United States Department of Agriculture

# Indiana Forests 2013
## Statistics, Methods, and Quality Assurance

Forest Service

Northern Research Station

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# 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)[1]:

- 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 nationally consistent 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.

[1] Citations are available in Indiana Forests 2013, located at http://dx.doi.org/10.2737/NRS-RB-107.

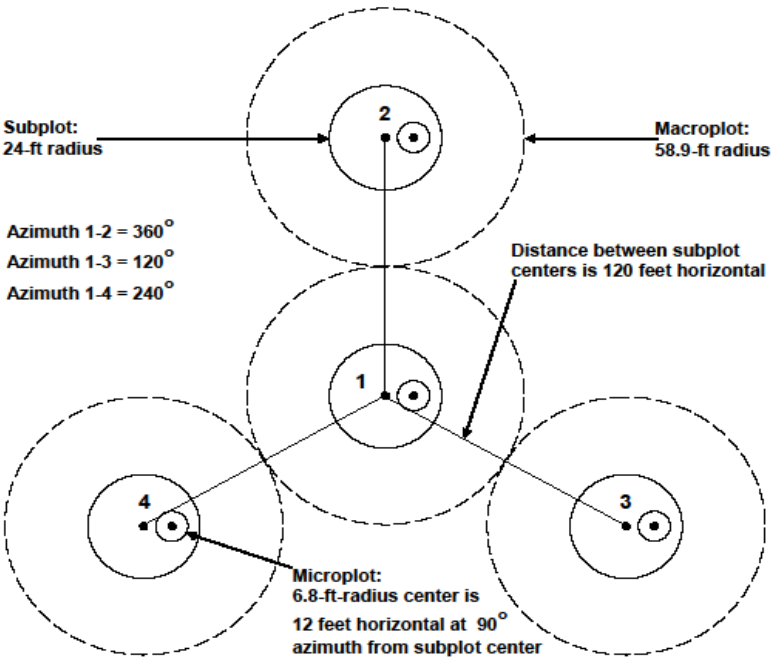


Figure 111.—National Forest Inventory and Analysis plot design (adapted from Bechtold and Patterson 2005).

## Plot Configuration

The national FIA plot design consists of four 24-ft-radius subplots configured as a central subplot and three peripheral subplots (Fig. 111). Centers of the peripheral subplots are located 120 feet from the central subplot and at azimuths of 360°, 120°, and 240° from the center of the central subplot. Each tree with a diameter at breast height (d.b.h.) of 5 inches or greater is measured on these subplots. Each subplot contains a 6.8-foot-radius microplot with center located 12 feet east of the subplot center on which each tree with a 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

Based on historical sampling errors, 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 is 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); that is, the plots measured in 2004 were measured again in 2009, and the plots measured in 2008 were measured again in 2013. For estimation purposes, the measurement of each panel of plots is considered an independent, equal probability sample of all lands in a state and the remeasurement of a panel is considered an equal probability sample of change occurring on all lands in a state.

## Three-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 to increase 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-plus (P2+), in which less data are collected per plot but more plots are sampled. 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 are discussed in greater detail in the following sections.

### Phase 1

Aerial photographs, digital orthoquads (DOQs: digitally scanned aerial photographs), and satellite imagery are used for initial plot measurement 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 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) (Homer et al. 2007, Huang et al. 2001). 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 to 100) 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).

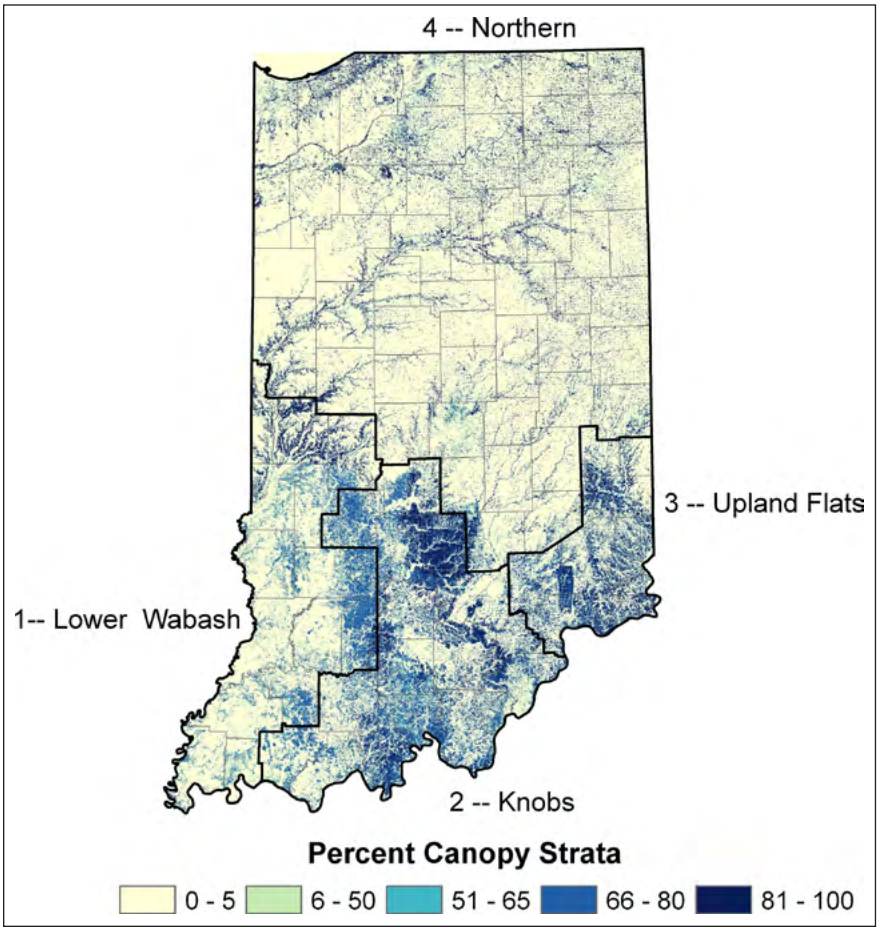


Figure 112.—Percent canopy strata groupings by inventory unit, Indiana.

## Strata Construction

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 center subplot. The percent canopy cover stratification scheme consists of five groupings: 0 to 5 percent, 6 to 50 percent, 51 to 65 percent, 66 to 80 percent, and 81 to 100 percent. These groupings were based on observed natural clumping of pixel values and are presented in Figure 112. 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 Indiana, ownership layers were derived from a combination of datasets: Protected Areas database (Conservation Biology Institute 2012), Managed Lands in Indiana dataset (Indiana Natural Heritage Data Center 2015), and the U.S. Census Bureau TIGER dataset (U.S. Census Bureau 2000). Datasets were projected to Albers Conical Equal Area using the NAD83 Datum, GRS 1980 Spheroid and then rasterized to a spatial resolution of 30 m. The data were then merged to classify pixels into four ownership classes: other public, private, inland census water, and Hoosier National Forest (Fig. 113). 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

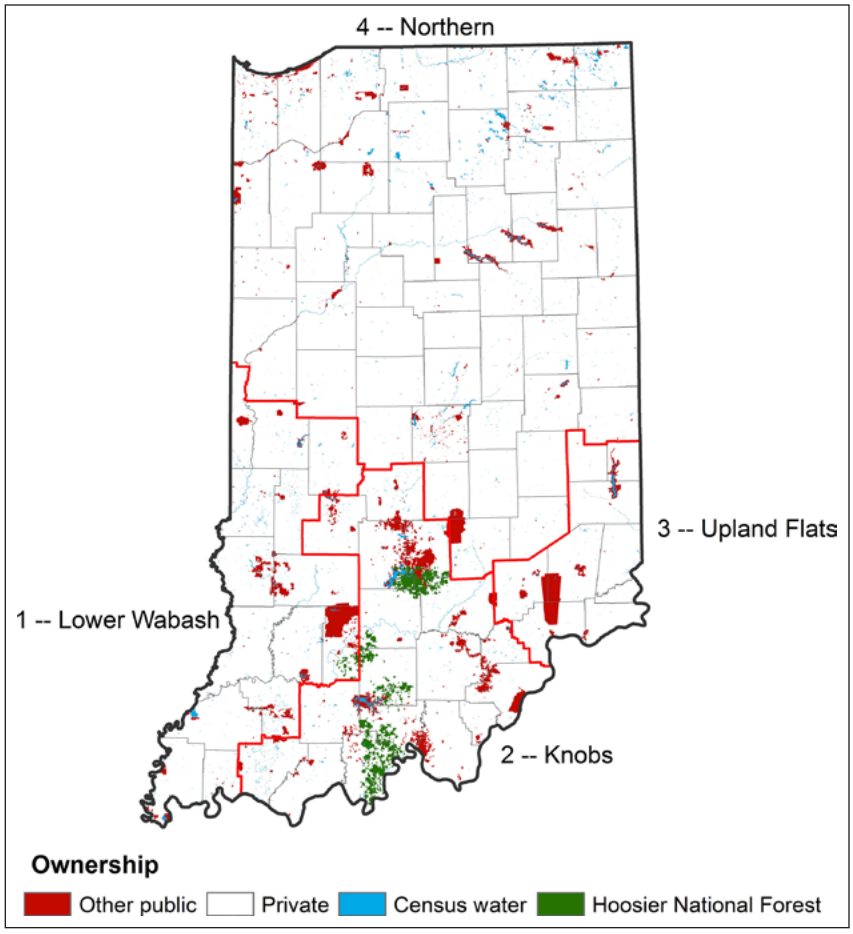


Figure 113.—Land ownership classes used for stratification, Indiana, 2013.

water estimation units use an alternative minimum of two plots per stratum. The largest ownership class, based on pixel counts, was private ownership at over 22 million acres (Fig. 114). Every ownership pixel was also assigned to a county based on the location of the pixel center.

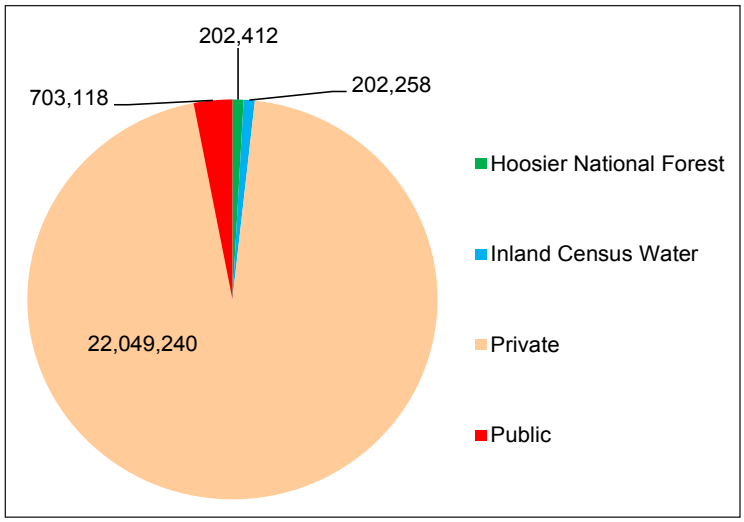


Figure 114.—Ownership class acreages based on pixel counts, Indiana, 2013.

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 (Landsat Thematic Mapper [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 Indiana 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 other information 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 (percentage 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, other Federal agencies, state natural resource agencies, universities, and the Forest Health Monitoring (FHM) program. The FHM program consists of four interrelated and complementary activities: detection monitoring, evaluation monitoring, 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 approximately every 95,000 acres. P3 measurements are obtained by field crews during the growing season and include an extended suite of ecological data for Indiana:

- Lichen diversity and abundance (data collected in inventory years 2002 through 2005)
- Soil quality–erosion, compaction, and chemistry (data collected 2000 through 2005)

- Vegetation diversity and structure (data collected in inventory years 2001 through 2003 and 2007 through 2010)
- Down woody material (data collected in inventory years 2001 through 2010)
- Incidence and severity of ozone injury for selected bioindicator species that are also monitored as part of an associated sampling scheme (data collected in inventory years 1999 through 2010)
- 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. Forest 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 1995) 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-plus

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 2014) includes details on sampling sapling length, advance tree seedling regeneration (ATSR), vegetation profiles, invasive plants, down woody materials (DWM), soils, and tree crowns.

### Advance Tree Seedling Regeneration

The tree seedling sample is designed to inventory and monitor the forest's regenerative capacity (McWilliams et al. 2015). Tree seedling counts are used along with the sapling tally to estimate 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 was changed to the P2+ sample (12.5 percent) in 2012.

### Down Woody Materials

Down woody materials are important components of forest ecosystems across the country. DWM are dead material on the ground in various stages of decay. Down wood components 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 Indiana Tables IN-1 through IN-65[2]) are based on data observed on the 7,065 Phase 2 plots across Indiana. 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 186 Phase 3 plots.

Approximately 20 percent of the Phase 2 observations were acquired each year from October 1, 2008 through September 30, 2013 (the last plot was actually measured on December 17, 2013). These observations are collectively called the 2013 inventory. These plots are positioned within 40 strata combinations located within 13 estimation unit combinations (Table A; lettered tables begin on page 27 of this document) defined by five Phase 1 canopy cover classes (0 to 5 percent, 6 to 50 percent, 51 to 65 percent, 66 to 80 percent, and 81 to 100 percent) or collapsed canopy cover classes, a land ownership classification (based on information obtained from the Indiana Department of Natural Resources), and four inventory units (where an inventory unit is a grouping of counties based on ecological similarities). Procedures described in Bechtold and Patterson (2005) for stratified estimation with observed stratum areas were used in conjunction with the strata in Table A to produce all estimates. Table A shows the total area and number of plots within each stratum.

## Integration with Previous Inventories

Previous inventories of Indiana's forest resources were completed in 1950 (Winters 1953), 1967 (Spencer 1969), 1986 (Smith and Golitz 1988), 1998 (Schmidt et al. 2000), 2003 (Woodall et al. 2005), and 2008 (Woodall et al. 2011). The first complete remeasurement of an annual inventory was completed in 2003 (Woodall et al. 2005) and consisted of data collected from 1999 to 2003. The second complete remeasurement of an annual inventory was completed in 2008 (Woodall et al. 2011) and consisted of data collected from 2004 to 2008. The third complete remeasurement of an annual inventory was completed in 2013.

[2] Tables labeled with the State abbreviation followed by a number (e.g., Table IN-1) are located in a supplemental file titled "Summary Tables for Indiana Forests 2013: Statistics, Methods, and Quality Assurance" found at http://dx.doi.org/10.2737/NRS-RB-107. Tables labeled with letters (e.g., Table A) begin on page 27.

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 is relatively uncomplicated. Comparisons with the earlier inventories (1998, 1986, 1967, and 1950) 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. The new design uses fixed-radius subplots exclusively. Prior to this new plot design, fixed and variable-radius subplots were used in the 1998, 1986, and 1967 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 reserved status have been implemented with version 6.0 of the FIA field manual 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 2013, 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 reserved status definition. Small but significant changes are associated with timberland acreage (-1.5 percent), number of trees (-1.8 percent), all live volume (-1.7 percent), and biomass (-1.8 percent). The impact on harvest removals of growing-stock trees was quite small (-0.004 percent), but the impact on the estimate of annual other removals of growing-stock trees on timberland was very large (38.7 percent). This large increase in other removals is the result of improved consistency in reserved status determination. The improved implementation of the reserved 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 Indiana is based on a sample of 7,065 plots located randomly across the State (total area of 23.16 million acres), or a sampling rate of about one plot for every 3,278 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 if a 100-percent inventory had been taken using these methods, the results would have been within the limits indicated (i.e., 68 percent confidence interval).

The sampling errors for State-level estimates of the major attributes presented in this report are presented in Table B. Table IN-65 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 IN-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:

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

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 maple/beech/birch forest-type group for the State, proceed as follows:

Total area of the maple/beech/birch in the State (see Table IN-3) = 319,600 acres

Total area of all forest land in the State (see Table IN-3) = 4,875,400 acres

State total error for forest land area (see Table B) = 1.06 percent

Sampling error = $E = \frac{(1.06)\sqrt{(4{,}875{,}400)}}{\sqrt{(319{,}600)}}$ = 4.14 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.

## 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 different 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 Indiana 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, Indiana, 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 FIA in the NRS region.

In Indiana many variables, such as diameter at breast height, have a low tolerance (± 0.1 in.) and a high percentage of data within the tolerance (95.6 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 (81.3 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 methods available and have been 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.

## 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. 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 used in this report are presented by Hahn and Hansen (1991), along with the model forms, the methods used in model development, and the model parameter estimates. The estimated prediction errors are based on observations of 10,453 trees measured in the 1989 Missouri statewide inventory. For gross cubic-foot volume in live trees, an overall overprediction of 2.5 percent was found across all species, with an underprediction of 4.3 percent in trees less than 10.0 inches d.b.h. and an overprediction of 7.1 in trees 20.0 inches d.b.h. and larger. Similar prediction errors were observed in the board foot estimates.

When 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 above.

Nonresponse has two effects on the sample. First, it reduces the sample size, which 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 2009-2013 Indiana inventory, a total of 7,065 sample plots were selected for observation. Nearly 97 percent of these are included in the sample used to estimate current resources. Crews were unable to obtain owner permission to measure all or part of 215 plots, hazardous conditions prevented measuring all or part of another 13 plots, and 1 plot was not measured for reasons other than those specified above.

Even though an overall nonresponse rate of 1 percent is relatively low, it 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. Observations for plots on nonforest and water land classes rarely require crews to physically enter the land, and permission is not needed because the observation can be obtained from aerial photos or other sources of remotely sensed information. Therefore, nonresponse is of most concern for plots on privately-owned forest land.

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 this stratified estimation process, 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 class and 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 Indiana 2013 inventory.

In Table IN-1 of this report we acknowledge denied access and hazardous as two land classes in Indiana 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, or other circumstances that caused us to drop plots from a specific inventory cycle may be different.

## GLOSSARY

**Accretion:** The estimated net growth on trees that were measured during the previous inventory. (Average annual accretion is calculated by dividing net growth by the number of growing seasons between surveys.) It does not include growth on trees cut during the period or those trees that died. This component uses the incremental change in volume between two inventories.

**Annual mortality of growing stock:** The average cubic-foot volume of wood in growing-stock trees that died in one year.

**Annual mortality of sawtimber:** The average board-foot volume of wood in sawtimber trees that died in one year.

**Annual net growth of growing stock:** The annual change in cubic-foot volume of wood in live growing-stock trees plus the total volume of trees entering all of the diameter classes greater than 5.0 inches d.b.h. through ingrowth. All volume losses through natural causes must be deducted. Natural causes include mortality except that which is due to logging damage, timber stand improvement activities, or conversion to nonforest land use.

**Annual net growth of sawtimber:** The annual change in board-foot volume of wood in live sawtimber trees plus the total volume of trees reaching sawtimber size, minus volume losses resulting from natural causes.

**Annual removals from growing stock:** The average cubic-foot volume of wood in live growing-stock trees removed annually for roundwood forest products plus the volume in logging residues or mortality due to logging damage (harvest removals). This component

of change also includes the volumes of growing-stock trees removed due to land use changes (other removals).

**Annual removals from sawtimber:** The average board-foot volume of wood in live sawtimber trees removed annually for roundwood forest products plus the volume in logging residues or mortality due to logging damage (harvest removals). This component of change also includes the volumes of sawtimber trees removed due to land use changes (other removals).

**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. 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.

*Saplings*: Total aboveground biomass of a tree from 1 to 4.9 inches diameter measured at the root collar (d.r.c.) or at breast eight (d.b.h.).

*Stump*: Biomass of a tree 5 inches d.b.h. and larger from the ground to a height of 1 foot.

**Board foot:** A unit of lumber measuring 1-foot long, 1-foot wide, and 1-inch thick, or its equivalent. International ¼-inch rule is used as the U.S. Forest Service standard log rule in the eastern United States.

**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.

**Census water:** Lakes, reservoirs, ponds, and similar bodies of water 4.5 acres in size or larger; and rivers or canals more than 200 feet wide (U.S. Census Bureau definition).

**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.

**Condition:** A delineation of a land area based upon land use, forest type, stand size, regeneration status, reserved status, tree density, and owner class.

**Corporate:** Pertaining to 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.

**Covariance:** The strength of association between two variables.

**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 at breast height (d.b.h.):** The diameter outside bark of a standing tree measured at 4.5 feet above the ground.

**Diameter at root collar (d.r.c.):** The diameter outside bark of a seedling or sapling measured at the root collar.

**Diameter class:** A classification of trees based on diameter outside bark (d.o.b.) measured at breast height (4.5 feet above ground). 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 (d.r.c.) measurement is acquired for multi-stemmed woodland species (e.g., Rocky Mountain Juniper).

**Down woody materials (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.

**Dry ton:** A unit of measure of dry weight equivalent to 2,000 pounds or 907.184 kg.

**Dry weight:** The weight of wood and bark as it would be if it had been oven dried; usually expressed in pounds or tons.

**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. Major eastern forest-type groups include:

> **White/red/jack pine:** Forests in which eastern white pine, red pine, or jack pine, singly or in combination, comprise a plurality of the stocking. Common associates include hemlock, aspen, birch, and maple.
>
> **Oak/pine:** Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking, but in which pine or eastern redcedar comprises 25-50 percent of the stocking. Common associates include gum, hickory, and yellow-poplar.
>
> **Oak/hickory:** Forests in which upland oaks or hickory, singly or in combination, comprise a plurality of the stocking except where pines comprise 25-50 percent, in which case the stand is classified as oak-pine. Common associates include yellow-poplar, elm, maple, and black walnut.
>
> **Oak/gum/cypress:** Bottomland forests in which tupelo, blackgum, sweetgum, oaks, or southern cypress, singly or in combination, comprise a plurality of the stocking except where pines comprise 25-50 percent, in which case the stand is classified as oak-pine. Common associates include cottonwood, willow, ash, elm, hackberry, and maple.
>
> **Elm/ash/cottonwood:** Forests in which elm, ash, or cottonwood, singly or in combination, comprise a plurality of the stocking. Common associates include willow, sycamore, beech, and maple.
>
> **Maple/beech/birch:** Forests in which maple, beech, or yellow birch, singly or in combination, comprise a plurality of the stocking. Common associates include hemlock, elm, basswood, and white pine.
>
> **Aspen/birch:** Forests in which aspen, balsam poplar, paper birch, or gray birch, singly or in combination, comprise a plurality of the stocking. Common associates include maple and balsam fir.

**Fuel class:** Categories of forest fire fuels defined by the approximate amount of time it takes for moisture conditions to fluctuate. Large coarse woody debris pieces take longer to dry out than smaller fine woody pieces.

> *1,000-hour fuels*: Coarse woody debris with a transect diameter ≥3.0 inches and ≥3.0 feet long.

*100-hour fuels*: Fine woody debris with a transect diameter from 1.0 to 2.9 inches.

*10-hour fuels*: Fine woody debris with a transect diameter from 0.25 to 0.9 inches.

1-*hour fuels*: Fine woody debris with a transect diameter ≤0.24 inches

**Gross growth:** The sum of accretion and ingrowth.

**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 only includes trees 5.0 inches d.b.h. and larger.

**Growing-stock trees:** Live trees of commercial species classified as poletimber or sawtimber that are not rough or rotten trees.

**Growing-stock volume:** Net or gross volume in cubic feet of growing-stock trees 5.0 inches and larger d.b.h. measured from the 1-foot stump to a minimum 4.0-inch top diameter outside bark on the central stem, or to the point where the central stem splits into limbs. Net volume equals gross volume minus deduction for cull defects.

**Hard maple:** Maple species such as sugar maple and black maple.

**Hardwood tree:** 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.

**Ingrowth:** The estimated net volume of trees that became 5.0 inches and larger d.b.h. during the period between inventories. Divide by the number of growing seasons between surveys to calculate average annual ingrowth. Also, the estimated net volume of trees 5.0 inches and larger d.b.h. that are growing on land that was reclassified from noncommercial forest land or nonforest land to timberland.

**Introduction:** The intentional or unintentional escape, release, dissemination, or placement of a species into an ecosystem as a result of human activity. "Introduced" is not synonymous and should not be confused with the term "invasive" (USDA definition).

**Invasive species:** Those species whose introduction does, or is likely to, cause economic or environmental harm or harm to human health. For the purpose of this policy only, a plant species is considered "invasive" only when it occurs on the Federal or State-specific noxious weed list or a list developed by the State-specific Department of Agriculture with their partners and approved by the State Technical Committee which prohibits or cautions its use due to invasive qualities (USDA definition).

**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.

**Land use:** A classification of land that indicates the primary use at the time of the inventory. Major categories are forest land and nonforest land.

**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 board-foot volume:** The gross volume in board feet less the deductions for rot, roughness, and poor form. Volume is computed from the 1-foot stump to a minimum 7.0-inch diameter outside bark for softwoods and a minimum 9.0-inch outside bark for hardwoods on the central stem. This estimate includes all softwoods 9.0 inches d.b.h. and larger and all hardwoods 11.0 inches d.b.h. and larger.

**Net cubic-foot volume:** 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.

**Noncensus water:** Streams and rivers 120 to 200 feet wide and bodies of water 1 to 4.5 acres in size, where the U.S. Bureau of the Census (1990) classifies such water as land.

**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 Bureau of the Census 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.)

**Nonnative species:** Within a particular ecosystem, any species (including its seeds, eggs, spores, or other biological material capable of propagating that species) that is not native to that ecosystem (USDA definition).

**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.

**Owner class:** A classification of land into categories of ownership, including:

> *Forest industry*: Land owned by private companies which operate primary wood-using mills.
>
> *Nonindustrial private*: Land owned by other corporate (e.g., real estate investment trusts and timber investment management organizations), individuals, or trusts (nongovernment organizations) and who do not operate primary wood-using mills.
>
> *Public*: Land owned by federal, state, county, or municipal government.

**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:

> *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 pulp mills that convert pulpwood into paper.

**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 uses. Roundwood products include saw logs, veneer, cooperage logs, bolts, pulpwood logs, fuelwood, pilings, poles posts, ties, mine timbers, and various other round or split products.

**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 ¼-inch rule (unless specified otherwise), from stump to a minimum 7.0 inches top diameter outside bark (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.

**Soft maple:** Maple species such as red maple, silver maple, and box elder.

**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 Indiana are:

> *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.
>
> *Histisols*: Organic soils that form in saturated wet conditions. These can occur in any wet area and can be very productive when drained.
>
> *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 semihumid areas mostly under prairie vegetation. These are some of the most productive soils.

*Spodosols*: Mineral soils that form in humid climates usually where it is cold and temperate. Most of these soils develop naturally under forests. They are not naturally very fertile but can be productive with fertilizer.

**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.

**Standing dead tree:** A standing dead tree must be at least 5 inches d.b.h. and larger; is at least 4.5 feet in height; and has a lean of less than 45 degrees from the vertical. A snag should be self-supported or supported by another tree.

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

*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.

**Stocking class:** At the tree level, stocking is the density expressed as a percent of total tree density required to fully utilize the growth potential of the land. At the stand level it is expressed as the sum of the stocking values of all trees sampled. An overstocked stand has stocking ≥100 percent, fully stocked stands contain 60 to 99 percent of full stocking, moderately stocked stands are 35 to 59 percent of full stocking, and poorly stocked stands have only 10 to 34 percent of full stocking. A nonstocked stand has less than 10 percent of full stocking.

**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 pulp mills that are used as pulpwood chips or other products.

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

**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 class:** A classification of tree quality or condition of the tree for saw log production. Tree class for sawtimber-size trees are based on current conditions. Tree class for poletimber-size trees is based on the prospected determination or forecast of the potential tree quality when the tree reaches sawtimber size.

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

**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.

**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 aesthetic 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.

**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 IN-1) report estimates of forest characteristics collected during this inventory period, including estimates of forested area, number of trees, volume, and growth. These tables can be found in a supplemental file "Summary Tables for Indiana Forests 2013: Statistics, Methods, and Quality Assurance" found at http://dx.doi.org/10.2737/NRS-RB-107.

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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, Indiana, 2013

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

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

Table D.—Average differences and sampling errors between standard field and quality assurance crew observations on blind-check plots, Indiana, 2013

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

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

| Forest Inventory Unit[a] and Ownership layer[b] | Strata: Canopy cover class[c] | Area (acres)[d] | Plots: 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] |
|---|---|---|---|---|---|---|---|---|---|---|
| Lower Wabash | | | | | | | | | | |
| Hoosier NF | 66 - 80 | 11,235 | 5 | 0 | 5 | 5 | 5 | 5 | 5 | 0 |
| | 81 - 100 | 2,648 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| | Total | 13,883 | 6 | 0 | 6 | 6 | 6 | 6 | 6 | 0 |
| Inland Census Water | 0 - 100 | 49,735 | 12 | 9 | 3 | 2 | 2 | 9 | 1 | 1 |
| | Total | 49,735 | 12 | 9 | 3 | 2 | 2 | 9 | 1 | 1 |
| Private | 0 - 5 | 2,448,236 | 714 | 624 | 90 | 79 | 58 | 477 | 49 | 11 |
| | 6 - 50 | 271,918 | 92 | 25 | 67 | 60 | 55 | 56 | 42 | 7 |
| | 51 - 65 | 139,194 | 35 | 6 | 29 | 26 | 24 | 22 | 17 | 3 |
| | 66 - 80 | 417,785 | 131 | 1 | 130 | 116 | 114 | 87 | 86 | 14 |
| | 81 - 100 | 187,498 | 67 | 1 | 66 | 61 | 60 | 39 | 39 | 5 |
| | **Total** | 3,464,631 | 1,039 | 657 | 382 | 342 | 311 | 681 | 233 | 40 |
| Public | 0 - 5 | 37,861 | 13 | 11 | 2 | 2 | 2 | 7 | 1 | 0 |
| | 6 - 65 | 29,190 | 10 | 1 | 9 | 9 | 9 | 8 | 7 | 0 |
| | 66 - 100 | 95,335 | 32 | 0 | 32 | 32 | 32 | 25 | 25 | 0 |
| | **Total** | 162,386 | 55 | 12 | 43 | 43 | 43 | 40 | 33 | 0 |
| | **Unit total** | 3,690,635 | 1,112 | 678 | 434 | 393 | 362 | 736 | 273 | 41 |
| Knobs | | | | | | | | | | |
| Hoosier NF | 0 - 65 | 27,811 | 10 | 0 | 10 | 10 | 10 | 10 | 10 | 0 |
| | 66 - 80 | 78,644 | 35 | 0 | 35 | 35 | 35 | 32 | 32 | 0 |
| | 81 - 100 | 82,074 | 31 | 0 | 31 | 31 | 31 | 28 | 28 | 0 |
| | **Total** | 188,529 | 76 | 0 | 76 | 76 | 76 | 70 | 70 | 0 |
| Inland Census Water | 0 - 100 | 46,982 | 12 | 10 | 2 | 2 | 2 | 7 | 2 | 0 |
| | **Total** | 46,982 | 12 | 10 | 2 | 2 | 2 | 7 | 2 | 0 |
| Private | | | | | | | | | | |
| | 0 - 5 | 1,982,404 | 631 | 519 | 112 | 103 | 89 | 418 | 62 | 9 |
| | 6 - 50 | 287,063 | 67 | 20 | 47 | 42 | 36 | 43 | 31 | 5 |
| | 51 - 65 | 242,929 | 75 | 3 | 72 | 58 | 56 | 44 | 44 | 14 |
| | 66 - 80 | 793,516 | 228 | 3 | 225 | 201 | 198 | 149 | 147 | 24 |
| | 81 - 100 | 400,865 | 124 | 0 | 124 | 109 | 108 | 71 | 71 | 15 |
| | **Total** | 3,706,777 | 1,125 | 545 | 580 | 513 | 487 | 725 | 355 | 67 |
| Public | | | | | | | | | | |
| | 0 - 65 | 50,560 | 15 | 4 | 11 | 10 | 10 | 11 | 7 | 1 |
| | 66 - 80 | 85,703 | 31 | 0 | 31 | 31 | 31 | 25 | 25 | 0 |
| | 81 - 100 | 104,400 | 36 | 0 | 36 | 36 | 36 | 24 | 24 | 0 |
| | **Total** | 240,663 | 82 | 4 | 78 | 77 | 77 | 60 | 56 | 1 |
| | **Unit total** | 4,182,951 | 1,295 | 559 | 736 | 668 | 642 | 862 | 483 | 68 |
| Upland Flats | | | | | | | | | | |
| Inland Census Water | 0 - 100 | 11,739 | 4 | 4 | 0 | 0 | 0 | 3 | 0 | 0 |
| | **Total** | 11,739 | 4 | 4 | 0 | 0 | 0 | 3 | 0 | 0 |
| Private | 0 - 5 | 837,594 | 256 | 198 | 58 | 47 | 39 | 159 | 26 | 11 |
| | 6 - 50 | 114,655 | 28 | 10 | 18 | 17 | 15 | 19 | 11 | 1 |
| | 51 - 65 | 86,427 | 28 | 2 | 26 | 25 | 24 | 18 | 17 | 1 |
| | 66 - 80 | 230,140 | 78 | 4 | 74 | 66 | 65 | 49 | 45 | 8 |
| | 81 - 100 | 272,042 | 85 | 0 | 85 | 74 | 74 | 52 | 52 | 11 |
| | **Total** | 1,540,858 | 475 | 214 | 261 | 229 | 217 | 297 | 151 | 32 |
| Public | 0 - 100 | 97,923 | 28 | 3 | 25 | 16 | 16 | 12 | 9 | 9 |
| | **Total** | 97,923 | 28 | 3 | 25 | 16 | 16 | 12 | 9 | 9 |
| | **Unit total** | 1,650,520 | 507 | 221 | 286 | 245 | 233 | 312 | 160 | 41 |

continued

**Table A.—continued**

| Forest Inventory Unit[a] and Ownership layer[b] | Strata: Canopy cover class[c] | Area (acres)[d] | Plots: 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] |
|---|---|---|---|---|---|---|---|---|---|---|
| Northern | | | | | | | | | | |
| Inland Census Water | 0 - 100 | 93,802 | 23 | 21 | 2 | 2 | 0 | 18 | 2 | 0 |
| | **Total** | 93,802 | 23 | 21 | 2 | 2 | 0 | 18 | 2 | 0 |
| Private | 0 - 5 | 11,501,569 | 3,516 | 3,261 | 255 | 230 | 160 | 2,331 | 154 | 25 |
| | 6 - 50 | 397,564 | 113 | 64 | 49 | 45 | 36 | 69 | 31 | 4 |
| | 51 - 65 | 230,275 | 71 | 21 | 50 | 47 | 43 | 49 | 33 | 3 |
| | 66 - 80 | 382,344 | 107 | 11 | 96 | 84 | 81 | 69 | 62 | 12 |
| | 81 - 100 | 825,220 | 251 | 7 | 244 | 213 | 211 | 149 | 142 | 31 |
| | **Total** | 13,336,972 | 4,058 | 3,364 | 694 | 619 | 531 | 2,667 | 422 | 75 |
| Public | 0 - 5 | 65,401 | 21 | 17 | 4 | 4 | 3 | 16 | 3 | 0 |
| | 6 - 65 | 36,206 | 12 | 5 | 7 | 6 | 6 | 6 | 4 | 1 |
| | 66 - 80 | 26,345 | 10 | 2 | 8 | 8 | 7 | 6 | 4 | 0 |
| | 81 - 100 | 74,195 | 27 | 0 | 27 | 25 | 25 | 17 | 17 | 2 |
| | **Total** | 202,147 | 70 | 24 | 46 | 43 | 41 | 45 | 28 | 3 |
| | **Unit total** | 13,632,921 | 4,151 | 3,409 | 742 | 664 | 572 | 2,730 | 452 | 78 |
| | **State total** | 23,157,027 | 7,065 | 4,867 | 2,198 | 1,970 | 1,809 | 4,640 | 1,368 | 228 |

[a] Counties in each Forest Inventory Unit used to define the estimation strata:

| Lower Wabash | Knobs | Upland Flats | Northern | |
|---|---|---|---|---|
| Clay | Brown | Dearborn | Adams | La Porte |
| Daviess | Clark | Fayette | Allen | Lagrange |
| Gibson | Crawford | Franklin | Bartholomew | Lake |
| Greene | Dubois | Jefferson | Benton | Madison |
| Knox | Floyd | Jennings | Blackford | Marion |
| Martin | Harrison | Ohio | Boone | Marshall |
| Parke | Jackson | Ripley | Carroll | Miami |
| Pike | Lawrence | Switzerland | Cass | Montgomery |
| Posey | Monroe | Union | Clinton | Newton |
| Putnam | Morgan | | De Kalb | Noble |
| Sullivan | Orange | | Decatur | Porter |
| Vanderburgh | Owen | | Delaware | Pulaski |
| Vermillion | Perry | | Elkhart | Randolph |
| Vigo | Scott | | Fountain | Rush |
| | Spencer | | Fulton | Shelby |
| | Warrick | | Grant | St. Joseph |
| | Washington | | Hamilton | Starke |
| | | | Hancock | Steuben |
| | | | Hendricks | Tippecanoe |
| | | | Henry | Tipton |
| | | | Howard | Wabash |
| | | | Huntington | Warren |
| | | | Jasper | Wayne |
| | | | Jay | Wells |
| | | | Johnson | White |
| | | | Kosciusko | Whitley |

[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, Indiana, 2013**

| Item | State total | Sampling error |
|---|---|---|
| Growing stock: | *million cubic feet* | *percent* |
| Volume | 9,145.70 | 1.80 |
| Average annual net growth | 216.2 | 4.20 |
| Average annual removals | 65.6 | 15.10 |
| Average annual mortality | 85.3 | 7.50 |
| Sawtimber: | *million board feet* [a] | |
| Volume | 36,109.3 | 2.02 |
| Average annual net growth | 988.3 | 4.38 |
| Average annual removals | 323.3 | 14.98 |
| Average annual mortality | 301.7 | 9.46 |
| Area: | *thousand acres* | |
| Forest land | 4875.4 | 1.06 |
| Timberland | 4716.2 | 1.15 |
| Biomass (aboveground live trees and saplings): | *million dry tons* | |
| Forest land | 270.4 | 1.50 |
| Timberland | 260.8 | 1.60 |

All results are for timberland except where indicated.

[a] International ¼-inch rule.

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

| Variable | Tolerance | Objective | Indiana | | All NRS states | |
|---|---|---|---|---|---|---|
| | | | Data within tolerance | Observations | Data within tolerance | Observations |
| Plot Level | | ---------*percent*--------- | | *number* | *percent* | *number* |
| Distance to Road | No Tolerance | 90.0 | 80.2 | 121 | 81.7 | 2,420 |
| Water on Plot | No Tolerance | 90.0 | 82.6 | 121 | 86.7 | 2,420 |
| Elevation | ±50 feet | 99.0 | 85.8 | 120 | 87.9 | 2,197 |
| Latitude - decimal degrees | ±0.0001 degree | 99.0 | 100.0 | 120 | 100.0 | 2,201 |
| Longitude - decimal degrees | ±0.0001 degree | 99.0 | 85.8 | 120 | 87.5 | 2,201 |
| Condition Level | | | | | | |
| Condition Status | No Tolerance | 99.0 | 99.0 | 210 | 99.1 | 4,141 |
| Reserve Status | No Tolerance | 99.0 | 99.0 | 210 | 99.5 | 4,141 |
| Owner Group | No Tolerance | 99.0 | 98.5 | 134 | 98.7 | 2,889 |
| Forest Type (Type) | No Tolerance | 95.0 | 84.3 | 134 | 90.6 | 2,889 |
| Forest Type (Group) | No Tolerance | 99.0 | 94.0 | 134 | 95.3 | 2,889 |
| Stand Size | No Tolerance | 99.0 | 94.0 | 134 | 91.2 | 2,889 |
| Regeneration Status | No Tolerance | 99.0 | 98.5 | 134 | 98.5 | 2,889 |
| Tree Density | No Tolerance | 99.0 | 99.3 | 134 | 97.7 | 2,889 |
| Owner Class | No Tolerance | 99.0 | 97.0 | 134 | 95.9 | 2,889 |
| Owner Status | No Tolerance | 99.0 | 99.3 | 134 | 99.2 | 2,889 |
| Regeneration Species | No Tolerance | 99.0 | 97.0 | 134 | 98.4 | 2,889 |
| Stand Age | ±10 percent | 95.0 | 81.3 | 134 | 87.2 | 2,889 |
| Disturbance 1 | No Tolerance | 99.0 | 85.8 | 134 | 90.4 | 2,868 |
| Disturbance 2 | No Tolerance | 99.0 | 95.2 | 21 | 89.0 | 547 |
| Disturbance 3 | No Tolerance | 99.0 | 100.0 | 1 | 97.3 | 75 |
| Treatment 1 | No Tolerance | 99.0 | 94.0 | 134 | 97.7 | 2,868 |
| Treatment Year 1 | ±1 year | 99.0 | 100.0 | 6 | 94.9 | 156 |
| Treatment 2 | No Tolerance | 99.0 | 71.4 | 14 | 83.9 | 218 |
| Treatment Year 2 | ±1 year | 99.0 | . | . | 97.6 | 41 |
| Treatment 3 | No Tolerance | 99.0 | 100.0 | 4 | 94.5 | 73 |
| Treatment Year 3 | ±1 year | 99.0 | . | . | 80.0 | 5 |
| Physiographic Class | No Tolerance | 80.0 | 86.6 | 134 | 84.9 | 2,889 |
| Present Nonforest Use | No Tolerance | 99.0 | 94.3 | 210 | 94.6 | 4,141 |
| Boundary Level | | | | | | |
| Boundary Change | No Tolerance | 99.0 | 86.5 | 37 | 81.8 | 868 |
| Constrasting Condition | No Tolerance | 99.0 | 91.9 | 37 | 95.5 | 868 |
| Left Azimuth | ±10 degrees | 90.0 | 83.8 | 37 | 87.1 | 868 |
| Corner Mapped | No Tolerance | 90.0 | 81.1 | 37 | 94.8 | 868 |
| Corner Azimuth | ±10 degrees | 90.0 | 100.0 | 3 | 92.8 | 83 |
| Corner Distance | ±1 foot | 90.0 | 100.0 | 3 | 91.6 | 83 |
| Right Azimuth | ±10 degrees | 90.0 | 81.1 | 37 | 87.1 | 868 |
| Subplot Level | | | | | | |
| Subplot Center Condition | No Tolerance | 99.0 | 97.1 | 488 | 98.3 | 10,100 |
| Microplot Center Condition | No Tolerance | 99.0 | 96.9 | 488 | 98.1 | 10,100 |
| Slope | ±10 percent | 90.0 | 95.4 | 414 | 98.8 | 8,565 |
| Aspect | ±10 degrees | 90.0 | 86.5 | 394 | 94.7 | 8,360 |
| Snow/Water Depth | ±0.5 foot | | 81.2 | 414 | 67.7 | 8,604 |

continued

**Table C.—continued**

| Variable | Tolerance | Objective | Indiana | | All NRS states | |
|---|---|---|---|---|---|---|
| | | | Data within tolerance | Observations | Data within tolerance | Observations |
| Tree Level | | | | | | |
| D.b.h. | ±0.1 inch per 20 inches | 95.0 | 95.8 | 1,847 | 95.6 | 37,635 |
| D.r.c. | ±0.1 inch per 20 inches | 95.0 | . | . | 73.9 | 69 |
| Azimuth | ±10 degrees | 90.0 | 99.1 | 1,937 | 99.3 | 42,172 |
| Horizontal Distance | ±0.2 foot per 1.0 foot | 90.0 | 98.8 | 1,937 | 98.7 | 42,172 |
| Species | No Tolerance | 95.0 | 98.1 | 1,972 | 98.4 | 42,475 |
| Tree Genus | No Tolerance | 99.0 | 99.6 | 1,972 | 99.6 | 42,433 |
| Tree Status | No Tolerance | 95.0 | 98.0 | 1,972 | 98.9 | 42,481 |
| Rotten/Missing Cull | ±10 percent | 90.0 | 98.8 | 1,465 | 98.4 | 27,670 |
| Total Length | ±10 percent | 90.0 | 79.6 | 1,433 | 79.7 | 27,368 |
| Actual Length | ±10 percent | 90.0 | 78.3 | 129 | 74.0 | 3,340 |
| Compacted Crown Ratio | ±10 percent | 80.0 | 89.4 | 1,757 | 83.0 | 35,071 |
| Uncompacted Crown Ratio (P3) | ±10 percent | 90.0 | 82.4 | 51 | 78.2 | 1,984 |
| Crown Class | No Tolerance | 85.0 | 80.1 | 1,757 | 81.8 | 35,071 |
| Decay Class | ±1 class | 90.0 | 93.7 | 223 | 96.0 | 6,211 |
| Cause of Death | No Tolerance | 80.0 | 74.9 | 223 | 83.6 | 6,211 |
| Condition | No Tolerance | 99.0 | 97.9 | 1,972 | 98.3 | 42,481 |
| Crown Position | No Tolerance | | 87.5 | 40 | 95.1 | 1,622 |
| Crown Light Exposure | ±1 class | 85.0 | 90.2 | 51 | 98.0 | 1,984 |
| Sapling Crown Vigor Class | No Tolerance | 85.0 | 81.8 | 11 | 95.0 | 362 |
| Crown Density | ±10 percent | 90.0 | 92.5 | 40 | 92.4 | 1,622 |
| Crown Dieback | ±10 percent | 90.0 | 100.0 | 40 | 98.0 | 1,622 |
| Transparency | ±10 percent | 90.0 | 95.0 | 40 | 98.2 | 1,622 |
| Tree Class | No Tolerance | 90.0 | 93.1 | 1,867 | 92.4 | 38,026 |
| Damage Agent 1 | No Tolerance | 90.0 | 86.5 | 1,757 | 90.2 | 35,071 |
| Damage Agent 2 | No Tolerance | 90.0 | 84.1 | 410 | 78.2 | 6,760 |
| Tree Grade | No Tolerance | 90.0 | 65.0 | 551 | 74.8 | 8,251 |
| D.b.h.-Live & Trees with Decay Code 1 or 2 | ±0.1 inch per 20 inches | 95.0 | 95.6 | 1,774 | 95.4 | 35,903 |
| D.b.h.-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 | 80.8 | 1,301 | 81.4 | 21,658 |
| Total Length-trees less than 40 feet | ±10 percent | 90.0 | 68.2 | 132 | 73.1 | 5,710 |
| Total Length-trees less than 5 inches DBH | ±10 percent | 90.0 | 54.5 | 11 | 70.8 | 349 |
| Seedling Level | | | | | | |
| Species | No Tolerance | 85.0 | 85.6 | 620 | 92.5 | 8,648 |
| Genus | No Tolerance | 90.0 | 91.8 | 620 | 96.8 | 8,648 |
| Seedling Count | ±20 percent | 90.0 | 58.5 | 620 | 63.1 | 8,648 |
| Seedling Count (coded) | No Tolerance | 90.0 | 62.6 | 620 | 69.3 | 8,648 |
| Site Tree Level | | | | | | |
| Condition List | No Tolerance | 99.0 | 94.2 | 171 | 93.1 | 2,775 |
| Diameter | ±0.1 inch per 20 inches | 95.0 | 95.9 | 171 | 98.0 | 2,775 |
| Species | No Tolerance | 95.0 | 98.8 | 171 | 99.3 | 2,775 |
| Genus | No Tolerance | 99.0 | 100.0 | 171 | 100.0 | 2,775 |
| Azimuth | ±10 degrees | 90.0 | 100.0 | 171 | 99.1 | 2,775 |
| Distance | ±5 feet | 90.0 | 98.2 | 171 | 99.3 | 2,775 |
| Total Length | ±10 percent | 90.0 | 97.7 | 171 | 98.5 | 2,775 |
| Diameter Age | ±5 years | 95.0 | 94.2 | 171 | 98.0 | 2,775 |

**Table D.—Average differences and sampling errors between standard field and quality assurance crew observations on blind-check plots, Indiana, 2013**

| Variable | Unit of measure | Indiana | | | | All NRS states | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Relative bias | 95% CI limits | | Number of observations | Relative bias | 95% CI limits | | Number of observations |
| | | | Lower | Upper | | | Lower | Upper | |
| Plot Level | | | | | | | | | |
| Elevation | foot | 3.18 | -2.86 | 9.83 | 120 | 225.42 | 46.68 | 449.57 | 2,197 |
| Latitude - decimal degrees | degree | 0.00 | 0.00 | 0.00 | 120 | 0.00 | 0.00 | 0.00 | 2,201 |
| Longitude - decimal degrees | degree | -0.01 | -0.02 | 0.00 | 120 | -0.00 | -0.01 | -0.00 | 2,201 |
| Condition Level | | | | | | | | | |
| Stand Age | number | -0.28 | -1.11 | 0.50 | 134 | -0.25 | -0.82 | 0.43 | 2,889 |
| Boundary Level | | | | | | | | | |
| Left Azimuth | degree | 10.38 | 0.30 | 24.80 | 37 | 0.08 | -2.44 | 2.66 | 868 |
| Corner Azimuth | degree | 2.67 | -2.00 | 10.00 | 3 | 6.00 | -0.62 | 18.80 | 83 |
| Corner Distance | foot | -0.67 | | -0.33 | 3 | -0.10 | -0.50 | 0.19 | 83 |
| Right Azimuth | degree | -17.46 | -42.53 | -0.04 | 37 | 1.61 | -1.10 | 4.59 | 868 |
| Subplot Level | | | | | | | | | |
| Slope | percent | 0.92 | 0.43 | 1.57 | 414 | 0.04 | -0.05 | 0.13 | 8,565 |
| Aspect | degree | 3.69 | -0.71 | 9.16 | 394 | 0.29 | -0.33 | 0.92 | 8,360 |
| Snow/Water Depth | foot | -0.19 | -0.43 | 0.02 | 414 | -0.28 | -0.39 | -0.17 | 8,604 |
| Tree Level | | | | | | | | | |
| D.b.h. | inch | -0.02 | -0.03 | -0.01 | 1,847 | -0.00 | -0.00 | 0.00 | 37,635 |
| D.r.c. | inch | | | | | 0.06 | -0.10 | 0.23 | 69 |
| Azimuth | degree | -0.23 | -0.59 | 0.20 | 1,937 | -0.03 | -0.09 | 0.03 | 42,172 |
| Horizontal Distance | foot | -0.00 | -0.02 | 0.03 | 1,937 | -0.00 | -0.01 | 0.00 | 42,172 |
| Rotten/Missing Cull | percent | -0.56 | -0.75 | -0.38 | 1,465 | -0.15 | -0.20 | -0.11 | 27,670 |
| Total Length | foot | 1.43 | 0.78 | 2.06 | 1,433 | 0.21 | 0.09 | 0.33 | 27,368 |
| Actual Length | foot | -1.64 | -6.28 | 1.54 | 129 | -1.46 | -2.62 | -0.50 | 3,340 |
| Compacted Crown Ratio | percent | -0.25 | -0.66 | 0.18 | 1,757 | 0.11 | -0.01 | 0.20 | 35,071 |
| Uncompacted Crown Ratio (P3) | percent | -1.63 | -4.30 | 0.91 | 51 | -3.07 | -3.80 | -2.24 | 1,984 |
| Crown Density | percent | 0.25 | -1.69 | 2.25 | 40 | -0.87 | -1.17 | -0.50 | 1,622 |
| Crown Dieback | percent | -3.88 | -4.63 | -3.00 | 40 | -0.19 | -0.48 | 0.11 | 1,622 |
| Transparency | percent | -5.63 | -7.44 | -4.00 | 40 | -0.69 | -1.00 | -0.38 | 1,622 |
| D.b.h.-Live & Trees with Decay Code 1 or 2 | inch | -0.02 | -0.03 | -0.01 | 1,774 | 0.00 | -0.00 | 0.00 | 35,903 |
| D.b.h.-Trees with Decay Codes 3, 4 or 5 | inch | -0.06 | -0.09 | -0.03 | 73 | -0.02 | -0.05 | -0.01 | 1,732 |
| Total Length-trees 40 feet and greater | foot | 1.52 | 0.88 | 2.06 | 1,301 | 0.70 | 0.58 | 0.83 | 21,658 |
| Total Length-trees less than 40 feet | foot | 0.56 | -3.84 | 3.92 | 132 | -1.67 | -2.00 | -1.39 | 5,710 |
| Total Length-trees less than 5 inches DBH | foot | -7.73 | -15.36 | -0.20 | 11 | -1.53 | -2.82 | -0.05 | 349 |
| Seedling Level | | | | | | | | | |
| Seedling Count | number | -18.96 | -26.11 | -11.24 | 616 | -12.53 | -14.37 | -10.94 | 8,496 |
| Seedling Count (coded) | number | -0.02 | -0.10 | 0.07 | 620 | -0.00 | -0.02 | 0.02 | 8,648 |
| Site Tree Level | | | | | | | | | |
| Diameter | inch | -0.02 | -0.05 | 0.00 | 171 | 0.00 | -0.01 | 0.01 | 2,775 |
| Azimuth | degree | -0.30 | -0.51 | -0.13 | 171 | 0.14 | -0.18 | 0.47 | 2,775 |
| Distance | foot | 0.14 | 0.01 | 0.30 | 171 | 0.04 | -0.00 | 0.08 | 2,775 |
| Total Length | foot | -0.00 | -0.55 | 0.59 | 171 | -0.04 | -0.22 | 0.13 | 2,775 |
| Diameter Age | year | -0.33 | -1.07 | 0.42 | 171 | 0.00 | -0.09 | 0.11 | 2,775 |

**Table E.—FIA nonresponse by strata, Indiana, 2013**

| Forest Inventory Unit[a] and Ownership layer[b] | Canopy cover class[c] | Number of plots selected | Sampled | Denied access | Hazardous | Other | Response rate |
|---|---|---|---|---|---|---|---|
| | | *number of plots* | | | | | *percent* |
| Lower Wabash | | | | | | | |
| Hoosier National Forest | 66 - 80 | 5 | 5 | 0 | 0 | 0 | 100.0 |
| | 81 - 100 | 1 | 1 | 0 | 0 | 0 | 100.0 |
| | **Total** | 6 | 6 | 0 | 0 | 0 | 100.0 |
| Inland Census Water | 0 - 100 | 12 | 11 | 1 | 0 | 0 | 91.7 |
| | **Total** | 12 | 11 | 1 | 0 | 0 | 91.7 |
| Private | 0 - 5 | 714 | 703 | 10 | 1 | 0 | 98.4 |
| | 6 - 50 | 92 | 85 | 7 | 0 | 0 | 91.8 |
| | 51 - 65 | 35 | 32 | 3 | 0 | 0 | 91.4 |
| | 66 - 80 | 131 | 117 | 13 | 1 | 0 | 89.1 |
| | 81 - 100 | 67 | 61 | 5 | 1 | 0 | 90.5 |
| | **Total** | 1,039 | 996 | 39 | 4 | 0 | 95.9 |
| Public | 0 - 5 | 13 | 13 | 0 | 0 | 0 | 100.0 |
| | 6 - 65 | 10 | 10 | 0 | 0 | 0 | 100.0 |
| | 66 - 100 | 32 | 32 | 0 | 0 | 0 | 100.0 |
| | **Total** | 55 | 55 | 0 | 0 | 0 | 100.0 |
| | **Unit Total** | 1,112 | 1,068 | 40 | 4 | 0 | 96.1 |
| Knobs | | | | | | | |
| Hoosier NF | 0 - 65 | 10 | 10 | 0 | 0 | 0 | 100.0 |
| | 66 - 80 | 35 | 35 | 0 | 0 | 0 | 100.0 |
| | 81 - 100 | 31 | 31 | 0 | 0 | 0 | 100.0 |
| | **Total** | 76 | 76 | 0 | 0 | 0 | 100.0 |
| Inland Census Water | 0 - 100 | 12 | 12 | 0 | 0 | 0 | 100.0 |
| | **Total** | 12 | 12 | 0 | 0 | 0 | 100.0 |
| Private | 0 - 5 | 631 | 621 | 9 | 1 | 0 | 98.4 |
| | 6 - 50 | 67 | 62 | 5 | 0 | 0 | 92.2 |
| | 51 - 65 | 75 | 61 | 14 | 0 | 0 | 81.3 |
| | 66 - 80 | 228 | 200 | 27 | 0 | 0 | 87.8 |
| | 81 - 100 | 124 | 107 | 15 | 2 | 0 | 86.5 |
| | **Total** | 1,125 | 1,051 | 70 | 4 | 0 | 93.5 |
| Public | 0 - 65 | 15 | 14 | 0 | 1 | 0 | 91.3 |
| | 66 - 80 | 31 | 31 | 0 | 0 | 0 | 100.0 |
| | 81 - 100 | 36 | 36 | 0 | 0 | 0 | 100.0 |
| | **Total** | 82 | 81 | 0 | 1 | 0 | 98.4 |
| | **Unit Total** | 1,295 | 1,220 | 70 | 5 | 0 | 94.2 |
| Upland Flats | | | | | | | |
| Inland Census Water | 0 - 100 | 4 | 4 | 0 | 0 | 0 | 100.0 |
| | **Total** | 4 | 4 | 0 | 0 | 0 | 100.0 |
| Private | 0 - 5 | 256 | 245 | 11 | 1 | 0 | 95.5 |
| | 6 - 50 | 28 | 27 | 1 | 0 | 0 | 96.4 |
| | 51 - 65 | 28 | 27 | 1 | 0 | 0 | 96.4 |
| | 66 - 80 | 78 | 69 | 8 | 0 | 0 | 88.9 |
| | 81 - 100 | 85 | 72 | 13 | 0 | 0 | 84.6 |
| Private Unit | **Total** | 475 | 440 | 34 | 1 | 0 | 92.6 |

continued

**Table E.—continued**

| Forest Inventory Unit[a] and Ownership layer[b] | Canopy cover class[c] | Number of plots selected | Sampled | Denied access | Hazardous | Other | Response rate |
|---|---|---|---|---|---|---|---|
| Public Unit | 0 -100 | 28 | 19 | 4 | 5 | 0 | 67.9 |
| | **Total** | 28 | 19 | 4 | 5 | 0 | 67.9 |
| | **Unit Total** | 507 | 463 | 38 | 6 | 0 | 91.3 |
| Northern | | | | | | | |
| Inland Census Water | 0 - 100 | 23 | 23 | 0 | 0 | 0 | 100.0 |
| | **Total** | 23 | 23 | 0 | 0 | 0 | 100.0 |
| Private | 0 - 5 | 3,516 | 3,488 | 28 | 0 | 0 | 99.2 |
| | 6 - 50 | 113 | 108 | 4 | 1 | 0 | 95.4 |
| | 51 - 65 | 71 | 68 | 3 | 0 | 0 | 95.8 |
| | 66 - 80 | 107 | 94 | 12 | 0 | 0 | 88.3 |
| | 81 - 100 | 251 | 216 | 34 | 2 | 0 | 85.9 |
| | **Total** | 4,058 | 3,974 | 81 | 3 | 0 | 97.9 |
| Public | 0 - 5 | 21 | 21 | 0 | 0 | 0 | 100.0 |
| | 6 - 65 | 12 | 11 | 0 | 1 | 0 | 91.7 |
| | 66 - 80 | 10 | 10 | 0 | 0 | 0 | 100.0 |
| | 81 - 100 | 27 | 25 | 1 | 1 | 0 | 91.7 |
| | **Total** | 70 | 67 | 1 | 2 | 0 | 95.4 |
| | **Unit Total** | 4,151 | 4,064 | 82 | 5 | 0 | 97.9 |
| | **State Total** | 7,065 | 6,815 | 230 | 20 | 0 | 96.5 |

[a] Counties in each Forest Inventory Unit used to define the estimation strata:

| **Lower Wabash** | **Knobs** | **Upland Flats** | **Northern** | |
|---|---|---|---|---|
| Clay | Brown | Dearborn | Adams | La Porte |
| Daviess | Clark | Fayette | Allen | Lagrange |
| Gibson | Crawford | Franklin | Bartholomew | Lake |
| Greene | Dubois | Jefferson | Benton | Madison |
| Knox | Floyd | Jennings | Blackford | Marion |
| Martin | Harrison | Ohio | Boone | Marshall |
| Parke | Jackson | Ripley | Carroll | Miami |
| Pike | Lawrence | Switzerland | Cass | Montgomery |
| Posey | Monroe | Union | Clinton | Newton |
| Putnam | Morgan | | De Kalb | Noble |
| Sullivan | Orange | | Decatur | Porter |
| Vanderburgh | Owen | | Delaware | Pulaski |
| Vermillion | Perry | | Elkhart | Randolph |
| Vigo | Scott | | Fountain | Rush |
| | Spencer | | Fulton | Shelby |
| | Warrick | | Grant | St. Joseph |
| | Washington | | Hamilton | Starke |
| | | | Hancock | Steuben |
| | | | Hendricks | Tippecanoe |
| | | | Henry | Tipton |
| | | | Howard | Wabash |
| | | | Huntington | Warren |
| | | | Jasper | Wayne |
| | | | Jay | Wells |
| | | | Johnson | White |
| | | | Kosciusko | Whitley |

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

[c] Canopy cover class = Derived from 2001 National Land Cover Dataset (Homer et al. 2007).