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FOREST INVENTORY METHODS

Strategic Model

The Forest Inventory and Analysis program of the Northern Research Station (NRS-FIA) is part of the national enhanced FIA program that focuses on a set of six strategic objectives (McRoberts 2005)[1]:

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

To ensure that these six strategic 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 of estimates of prescribed core variables
- Publication of statewide tables of 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 the detection monitoring by the U.S. Forest Service's Forest Health Monitoring (FHM) program.

[1] Citations available in Delaware Forests 2013 available at https://doi.org/10.2737.NRS-RB-115.

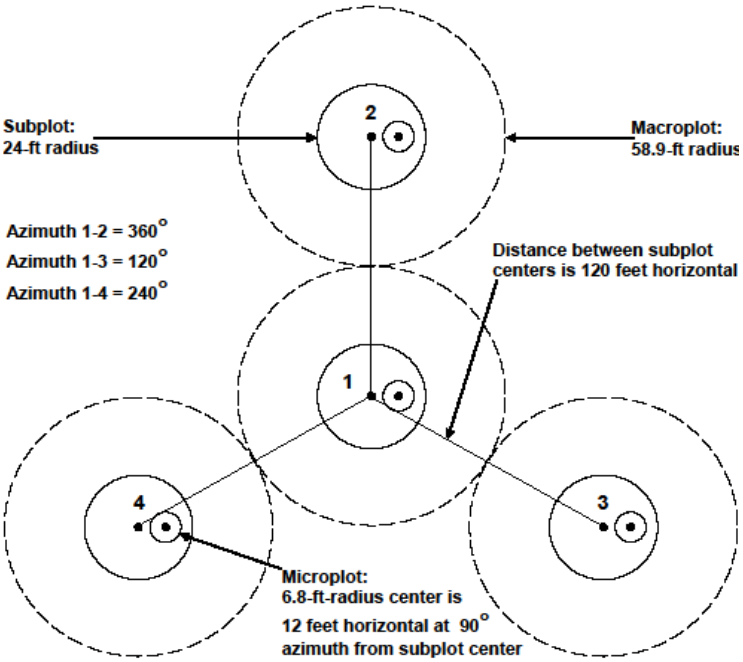

Figure 78.—National Forest Inventory and Analysis plot design (adapted from Bechtold and Patterson 2005).

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. 78). Centers of the peripheral subplots are located at distances of 120 feet from the central subplot at azimuths of 0º, 120º, and 240º from the center of the central subplot. Trees with a diameter at breast height (d.b.h.) of 5 inches or greater are measured on these subplots. Each subplot contains a 6.8-foot-radius microplot with center located 12 feet east of the subplot center on which each tree with a d.b.h. between 1 and 5 inches is measured. Forest conditions that occur on any of the four subplots are identified and recorded. If the area of the condition is 1 acre or greater, the condition is mapped on the subplot. Factors that differentiate forest conditions include forest type, stand-size class, stand origin, land use, ownership, and density.

Sample Design

Based on historical sampling errors, a sampling intensity of about one plot per 6,000 acres is necessary to satisfy national FIA precision guidelines. Therefore, FIA divided the area of the United States into nonoverlapping, 5,937-acre hexagons and established a sample plot location in each hexagon. This array of field plots is designated the Federal base sample, and measurements taken on these plots are funded by the Federal Government. Because of Delaware's small size, the number of inventory plots in the State was doubled, resulting in a sampling intensity of about one plot per 3,000 acres. The hexagon grid and plot location selection method used in Delaware was the same as described above for the Federal sample, however two plots were located in each hexagon.

The Federal base sample was systematically divided into five interpenetrating, nonoverlapping panels or subsamples, each of which provides complete, systematic coverage of a state. Each year, the plots in a single panel are measured and panels are selected on a 5-year, rotating basis (McRoberts 1999) such that plots measured in 2004 were remeasured in 2009. 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. P3 has been replaced by Phase 2-plus (P2+). In P2+ less data are collected per plot but more plots are sampled. Otherwise, P2+ and P3 follow the same paradigm, focusing on forest and ecosystem health. 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 via remotely sensed data and stratification. P1 plot measurement consists of observations of conditions at the plot locations using aerial photographs or DOQs. Analysts determine a digitized geographic location for each field plot, and a human interpreter assigns the plot a land cover/use. 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 nonforested land that currently is below minimum stocking levels. All plot locations that could possibly contain accessible forest land plus any additional plots that contained forest land at the previous 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 by using ancillary data. Thus, the land area is stratified by using remotely sensed data to facilitate stratified estimation. NRS-FIA uses canopy density classes to derive strata. Canopy density data are derived from the National Land Cover Database (NLCD) 2011 and the U.S. Forest Service Tree Canopy cartographic (TCC) 2011 dataset, which was produced through a cooperative project conducted by the Multi-Resolution Land Characteristics Consortium. TCC 2011 is the NLCD tree canopy cover product that covers the contiguous United States at a medium spatial resolution (30 meters). It was produced by the U.S. Forest Service's Remote Sensing Applications Center using a Random Forests™ regression algorithm (Breiman 2001). The layer consists of a single raster layer: percent tree canopy cover. Pixels characterize subtle variations in forest canopy density as a percentage estimate of forest canopy cover (0 to 100 percent) within every 30-m pixel over the United States. In other words, each individual value represents the area or proportion of that 30-m cell covered by tree canopy. Homer et al. (2015) describe the methods used to create the NLCD 2011. Coulston et al. (2012) describe the methods for mapping canopy density for TCC.

Strata Construction

The strata construction methods used were developed to work well across 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 (Fig. 79). These groupings were based on observed natural clumping of pixel values.

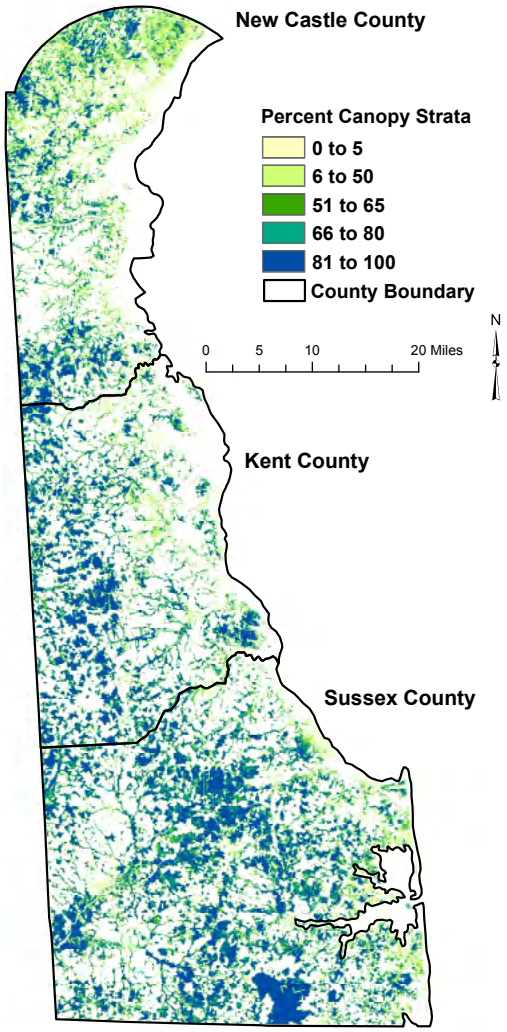

Figure 79.—Percent canopy strata groupings, Delaware, 2011.

In addition to the classification of every pixel into one of the five canopy cover classes, every pixel was also assigned to an ownership class. The Protected Areas database (Conservation Biology Institute 2010) was initially used and then state-specific data were added. The largest ownership class, based on pixel counts, was private ownership Every pixel was also assigned to a county based on the location of the pixel center. 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. These collapsed classes defined the strata used in the estimation. NRS-FIA required a minimum of 10 plots per stratum. Stratified estimation requires the completion of two tasks. First, each plot must be assigned to a single stratum. Next, the proportion of the total area in each stratum must be calculated. 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 are presented in the estimation section of this report.

P2

All plots are prescreened in P1 to determine which plots require a field visit in P2. Expert photointerpreters examine each plot on high resolution imagery to identify the potential for forest cover. If there is a potential for forest cover, that plot is visited. Before visiting plot locations, field crews consult county land records to determine the ownership of plots and then seek permission from private landowners to measure plots on their lands. At the plot, field crews determine the location of the geographic center of the center subplot using global positioning system (GPS) receivers. They record condition-level observations that include land cover, forest type, stand origin, stand age, stand-size class, site productivity class, history of forest disturbance, and land use for every condition (major land use of forest stand at least 1 acre in size) that occurs on the plot. Crews also record information on condition boundaries when multiple conditions are found on a plot.

For each tree, field crews record a variety of observations and measurements including condition, species, live/dead status, lean, diameter, height, crown ratio (percentage of tree height represented by crown), crown class (dominant, codominant, suppressed), damage, and decay status. All trees measured in the previous measurement of the plot are remeasured or otherwise accounted for, and any new trees that have grown onto the plot are measured. Office staff use statistical models based on field-crew measurements to calculate values for additional variables including individual tree volume, per unit area estimates of number of trees, volume, and biomass by plot, condition, species group, and live/dead status. The remeasurement of every tree enables the calculation of components of change including growth, mortality, and removals. Additional details on data collection procedures used in P2 of this inventory are described in version 5.0 of the Forest Inventory and Analysis core field guide (U.S. Forest Service 2010), and O'Connell et al. (2014) describe the P2 database.

P3 (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. Finally, research on monitoring techniques focuses on developing and refining indicator measurements to improve the efficiency and reliability of data collection and analysis at all levels of the program.

The ground survey portion of the FHM detection monitoring program was integrated into the FIA program as P3 in 1999. The P3 sample consists of a 1:16 subset of the P2 plots with one P3 plot for approximately every 96,000 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, and down woody material. 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. Additional information on the collection procedures used in P3 of this inventory are available at http://www.nrs.fs.fed.us/fia/topics/.

P3 variables were 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 serve as the Nation's environmental report card and 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 onward)

For most forest health indicators, P2+ is a more refined and statistically powerful version of P3, collecting only the more important attributes and sampling a greater number of plots. The P3 sample included approximately 6.3 percent of the P2 plots. Since 2012, P2+ protocols have been completed on approximately 12.5 percent of the P2 plots (including the historical P3 plots) and may be completed on up to approximately 25 percent of the plots depending upon future funding. The soils indicator is the one exception which will remain with the 6.3 percent sample intensity using the historical P3 plots and sampling protocol. The field guide for collecting attributes on P2+ plots (U.S. Forest Service 2016) 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 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, as well as an indication of the expected future forest composition.

Vegetation Profile

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

Invasive Plants

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

Down Woody Materials

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

- Quality and status of wildlife habitats
- Structural diversity within a forest

- Fuel loading and fire behavior
- Carbon sequestration (amount of carbon tied up in dead wood)
- Storage and cycling of nutrients and water (important for site productivity)

Soils

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

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

Crowns

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

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

Estimation

The FIA sample includes 436 plots (386 sampled plots) located across Delaware. These plots are located within 9 unique strata (Table A; see page 24) defined by combinations of the five P1 canopy cover classes: (1) 0 to 5 percent, (2) 6 to 50 percent, (3) 51 to 65 percent, (4) 66 to 80 percent, and (5) 81 to 100 percent, a land ownership classification created from the Protected Areas Database, and county groups (FIA units). Nationally consistent algorithms were used to assign forest type and stand-size class to each condition observed on a plot. For NRS-FIA, panels are measured on an annual basis so that five panel estimates are equivalent to 5-year moving average estimates. Field plot measurements are combined with P1 estimates in the compilation process and table production. Procedures described in Bechtold and Patterson (2005) for stratified estimation with observed stratum areas were used in conjunction with the strata presented in Table A to produce all estimates.

Integration with Previous Inventories

In 2013, NRS-FIA completed the second full annual inventory of plots in Delaware, which consists of panels surveyed in 2009, 2010, 2011, 2012, and 2013. Previous inventories of Delaware's forest resources were in 1957 (Ferguson 1959), 1972 (Ferguson and Mayer 1974), 1986 (Frieswyk and DiGiovanni 1989), 1999 (Griffith and Widmann 2001), and 2008 (Lister et al. 2011).

Data from new inventories are often 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 2008 and 2013 inventories; therefore comparisons made between these inventories are relatively uncomplicated.

Comparisons with the earlier inventories are more problematic as there were changes in plot design, measurements taken, and classification methods between each of these inventories. For the sake of consistency, a new, national plot design was implemented by all four regional FIA units in 1999. The new design uses fixed-radius subplots exclusively. Prior to this new plot design, fixed- and variable-radius subplots were used. 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 2013, timberland estimates generated for earlier annual inventories will differ from previously published estimates. The 2012 inventory was the last inventory in which all data were available under the previous 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 (- 6 percent). Estimates of growth, mortality, and removals on growing stock changed by - 6 percent, -12 percent, and -11 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

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.

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 had been observed and included in the estimate. The 2013 inventory of Delaware is based on a sample of 847 plots located randomly across the State (a total area of about 1.3 million acres), a sampling rate of approximately 1 plot for every 2,974 acres.

The procedures for statistical estimation outlined in the previous section and described in detail in Bechtold and Patterson (2005) provide the estimates of the population totals and means presented in this report. Along with every estimate is an associated sampling error that is typically expressed as a percentage of the estimated value but that can also be expressed in the same units as the estimate or as a confidence interval (the estimated value plus or minus the sampling error). This sampling error is the primary measure of the reliability of an estimate. A sampling error can be interpreted to mean that had a 100-percent inventory been taken using these methods, the chances are two out of 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 DE-65 presents sampling errors for these estimates at county group levels.[2] Estimates for classifications smaller than the State totals presented in Table B will have larger sampling errors. For example, Table DE-60 shows that the sampling error for timberland area in any county is higher than that for total timberland area in the State. To compute an approximate sampling error for an estimate that is smaller than a State total, use the following formula:

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

Where

E = approximate sampling error for smaller estimate

SE = sampling error for State total estimate (percent)

For example, to compute the approximate error on the area of private forest land in the State, proceed as follows:

Total area of private forest land in the State (see Table DE-2) = 279,200 acres

Total area of all forest land in the State from (see Table DE-2) = 362,100 acres

State total error for forest land area (see Table B) = 3.7 percent

Sampling error = $E = \frac{(3.7)\sqrt{(362{,}100)}}{\sqrt{(279{,}200)}}$ = 4.21 percent

[2] Tables labeled with the State abbreviation followed by a number (e.g., Table DE-1) are located in a supplemental file labeled "Delaware Forests 2013 Estimate Tables" available at https://dx.doi.org/102737/NRS-RB-115. Tables labeled with letters (e.g., Table A) begin on page 23.

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 forest inventory data summarization tools (EVALIDator, DATIM, etc.), available at https://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, 30 to 70 trees are observed with 15 to 20 attributes recorded for 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), then the estimates that use this observation (such as volume) will reflect this bias. Even if measurements are unbiased, high levels of random error in the measurements will add to the total random error of the estimation process.

To ensure that all FIA observations are made to the highest standards possible, a regular program of quality assurance and quality control 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. To assess the quality of the data collected by these trained crews, a random sample of at least 4 percent of all plots are measured independently by a different expert crew. These independent measurements are referred to as blind checks, and the purpose of these blind checks is to assess the quality of field measurements. The second measurement on these 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 quality of field measurements is assessed nationally through a set of measurement quality objectives (MQOs) that are set for every data item collected. Each MQO consists of two parts: a tolerance or acceptable level of measurement error, and an objective in terms of the 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. The columns labeled "Delaware" come from blind check measurements of plots used in this report, and the columns labeled "All NRS States" come from all measurements made by FIA crews within the entire 24-state area where the Northern Research Station implemented the FIA program from 2009 through 2013. Training and supervision of crews is a regional effort, and crews often work in more than one state. Regional data quality observations reflect the overall measurement quality of all data collected by FIA in the NRS region.

In addition to the percent compliance to measurement quality objectives, 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.

The 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 the measurements. These methods have been identified as the best available and were selected for use nationwide by FIA; they are commonly used by other similar natural resource inventories. A basic assumption is that the methods, when correctly applied, provide unbiased observations of the attribute they are designed to measure. Under this assumption, relative bias observations in Table D provide observations of bias due to the difference in experience and training between the field and QA crews. In most cases there is no significant bias.

Prediction Error

Errors associated with using mathematical models (such as volume models) to provide observations of the attributes of interest based on sample attributes are referred to as prediction errors. Area, number of trees, volume, biomass, growth, removals, and mortality are the primary attributes of interest presented in this report. Area and number of trees estimates are based on direct observation and do not involve the use of prediction models; however, FIA estimates of volume, biomass, growth, removals, and mortality use model-based predictions in the estimation process. 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.

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

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

Nonresponse has two effects on the sample. First, it reduces the sample size, which is reflected in the sampling errors. Second, nonresponse can bias the estimates if the portion of the population not being sampled differs from the portion being sampled. In FIA, unlike many survey samples, nonresponse rates are relatively low. In the 2013 Delaware inventory, a total of 436 sample plots were selected for field visits. Of the total sample plots selected for field visits, 386 are in the sample used for the estimation of the current resources (Table E). There were 50 plots where crews were unable to obtain owner permission to measure the plot or where hazardous conditions prevented the crew from measuring the plot.

Even though an overall response rate of 88.6 percent is relatively high, it can cause considerable bias if not properly accounted for. The major source of nonresponse is denied access to plots. Denied access plots primarily occur on lands in private ownership. Also, the observations needed for plots on nonforest and water classes do not usually require crews to physically enter the land, and permission is not needed to obtain the observation because it can be obtained from aerial photos or other remotely sensed information sources.

The stratified estimation process used by NRS-FIA with strata defined by three ownership classes (inland census water, other public, and private) and five canopy cover classes reduces the possible effects of bias caused by nonresponse. Under this stratified estimation process, nonresponses are removed from the sample and stratum estimates are obtained from only those plots with valid observations. 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 Delaware 2013 inventory and for all FIA inventories conducted by the Northern Research Station over the same period.

The nonresponse plots in this inventory were not permanently removed from the FIA system of plots. In future inventories, attempts will again be made to measure these plots. At that time permission to access these plots may be obtained, the hazardous conditions may have changed, or other circumstances that caused plots to be dropped from a specific inventory cycle may be different.

GLOSSARY

Accretion: The estimated net growth on trees that were measured during the previous inventory. Average annual accretion is calculated by dividing net growth by the number of growing seasons between surveys. It does not include growth on trees cut during the period nor those trees that died. This component uses the incremental change in volume between two inventories.

Average annual mortality of growing stock: The average annual change in cubic-foot volume of sound wood in growing-stock trees that died over a defined measurement cycle.

Average annual mortality of sawtimber: The average annual change in board-foot volume of sound wood in sawtimber trees that died over a defined measurement cycle.

Average annual net growth of growing stock: The average annual change in cubic-foot volume of sound wood in live growing-stock trees, and the total volume of trees entering diameter classes greater than or equal to 5.0 inches d.b.h., through ingrowth, less volume losses resulting from natural causes. Natural causes include mortality except that due to logging damage, timber stand improvement, or conversion to a nonforest land use.

Average annual net growth of sawtimber: The average annual change in the board-foot volume of live sawtimber trees, and the total volume of trees reaching sawtimber size, less volume losses resulting from natural causes. Natural causes include mortality except that due to logging damage, timber stand improvement, or conversion to a nonforest land use.

Average annual removals from growing stock: The average cubic-foot volume of wood in live growing-stock trees removed annually for roundwood forest products, in addition to the volume in logging residues or mortality due to logging damage (harvest removals). This component of change also includes the volumes of growing-stock trees removed due to land-use changes (other removals).

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

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

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

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

Bulk density: The mass of soil per unit of 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.

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 currently or prospectively suitable for industrial wood products; excludes species of typically small size, poor form, or inferior quality, e.g., hawthorn (*Crataegus* spp.) and *sumac (Rhus* spp.).

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.

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

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

County and municipal: A class of public lands owned by counties or local public agencies, or lands leased by these governmental units for more than 50 years.

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 decrement: The net volume of rough and rotten cull trees in the previous inventory that are classified as growing-stock trees in the current inventory. Average annual cull decrement is calculated by dividing the net volume by the number of growing seasons between inventories.

Cull increment: The net volume of growing-stock trees in the previous inventory that are classified as rough and rotten cull trees in the current inventory. Average annual cull increment is calculated by dividing net volume by the number of growing seasons between inventories.

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

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

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

Diameter class: A classification of trees based on diameter at breast height (d.b.h.), which is the diameter outside bark measured at 4.5 feet above the ground. With 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches d.b.h. A diameter at root collar (d.r.c.) measurement is taken for multi-stemmed woodland species such as Rocky Mountain juniper (*Juniperus scopulorum*).

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

Dry ton: A unit of measure of dry weight equivalent to 2,000 pounds or 907.1848 Kg.

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

Duff: A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer

is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) can no longer be identified.

Effective cation exchange capacity (ECEC): The sum of cations that a soil can adsorb in its natural pH. 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 industry: An ownership class of private lands owned by companies or individuals operating wood-using plants.

Forest land: Land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest type: A classification of forest land based on the species presently forming a plurality of the live-tree stocking.

Forest-type group: A combination of forest types that share closely associated species or site requirements and are generally combined for brevity of reporting. Major eastern forest-type groups include the following:

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

oak/pine. Common associates include cottonwood, willow, ash, elm, hackberry, and maple.

Elm/ash/cottonwood: Forests in which elm, ash, or cottonwood, singly or in combination, comprise a plurality of the stocking. Common associates include willow, sycamore, beech, and maple.

Maple/beech/birch: Forests in which maple, beech, or yellow birch, singly or in combination, comprise a plurality of the stocking. Common associates include hemlock, elm, basswood, and white pine.

Aspen/birch: Forests in which aspen, balsam poplar, paper birch, or gray birch, singly or in combination, comprise a plurality of the stocking. Common associates include maple and balsam fir.

Gross growth: The sum of accretion and ingrowth.

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

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

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.

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

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

Invasive species: Those species whose introduction does, or is likely to, cause economic or environmental harm or harm to human health. For the purpose of this policy only, a plant species is considered "invasive" only when it occurs on the Federal or State-specific noxious weed list or a list developed by the State-specific Department of Agriculture with their

partners and approved by the State Technical Committee, which prohibits or cautions its use due to invasive qualities (USDA definition).

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

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

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

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

> **Bole:** Biomass of a tree from 1 foot above the ground to a 4-inch top outside bark or to a point where the central stem breaks into limbs.
>
> **Tops and limbs:** Total biomass of a tree from a 1-foot stump minus the bole.
>
> **Saplings:** Total aboveground biomass of a tree from 1.0 to 4.9 inches in d.b.h.
>
> **Stump:** Biomass of a tree 5.0 inches d.b.h. and larger from the ground to a height of 1 foot.

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 government.

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

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

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

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

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

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

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

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.)

Nonindustrial private: An ownership class of private lands where the owner does not operate wood-using plants.

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.

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 (O_3) produced primarily through sunlight-driven chemical reactions of nitrogen dioxide and hydrocarbons in the atmosphere and causing foliar injury to deciduous trees, conifers, shrubs, and herbaceous species.

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

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

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

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

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

Primary wood-using mill: A mill that converts roundwood products into other wood products. Common examples are sawmills that convert saw logs into lumber and 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 include saw logs, veneer, cooperage logs, bolts, pulpwood logs, fuelwood, pilings, posts and poles, 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.

Sapling: Live tree 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 in board-feet (International ¼-Inch Rule) or cubic-feet of the sawlog portion of live sawtimber trees measured from the 1-foot stump to a minimum 7.0 inches top diameter outside bark (for softwoods) or 9.0 inches top diameter outside bark (for hardwoods), on the central stem, or to the point where the central stem splits into smaller limbs. Net volume equals gross volume minus deduction for rough and rotten cull.

Seedling: Live tree smaller than 1.0 inch d.b.h. / d.r.c. and at least 6.0 inches in height for softwoods and 12.0 inches in height for hardwoods.

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

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

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

Sound dead: The net volume in salvable dead trees.

Species group: A combination of tree species that share closely associated understory plants or site requirements.

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

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

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

> **Nonstocked:** Forest land stocked with less than 10 percent of full stocking with live trees. Examples are recently cutover areas or recently reverted agricultural fields.
>
> **Seedling-sapling:** Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in seedlings or saplings or both.
>
> **Poletimber:** Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of poletimber exceeds that of sawtimber.
>
> **Sawtimber:** Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of sawtimber is at least equal to that of poletimber.

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

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

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

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

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

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

Total live tree biomass: The total mass of live trees and associated saplings expressed in pounds or tons (dry weight) per unit area. The total tree and sapling biomass (excluding foliage) has five 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 splits into smaller limbs. This includes perturbing twigs from the central stem.
>
> **Tops and limbs:** Total biomass of a tree from the 12-inch stump minus the bole. This does not include any twigs perturbing from the central stem below the 4-inch top.
>
> **Saplings:** Total biomass of trees from 1.0 to 4.9 inches diameter measured at the root collar d.b.h. or d.r.c.
>
> **Stump:** Total biomass of a tree 5.0 inches d.b.h. and larger from the ground to a height of 1 foot.
>
> **Belowground:** Total biomass of the belowground portion of the stump and the coarse roots of all trees and saplings.

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

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

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

Unreserved forest land: Forest land not withdrawn from harvest by statute or administrative regulation. 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 esthetic purposes.

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

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

TABLES

Tables labeled with the State abbreviation followed by a number (e.g., Table DE-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 "Delaware Forests 2013 Estimate Tables" at https://doi.org/102737/NRS-RB-115.

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 control objectives.

Table A.—Area and number of plots in each stratum used for stratification and estimation, Delaware, 2013

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

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

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

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

Table A.—Area and number of plots in each stratum used for stratification and estimation, Delaware, 2013

Estimation unit description [a]	Canopy cover stratum [b]	Area (Acres)	Selected [c]	Office selected [d]	Field selected [e]	Field sampled [f]	Field sampled forested [g]	Total plots sampled for change [h]	Field sampled plots for change [i]	Not measured [j]
Inland Census Water Unit 1	Canopy cover 0 - 100	45986	11	11	0	0	0	11	0	0
Private Unit 1	Canopy cover 0 - 5	640174	195	180	15	10	5	194	14	5
Private Unit 1	Canopy cover 51 - 65	46585	15	1	14	12	10	15	14	2
Private Unit 1	Canopy cover 6 - 50	156418	51	19	32	28	24	47	28	4
Private Unit 1	Canopy cover 66 - 80	106611	37	1	36	24	22	30	29	12
Private Unit 1	Canopy cover 81 - 100	166658	74	0	74	50	50	60	60	24
Public Unit 1	Canopy cover 0 - 5	62974	27	20	7	7	4	27	7	0
Public Unit 1	Canopy cover 6 - 80	34471	13	2	11	11	8	12	11	0
Public Unit 1	Canopy cover 81 - 100	36956	13	0	13	13	13	13	13	0

[a] Estimation unit description: Description of the subpopulation undergoing poststratification. County groups are defined by one or more contiguous counties used for population estimation.

[b] Canopy cover stratum: A stratum within each estimation unit defined by partitioning the full range of percent canopy (0 - 100%) into five strata.

[c] Selected: The number of plots selected when the sample was drawn.

[d] Office selected: The number of plots determined to have no chance of being forested during a prefield interpretation procedure. These plots are withheld from field sampling and considered remotely sampled.

[e] Field selected: The number of plots determined to have some chance of being forested, or that were forested or nonsampled on a previous visit.

[f] Field sampled: The number of field selected plots that were successfully sampled in the field.

[g] Field sampled forested: The number of field selected plots that were successfully sampled in the field and found to intersect forest land.

[h] Total plots sampled for change: The number of plots included in the sample that were successfully sampled in the previous cycle.

[i] Field sampled plots for change: The number of plots included in the sample that were successfully sampled in the previous cycle and that were sent to the field for sampling.

[j] Not measured: The number of plots that were selected as part of the sample, but were completely nonsampled.

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

Item	State total	Sampling error
Growing stock on timberland	*million cubic feet*	*percent*
Volume	811.4	6.26
Average annual net growth	16.4	11.12
Average annual removals	6.9	39.02
Average annual mortality	6.7	18.88
Sawtimber on timberland	*million board feet* [a]	
Volume	3,112.5	7.79
Average annual net growth	80.4	11.13
Average annual removals	19.4	45.93
Average annual mortality	23.0	27.36
Area	*thousand acres*	
Forest land	362.1	3.69
Timberland	346.7	4.1
Biomass (aboveground live trees and saplings)	*million dry tons*	
Forest land	25.7	5.11
Timberland	24.4	5.52

[a] International ¼-inch Rule.

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

Variable	Tolerance	Objective	Delaware		All NRS states	
			Data within tolerance	Number of observations	Data within tolerance	Number of observations
Plot level		---------*percent*---------			*percent*	
Distance to road	No Tolerance	90.0	100.0	5	81.7	2,420
Water on plot	No Tolerance	90.0	80.0	5	86.7	2,420
Elevation	±50 feet	99.0	100.0	2	87.9	2,197
Latitude - decimal degrees	±0.0001 degree	99.0	100.0	2	100.0	2,201
Longitude - decimal degrees	±0.0001 degree	99.0	100.0	2	87.5	2,201
Condition level						
Condition status	No Tolerance	99.0	100.0	13	99.1	4,141
Reserve status	No Tolerance	99.0	100.0	13	99.5	4,141
Owner group	No Tolerance	99.0	100.0	6	98.7	2,889
Forest type (type)	No Tolerance	95.0	83.3	6	90.6	2,889
Forest type (group)	No Tolerance	99.0	83.3	6	95.3	2,889
Stand size	No Tolerance	99.0	100.0	6	91.2	2,889
Regeneration status	No Tolerance	99.0	100.0	6	98.5	2,889
Tree density	No Tolerance	99.0	100.0	6	97.7	2,889
Owner class	No Tolerance	99.0	100.0	6	95.9	2,889
Owner status	No Tolerance	99.0	100.0	6	99.2	2,889
Regeneration species	No Tolerance	99.0	100.0	6	98.4	2,889
Stand age	±10 percent	95.0	100.0	6	87.2	2,889
Disturbance 1	No Tolerance	99.0	100.0	6	90.4	2,868
Disturbance 2	No Tolerance	99.0	.	.	89.0	547
Disturbance 3	No Tolerance	99.0	.	.	97.3	75
Treatment 1	No Tolerance	99.0	100.0	6	97.7	2,868
Treatment year 1	±1 year	99.0	.	.	94.9	156
Treatment 2	No Tolerance	99.0	.	.	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	100.0	6	84.9	2,889
Present nonforest use	No Tolerance	99.0	92.3	13	94.6	4,141
Boundary level						
Boundary change	No Tolerance	99.0	100.0	3	81.8	868
Constrasting condition	No Tolerance	99.0	100.0	3	95.5	868
Left azimuth	±10 degrees	90.0	100.0	3	87.1	868
Corner mapped	No Tolerance	90.0	100.0	3	94.8	868
Corner azimuth	±10 degrees	90.0	.	.	92.8	83
Corner distance	±1 foot	90.0	.	.	91.6	83
Right azimuth	±10 degrees	90.0	100.0	3	87.1	868
Subplot level						
Subplot center condition	No Tolerance	99.0	100.0	24	98.3	10,100
Microplot center condition	No Tolerance	99.0	100.0	24	98.1	10,100
Slope	±10 percent	90.0	100.0	16	98.8	8,565
Aspect	±10 degrees	90.0	100.0	16	94.7	8,360
Snow/water depth	±0.5 foot		93.8	16	67.7	8,604

continued

Variable	Tolerance	Objective	Delaware		All NRS states	
			Data within tolerance	Number of observations	Data within tolerance	Number of observations
Tree level						
D.b.h.	±0.1 inch per 20 inches	95.0	97.8	89	95.6	37,635
D.r.c.	±0.1 inch per 20 inches	95.0	.	.	73.9	69
Azimuth	±10 degrees	90.0	100.0	102	99.3	42,172
Horizontal distance	±0.2 foot per 1.0 foot	90.0	99.0	102	98.7	42,172
Species	No Tolerance	95.0	100.0	102	98.4	42,475
Tree genus	No Tolerance	99.0	100.0	102	99.6	42,433
Tree status	No Tolerance	95.0	100.0	102	98.9	42,481
Rotten/missing cull	±10 percent	90.0	100.0	74	98.4	27,670
Total length	±10 percent	90.0	81.1	74	79.7	27,368
Actual length	±10 percent	90.0	66.7	6	74.0	3,340
Compacted crown ratio	±10 percent	80.0	88.0	83	83.0	35,071
Uncompacted crown ratio	±10 percent	90.0	82.5	40	78.2	1,984
Crown class	No Tolerance	85.0	91.6	83	81.8	35,071
Decay class	±1 class	90.0	100.0	13	96.0	6,211
Cause of death	No Tolerance	80.0	84.6	13	83.6	6,211
Condition	No Tolerance	99.0	100.0	102	98.3	42,481
Crown position	No Tolerance	85.0	77.8	36	95.1	1,622
Crown light exposure	±1 class	85.0	95.0	40	98.0	1,984
Sapling crown vigor class	No Tolerance	85.0	100.0	4	95.0	362
Crown density	±10 percent	90.0	80.6	36	92.4	1,622
Crown dieback	±10 percent	90.0	100.0	36	98.0	1,622
Transparency	±10 percent	90.0	100.0	36	98.2	1,622
Tree class	No Tolerance	90.0	87.6	89	92.4	38,026
Damage agent 1	No Tolerance	90.0	91.6	83	90.2	35,071
Damage agent 2	No Tolerance	90.0	92.9	14	78.2	6,760
Tree grade	No Tolerance	90.0	84.0	25	74.8	8,251
D.b.h.-Live & trees with decay code 1 or 2	±0.1 inch per 20 inches	95.0	97.6	85	95.4	35,903
D.b.h.-Trees with decay codes 3, 4, or 5	±1 inch per 20 inches	95.0	100.0	4	99.5	1,732
Total length-trees 40 feet and greater	±10 percent	90.0	81.7	60	81.4	21,658
Total length-trees less than 40 feet	±10 percent	90.0	78.6	14	73.1	5,710
Total length-trees less than 5 inches d.b.h.	±10 percent	90.0	25.0	4	70.8	349
Seedling level						
Species	No Tolerance	85.0	100.0	9	92.5	8,648
Genus	No Tolerance	90.0	100.0	9	96.8	8,648
Seedling count	±20 percent	90.0	88.9	9	63.1	8,648
Seedling count (coded)	No Tolerance	90.0	88.9	9	69.3	8,648
Site Tree level						
Condition list	No Tolerance	99.0	100.0	3	93.1	2,775
Diameter	±0.1 inch per 20 inches	95.0	66.7	3	98.0	2,775
Species	No Tolerance	95.0	100.0	3	99.3	2,775
Genus	No Tolerance	99.0	100.0	3	100.0	2,775
Azimuth	±10 degrees	90.0	66.7	3	99.1	2,775
Distance	±5 feet	90.0	66.7	3	99.3	2,775
Total length	±10 percent	90.0	100.0	3	98.5	2,775
Diameter age	±5 years	95.0	100.0	3	98.0	2,775

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

Variable	Unit of measure	Delaware				All NRS states			
		Relative bias	95% CI limits		Number of observations	Relative bias	95% CI limits		Number of observations
			Lower	Upper			Lower	Upper	
Plot level									
Elevation	foot	30.00	22.00	38.00	2	225.42	46.68	449.57	2,197
Latitude - decimal degrees	degree	0.00	0.00	0.00	2	0.00	0.00	0.00	2,201
Longitude - decimal degrees	degree	-0.00	-0.00	-0.00	2	-0.00	-0.01	-0.00	2,201
Condition level									
Stand age	number	-0.17	-0.50	0.00	6	-0.25	-0.82	0.43	2,889
Boundary level									
Left azimuth	degree	0.00	0.00	0.00	3	0.08	-2.44	2.66	868
Corner azimuth	degree					6.00	-0.62	18.80	83
Corner distance	foot					-0.10	-0.50	0.19	83
Right azimuth	degree	0.00	0.00	0.00	3	1.61	-1.10	4.59	868
Subplot level									
Slope	percent	-0.25	-0.88	0.00	16	0.04	-0.05	0.13	8,565
Aspect	degree	0.00	0.00	0.00	16	0.29	-0.33	0.92	8,360
Snow/water depth	foot	0.06	0.00	0.19	16	-0.28	-0.39	-0.17	8,604
Tree level									
D.b.h.	inch	0.02	0.00	0.03	89	-0.00	-0.00	0.00	37,635
D.r.c.	inch					0.06	-0.10	0.23	69
Azimuth	degree	-0.09	-0.27	0.10	102	-0.03	-0.09	0.03	42,172
Horizontal distance	foot	-0.00	-0.02	0.01	102	-0.00	-0.01	0.00	42,172
Rotten/missing cull	percent	-0.03	-0.44	0.30	74	-0.15	-0.20	-0.11	27,670
Total length	foot	-2.90	-6.20	-0.36	74	0.21	0.09	0.33	27,368
Actual length	foot	2.30	-6.49	11.46	6	-1.46	-2.62	-0.50	3,340
Compacted crown ratio	percent	0.05	-1.55	1.59	83	0.11	-0.01	0.20	35,071
Uncompacted crown ratio	percent	-0.53	-3.04	1.69	40	-3.07	-3.80	-2.24	1,984
Crown density	percent	-2.36	-5.21	0.56	36	-0.87	-1.17	-0.50	1,622
Crown dieback	percent	0.28	-0.42	0.97	36	-0.19	-0.48	0.11	1,622
Transparency	percent	-4.58	-5.69	-3.61	36	-0.69	-1.00	-0.38	1,622
D.b.h.-Live & trees with decay code 1 or 2	inch	0.02	-0.00	0.04	85	0.00	-0.00	0.00	35,903
D.b.h.-Trees with decay codes 3, 4, or 5	inch	-0.03	-0.08	0.00	4	-0.02	-0.05	-0.01	1,732
Total length-trees 40 feet and greater	foot	-3.44	-7.13	-0.26	60	0.70	0.58	0.83	21,658
Total length-trees less than 40 feet	foot	-0.56	-3.90	3.39	14	-1.67	-2.00	-1.39	5,710
Total length-trees less than 5 inches d.b.h.	foot	-21.22	-66.54	13.24	4	-1.53	-2.82	-0.05	349
Seedling level									
Seedling count	number	7.78	0.00	18.89	9	-12.53	-14.37	-10.94	8,496
Seedling count (coded)	number	0.11	0.00	0.33	9	-0.00	-0.02	0.02	8,648
Site Tree level									
Diameter	inch	0.67	0.10	1.80	3	0.00	-0.01	0.01	2,775
Azimuth	degree	53.00	0.00	159.00	3	0.14	-0.18	0.47	2,775
Distance	foot	-2.13	-6.90	0.40	3	0.04	-0.00	0.08	2,775
Total length	foot	-2.92	-10.00	0.83	3	-0.04	-0.22	0.13	2,775
Diameter age	number	0.67	0.00	1.00	3	0.00	-0.09	0.11	2,775

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

Owner and strata(um)	Number of plots selected	Sampled	Denied access	Hazardous	Other	Response rate
	number of plots					*percent*
Inland Census Water:						
1, 2, 3, 4, 5	11.00	11.00	0.00	0.00	0.00	100.00
Private:						
1	195.00	189.75	5.25	0.00	0.00	97.31
2	51.00	46.50	4.00	0.00	0.50	91.18
3	15.00	11.75	3.25	0.00	0.00	78.33
4	37.00	24.50	12.50	0.00	0.00	66.22
5	74.00	50.00	23.00	0.00	1.00	67.57
Public:						
1	27.00	27.00	0.00	0.00	0.00	100.00
5	13.00	12.98	0.02	0.00	0.00	99.88
2, 3, 4	13.00	12.75	0.25	0.00	0.00	98.08
Total:						
	436.00	386.23	48.27	0.00	1.50	88.58

Strata codes:
1: Canopy cover 0 - 5
2: Canopy cover 6 - 50
3: Canopy cover 51 - 65
4: Canopy cover 66 - 80
5: Canopy cover 81 - 100