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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 6 objectives are achieved, 10 strategic approaches have been prescribed:

- A national set of prescribed core variables with a national field manual that prescribes 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 available in Iowa Forests, 2013, located at http://dx.doi.org/10.2737/NRS-RB-102.

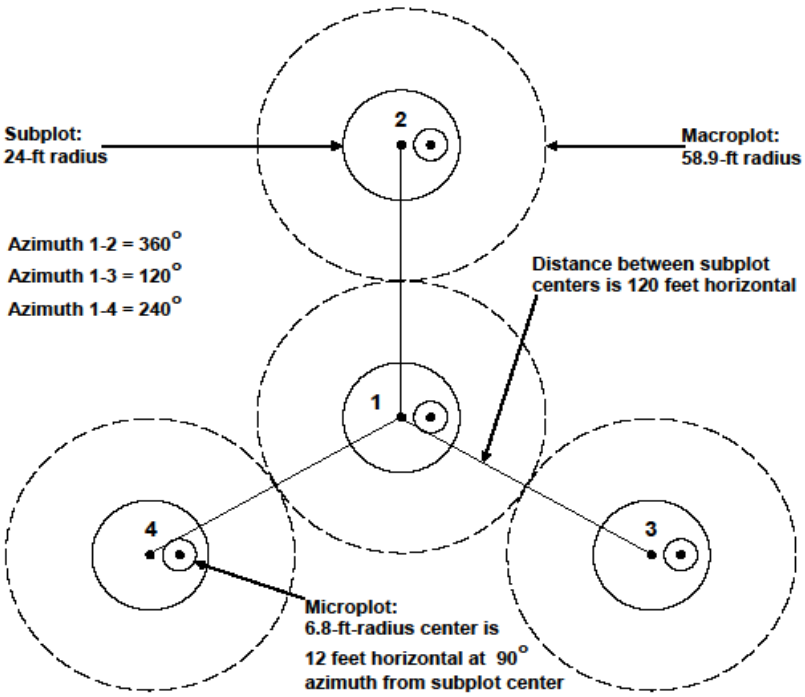

Figure 79.—FIA plot design (adapted from Bechtold and Patterson 2005).

Plot Configuration

The national FIA plot design consists of four 24-foot-radius subplots (1/24th acre) configured as a central subplot and three peripheral subplots (Fig. 79). Centers of the peripheral subplots are located at distances of 120 feet from the central subplot and at azimuths of 360º, 120º, and 240º 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 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. The 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 three 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. 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. 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 location using aerial photographs or DOQs. Analysts determine a digitized geographic location for each field plot, and a human interpreter assigns the plot a land cover/use. Lands satisfying FIA's definition of forest land include commercial timberland, some pastured land with trees, forest plantations, unproductive forested land, and reserved, noncommercial forested land. In addition, forest land requires minimum stocking levels, a 1-acre minimum area, and a minimum bole-to-bole width of 120 feet with continuous canopy. Forest land excludes wooded strips and windbreaks less than 120 feet wide and idle farmland or other previously nonforest land that currently is below minimum stocking levels. All plot locations that could possibly contain forest land at either the previous or current measurement, are selected for further measurement via field-crew visits during 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.

Currently, NRS-FIA uses canopy density classes to derive strata. Canopy density data were derived from the National Land Cover Database (NLCD) of 2001 (Homer et al. 2007). The NLCD 2001 canopy density layer for the United States was produced through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.mrlc.gov/). The layer characterizes subtle variations of forest canopy density as a percentage estimate of forest canopy cover (0-100) within every 30 meter pixel over the United States. The method used to map canopy density for NLCD 2001 is described in detail in Homer et al. (2007).

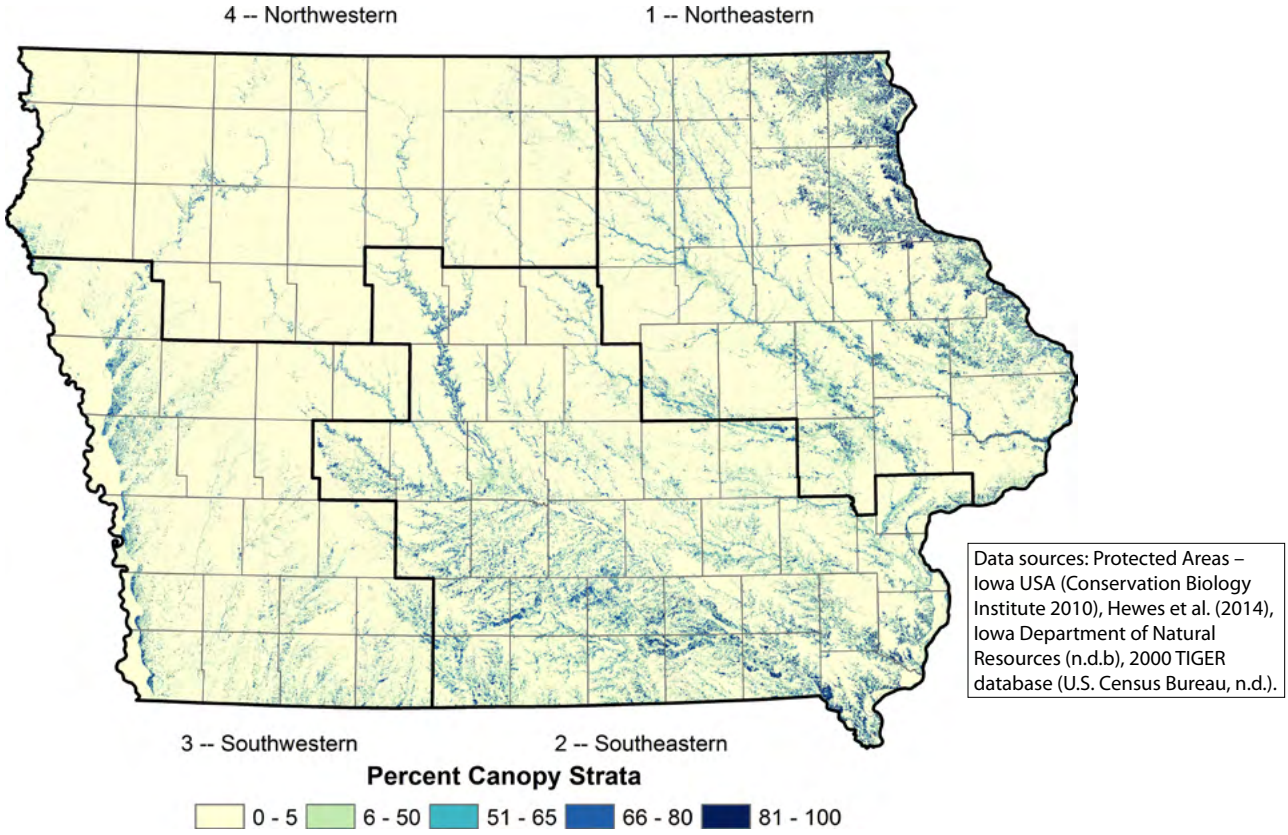

Figure 80.—Forest ownership, Iowa, 2013 (from Iowa 2013 Data Processing Summary Report).

Strata Construction

The current strata categorizations we use were optimized for the entire NRS-FIA region. By using plot location information (center of the center subplot), a percent canopy density value is assigned to each plot. Plots are then aggregated into one of 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 groups were based on observed natural clumping of pixel values and are presented in Figure 80.

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

In addition to the classification of every pixel into one of the five canopy strata, every pixel was also assigned to an ownership stratum. The Protected Areas database (Conservation Biology Institute 2010) was initially used and then state-specific data were added. In Iowa, ownership layers derived from Iowa (Iowa Department of Natural Resources n.d.b) and the Protected Areas database (Conservation Biology Institute 2010) were used to classify pixels into three ownership classes: (1) other public, (2) private, and (3) census water (Fig. 81). See the Iowa 2013 Data Processing Summary Report[2] for more details. The largest ownership class, based on pixel counts, was private ownership at more than 35 million acres (Table 10). Every pixel was also assigned to a county based on the location of the pixel center.

[2] Gormanson, D.; Hatfield, M.; O'Connell, B.; Barnett, C.; Sowers, P.; Wazenegger, J., comps. 2014. Iowa 2013 data processing summary report. Feb. 14. 57 p. Unpublished report on file at U.S. Department of Agriculture, Forest Service, Northern Research Station, St. Paul, MN.

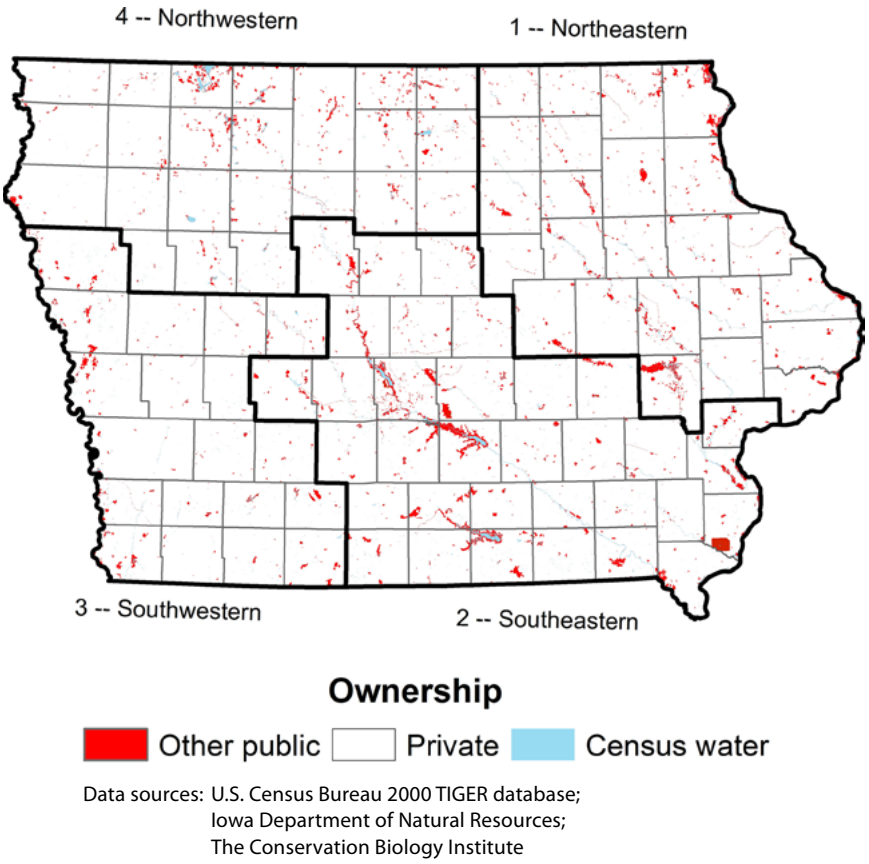

Figure 81.—Iowa forest ownership (from Iowa 2013 Data Processing Summary Report)

Table 10.—Ownership class acreages based on pixel counts

Ownership class	Acres
Inland census water	256,961
Private	35,083,585
Public	672,981

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 not a sufficient number of plots within a canopy cover class/ownership class/county for valid estimation purposes, then specific 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 will not be collapsed with another estimation unit regardless of the plot count. Also, the inland census water estimation units use an alternative minimum of two plots per stratum.

Stratified estimation requires that two tasks be accomplished. First, each plot must be assigned to a single stratum. Next, the proportion of the total area in each stratum must be calculated (tree canopy 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 Iowa are presented in the Estimation section of this report after the descriptions of P2 and P3.

Phase 2

In P2, field crews record a variety of data for plot locations determined in P1 to determine whether a field visit is required, regardless of current forest land use. 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. Once they are at the plot location, the field crews determine the location of the geographic center of the center subplot by using global positioning system (GPS) receivers. They record condition-level observations that include land cover, forest type, stand origin, stand age, stand-size class, site-productivity class, forest disturbance history, and land use for every condition (major land use of forest stand at least 1 acre in size) that occurs on the plot. They 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, volume, and biomass by plot, condition, species group, and live/dead status. The remeasurement of every plot enables the estimation of land use change; the remeasurement of every tree enables the calculation of components of change including growth, mortality, and removals. For details of the data collection procedures used in P2 see U.S. Forest Service (2010, 2016). 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, and universities, and it is partially integrated with 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. The intensive site ecosystem monitoring program conducts research into 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.

In 1999, the ground-survey portion of the FHM detection monitoring program was integrated into the FIA program as P3 and continued through 2010. The P3 sample consists of a 1:16 subset of the P2 plots with one P3 plot for about every 95,000 acres.

P3 measurements are obtained by field crews during the growing season and include an extended suite of ecological data: lichen diversity and abundance, soil quality (erosion, compaction, and chemistry), vegetation diversity and structure, down woody materials (DWM), and tree crowns. The incidence and severity of ozone injury for selected bioindicator species also are monitored as part of an associated sampling scheme.

All P3 measurements are collected on each P3 plot at the same time as the P2 measurements. For more information on the collection procedures used in P3 see U.S. Forest Service (2005). O'Neill et al. (2005), Schulz et al. (2009), Woodall and Monleon (2008), Schomaker et al. (2007), and Smith et al. (2008) provide additional information on sampling and analysis of P3. Woodall et al. (2010) describe the P3 database. For additional information on P3 and other research topics see U.S. Forest Service (2012).

P3 variables are selected to address specific criteria outlined by the Montreal Process working group (Montreal Process 1999) for the conservation and sustainable management of temperate and boreal forests 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 Criteria and Indicators (for more information, see Woodall et al. 2011).

Phase 2+ (2012-ongoing). 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 about 6.25 percent of the P2 plots. Since 2012, P2+ protocols have been completed on about 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 that will remain with the 6.25 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. Except for an invasive plants inventory, P3 and P2+ were not implemented in any state in 2011.

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 (heights), 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 provide 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 2007 through 2011 but changed to the P2+ sample (12.5 percent) since 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 topsoils 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 live crown length divided by the total tree length.

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

Estimation

Most of the estimates and analysis of forest resources presented in this report, including all of the estimates in Tables IA-1 through IA-32a, IA-54 through IA-61a, and IA-65, are based on data observed on the 6,067 P2 plots across Iowa. P3 and P2+ analyses are based on 299 and 293 plots, respectively.

P2 plots collected in the 2013 inventory are located within 28 estimation strata defined by five P1 canopy cover classes or collapsed canopy cover classes (see Strata Construction), ownership classes, and inventory units (Table A). Procedures described in Scott et al. (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

The first three inventories of Iowa were completed in 1954, 1974, and 1990 (Thornton and Morgan 1959, Spencer and Jakes 1980, and Leatherberry et al. 1992, respectively). Iowa's fourth inventory (the first conducted under the annual inventory system) was completed in 2003 and consisted of data collected in five panels over 5 years (1999, 2000, 2001, 2002, and 2003) (Leatherberry et al. 2006). The fifth inventory (the first complete remeasurement of an annual inventory) was completed in 2008 (Nelson et al. 2011) and consisted of data collected in 2004, 2005, 2006, 2007, and 2008. The sixth inventory (the second complete remeasurement of an annual inventory) was completed in 2013. This sixth inventory includes the five panels of data collected in 2009, 2010, 2011, 2012, and 2013.

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

Comparisons with the earlier inventories (1990, 1974, and 1954) 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 four FIA regions 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 1990 and 1974 Iowa inventories, respectively. 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 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 P3 indicator sampling protocols, see U.S. Forest Service (2005) 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 has been implemented with version 6.0 of the FIA field manual, which took effect with the 2013 inventory year (which began October 2012). Furthermore, all previously collected annual inventory data (1999 to present) have been updated using the new standardized interpretation.

Starting with this report, timberland estimates generated for earlier annual inventories will differ from previously published estimates. The 2012 inventory was the last inventory in which all data were available under the previous implementation. A comparison of improved versus previous implementations of reserved status revealed the following differences in estimates for the 2012 inventory. Small but significant changes are associated with timberland acreage (-3 percent). Estimates of growth, mortality, and removals on growing stock changed by -1 percent, -11 percent, and -1 percent, respectively, as a result of the change in how reserved status is implemented.

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.

Quality of the Estimates

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; this variability 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. For each of these sources of error, a definition within the context of the FIA inventory is provided along with a discussion of methods used to quantify and reduce this error. 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 acre and every tree in Iowa) had been observed and included in the sample. The 2013 inventory of Iowa is based on a sample of 6,067 plots

located randomly across the State (total area of 36.0 million acres), or a sampling rate of about one plot for every 5,936 acres of land, noncensus water, and inland census water. The plots are located randomly within a hexagonal grid that covers the United States. The result is treated as a simple random sample (Reams et al. 2005).

The procedures for statistical estimation outlined in the previous section and described in detail in Scott et al. (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 but that can also be expressed in the same units as a confidence interval (the estimated value plus or minus the sampling error). A sampling error can be interpreted to mean that if a 100 percent inventory had been taken using these methods, the chances are two in three that 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 shown in Table B. Table IA-65[2] presents sampling errors for these estimates at the FIA inventory unit and county levels.

Estimates for classifications smaller than the State totals in Table B[3] will have larger sampling errors. For example, Table IA-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:

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

Where

E = approximate sampling error for smaller estimate

SE = sampling error for State total estimate (percent)

For example, to compute the approximate error on the area of forest land in the elm/ash/cottonwood forest-type group for the State, proceed as follows:

The total area of the elm/ash/cottonwood group in the State from Table IA-6 is 684,600 acres.

The total area of all forest land in the State from Table IA-6 is 2,966,500 acres.

The State total error for forest land area from Table B is 2.20 percent.

Using formula (1):

Sampling error = $E = \frac{(2.20)\sqrt{(2{,}966{,}500)}}{\sqrt{(684{,}600)}}$ = 4.58 percent.

[3] Tables labeled with the State abbreviation (IA) followed by a number (e.g., Table IA-1) are located in a supplemental file titled "Iowa forest inventory summary tables" located at http://dx.doi.org/10.2737/NRS-RB-102. Tables labeled with letters (e.g., Table A) are located on pages 29-38.

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/.

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. In addition, 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. In many cases, especially for variables observed without the aid of an instrument, there is no practical way to identify an absolute true value.

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 intensive crew training. All crew members must pass a certification session for every new field guide version released (typically an annual event) and must be annually assessed at a minimum of four check plots (work of crew member is graded). New FIA crews have 8 weeks of one-on-one training followed by training plots (no official grading) and check plots at random times. Communication among crews is continuous, addressing issues and questions as needed. Errors found in initial measurements are corrected on training plots but not normally corrected on check plots.

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 expert crew. These independent measurements are referred to as blind checks. The second measurement on the blind check plots is done by a quality assurance (QA) crew. In all cases, QA crews have as much or more experience and training in FIA field measurements than standard FIA crews. The standard crew and QA crew measurements are recorded and stored in a database, but they are not compared in the field and no initial measurements are changed.

The quality of field measurements is assessed nationally through a set of measurement quality objectives (MQOs) that are set for every data item we collect. Each MQO consists of two parts: a tolerance or acceptable level of measurement error and an objective in terms of the percentage of measurements within tolerance. The 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 "Iowa" are based on blind check measurements of plots used in this report. The columns labeled "All NRS States" come from all measurements made by FIA crews within the entire 24-state area (Connecticut, Delaware, Illinois, Indiana, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, West Virginia, and Wisconsin) where the Northern Research Station implemented the FIA program in 2009 through 2013. Training and supervision of crews are 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 Iowa, many variables such as diameter at breast height (d.b.h.) have a low tolerance (±0.1 inch per 20 inches) and a high percentage of data within the tolerance (96.4 percent). Measurements for determining tree size class are precise. In contrast, a few variables such as seedling count have a larger tolerance (±20 percent) and fewer data within the tolerance (69.2 percent). The estimate of stand age is based on the composition of all age classes within a stand; the tolerance for stand age is ±10 percent and 94.7 percent of data fall within this tolerance. 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 the standard field-crew measurements to be higher or lower than those 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. Relative bias is reported only for variables that are measurements of continuous attributes (e.g., diameter and height). Relative bias is not appropriate for coded variables (e.g., crown class and tree status).

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 were the best available and were selected for nationwide use by FIA; they are commonly used by similar natural resource inventories. A basic assumption is that the methods, when applied correctly, 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.

Of 11,335 trees measured during both the current (2013) and previous (2008) inventory, only 150 (just over 1 percent) were given a different species code by the field crews between the current and previous inventories. The species with the most frequent difference was sugar maple, with 47 trees, 46 of which were previously identified as black maple. There was also minor confusion among some species of hickory, oak, ash, and elm.

Prediction Error

Errors associated with using mathematical models (such as volume models) to provide 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 involve the use of prediction models. Models are used to predict volume and biomass estimates of individual trees. Change estimates such as growth, mortality, and removals are based on these model-based predictions of volume from both the current plot measurements and the measurements taken in the previous inventory.

Estimates of prediction errors associated with the volume models in this report were presented by Hahn (1984), along with model forms, methods used in model development, and model-parameter estimates. The estimated prediction errors are based on observations of 101,642 trees measured in the forest inventories of Michigan (1980), Minnesota (1977), and Wisconsin (1968). For gross cubic-foot volume of a live tree, standard errors ranged from 1.47 to 28.13 cubic feet (Hahn 1984). For board-foot volume of a live tree, standard errors ranged from 14.49 to 189.95 board feet (Hahn 1984).

In comparing FIA estimates to other data sources, users need to be aware of the prediction models used in both estimates. If both estimates are based on the same prediction models with matching fitted parameter values, then 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 refers to the error caused by not being able to observe some of the elements in the sample. In FIA, 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 getting to 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. The reduced sample size is reflected in the sampling errors discussed in the preceding paragraphs. Second, nonresponse can bias the estimates if the portion of the population not being sampled differs from the portion being sampled.

In FIA, unlike many survey samples, nonresponse rates are relatively low. In the 2013 Iowa inventory, 6,067 sample plots were selected for observation. Almost 99 percent of these are included in the sample used to estimate current resources. On 60 plots, crews were unable to obtain owner permission to measure the plot or part of the plot; hazardous conditions on 2 plots prevented the crew from measuring all or part of the plot.

Even an overall nonresponse rate of 1 percent can cause considerable bias if not properly accounted for. The major source of nonresponse is denied access to plots, which occurs primarily on lands in private ownership. Also, observations for plots on nonforest and water land classes rarely require crews to physically enter the land, and permission is not needed because the observation can be obtained from aerial photos or other sources of remotely sensed information.

The stratified estimation process used by NRS-FIA with strata defined by ownership classes and canopy cover class reduces the possible effects of bias caused by nonresponse. Under the stratified estimation process used by FIA, nonresponses are removed from the sample, and stratum estimates (means, totals, and sampling errors) are obtained only from plots with valid observations. The net effect in the estimates of means and totals is that the average of the observed plots within the stratum (ownership 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 Iowa 2013 inventory and for all NRS-FIA inventories conducted in the Midwest by the Northern Research Station over the same period.

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

Conducting Tests for Statistically Significant Differences

We often try to determine whether the difference between estimates is statistically significant. Past analyses may have reported a significant difference when the ranges of two estimates fail to overlap based on one standard error for the level of uncertainty. Pairs of estimates that include remeasured plots are not independent observations and thus have covariance; testing for statistical differences necessitates accounting for covariance (Westfall et al. 2013). Standard analytical tools accounting for covariance in FIA estimates are not available, so this report does not attempt to identify statistically significant differences. Ongoing development of analytical tools accounting for covariance will make it possible to identify statistically significant differences in the future.

Other Sources of Data

Maps

Maps in this report were constructed by various methods and from a number of data sources (see map descriptions and credits). Basal area, forest-type group, and forest/nonforest cover were mapped across the State by using data from FIA plots which are distinct points. We used a technique known as k-nearest neighbors estimation to accomplish this (Wilson et al. 2012). The approach uses the modeling techniques of k-nearest neighbors and canonical correspondence analysis, where model predictions are calculated by using a weighting of nearest neighbors based on proximity in a feature space derived from the model. We were able to assign actual field-measured estimates to surrounding areas using the FIA plot data (2009 inventory), 250 m Moderate Resolution Imaging Spectroradiometer imagery (2001-2008), 30 m NLCD 2001 canopy cover (Homer et al. 2007), and climate and topographic data. A nonforest mask derived by Wilson et al. (2012) was applied to maps in this report so that attributes are shown only on forest land.

National Woodland Owner Survey

The National Woodland Owner Survey (NWOS) is conducted by FIA as the social complement to FIA's biophysical inventory. The goal of the NWOS is to increase our understanding of the least understood group of owners: families, individuals, and other unincorporated groups; this diverse and dynamic group is collectively referred to as "family forest owners," (Butler et al. 2016a). The NWOS seeks to answer these questions:

- Who owns the forests of the United States?
- Why do they own forest land?
- What have they done with the forest land in the past?
- What do they intend to do with it in the future?

Questionnaires were mailed to randomly selected private forest ownerships across the State following established survey protocols (Butler et al. 2016a). An ownership is a legal entity that has legal rights over a specific resource. In the case of family ownerships, it is composed of one or more owners (that is, individuals). The data provided in this report are based on the responses from 153 family forest ownerships (with 10 or more acres of forest land) from Iowa who participated in the NWOS between 2011 and 2013. Of those potential respondents successfully contacted, 55.7 percent responded. In addition to the results provided in this report, other results from the NWOS on private forest ownerships of Iowa, and other states, are available in Butler et al. (2016b). Details about NWOS sampling design, estimates, and analysis procedures are available in Butler et al. (2016a). These materials and other information pertaining to the NWOS can be accessed at www.fia.fs.fed.us/nwos.

Timber Product Output Survey

The timber product output (TPO) survey is a cooperative effort of the Forestry Bureau of the Iowa Department of Natural Resources (IADNR) and FIA. The IADNR canvassed all primary wood-using mills within the State using mail questionnaires supplied by FIA. These questionnaires are designed to determine the size and composition of Iowa's primary wood-using industry, its use of roundwood, and its generation and disposition

of wood residues. The IADNR then contacted nonresponding mills through additional mailings, telephone calls, and personal contacts until achieving nearly a 100 percent response from primary processors. Completed questionnaires were forwarded to FIA for compilation and analysis. This general process also is completed by other agencies in neighboring states. All of this information is combined to determine the timber product output for Iowa.

As part of data processing and analysis, all industrial roundwood volumes reported on the questionnaires were converted to standard units of measure by using regional conversion factors. Timber removals by source of material and harvest residues generated during logging were estimated from standard product volumes by using factors developed from logging utilization studies previously conducted by FIA in Missouri, Minnesota, and Wisconsin (unpublished data; contact FIA TPO staff).

GLOSSARY

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

Average annual net growth: The average annual change in the volume of trees during the period between inventories. Components include the change in volume of trees that have met the minimum size requirements over the inventory period, plus the volume of trees reaching the minimum size during the period (ingrowth), minus the volume of trees that died during the period, minus the volume of cull during the period. Mortality removals (trees killed in the harvesting process and left onsite) 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 onsite), and diversion removals (trees removed from the forest-land base due to a change from forest to nonforest land). This estimate can be provided in cubic feet for live and growing-stock trees or in board feet for sawtimber trees.

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

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

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

> **Bole:** Biomass of a tree from 1 foot above the ground to a 4-inch top outside bark or to a point where the central stem breaks into limbs.

Tops and limbs: Total biomass of a tree from a 1-foot stump minus the bole.

1- to 5-inch trees: Total aboveground biomass of a tree from 1 to 5 inches in diameter at breast height (d.b.h.).

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

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

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; excludes species of typically small size, poor form, or inferior quality.

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

Corporate: Pertaining to an ownership class of private lands owned by corporations.

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

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

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

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

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

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

Diameter class: A classification of trees based on diameter outside bark measured at breast height (4.5 feet above ground). The common abbreviation for "diameter at breast height" is d.b.h. With 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches d.b.h. A "diameter at root collar" or d.r.c. measurement is taken for multi-stemmed woodland species, such as 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, that are not self-supporting, and that are lying on the ground.

Duff: A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (such as 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 canopy cover by live tally trees of any size or that has had at least 10 percent canopy cover of live tally species in the past. The area must be at least 1 acre and 120 feet wide. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that meet the minimum tree stocking/cover and forest areas adjacent to urban and built-up lands. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide or less than 1 acre. Streams that are at least 30 feet but less than 120 feet in width are considered noncensus water, which is a nonforest land use (definition from U.S. Forest Service, Forest Inventory and Analysis 2014).

Forest type: A classification of forest land based on the species currently forming a plurality of the live-tree stocking. If softwood species predominate (50 percent or more), then the forest type will be one of the softwood types. If hardwood species predominate, then the forest type will be one of the hardwood types. For the eastern United States, there are mixed hardwood-pine forest types when the pine and 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. The following are common or well-known forest types in the State of Iowa:

Eastern redcedar: Associates—gray birch, red maple, sweet birch, Virginia Pine, shortleaf pine, oak. Sites—usually dry uplands and abandoned fields on limestone outcrops and other shallow soils but can grow well on good sites. Softwood forest type and member of the other eastern softwoods forest-type group.

Eastern redcedar/hardwood: Associates—oak, hickory, walnut, ash, locust, dogwood, blackgum, hackberry, winged elm, shortleaf pine, and Virginia pine. Sites—usually dry uplands and abandoned fields. Hardwood forest type and member of the oak/pine forest-type group.

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

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

Northern red oak: Associates—black oak, scarlet oak, chestnut oak, and yellow-poplar. Sites—spotty distribution on ridge crests and north slopes in mountains but also found on rolling land, slopes, and benches on loamy soil. Hardwood forest type and member of the oak/hickory forest-type group.

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

Black walnut: Associates—yellow-poplar, white ash, black cherry, basswood, beech, sugar maple, oaks, and hickory. Sites—coves and well-drained bottoms. Hardwood forest type and member of the oak/hickory forest-type group.

Black locust: Associates—Many species of hardwoods and hard pines may occur with it in mixture, either having been planted or from natural seeding. Sites—may occur on any well-drained soil but best on dry sites, often in old fields. Hardwood forest type and member of the oak/hickory forest-type group.

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

Elm/ash/locust: Associates—Black locust, silver maple, boxelder, blackbead ebony, American elm, slippery elm, rock elm, red maple, green ash predominate. Found in the Midwest, unknown in the Northeast. Sites—upland. Hardwood forest type and member of the oak/hickory forest-type group.

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

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

River birch/sycamore: Associates—red maple, black willow, and other moist-site hardwoods. Sites—moist soils at edges of creeks and rivers. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Cottonwood: Associates—willow, white ash, green ash, and sycamore. Sites—streambanks where bare, moist soil is available. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Willow (includes peachleaf and black willow): Associates—cottonwood, green ash, sycamore, pecan, American elm, red maple, and boxelder. Sites—streambanks where bare, moist soil is available. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

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

Sugarberry/hackberry/elm/green ash (includes American, winged, cedar, slippery and rock elm): Associates—boxelder, pecan, blackgum, persimmon, honeylocust, red maple, and hackberry. Sites—low ridges and flats in floodplains. Hardwood forest type and member of the elm/ash/cottonwood forest-type group. This type was renamed to green ash/red maple/elm for this report. In Iowa, sugarberry is not part of this type.

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

Cottonwood/willow (includes peachleaf, black, and Bebb willow): Associates—white ash, green ash, sycamore, American elm, red maple, and boxelder. Sites—streambanks where bare, moist soil is available. Hardwood forest type and member of the elm/ash/cottonwood forest-type group.

Sugar maple/yellow birch: Associates—butternut, basswood, red maple, hemlock, northern red oak, white ash, white pine, black cherry, sweet birch, American elm, rock elm, and eastern hophornbeam. Sites—fertile, moist, well-drained sites. Hardwood forest type and member of the maple/beech/birch forest-type group. (Note: Sugar maple/beech/yellow birch is labeled as sugar maple/yellow birch in this report, due to absence of beech from Iowa.)

Black cherry: Associates—sugar maple, northern red oak, red maple, white ash, basswood, sweet birch, butternut, American elm, and hemlock. Sites—fertile, moist, well-drained sites. Hardwood forest type and member of the maple/beech/birch forest-type group.

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

Aspen: Associates—Engelmann spruce, lodgepole pine, ponderosa pine, Douglas-fir, subalpine fir, white fir, white spruce, balsam poplar, and paper birch. Sites—Aspen has the capacity to grow on a variety of sites and soils, ranging from shallow stony soils and loamy sands to heavy clays. Hardwood forest type and member of the aspen/birch forest-type group.

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

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

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

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, growing stock includes only trees 5.0 inches d.b.h. and larger.

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

> **Soft hardwoods:** A category of hardwood species with wood generally of low specific gravity (less than 0.5). Notable examples include red maple, paper birch, quaking aspen, and American elm.
>
> **Hard hardwoods:** A category of hardwood species with wood generally of high specific gravity (greater than 0.5). Notable examples include sugar maple, yellow birch, black walnut, and oaks.

Industrial wood: All commercial roundwood products except fuelwood.

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 floodplains; streams, sloughs, estuaries, and canals less than 200 feet wide; and lakes, reservoirs, and ponds less than 4.5 acres in area.

Litter: Undecomposed or only partially decomposed organic material that can be readily identified, such as plant leaves and twigs.

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

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

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

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

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

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

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

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

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

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 as follows:

> **Xeric:** Very dry soils where excessive drainage seriously limits both growth and species occurrence. These sites are usually on upland and upper half slopes.
>
> **Xeromesic:** Moderately dry soils where excessive drainage limits growth and species occurrence to some extent. These sites are usually on the lower half slopes.
>
> **Mesic:** Deep, well-drained soils. Growth and species occurrence are limited only by climate. These include all cove sites (small sheltered bays) and bottomlands (low land) along intermittent streams.
>
> **Hydromesic:** Moderately wet soils where insufficient drainage or infrequent flooding limits growth and species occurrence to some extent.
>
> **Hydric:** Very wet sites where excess water seriously limits both growth and species occurrence.

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

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

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

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

Reserved forest land: Forest land withdrawn from timber utilization through statute, administrative regulation, or designation without regard to productive status. Examples include national forest wilderness areas, national parks, and national monuments.

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

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

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

Roundwood products: Logs, bolts, and other round timber generated from harvesting trees for industrial or consumer use. Roundwood products are saw logs, veneer, cooperage logs, pulpwood logs, fuelwood, pilings, poles and 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 diameter outside bark (d.o.b.).

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

Seedlings: Live trees less than 1.0 inch d.b.h. or d.r.c. and at least 6.0 inches in height for softwoods and 12.0 inches in height for hardwoods.

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.

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

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

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

> **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.

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

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.)

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

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

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

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, or residential subdivisions; 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 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.

Tables labeled with the State abbreviation followed by a number (e.g., Table IA-1) report estimates of forest characteristics collected during this inventory period, including estimates of forested area, number of trees, and volume growth. These tables can be found in a supplemental file labeled "Iowa forest inventory summary tables" at http://dx.doi.org/10.2737/NRS-RB-102.

Table A.—Area and number of plots in each stratum, Iowa, 2009-2013

Table B.—State-level estimates of major forest resource attributes and their sampling errors, Iowa, 2009-2013

Table C.—Compliance to measurement quality objectives (MQOs) tolerances of variables based on blind check plots, Iowa, 2009-2013

Table D.—Observed relative bias values (average [field crew - QA crew]) for measurement variables based on blind check plots, Iowa, 2009-2013

Table E.—FIA nonresponse by stratum, Iowa, 2009-2013

Table A.—Area and number of plots in each stratum, Iowa, 2009-2013

Forest Inventory Unit [a] and ownership layer [b]	Strata: Canopy cover class [c]	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]
1 - Northeastern										
Inland census water	0 - 100	75,406	12	8	4	4	3	11	3	0
	Total	75,406	12	8	4	4	3	11	3	0
Private	0 - 5	7,632,061	1,295	1,240	55	49	36	1,291	51	6
	6 - 50	398,138	79	36	43	38	34	77	41	5
	51 - 65	146,126	29	6	23	21	20	28	22	2
	66 - 80	173,138	24	8	16	15	14	23	15	1
	81 - 100	646,046	98	3	95	86	84	86	83	9
	Total	8,995,509	1,525	1,293	232	209	188	1,505	212	23
Public	0 - 5	62,691	14	10	4	4	4	14	4	0
	6 - 100	122,565	12	1	11	11	11	12	11	0
	Total	185,256	26	11	15	15	15	26	15	0
	Unit Total	9,256,171	1,563	1,312	251	228	206	1,542	230	23
2 - Southeastern										
Inland census water	0 - 100	109,825	18	14	4	4	3	18	4	0
	Total	109,825	18	14	4	4	3	18	4	0
Private	0 - 5	9,203,249	1,565	1,475	90	87	64	1,560	85	3
	6 - 50	438,654	64	31	33	30	26	61	30	3
	51 - 65	209,917	24	3	21	20	18	23	20	1
	66 - 80	245,652	33	8	25	24	23	31	23	1
	81 - 100	840,131	149	3	146	135	134	140	137	11
	Total	10,937,603	1,835	1,520	315	296	265	1,815	295	19
Public	0 - 5	130,959	19	12	7	7	7	19	7	0
	6 - 80	59,076	14	1	13	13	11	14	13	0
	81 - 100	100,527	20	0	20	20	20	20	20	0
	Total	290,562	53	13	40	40	38	53	40	0
	Unit Total	11,337,990	1,906	1,547	359	340	306	1,886	339	19

continued

Table A.—continued

Forest Inventory Unit [a] and ownership layer [b]	Strata: Canopy cover class [c]	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]
3 - Southwestern										
Inland census water	0 - 100	27,298	4	3	1	1	1	4	1	0
	Total	27,298	4	3	1	1	1	4	1	0
Private	0 - 5	6477082	1091	1049	42	41	29	1088	39	1
	6 - 50	184171	25	14	11	9	7	23	9	2
	51 - 80	159937	20	2	18	15	14	19	17	3
	81 - 100	166625	39	1	38	35	34	37	36	3
	Total	6,987,815	1,175	1,066	109	100	84	1,167	101	9
Public	0 - 100	92,327	20	5	15	15	15	20	15	0
	Total	92,327	20	5	15	15	15	20	15	0
	Unit Total	7,107,440	1,199	1,074	125	116	100	1,191	117	9
4 - Northwestern										
Inland census water	0 - 100	44,432	5	5	0	0	0	5	0	0
	Total	44,432	5	5	0	0	0	5	0	0
Private	0 - 5	7,986,829	1,347	1,333	14	14	11	1,347	14	0
	6 - 50	73,135	11	8	3	3	3	10	2	0
	51 - 100	102,695	16	3	13	9	9	15	12	4
	Total	8,162,659	1,374	1,344	30	26	23	1,372	28	4
Public	0 - 100	104,836	20	14	6	6	6	20	6	0
	Total	104,836	20	14	6	6	6	20	6	0
	Unit Total	8,311,927	1,399	1,363	36	32	29	1,397	34	4
	State Total	36,013,528	6,067	5,296	771	716	641	6,016	720	55

continued

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

1 - Northeastern	2 - Southeastern	3 - Southwestern	4 - Northwestern
Allamakee	Appanoose	Adair	Buena Vista
Benton	Boone	Adams	Calhoun
Black Hawk	Clarke	Audubon	Cerro Gordo
Bremer	Dallas	Carroll	Cherokee
Buchanan	Davis	Cass	Clay
Butler	Decatur	Crawford	Dickinson
Cedar	Des Moines	Fremont	Emmet
Chickasaw	Guthrie	Greene	Franklin
Clayton	Hamilton	Harrison	Hancock
Clinton	Hardin	Mills	Humboldt
Delaware	Henry	Monona	Ida
Dubuque	Iowa	Montgomery	Kossuth
Fayette	Jasper	Page	Lyon
Floyd	Jefferson	Pottawattamie	O'Brien
Grundy	Keokuk	Ringgold	Osceola
Howard	Lee	Shelby	Palo Alto
Jackson	Louisa	Taylor	Plymouth
Johnson	Lucas	Union	Pocahontas
Jones	Madison	Woodbury	Sac
Linn	Mahaska		Sioux
Mitchell	Marion		Winnebago
Scott	Marshall		Worth
Tama	Monroe		Wright
Winneshiek	Muscatine		
	Polk		
	Poweshiek		
	Story		
	Van Buren		
	Wapello		
	Warren		
	Washington		
	Wayne		
	Webster		

[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 or digital orthoquads, or both.

[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 are used to estimate change variables (e.g., 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, Iowa, 2009-2013

Item	State total	Sampling error
Growing stock:	million cubic feet	percent
Volume	3,077.20	4.70
Average annual net growth	70.8	8.60
Average annual removals	36.0	25.49
Average annual mortality	47.5	11.60
Sawtimber:	million board feet [a]	
Volume	11,658.0	5.34
Average annual net growth	319.9	8.75
Average annual removals	88.3	27.38
Average annual mortality	171.0	13.97
Area:	thousand acres	
Forest land	2,966.50	2.20
Timberland	2,850.40	2.40
Biomass (aboveground live trees and saplings):	million dry tons	
Forest land	122.7	3.30
Timberland	117.1	3.40

[a] International ¼-inch rule.

All results for timberland except where indicated.

Table C.—Compliance to measurement quality objectives (MQOs) tolerances of variables based on blind check plots, Iowa, 2009-2013

Variable	Tolerance	Objective	Iowa		All NRS states	
			Data within tolerance	Observations	Data within tolerance	Observations
Plot Level		-------*percent*-------		*number*	*percent*	*number*
Distance to Road	No Tolerance	90.0	94.2	69	81.7	2,420
Water on Plot	No Tolerance	90.0	98.6	69	86.7	2,420
Elevation	±50 feet	99.0	93.0	71	87.9	2,197
Latitude - decimal degrees	±0.0001 degree	99.0	100.0	71	100.0	2,201
Longitude - decimal degrees	±0.0001 degree	99.0	93.0	71	87.5	2,201
Condition Level						
Condition Status	No Tolerance	99.0	100.0	149	99.1	4,141
Reserved Status	No Tolerance	99.0	99.3	149	99.5	4,141
Owner Group	No Tolerance	99.0	100.0	75	98.7	2,889
Forest Type (Type)	No Tolerance	95.0	89.3	75	90.6	2,889
Forest Type (Group)	No Tolerance	99.0	100.0	75	95.3	2,889
Stand Size	No Tolerance	99.0	92.0	75	91.2	2,889
Regeneration Status	No Tolerance	99.0	100.0	75	98.5	2,889
Tree Density	No Tolerance	99.0	100.0	75	97.7	2,889
Owner Class	No Tolerance	99.0	93.3	75	95.9	2,889
Owner Status	No Tolerance	99.0	100.0	75	99.2	2,889
Regeneration Species	No Tolerance	99.0	100.0	75	98.4	2,889
Stand Age	±10 percent	95.0	94.7	75	87.2	2,889
Disturbance 1	No Tolerance	99.0	90.7	75	90.4	2,868
Disturbance 2	No Tolerance	99.0	100.0	17	89.0	547
Disturbance 3	No Tolerance	99.0	100.0	1	97.3	75
Treatment 1	No Tolerance	99.0	100.0	75	97.7	2,868
Treatment Year 1	±1 year	99.0	100.0	1	94.9	156
Treatment 2	No Tolerance	99.0	100.0	1	83.9	218
Treatment Year 2	±1 year	99.0	.	.	97.6	41
Treatment 3	No Tolerance	99.0	.	.	94.5	73
Treatment Year 3	±1 year	99.0	.	.	80.0	5
Physiographic Class	No Tolerance	80.0	98.7	75	84.9	2,889
Present Nonforest Use	No Tolerance	99.0	94.6	149	94.6	4,141
Boundary Level						
Boundary Change	No Tolerance	99.0	89.5	38	81.8	868
Contrasting Condition	No Tolerance	99.0	97.4	38	95.5	868
Left Azimuth	±10 degrees	90.0	89.5	38	87.1	868
Corner Mapped	No Tolerance	90.0	100.0	38	94.8	868
Corner Azimuth	±10 degrees	90.0	100.0	2	92.8	83
Corner Distance	±1 foot	90.0	100.0	2	91.6	83
Right Azimuth	±10 degrees	90.0	94.7	38	87.1	868
Subplot Level						
Subplot Center Condition	No Tolerance	99.0	99.3	288	98.3	10,100
Microplot Center Condition	No Tolerance	99.0	99.3	288	98.1	10,100
Slope	±10 percent	90.0	99.0	208	98.8	8,565
Aspect	±10 degrees	90.0	99.0	205	94.7	8,360
Snow/Water Depth	±0.5 foot		80.8	208	67.7	8,604

continued

Table C.—continued

Variable	Tolerance	Objective	Iowa		All NRS states	
			Data within tolerance	Observations	Data within tolerance	Observations
Tree Level		-------*percent*-------		*number*	*percent*	*number*
D.b.h.	±0.1 inch per 20 inches	95.0	96.4	924	95.6	37,635
D.r.c.	±0.1 inch per 20 inches	95.0	.	.	73.9	69
Azimuth	±10 degrees	90.0	99.4	1,046	99.3	42,172
Horizontal Distance	±0.2 foot per 1.0 foot	90.0	98.9	1,046	98.7	42,172
Species	No Tolerance	95.0	99.5	1,057	98.4	42,475
Tree Genus	No Tolerance	99.0	100.0	1,057	99.6	42,433
Tree Status	No Tolerance	95.0	99.8	1,057	98.9	42,481
Rotten/Missing Cull	±10 percent	90.0	99.0	726	98.4	27,670
Total Length	±10 percent	90.0	90.9	724	79.7	27,368
Actual Length	±10 percent	90.0	92.6	94	74.0	3,340
Compacted Crown Ratio	±10 percent	80.0	95.2	852	83.0	35,071
Uncompacted Crown Ratio (P3)	±10 percent	90.0	92.8	69	78.2	1,984
Crown Class	No Tolerance	85.0	87.8	852	81.8	35,071
Decay Class	±1 class	90.0	98.8	163	96.0	6,211
Cause of Death	No Tolerance	80.0	88.3	163	83.6	6,211
Condition	No Tolerance	99.0	99.3	1,057	98.3	42,481
Crown Position	No Tolerance		96.7	60	95.1	1,622
Crown Light Exposure	±1 class	85.0	100.0	69	98.0	1,984
Sapling Crown Vigor Class	No Tolerance	85.0	100.0	9	95.0	362
Crown Density	±10 percent	90.0	100.0	60	92.4	1,622
Crown Dieback	±10 percent	90.0	96.7	60	98.0	1,622
Transparency	±10 percent	90.0	100.0	60	98.2	1,622
Tree Class	No Tolerance	90.0	95.2	926	92.4	38,026
Damage Agent 1	No Tolerance	90.0	93.2	852	90.2	35,071
Damage Agent 2	No Tolerance	90.0	80.8	146	78.2	6,760
Tree Grade	No Tolerance	90.0	87.4	238	74.8	8,251
D.b.h.-Live & Trees with Decay Code 1 or 2	±0.1 inch per 20 inches	95.0	96.3	889	95.4	35,903
D.b.h.-Trees with Decay Codes 3, 4, or 5	±1 inch per 20 inches	95.0	100.0	35	99.5	1,732
Total Length-trees 40 feet and greater	±10 percent	90.0	91.1	529	81.4	21,658
Total Length-trees less than 40 feet	±10 percent	90.0	90.3	195	73.1	5,710
Total Length-trees less than 5 inches d.b.h.	±10 percent	90.0	88.9	9	70.8	349
Seedling Level						
Species	No Tolerance	85.0	92.5	227	92.5	8,648
Genus	No Tolerance	90.0	97.8	227	96.8	8,648
Seedling Count	±20 percent	90.0	69.2	227	63.1	8,648
Seedling Count (coded)	No Tolerance	90.0	76.2	227	69.3	8,648
Site Tree Level						
Condition List	No Tolerance	99.0	100.0	118	93.1	2,775
Diameter	±0.1 inch per 20 inches	95.0	98.3	118	98.0	2,775
Species	No Tolerance	95.0	100.0	118	99.3	2,775
Genus	No Tolerance	99.0	100.0	118	100.0	2,775
Azimuth	±10 degrees	90.0	100.0	118	99.1	2,775
Distance	±5 feet	90.0	100.0	118	99.3	2,775
Total Length	±10 percent	90.0	100.0	118	98.5	2,775
Diameter Age	±5 years	95.0	99.2	118	98.0	2,775

Table D.—Observed relative bias values (average [field crew - QA crew]) for measurement variables based on blind check plots, Iowa, 2009-2013

Variable	Unit of measure	Iowa				All NRS states			
		Relative bias	95% CI limits		Observations	Relative bias	95% CI limits		Observations
			Lower	Upper			Lower	Upper	
Plot Level					*number*				*number*
Elevation	foot	-0.38	-8.39	7.04	71	225.42	46.68	449.57	2,197
Latitude - decimal degrees	degree	0.00	0.00	0.00	71	0.00	0.00	0.00	2,201
Longitude - decimal degrees	degree	-0.01	-0.02	0.00	71	0.00	-0.01	0.00	2,201
Condition Level									
Stand Age	year	0.17	-0.62	1.32	75	-0.25	-0.82	0.43	2,889
Treatment Year 1	year	0.00	0.00	0.00	1	0.13	0.02	0.24	156
Treatment Year 2	year					-0.15	-0.39	0.07	41
Treatment Year 3	year					-0.60	-1.40	0.00	5
Boundary Level									
Contrasting Condition	cond	-0.03	-0.08	0.00	38	0.01	0.00	0.03	868
Left Azimuth	degree	4.18	-1.18	14.24	38	0.08	-2.44	2.66	868
Corner Azimuth	degree	2.50	0.00	5.00	2	6.00	-0.62	18.80	83
Corner Distance	foot	0.00	0.00	0.00	2	-0.10	-0.50	0.19	83
Right Azimuth	degree	6.55	0.66	17.46	38	1.61	-1.10	4.59	868
Subplot Level									
Slope	percent	0.05	-0.29	0.49	208	0.04	-0.05	0.13	8,565
Aspect	degree	-0.26	-0.78	0.06	205	0.29	-0.33	0.92	8,360
Snow/Water Depth	foot	-0.62	-0.99	-0.22	208	-0.28	-0.39	-0.17	8,604
Tree Level									
D.b.h.	inch	-0.02	-0.03	-0.01	924	0.00	0.00	0.00	37,635
D.r.c.	inch					0.06	-0.10	0.23	69
Azimuth	degree	-0.13	-0.36	0.02	1,046	-0.03	-0.09	0.03	42,172
Horizontal Distance	foot	0.02	0.00	0.05	1,046	0.00	-0.01	0.00	42,172
Rotten/Missing Cull	percent	-0.29	-0.52	-0.10	726	-0.15	-0.20	-0.11	27,670
Total Length	foot	0.39	-0.09	0.94	724	0.21	0.09	0.33	27,368
Actual Length	foot	-0.93	-1.94	0.22	94	-1.46	-2.62	-0.50	3,340
Compacted Crown Ratio	percent	-0.82	-1.27	-0.34	852	0.11	-0.01	0.20	35,071
Uncompacted Crown Ratio (P3)	percent	-0.16	-2.03	1.61	69	-3.07	-3.80	-2.24	1,984
Crown Density	percent	0.67	0.00	1.38	60	-0.87	-1.17	-0.50	1,622
Crown Dieback	percent	1.40	-0.92	5.19	60	-0.19	-0.48	0.11	1,622
Transparency	percent	0.17	-0.17	0.50	60	-0.69		-0.38	1,622
D.b.h.-Live & Trees with Decay Code 1 or 2	inch	-0.02	-0.03	-0.01	889	0.00	0.00	0.00	35,903
D.b.h.-Trees with Decay Codes 3, 4, or 5	inch	-0.06	-0.11	-0.02	35	-0.02	-0.05	-0.01	1,732
Total Length-trees 40 feet and greater	foot	1.13	0.62	1.65	529	0.70	0.58	0.83	21,658
Total Length-trees less than 40 feet	foot	-1.62	-2.42	-0.77	195	-1.67	-2.00	-1.39	5,710
Total Length-trees less than 5 inches d.b.h.	foot	1.96	-1.39	5.82	9	-1.53	-2.82	-0.05	349
Seedling Level									
Seedling Count	number	-11.29	-19.44	-4.03	216	-12.53	-14.37	-10.94	8,496
Seedling Count (coded)	number	-0.07	-0.18	0.01	227	0.00	-0.02	0.02	8,648
Site Tree Level									
Diameter	inch	0.00	0.00	0.00	118	0.00	-0.01	0.01	2,775
Azimuth	degree	0.02	-0.04	0.09	118	0.14	-0.18	0.47	2,775
Distance	foot	0.00	-0.01	0.01	118	0.04	0.00	0.08	2,775
Total Length	foot	-0.06	-0.25	0.05	118	-0.04	-0.22	0.13	2,775
Diameter Age	year	-0.17	-0.62	0.00	118	0.00	-0.09	0.11	2,775

Table E.—FIA nonresponse by stratum, Iowa, 2009-2013

Forest Inventory Unit [a] and ownership layer [b]	Canopy cover class [c]	Number of plots selected	Sampled	Denied access	Hazardous	Other	Response rate (%)
1 - Northeastern							
Inland census water	0-100	12	12	0	0	0	100.0
	Total	12	12	0	0	0	100.0
Private	0-5	1,295	1,289	6	0	0	99.5
	6-50	79	74	5	0	0	93.7
	51-65	29	27	2	0	0	93.1
	66-80	24	23	2	0	0	93.8
	81-100	98	87	10	1	0	89.2
	Total	1,525	1,500	25	1	0	98.4
Public	0-5	14	14	0	0	0	100.0
	66-100	12	12	0	0	0	100.0
	Total	26	26	0	0	0	100.0
	Unit Total	1,563	1,538	25	1	0	98.4
2 - Southeastern							
Inland census water	0-100	18	18	0	0	0	100.0
	Total	18	18	0	0	0	100.0
Private	0-5	1,565	1,561	4	0	0	99.7
	6-50	64	61	3	0	0	95.3
	51-65	24	23	1	0	0	93.8
	66-80	33	32	1	0	0	97.0
	81-100	149	138	12	0	0	92.3
	Total	1,835	1,814	21	0	0	98.9
Public	0-5	19	19	0	0	0	100.0
	6-80	14	14	0	0	0	98.2
	81-100	20	20	0	0	0	100.0
	Total	53	53	0	0	0	99.5
	Unit Total	1,906	1,885	21	1	0	98.9
3 - Southwestern							
Inland census water	0-100	4	4	0	0	0	100.0
	Total	4	4	0	0	0	100.0
Private	0-5	1,091	1,089	2	0	0	99.8
	6-50	25	22	3	0	0	89.0
	51-80	20	17	3	0	0	85.0
	81-100	39	36	3	0	0	92.3
Private Unit	**Total**	1,175	1,164	11	0	0	99.1
Public Unit	0 -100	20	20	0	0	0	98.8
	Total	20	20	0	0	0	98.8
	Unit Total	1,199	1,188	11	1	0	99.1
4 - Northwestern							
Inland census water	0-100	5	5	0	0	0	100.0
	Total	5	5	0	0	0	100.0
Private	0 -5	1,347	1,347	0	0	0	100.0
	6-50	11	11	0	0	0	100.0
	51-100	16	12	4	0	0	75.0
	Total	1,374	1,370	4	0	0	99.7
Public	0-100	20	20	0	0	0	98.8
	Total	20	20	0	0	0	95.4
	Unit Total	1,399	1,395	4	0	0	99.7
	State Total	6,067	6,005	60	2	0	99.0

continued

Table E.—Footnote

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

1 - Northeastern	2 - Southeastern	3 - Southwestern	4 - Northwestern
Allamakee	Appanoose	Adair	Buena Vista
Benton	Boone	Adams	Calhoun
Black Hawk	Clarke	Audubon	Cerro Gordo
Bremer	Dallas	Carroll	Cherokee
Buchanan	Davis	Cass	Clay
Butler	Decatur	Crawford	Dickinson
Cedar	Des Moines	Fremont	Emmet
Chickasaw	Guthrie	Greene	Franklin
Clayton	Hamilton	Harrison	Hancock
Clinton	Hardin	Mills	Humboldt
Delaware	Henry	Monona	Ida
Dubuque	Iowa	Montgomery	Kossuth
Fayette	Jasper	Page	Lyon
Floyd	Jefferson	Pottawattamie	O'Brien
Grundy	Keokuk	Ringgold	Osceola
Howard	Lee	Shelby	Palo Alto
Jackson	Louisa	Taylor	Plymouth
Johnson	Lucas	Union	Pocahontas
Jones	Madison	Woodbury	Sac
Linn	Mahaska		Sioux
Mitchell	Marion		Winnebago
Scott	Marshall		Worth
Tama	Monroe		Wright
Winneshiek	Muscatine		
	Polk		
	Poweshiek		
	Story		
	Van Buren		
	Wapello		
	Warren		
	Washington		
	Wayne		
	Webster		

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

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