres[d]	Selected[e]	Nonforest office[f]	Field check[g]	Field check measured[h]	Forest measured[i]	Measured for change[j]	Field measured for change[k]	Not measured[l]
Private										
	0 - 5	1,915,392	322	267	55	47	43	314	47	8
	6 - 50	450,850	85	24	61	56	54	77	53	5
	51 - 65	246,579	47	5	42	39	37	45	40	3
	66 - 80	361,068	54	7	47	45	43	51	44	2
	81 - 100	1,669,511	280	3	277	254	254	260	257	23
	Total	4,643,400	788	306	482	441	431	747	441	41
Inland Census Water										
	0 - 100	129,608	25	19	6	6	6	25	6	0
Northwestern Ozark total		5,119,428	893	332	561	520	509	850	518	41
Prairie										
Other public										
	0 - 5	221,217	28	22	6	6	6	28	6	0
	6 - 50	117,847	17	3	14	14	14	17	14	0
	81 - 100	166,742	28	0	28	28	28	27	27	0
	Total	505,806	73	25	48	48	48	72	47	0
Private										
	0 - 5	14,747,062	2,506	2,304	202	175	145	2,485	181	27
	6 - 50	1,035,700	179	72	107	95	89	174	102	12
	51 - 65	493,901	79	18	61	52	48	69	51	9
	66 - 80	644,459	95	14	81	73	69	91	77	8
	81 - 100	2,053,322	362	16	346	322	314	340	324	24
	Total	18,974,444	3,221	2,424	797	717	665	3,159	735	80
Inland Census Water										
	0 - 100	180,663	31	27	4	4	4	31	4	0
Prairie total		19,660,913	3,325	2,476	849	769	717	3,262	786	80
Riverborder										
Mark Twain National Forest										
	0 - 65	7,081	2	1	1	1	1	2	1	0
	81 - 100	30,378	10	0	10	10	10	10	10	0
	Total	37,459	12	1	11	11	11	12	11	0
Other public										
	0 - 80	84,777	10	3	7	7	6	10	7	0
	81 - 100	94,457	21	0	21	21	21	21	21	0
	Total	179,234	31	3	28	28	27	31	28	0
Private										
	0 - 5	4,706,407	817	749	68	59	55	810	61	9
	6 - 50	594,945	101	44	57	55	51	97	53	2
	51 - 65	302,861	44	8	36	33	30	41	33	3
	66 - 80	386,945	66	12	54	41	41	59	47	13
	81 - 100	1,826,527	287	9	278	247	241	252	243	31
	Total	7,817,685	1,315	822	493	435	418	1,259	437	58
Inland Census Water										
	0 - 100	130,913	24	22	2	2	2	24	2	0
Riverborder total		8,165,291	1,382	848	534	476	458	1,326	478	58

Table A.—footnote

[a] The following table lists the counties in each Forest Inventory Unit used to define the estimation strata.

Eastern Ozark	Southwestern Ozark	Northwestern Ozark		Prairie	Riverborder
Bollinger	Barry	Benton	Adair	Knox	Boone
Butler	Christian	Camden	Andrew	Lafayette	Callaway
Carter	Douglas	Cedar	Atchison	Lawrence	Cape Girardeau
Crawford	Howell	Dallas	Audrain	Lewis	Cole
Dent	McDonald	Hickory	Barton	Lincoln	Dunklin
Iron	Newton	Laclede	Bates	Linn	Franklin
Madison	Ozark	Maries	Buchanan	Livingston	Gasconade
Oregon	Stone	Miller	Caldwell	Macon	Howard
Reynolds	Taney	Morgan	Carroll	Marion	Jefferson
Ripley	Texas	Phelps	Cass	Mercer	Mississippi
St. Francois	Webster	Polk	Chariton	Monroe	Moniteau
Shannon	Wright	Pulaski	Clark	Nodaway	Montgomery
Washington		St. Clair	Clay	Pettis	New Madrid
Wayne			Clinton	Pike	Osage
			Cooper	Platte	Pemiscot
			Dade	Putnam	Perry
			Daviess	Ralls	St. Charles
			De Kalb	Randolph	Ste. Genevieve
			Gentry	Ray	St. Louis
			Greene	Saline	Scott
			Grundy	Schuyler	Stoddard
			Harrison	Scotland	Warren
			Henry	Shelby	
			Holt	Sullivan	
			Jackson	Vernon	
			Jasper	Worth	
			Johnson		

[b] Ownership layer – Classification based on a number of data sources.

[c] Canopy cover class – Derived from 2001 National Land Cover Dataset.

[d] Acres – Total area defined by intersection of ownership and canopy cover layers within unit specified.

[e] Selected – Total number of plots selected to be sampled.

[f] Nonforest office – Selected plots whose observed classification is nonforest based on examination of aerial photographs and/or digital orthoquads.

[g] Field check – Selected plots that required field measurement.

[h] Field check measured– Field check plots where measurement was completed successfully. Excludes plots that were denied access, hazardous, or lost and measurement was not possible.

[i] Forest measured – Field check plots where forest condition was present on plot and measurement was completed in 2013 inventory. Plots are used to estimate current conditions, e.g., area, volume, number of trees, and biomass.

[j] Measured for change – All plots measured for change. Plots used to estimate change variables such as land use/cover, net growth, mortality and removals.

[k] Field measured for change – Field check plots measured for change.

[l] Not measured – Whole plot not sampled due to factors such as denied access, hazardous conditions, or lost location.

Table B.—State-level estimates of major forest resource attributes and their sampling errors, Missouri, 2013

Item	State total	Sampling error
Growing stock on forest land	*million cubic feet*	percent
Volume	16,965.6	1.29
Average annual net growth	402.5	3.90
Average annual removals	165.7	8.26
Average annual mortality	196.3	4.12
Sawtimber on timberland	*million board feet*[a]	
Volume	55,538.6	1.74
Average annual net growth	1,458.4	3.53
Average annual removals	675.4	8.81
Average annual mortality	631.2	5.56
Area	*thousand acres*	
Forest land	15,452.5	0.71
Timberland	14,909.6	0.79
Biomass (aboveground live trees and saplings)	*million dry tons*	
Forest land	641.5	1.00
Timberland	620.0	1.07

[a] International ¼-inch rule.

Table C.—Compliance to measurement quality objectives (MQO) tolerances of variables based on blind check plots, Missouri, 2013

Variable	Tolerance	Objective	Missouri		All NRS states	
			Data within tolerance	Observations	Data within tolerance	Observations
		percent		*number*	*percent*	*number*
Plot Level						
Distance to Road	No Tolerance	90.0	83.1	148	81.7	2,420
Water on Plot	No Tolerance	90.0	91.2	148	86.7	2,420
Elevation	±50 feet	99.0	85.1	148	87.9	2,197
Latitude - decimal degrees	±0.0001 degree	99.0	100.0	148	100.0	2,201
Longitude - decimal degrees	±0.0001 degree	99.0	95.3	148	87.5	2,201
Condition Level						
Condition Status	No Tolerance	99.0	99.6	257	99.1	4,141
Reserve Status	No Tolerance	99.0	99.6	257	99.5	4,141
Owner Group	No Tolerance	99.0	100.0	175	98.7	2,889
Forest Type (Type)	No Tolerance	95.0	90.3	175	90.6	2,889
Forest Type (Group)	No Tolerance	99.0	96.6	175	95.3	2,889
Stand Size	No Tolerance	99.0	89.7	175	91.2	2,889
Regeneration Status	No Tolerance	99.0	98.9	175	98.5	2,889
Tree Density	No Tolerance	99.0	97.1	175	97.7	2,889
Owner Class	No Tolerance	99.0	97.1	175	95.9	2,889
Owner Status	No Tolerance	99.0	98.9	175	99.2	2,889
Regeneration Species	No Tolerance	99.0	98.9	175	98.4	2,889
Stand Age	±10 percent	95.0	82.9	175	87.2	2,889
Disturbance 1	No Tolerance	99.0	89.1	175	90.4	2,868
Disturbance 2	No Tolerance	99.0	85.0	60	89.0	547
Disturbance 3	No Tolerance	99.0	92.3	13	97.3	75
Treatment 1	No Tolerance	99.0	94.9	175	97.7	2,868
Treatment Year 1	±1 year	99.0	85.7	7	94.9	156
Treatment 2	No Tolerance	99.0	100.0	16	83.9	218
Treatment Year 2	±1 year	99.0	.	.	97.6	41
Treatment 3	No Tolerance	99.0	.	.	94.5	73
Treatment Year 3	±1 year	99.0	.	.	80.0	5
Physiographic Class	No Tolerance	80.0	83.4	175	84.9	2,889
Present Nonforest Use	No Tolerance	99.0	92.2	257	94.6	4,141
Boundary Level						
Boundary Change	No Tolerance	99.0	75.0	52	81.8	868
Constrasting Condition	No Tolerance	99.0	100.0	52	95.5	868
Left Azimuth	±10 degrees	90.0	82.7	52	87.1	868
Corner Mapped	No Tolerance	90.0	100.0	52	94.8	868
Corner Azimuth	±10 degrees	90.0	100.0	4	92.8	83
Corner Distance	±1 foot	90.0	100.0	4	91.6	83
Right Azimuth	±10 degrees	90.0	78.8	52	87.1	868
Subplot Level						
Subplot Center Condition	No Tolerance	99.0	98.5	608	98.3	10,100
Microplot Center Condition	No Tolerance	99.0	98.4	608	98.1	10,100
Slope	±10 percent	90.0	98.6	517	98.8	8,565
Aspect	±10 degrees	90.0	93.7	504	94.7	8,360
Snow/Water Depth	±0.5 foot		87.6	517	67.7	8,604

continued

Table C.—continued

Variable	Tolerance	Objective	Missouri		All NRS states	
			Data within tolerance	Observations	Data within tolerance	Observations
		percent		*number*	*percent*	*number*
Tree Level						
DBH	±0.1 inch per 20 inches	95.0	95.8	2,281	95.6	37,635
DRC	±0.1 inch per 20 inches	95.0	.	.	73.9	69
Azimuth	±10 degrees	90.0	99.3	2,546	99.3	42,172
Horizontal Distance	±0.2 foot per 1.0 foot	90.0	99.2	2,546	98.7	42,172
Species	No Tolerance	95.0	97.6	2,548	98.4	42,475
Tree Genus	No Tolerance	99.0	99.8	2,545	99.6	42,433
Tree Status	No Tolerance	95.0	99.1	2,548	98.9	42,481
Rotten/Missing Cull	±10 percent	90.0	98.9	1,765	98.4	27,670
Total Length	±10 percent	90.0	74.8	1,756	79.7	27,368
Actual Length	±10 percent	90.0	75.8	157	74.0	3,340
Compacted Crown Ratio	±10 percent	80.0	83.5	2,164	83.0	35,071
Uncompacted Crown Ratio (P3)	±10 percent	90.0	77.1	275	78.2	1,984
Crown Class	No Tolerance	85.0	78.1	2,164	81.8	35,071
Decay Class	±1 class	90.0	98.3	354	96.0	6,211
Cause of Death	No Tolerance	80.0	76.8	354	83.6	6,211
Condition	No Tolerance	99.0	98.4	2,548	98.3	42,481
Crown Position	No Tolerance		96.6	237	95.1	1,622
Crown Light Exposure	±1 class	85.0	98.2	275	98.0	1,984
Sapling Crown Vigor Class	No Tolerance	85.0	86.8	38	95.0	362
Crown Density	±10 percent	90.0	89.9	237	92.4	1,622
Crown Dieback	±10 percent	90.0	98.3	237	98.0	1,622
Transparency	±10 percent	90.0	99.6	237	98.2	1,622
Tree Class	No Tolerance	90.0	91.1	2,288	92.4	38,026
Damage Agent 1	No Tolerance	90.0	90.5	2,164	90.2	35,071
Damage Agent 2	No Tolerance	90.0	78.6	392	78.2	6,760
Tree Grade	No Tolerance	90.0	73.4	556	74.8	8,251
DBH-Live & Trees with Decay Code 1 or 2	±0.1 inch per 20 inches	95.0	95.7	2,208	95.4	35,903
DBH-Trees with Decay Codes 3, 4 or 5	±1 inch per 20 inches	95.0	100.0	73	99.5	1,732
Total Length-trees 40 feet and greater	±10 percent	90.0	75.9	1,351	81.4	21,658
Total Length-trees less than 40 feet	±10 percent	90.0	71.4	405	73.1	5,710
Total Length-trees less than 5 inches DBH	±10 percent	90.0	76.3	38	70.8	349
Seedling Level						
Species	No Tolerance	85.0	88.1	899	92.5	8,648
Genus	No Tolerance	90.0	95.7	899	96.8	8,648
Seedling Count	±20 percent	90.0	60.2	899	63.1	8,648
Seedling Count (coded)	No Tolerance	90.0	64.0	899	69.3	8,648
Site Tree Level						
Condition List	No Tolerance	99.0	96.6	234	93.1	2,775
Diameter	±0.1 inch per 20 inches	95.0	98.3	234	98.0	2,775
Species	No Tolerance	95.0	99.1	234	99.3	2,775
Genus	No Tolerance	99.0	100.0	234	100.0	2,775
Azimuth	±10 degrees	90.0	100.0	234	99.1	2,775
Distance	±5 feet	90.0	100.0	234	99.3	2,775
Total Length	±10 percent	90.0	97.9	234	98.5	2,775
Diameter Age	±5 years	95.0	98.3	234	98.0	2,775

Table D.—Observed relative bias values (Average [field crew - QA crew]) for measurement variables based on blind check plots, Missouri, 2013

Variable	Unit of measure	Missouri				All NRS states			
		Relative bias	95% CI limits		Observations	Relative bias	95% CI limits		Observations
			Lower	Upper			Lower	Upper	
Plot Level					*number*				*number*
Elevation	foot	-2.18	-7.83	5.05	148	225.42	46.68	449.57	2,197
Latitude - decimal degrees	degree	0.00	0.00	0.00	148	0.00	0.00	0.00	2,201
Longitude - decimal degrees	degree	0.00	0.00	0.00	148	0.00	-0.01	0.00	2,201
Condition Level									
Stand Age	number	-0.98	-2.17	-0.02	175	-0.25	-0.82	0.43	2,889
Boundary Level									
Left Azimuth	degree	4.48	-4.68	18.62	52	0.08	-2.44	2.66	868
Corner Azimuth	degree	0.00	0.00	0.00	4	6.00	-0.62	18.80	83
Corner Distance	foot	-0.25	-0.75	0.00	4	-0.10	-0.50	0.19	83
Right Azimuth	degree	2.19	-1.59	7.07	52	1.61	-1.10	4.59	868
Subplot Level									
Slope	percent	0.07	-0.37	0.57	517	0.04	-0.05	0.13	8,565
Aspect	degree	-2.74	-5.52	-0.06	504	0.29	-0.33	0.92	8,360
Snow/Water Depth	foot	-0.14	-0.34	0.01	517	-0.28	-0.39	-0.17	8,604
Tree Level									
DBH	inch	0.01	0.00	0.02	2,281	0.00	0.00	0.00	37,635
DRC	inch					0.06	-0.10	0.23	69
Azimuth	degree	0.00	-0.15	0.19	2,546	-0.03	-0.09	0.03	42,172
Horizontal Distance	foot	0.00	-0.02	0.03	2,546	0.00	-0.01	0.00	42,172
Rotten/Missing Cull	percent	-0.05	-0.17	0.07	1,765	-0.15	-0.20	-0.11	27,670
Total Length	foot	0.48	-0.04	0.94	1,756	0.21	0.09	0.33	27,368
Actual Length	foot	-6.41	-18.07	0.95	157	-1.46	-2.62	-0.50	3,340
Compacted Crown Ratio	percent	0.69	0.27	1.20	2,164	0.11	-0.01	0.20	35,071
Uncompacted Crown Ratio (P3)	percent	-0.22	-2.01	1.28	275	-3.07	-3.80	-2.24	1,984
Crown Density	percent	-1.43	-2.27	-0.61	237	-0.87	-1.17	-0.50	1,622
Crown Dieback	percent	0.04	-0.60	0.85	237	-0.19	-0.48	0.11	1,622
Transparency	percent	0.19	-0.13	0.49	237	-0.69	-1.00	-0.38	1,622
DBH-Live & Trees with Decay Code 1 or 2	inch	0.01	0.00	0.02	2,208	0.00	0.00	0.00	35,903
DBH-Trees with Decay Codes 3, 4 or 5	inch	0.00	-0.02	0.03	73	-0.02	-0.05	-0.01	1,732
Total Length-trees 40 feet and greater	foot	1.22	0.73	1.75	1,351	0.70	0.58	0.83	21,658
Total Length-trees less than 40 feet	foot	-2.02	-3.19	-0.79	405	-1.67	-2.00	-1.39	5,710
Total Length-trees less than 5 inches DBH	foot	1.67	-2.09	4.60	38	-1.53	-2.82	-0.05	349
Seedling Level									
Seedling Count	number	-9.61	-13.61	-6.30	882	-12.53	-14.37	-10.94	8,496
Seedling Count (coded)	number	0.03	-0.04	0.09	899	0.00	-0.02	0.02	8,648
Site Tree Level									
Diameter	inch	0.00	-0.01	0.01	234	0.00	-0.01	0.01	2,775
Azimuth	degree	0.00	-0.07	0.06	234	0.14	-0.18	0.47	2,775
Distance	foot	0.01	-0.01	0.04	234	0.04	0.00	0.08	2,775
Total Length	foot	0.03	-0.32	0.38	234	-0.04	-0.22	0.13	2,775
Diameter Age	number	-0.18	-0.49	0.05	234	0.00	-0.09	0.11	2,775

Table E.—FIA nonresponse by strata, Missouri, 2013

Strata		Plots					
Forest Inventory Unit[a] and Ownership layer[b]	Canopy cover class[c]	Number of plots selected	Sampled	Denied access	Hazardous	Other	Response rate (%)
Eastern Ozark							
Mark Twain National Forest							
	0 - 65	13	13	0	0	0	100.0
	66 - 80	23	23	0	0	0	100.0
	81 - 100	271	271	0	0	0	100.0
	Total	307	307	0	0	0	100.0
Other public							
	0 - 80	16	16	0	0	0	100.0
	81 - 100	67	67	0	0	0	100.0
	Total	83	83	0	0	0	100.0
Private							
	0 - 5	224	214	10	0	0	95.5
	6 - 50	66	59	7	0	0	89.4
	51 - 65	35	33	2	0	0	94.3
	66 - 80	49	42	7	0	0	85.2
	81 - 100	439	382	57	0	0	87.0
	Total	813	730	83	0	0	89.7
Inland Census Water							
	0 - 100	2	2	0	0	0	100.0
Eastern Ozark total		1,205	1,122	83	0	0	93.1
Southwestern Ozark							
Mark Twain National Forest							
	0 - 65	5	5	0	0	0	100.0
	66 - 80	9	9	0	0	0	100.0
	81 - 100	114	114	0	0	0	100.0
	Total	128	128	0	0	0	100.0
Other public							
	0 - 100	23	23	0	0	0	100.0
Private							
	0 - 5	375	372	3	0	0	99.2
	6 - 50	67	64	3	0	0	95.5
	51 - 65	41	38	3	0	0	92.7
	66 - 80	59	55	3	1	0	93.6
	81 - 100	294	281	13	0	0	95.6
	Total	836	810	25	1	0	96.9
Inland Census Water							
	0 - 100	8	8	0	0	0	100.0
Southwestern Ozark total		995	969	25	1	0	97.4
Northwestern Ozark							
Mark Twain National Forest							
	0 - 65	1	1	0	0	0	100.0
	66 - 80	1	1	0	0	0	100.0
	81 - 100	43	43	0	0	0	100.0
	Total	45	45	0	0	0	100.0
Other public							
	0 - 80	17	17	0	0	0	100.0
	81 - 100	18	18	0	0	0	100.0
	Total	35	35	0	0	0	100.0

continued

Table E.—continued

Strata		Plots					
Forest Inventory Unit[a] and Ownership layer[b]	Canopy cover class[c]	Number of plots selected	Sampled	Denied access	Hazardous	Other	Response rate (%)
Private							
	0 - 5	322	314	8	0	0	97.5
	6 - 50	85	80	5	0	0	94.1
	51 - 65	47	44	3	0	0	93.1
	66 - 80	54	52	2	0	0	96.3
	81 - 100	280	257	22	1	0	91.7
	Total	788	747	41	1	0	94.7
Inland Census Water							
	0 - 100	25	25	0	0	0	100.0
Northwestern Ozark total		893	852	41	1	0	95.4
Prairie							
Other public							
	0 - 5	28	28	0	0	0	100.0
	6 - 50	17	17	0	0	0	100.0
	81 - 100	28	28	0	0	0	100.0
	Total	73	73	0	0	0	100.0
Private							
	0 - 5	2,506	2,478	28	0	0	98.9
	6 - 50	179	167	12	0	0	93.0
	51 - 65	79	70	9	0	0	88.3
	66 - 80	95	86	8	1	0	90.7
	81 - 100	362	337	24	1	0	93.2
	Total	3,221	3,138	81	2	0	97.4
Inland Census Water							
	0 - 100	31	31	0	0	0	100.0
Prairie total		3,325	3,242	81	2	0	97.5
Riverborder							
Mark Twain National Forest							
	0 - 65	2	2	0	0	0	100.0
	81 - 100	10	10	0	0	0	100.0
	Total	12	12	0	0	0	100.0
Other public							
	0 - 80	10	10	0	0	0	100.0
	81 - 100	21	21	0	0	0	100.0
	Total	31	31	0	0	0	100.0
Private							
	0 - 5	817	808	9	0	0	98.9
	6 - 50	101	99	2	0	0	97.8
	51 - 65	44	40	4	0	0	91.5
	66 - 80	66	53	13	0	0	79.9
	81 - 100	287	253	33	1	0	88.3
	Total	1,315	1,253	61	1	0	95.3
Inland Census Water							
	0 - 100	24	24	0	0	0	100.0
Riverborder total		1,382	1,320	61	1	0	95.5

[a] See footnote 1 in Table A for list of counties in each Forest Inventory Unit.

[b] Ownership layer – Classification based on a number of data sources.

[c] Canopy cover class – Derived from 2001 National Land Cover Dataset.