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# Colorado's Forest Resources, 2004–2013

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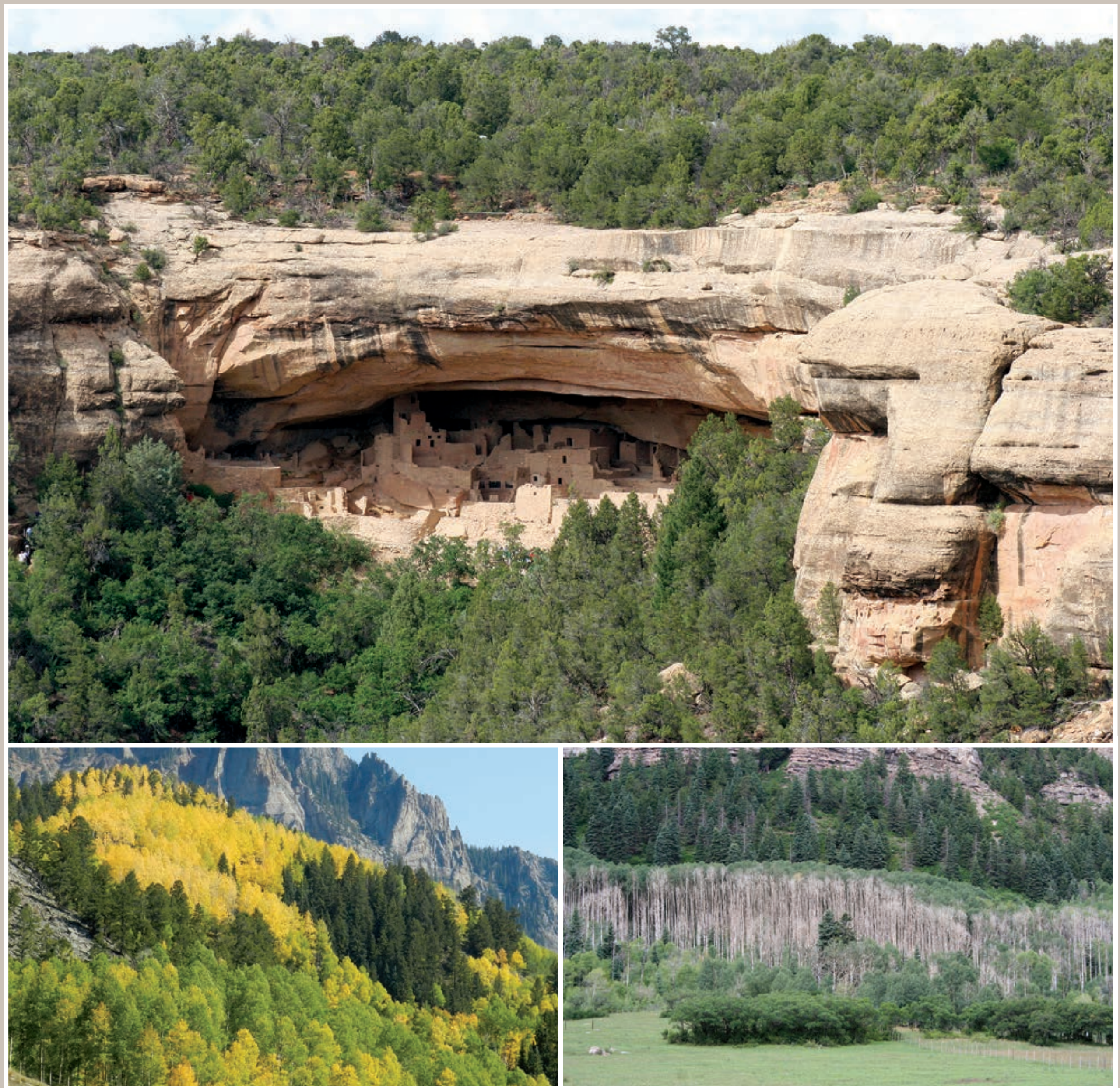

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## Abstract

This report presents a summary of the most recent inventory of Colorado's forests based on field data collected between 2004 and 2013. The report includes descriptive highlights and tables of area, numbers of trees, biomass, carbon, volume, growth, mortality, and removals. Most sections and tables are organized by forest type or forest-type group, species group, diameter class, or owner group. The report also describes the inventory's design, inventory terminology, and data reliability. Results show that Colorado's forest land covers 22.9 million acres. Forty-nine percent (11.1 million acres) of this forest land is administered by the USDA Forest Service, and another 24 percent (5.6 million acres) is privately owned. The State's most abundant forest type is pinyon/juniper, which covers more than 6 million acres. Engelmann spruce and other spruce species are the most abundant tree species by number of trees, and are also the most abundant by volume or biomass. Colorado's forests contain 35.2 billion cubic feet of net volume in trees 5.0 inches diameter and larger. Gross growth of all live trees 5.0 inches diameter and larger averaged 559.0 million cubic feet per year. Average annual mortality totaled 704.2 million cubic feet per year, and net growth was therefore –145.2 million cubic feet per year.

**Keywords:** forest inventory, monitoring, mortality, forest products, wildlife habitat, fire

***Cover photos:*** Top and bottom right: J.D. Shaw; bottom left: W.D. Shaw.

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# Contents

# Introduction

## Colorado's Annual Forest Inventory

The annual forest inventory of Colorado's forests follows sampling procedures specified by Federal legislation and the national Forest Inventory Analysis (FIA) program. In 1998, the Agricultural Research Extension and Education Reform Act, also known as the Farm Bill, mandated that inventories be conducted throughout the forests of the United States on an annual basis. This annual system integrates FIA and Forest Health Monitoring (FHM) sampling designs into a mapped-plot design, which includes a nationally consistent plot configuration with four fixed-radius subplots; a systematic national sampling design consisting of one plot per approximately 6,000 acres; annual measurement of a constant proportion of permanent plots; data or data summaries within 6 months after yearly sampling is completed; and a State summary report after 5 years. The inventory strategy for the western United States involves measurement of 10 systematic samples, or subpanels, where one subpanel is completed each year and all subpanels are measured over a 10-year period. Each subpanel is pre-assigned to be surveyed during a specific calendar year, which is referred to as inventory year (see Appendix A for standard FIA terminology). The year in which each plot was actually surveyed is recorded as its measurement year.

Interior West Forest Inventory and Analysis (IWFIA) implemented the new annual inventory strategy in Colorado in 2002. The most recent annual report for Colorado (Thompson et al. 2010) was based on inventory data from 2002 to 2006. This report is based on the aggregated data collected in measurement years 2004 to 2013. The aggregated dataset includes a total of 11,222 plots, where 3,949 plots contained at least one forested condition, 6,868 plots were entirely nonforest, and 405 plots were not sampled.

## Accessing Colorado's Forest Inventory Data

Forest Inventory Analysis data are publicly available from the national FIA website at www.fia.fs.fed.us. This site includes data downloads; online tools that allow users to perform custom queries; and documentation of FIA's field inventory protocols, database structure, and publications. For assistance with finding information on this site or with performing custom analyses, data users are encouraged to contact one of the members of the analysis team of the Interior West FIA Program who are listed as authors at the beginning of this report. Plot data may be downloaded in table form or summarized using a variety of online tools (http://fia.fs.fed.us/tools-data/default.asp).

## Comparisons With Previous Periodic Inventories

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 compatible. Two previous periodic inventories of Colorado's forest resources were completed in 1983 and 1959 (Benson and Green 1987; Miller and Choate 1964). There are two significant factors that cause incompatibility between the 2013 annual inventory of Colorado and the previous periodic inventory completed in 1983 (Benson and Green 1987).

*1. Inventory procedures:* The first factor is that inventory procedures varied by major ownership category in the previous inventory. In 1983, lands managed by National Forest Systems (NFS) and Bureau of Land Management (BLM) were not inventoried by IWFIA. The forest inventory estimates such as forest area, volume, growth, and mortality were supplied to IWFIA by NFS and BLM. The IWFIA only measured inventory plots on lands owned by State agencies and private individuals. The 1983 report merged this inventory data from the different sources to describe the status and condition of Colorado's forest resources. In the 2013 annual inventory, forest resource data were collected by IWFIA and Colorado State Forest Service on all lands meeting the definition of forest land regardless of ownership status or administrative status of the land. This included wilderness areas and other areas in reserved status. The 2013 inventory adhered to all national protocols such as plot configuration, field variables with nationally consistent meanings and measurements, and national precision standards. None of these national protocols were in place in 1983.

*2. Definitions:* The second factor is that many definitions of forest resource attributes have changed since 1983. The impact of these changes varies by inventory estimate. Forest land definitions, plot configuration, and procedures used to estimate forest type and stand size are some of the significant changes that have occurred since the previous inventory.

The 2013 inventory of Colorado's forests marks an important shift from its predecessors, both in measurements scope and timeliness. With the ability to measure one 10-percent panel of the total sample locations each year, it is now possible and practical to monitor emerging resource issues by providing yearly "snapshot" updates and longer term trend analysis. The resulting improvements in timeliness, combined with the national effort to standardize national inventory procedures, have transformed Colorado's forest inventory into a tool that can detect short-term trends, address relevant issues, examine ecological relationships, and evaluate human activities that will shape the forests of Colorado for the future. A more detailed analysis of the differences between the periodic and annual inventories is discussed in the *Comparisons between Colorado's Periodic and Annual Forest Inventories* section in the "Current Issues in Colorado's Forests" chapter.

## Overview of Standard and Supplemental Tables

Forest Inventory and Analysis produces a set of standard tables that incorporate most of the core FIA program, using both Phase 2 and 3 data. Appendix B presents tables B1–B37, which summarize annual forest inventory data collected in Colorado between 2004 and 2013 in terms of traditional FIA attributes. These tables encompass statistics for land area, numbers of trees, wood volume, biomass (oven-dry weight), growth, mortality, and sampling errors. Table B1 is the only table that includes all land cover types, and it summarizes the proportions of sample plots that were recorded as forest, nonforest, and nonsampled (e.g., due to inaccessibility). All other tables exclude nonforest land and therefore include only accessible forest land or timberland (see Appendix A for definitions). Table B37 shows sampling errors for area, volume, net growth, and mortality at the 67 percent confidence level.

# Inventory Methods

This chapter briefly describes five key aspects of the FIA program. The first four sections describe configuration of field plots, the national sample design, the three-phase inventory system, and sources of error, which are consistent among all States. The last section describes FIA's quality assurance program and presents the results of quality assessments in the current forest inventory of Colorado.

## Plot Configuration

The national FIA plot design consists of four 24-foot radius subplots configured as a central subplot and three peripheral subplots (USDA Forest Service 2013; see figure 1). Centers of the peripheral subplots are located at distances of 120 feet and at azimuths of 360 degrees, 120 degrees, and 240 degrees from the center of the central subplot. Each standing tree with a diameter at breast height (d.b.h.) for timber trees, or a diameter at root collar (d.r.c.) for woodland trees, of 5 inches or larger is measured on these subplots. Each subplot contains a 6.8-foot radius microplot with its center located 12 feet east of the subplot center on which each tree with a d.b.h./d.r.c. from 1 inch to 4.9 inches is also measured.

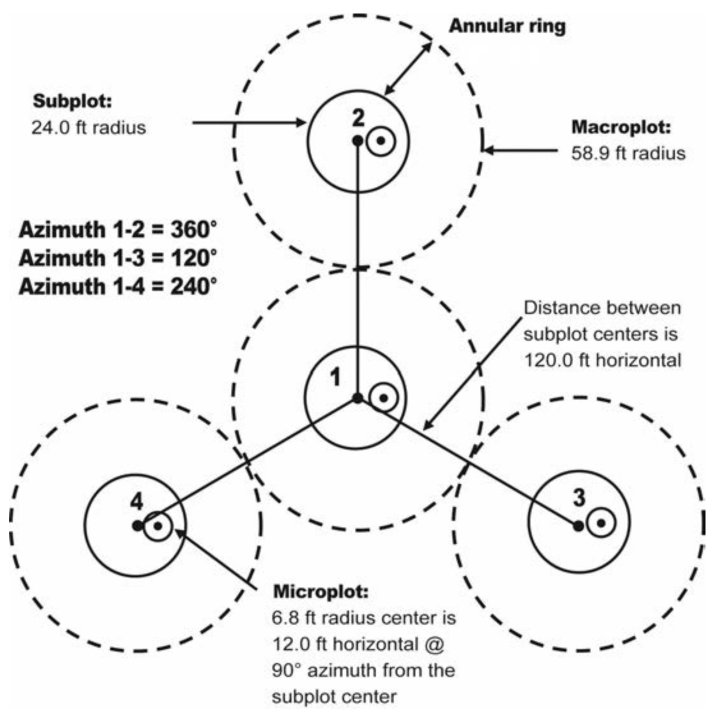


**Figure 1—**Plot configuration used by the Forest Inventory and Analysis program. Each plot consists of four subplots with a 24-foot radius.

To enable division of the forest into various domains of interest for analysis, it is important that the tree data recorded on these plots are properly associated with stand-level data. In addition to the tree data recorded on FIA plots, data are also gathered about the condition class in which the trees are located. A condition class (or condition) is the combination of discrete landscape and forest attributes that define and describe the area associated with a plot. The six variables that define distinct condition classes are forest type, stand origin, stand size, ownership group, reserved status, and stand density (Bechtold and Patterson 2005). In some cases, the plot footprint spans two or more conditions if there is a distinct change in any of these six variables. For example, the four subplots on a plot may intersect both forest and nonforest areas, the plot may include distinct stands differentiated by forest type and/or stand size, or the plot may straddle a boundary between two different ownership groups. All three of these examples would result in more than one condition per plot. Field crews assign numbers to condition classes in the order they are encountered on a plot. Each tree is assigned the number of the condition class in which it stands to enable partitioning of tree data into meaningful categories for analysis.

## Sample Design

Based on historic national standards, a sampling intensity of approximately one plot per 6,000 acres is necessary to satisfy national FIA precision guidelines for area and volume. Therefore, FIA divided the area of the United States into non-overlapping, 5,937-acre hexagons and established one plot in each hexagon using procedures designed to preserve existing plot locations from previous inventories. These sample plots, designated as the Federal base sample, were divided into five spatially interpenetrating panels and 10 subpanels, where each panel consists of two subpanels. In the eastern United States, two subpanels are measured each year such that the inventory cycle is on a 5-year rotation, while in the western United States, including Colorado, one subpanel is measured each year and inventory cycles are completed on a 10-year rotation (Gillespie 1999). For estimation purposes, the measurement of each subpanel of plots can be considered an independent, equal probability sample of all lands in a State, or all plots can be combined to represent the State.

## Three-Phase Inventory

The FIA conducts inventories in three phases. In Phase 1, remote sensing data are digitally analyzed to stratify each State into homogeneous groups such as forest and nonforest areas. Phase 2 relates to a permanent network of ground plots, where traditional inventory variables such as forest type and tree diameter are measured. In Phase 3, additional variables associated with forest and ecosystem health are measured on a subset of Phase 2 plots. The three phases of the enhanced FIA program are discussed in the following sections.

## Phase 1

Phase 1 uses remote sensing data to delineate homogeneous areas, or strata, throughout the entire State. Currently in the Interior West, only forest and nonforest strata are identified. The purpose of this delineation is to reduce the variance of FIA estimates through post-sampling stratification of field data. The initial Phase 1 strata map consisted of forest, nonforest, and census water strata (see Appendix A for definitions), which were delineated at a spatial resolution of 250 meters using a combination of 2004 MODIS satellite imagery, other geospatial datasets, and plot-based calibration data (Blackard et al. 2008). Calibration data in Colorado consisted of periodic and annual inventory plot locations that had been classified as forest, nonforest, or census water, based on field surveys or human interpretation of aerial photographs prior to 2004. In Colorado, the census water stratum and nonforest stratum are combined.

In most Interior West States, post-sampling stratification is based solely on forest and nonforest strata under the assumption that any Phase 2 nonresponse plots occur randomly across the plot grid. Nonresponse plots are defined as plot locations that cannot be sampled by a field crew. They typically occur when landowners or managers do not grant permission for field crews to access plot locations on their lands, although some plots are not sampled due to hazardous conditions that may be permanent in nature (e.g., sheer cliffs) or temporary hazards (e.g., current wildfires or active logging operations). When nonresponse plots do not occur randomly across the plot grid, the estimates of forest attributes may be biased (Patterson et al. 2012). The overall nonresponse rate in Colorado's forest inventory was relatively low at 3.6 percent. Future analyses will quantify the magnitude of the effect of nonresponse on FIA estimates, but for the purpose of this report, the effect is assumed to be small.

The FIA produces estimates at the scale of individual States, which can then be aggregated into regional estimates, as well as at smaller scales within each State. Within-State population estimates are constructed at two scales: survey units that are comprised of groups of counties, and smaller estimation units that represent individual counties. Colorado consists of five inventory units and 64 estimation units denoted as $g$, each containing $n_g$ ground plots. The area of each estimation unit is divided into strata of known size using the State's stratification map, which divides the total area of the estimation unit into 250-meter pixels and assigns each pixel to one of $H$ strata. Each stratum, $h$, within an estimation unit, $g$, then contains $n_{hg}$ ground plots where the Phase 2 attributes of interest are observed.

To illustrate, the area estimator for forest land within an estimation unit in Colorado is defined as:

$$\hat{A}_g = A_{Tg} \sum_{h=1}^{H} W_{hg} \frac{\sum_{i=1}^{n_{hg}} y_{ihg}}{n_{hg}}$$

where

$\hat{A}_g$ = total forest area (acres) for estimation unit *g,*

$A_{Tg}$ = total land area (acres) in estimation unit *g,*

$H$ = number of strata,

$W_{hg}$= proportion of Phase 1 pixels in estimation unit *g* that occur in stratum *h*,

$y_{ihg}$ = forest land condition proportion on Phase 2 plot *i* in stratum *h* in estimation unit *g, and*

$n_{hg}$ = total number of Phase 2 plots in stratum *h* in estimation unit *g*.

### Phase 2

Phase 2 pertains to FIA's network of permanent plot locations, where each plot is assigned spatial coordinates and represents approximately 6,000 acres. To minimize inventory costs, plots that are obviously and entirely nonforest are not designated for field sampling, and these plots are recorded as nonforest. A human interpreter examines each plot location using digital imagery from the National Agriculture Imagery Program and distinguishes plots that potentially contain forest or wooded land from those that do not intersect any forest or wooded land. This process is known as prefield interpretation, and it was historically considered part of Phase 1 because both prefield interpretation and Phase 1 relied on remote sensing data. However, Phase 1 delineation of forest and nonforest strata occurs independently of current prefield interpretation of the Phase 2 grid. Therefore, prefield data collection is considered part of Phase 2 and not part of Phase 1.

The status of each plot in the Phase 2 grid is eventually assigned as accessible forest land, nonforest land, or not sampled. Plots that were not designated for field sampling by prefield interpreters are automatically recorded as nonforest plots. For plots that are designated for field sampling, field crews record the plot status as accessible forest land if (a) they can physically visit the plot location, and (b) the plot satisfies FIA's definition of forest land (see Appendix A). Some field plots are recorded as nonforest because the field crew determines that they do not meet FIA's definition of forest land. A field plot may be recorded as non-sampled if a field crew cannot safely measure the plot or if they cannot obtain permission to access the plot location.

Before visiting privately owned plot locations, FIA crews identify each plot's ownership status by consulting county land records and then seek permission from private landowners to measure plots on their lands. Information about individual landowners and the existence of FIA plots on their property is considered confidential and is never shared with anyone, regardless of whether permission to access the plot location is granted. Table B1 (Appendix B) shows the total percentage of Phase 2 plot areas that represent forest, nonforest, and non-sampled conditions. Figure 2 illustrates the locations of FIA inventory plots that sampled forest land in Colorado.

Field crews record a variety of data on plot locations that contain accessible forest land. Crews locate the geographic center of the plot using geographic positioning system (GPS) receivers and then establish markers to facilitate relocation of the plot for future remeasurement. They record condition-level variables that include land use, forest type, stand origin, stand-size class, stand age, site

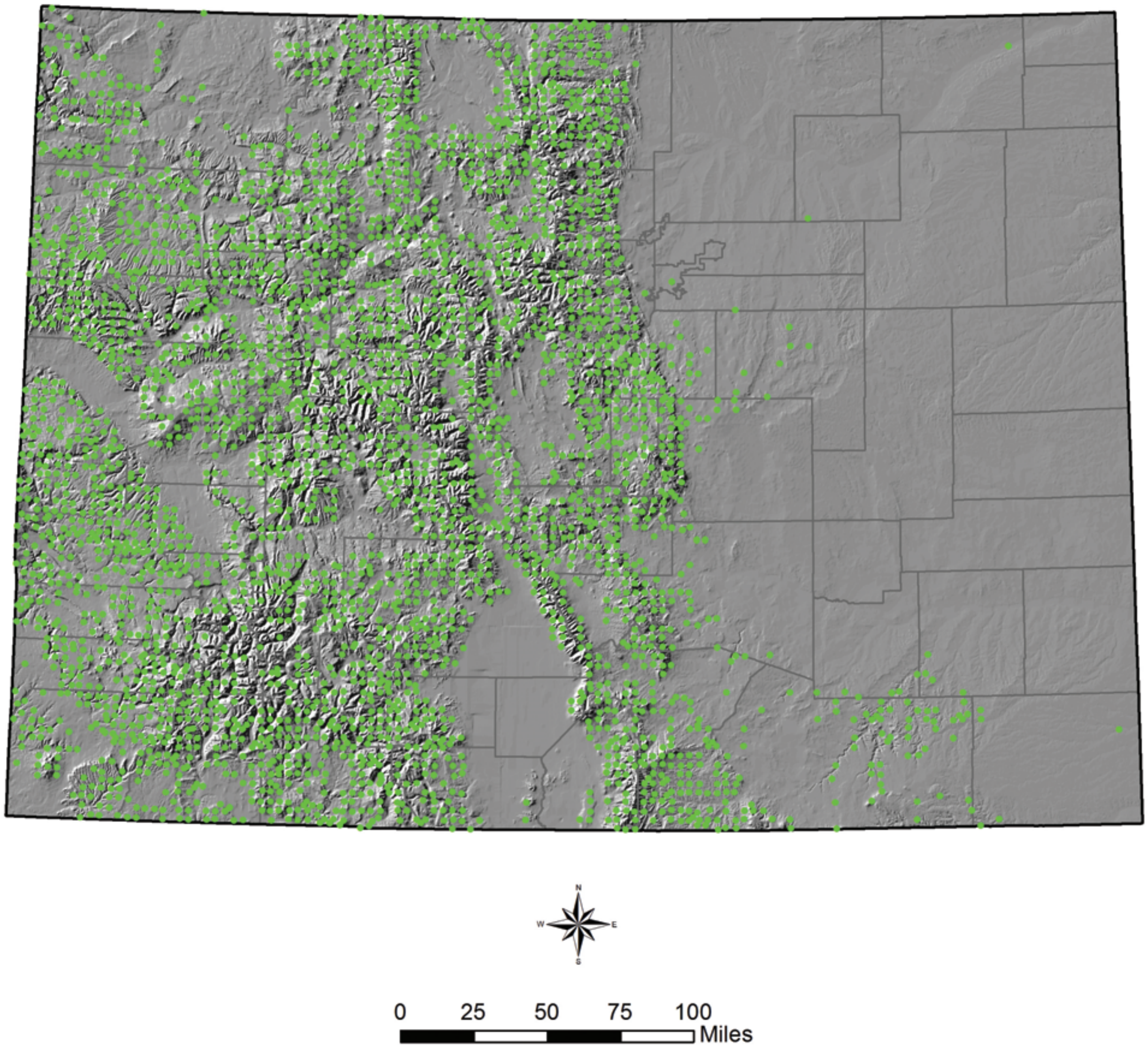


**Figure 2—**Map of Colorado illustrating approximate locations of FIA plots that sampled forest land, 2004–2013.

productivity class, forest disturbance history, silvicultural treatment, slope, aspect, and physiographic class. Some of these area attributes are measured or observed (e.g., regeneration status), some are assigned by definition (e.g., ownership group), and some are computed from tree data (e.g., percent stocking). For each tree on the plot, field crews record a variety of attributes including species, live/dead status, diameter, height, crown ratio, crown class, damage, and decay status. The field procedures used in Colorado's forest inventory are described in detail in the FIA field guide (USDA Forest Service 2013). Data analysts apply statistical models using field measurements to calculate additional variables such as volume and biomass for individual trees, as well as volume, biomass, growth, mortality, and number of trees per unit area.

### Phase 3

The third phase of the enhanced FIA program focuses on forest and ecosystem health. The Phase 3 sample consists of a 1/16 subset of the Phase 2 plots, which equates to one Phase 3 plot for approximately every 96,000 acres. Phase 3 plots include all the measurements collected on Phase 2 plots, plus an extended suite of ecological data pertaining to soil samples, down woody materials, lichen communities, tree crowns, and understory vegetation structure. Phase 3 measurements are obtained by field crews during the growing season. The entire suite of Phase 2 measurements is collected on each Phase 3 plot at the same time as the Phase 3 measurements.

## Sources of Error

### Sampling Error

The process of sampling (selecting a random subset of a population and calculating estimates from this subset) causes estimates to contain errors they would not have if every member of the population had been observed and included in the estimate. The 2004–2013 FIA inventory of Colorado is based on a sample of 10,990 plots (not including 410 nonresponse plots) systematically located across the State. The total area of Colorado is 66.6 million acres, so the sampling rate is approximately one plot for every 6,062 acres.

The statistical estimation procedures used to provide the estimates of the population totals presented in this report are described in detail in Bechtold and Patterson (2005). Along with every estimate is an associated sampling error that is typically expressed as a percentage of the estimated value, but it 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. An approximate 67 percent confidence interval constructed from the sampling error can be interpreted to mean that under hypothetical repeated sampling, approximately 67 percent of the confidence intervals calculated from the individual repeat samples would include the true population parameter if it were computed from a 100-percent inventory. The sampling errors for State-level estimates are presented in table B37 in Appendix B.

Because sampling error increases as the area or volume considered decreases, users should aggregate data categories as much as possible. Sampling errors obtained from this method are only approximations of reliability because homogeneity of variances is assumed. Users may compute statistical confidence for subdivisions of the reported data using the formula below:

$$SE_{\mathrm{s}} = SE_{\mathrm{t}} \frac{\sqrt{X_t}}{\sqrt{X_s}}$$

where

$SE_{\mathrm{s}}$ = sampling error for subdivision of State total,
$SE_{\mathrm{t}}$ = sampling error for State total,
$X_s$ = sum of values for the variable of interest (area, volume, biomass, etc.) for subdivision of State total, and
$X_t$ = sum of values (area, volume, biomass, etc.) for State total.

### Measurement Error

Measurement errors are errors associated with the methods and instruments used to observe and record the sample attributes. On FIA plots, attributes such as the diameter and height of a tree are measured with specialized 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 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 diameters consistently taken at a height other than 4.5 feet from the ground—then the estimates that use this observation (e.g., calculated 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 FIA observations meet the highest standards possible, a quality assurance program, described below, is integrated throughout all FIA data collection efforts.

### Prediction Error

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

## Quality Assurance

The FIA employs a Quality Assurance (QA) program to ensure the quality of all collected data. The QA program provides a framework to assure the production of complete, accurate, and unbiased forest information of known quality. There are two primary facets of FIA's QA program: quality control and quality assessment.

The FIA's quality control process operates via data quality inspectors, who assess individual field crews and then provide timely feedback to improve the crews' performance. This is accomplished by means of hot checks and cold checks. During a hot check, an inspector accompanies a field crew to a plot and provides immediate feedback on the quality of their measurements. Cold checks occur when an inspector visits a recently completed plot, typically in possession of the original crew's data but without the crew present, and then verifies each measurement and provides the crew an overall score as well as feedback on measurements that did not meet FIA specifications. On average, hot checks are done on 2 percent of all field-sampled plots and cold checks are done on 5 percent of field-sampled plots.

Quality assessment is the second facet of FIA's QA program, and this process quantifies the overall precision of field measurements by comparing two independent measurements of the same plot. The independent measurements are collected by means of blind checks, where a regular field crew collects measurements and then a second crew collects a second set of measurements, without knowledge of or access to the first crew's measurements (Pollard et al. 2006). Thus, these paired observations provide a means of assessing repeatability of FIA's field measurements.

Quality control and quality assessment both require a data quality standard that defines the target level of precision for field measurements. The FIA program has specific Measurement Quality Objectives (MQOs) that enumerate data quality standards for individual field-measured variables. These data quality objectives were developed from knowledge of measurement processes in forestry and forest ecology as well as the requirements of the FIA program. Measurement quality objectives for each variable consist of a measurement tolerance and a compliance standard. Measurement tolerances define the acceptable range of variability between two independent observations, and compliance standards define the target percentage of observations that should be within the measurement tolerance when recorded by two independent observers. The practicality of these MQOs, as well as the measurement uncertainty associated with a given field measurement, can be tested by comparing the results of quality assessments using blind check data.

Quality assessment data for Colorado's current inventory were collected between 2010 and 2013. The results of the QA analysis for this period are presented in tables 1 and 2. Table 1 describes tolerances for condition-level variables, and table 2 describes tree-level variables. Each variable and its associated measurement tolerance are followed by the percentage of total paired records that fall within one, two, three, and four times the tolerance. The last four columns show the number of observations that fell outside the tolerance. For example, table 1 shows that there were 64 paired records, representing 64 conditions that were measured independently by two field crews, for the variable "Forest Type." About 91 percent of those records fell within the tolerance of having no errors. The percentage of observations that fall within the 1X tolerance level is referred to as the observed compliance rate, which can be compared to the compliance standard for each variable's MQO to determine that variable's performance. Compliance standards and measurement tolerances for FIA's field measurements are listed within the field manual (USDA 2013).

The information in tables 1 and 2 shows variables with varying degrees of repeatability. For example, one condition-level regional variable that appears to be fairly repeatable is "Percent Bare Ground." At the 1X tolerance level, its observed compliance rate was about 94 percent. This represents that 94 percent of 64 paired observations were within plus or minus 10 percent of each other. In contrast, the compliance rate for "Percent Crown Cover" was only 63 percent, which indicates that further training may be required to improve the repeatability of this variable. The compliance rate for "Habitat Type 1," which has no tolerance variability, was only 55 percent. This low compliance rate warrants further investigation into the potential repeatability issues associated with evaluating habitat type, which can provide insight into successional status when combined with existing vegetation (such as tree numbers, size class, and species by habitat types or series). Habitat types are represented as a categorical value, and it is likely that the compliance

**Table 1**—Results of quality assessment for condition-level variables from 71 conditions in Colorado. Variables that did not have any non-null values recorded on any QA plots are not shown; these include secondary and tertiary disturbances and treatments, owner industrial status, and regeneration species.

| Variable | Tolerance | Percentage of data within tolerance | | | | Number of times data exceeded tolerance | | | | Number of records |
|---|---|---|---|---|---|---|---|---|---|---|
| | | @1x | @2x | @3x | @4x | @1x | @2x | @3x | @4x | |
| **National core variables** | | | | | | | | | | |
| Condition status | No errors | 98.6 | | | | 1 | | | | 71 |
| Reserve status | No errors | 98.6 | | | | 1 | | | | 71 |
| Owner group | No errors | 100.0 | | | | 0 | | | | 71 |
| Forest type | No errors | 90.6 | | | | 6 | | | | 64 |
| Stand size | No errors | 82.8 | | | | 11 | | | | 64 |
| Tree density | No errors | 100.0 | | | | 0 | | | | 64 |
| Disturbance 1 | No errors | 84.4 | | | | 10 | | | | 64 |
| Disturbance year 1 | ±1 yr | 14.3 | 14.3 | 14.3 | 14.3 | 6 | 6 | 6 | 6 | 7 |
| Treatment 1 | No errors | 98.4 | | | | 1 | | | | 64 |
| Treatment year 1 | ±1 yr | 50.0 | 100.0 | | | 1 | 0 | | | 2 |
| Physiographic class | No errors | 62.5 | | | | 24 | | | | 64 |
| **Regional variables** | | | | | | | | | | |
| Percent crown cover | ±10 % | 62.5 | 85.9 | 93.8 | 96.9 | 24 | 9 | 4 | 2 | 64 |
| Percent bare ground | ±10 % | 93.8 | 96.9 | 98.4 | 98.4 | 4 | 2 | 1 | 1 | 64 |
| Habitat type 1 | No errors | 54.7 | | | | 29 | | | | 64 |
| Habitat type 2 | No errors | 56.3 | | | | 28 | | | | 64 |

rate for habitat types would be higher if we could consider habitat type groups (or groups of types that are very similar) in our quality assurance analysis.

The tree measurements that have the biggest influence on estimates of forest volume are tree species, tree diameter, and tree height. As shown in table 2, the compliance rate for the variable "Species" was 96 percent. The diameter variables "d.b.h." and "d.r.c." represent the respective diameters of timber and woodland tree species (see Appendix C) whereas timber species are measured at breast height (4.5 feet above ground level), and woodland species are measured near ground level at root collar. The 1X compliance rates for diameter were almost 90 percent for both d.b.h., which has a tolerance of 0.1 inch, and almost 87 percent for d.r.c., which has a 0.2 inch per stem tolerance to allow for larger tolerances on multi-stemmed woodland trees. Tree height is represented by the variables "Total Length" and "Actual Length." Both variables have a tolerance level of ±10 percent of the observed length, and compliance rates at the 1X level were about 85 percent and 86 percent, respectively. The variable "crown class" was the least repeatable tree-level variable, with a 1X compliance rate of only 4 percent; as with the condition-level variable "percent crown cover," the compliance rate for "crown class" could likely be improved with additional clarification and training on the differences among crown class categories. The compliance rate for the variable "tree age" was also somewhat low at 31 percent. This is probably due to the difficulty of obtaining accurate tree ages. Several factors that might contribute to inconsistency among tree ages are (1) variation in age estimation when cores do

**Table 2**—Results of quality assessment for tree-level variables from 1,293 trees in Colorado.

| Variable | Tolerance | Percentage of data within tolerance | | | | Number of times data exceeded tolerance | | | | Number of records |
|---|---|---|---|---|---|---|---|---|---|---|
| | | @1x | @2x | @3x | @4x | @1x | @2x | @3x | @4x | |
| **National core variables** | | | | | | | | | | |
| Diameter (d.b.h.) | ±0.1 /20 in. | 89.8 | 95.8 | 97.0 | 97.9 | 114 | 47 | 33 | 24 | 1,118 |
| Diameter (d.r.c. using IW MQO) | ±0.2 in*#stems | 86.9 | 91.4 | 95.4 | 96.0 | 23 | 15 | 8 | 7 | 175 |
| Azimuth | ±10 º | 97.5 | 99.2 | 99.5 | 99.7 | 16 | 5 | 3 | 2 | 645 |
| Horizontal distance | ±0.2 /1.0 ft | 91.3 | 94.9 | 96.1 | 96.9 | 56 | 33 | 25 | 20 | 645 |
| Species | No tolerance | 96.2 | | | | 49 | | | | 1,293 |
| Tree status | No tolerance | 99.5 | | | | 7 | | | | 1,293 |
| Rotten/Missing cull | ±10 | 89.3 | 95.2 | 97.6 | 98.8 | 125 | 56 | 28 | 14 | 1,164 |
| Total length | ±10 | 85.2 | 95.9 | 98.5 | 99.2 | 192 | 53 | 19 | 10 | 1,293 |
| Actual length | ±10 | 85.5 | 96.4 | 98.6 | 99.3 | 144 | 36 | 14 | 7 | 996 |
| Compacted crown ratio | ±10 | 100.0 | | | | 0 | | | | 1,086 |
| Uncompacted crown ratio (P3) | ±10 | 76.8 | 93.8 | 97.8 | 99.1 | 222 | 59 | 21 | 9 | 958 |
| Crown class | No tolerance | 4.1 | | | | 1041 | | | | 1,086 |
| Decay class | ±1 class | 100.0 | | | | 0 | | | | 200 |
| Cause of death | No tolerance | 76.9 | | | | 24 | | | | 104 |
| Mortality year | ±2 yr | 76.9 | 96.2 | 99.0 | 100.0 | 24 | 4 | 1 | 0 | 104 |
| Condition class | No tolerance | 99.0 | | | | 13 | | | | 1,293 |
| **Regional variables** | | | | | | | | | | |
| Mistletoe | ±1 class | 98.4 | 98.8 | 99.4 | 99.8 | 17 | 13 | 7 | 2 | 1,086 |
| Number of stems | ±1 stem | 96.6 | 97.7 | 99.4 | 100.0 | 6 | 4 | 1 | 0 | 175 |
| Percent missing top | ±10 | 97.0 | 97.0 | 97.0 | 97.0 | 35 | 35 | 35 | 35 | 1,164 |
| Sound dead | ±10 | 49.7 | 49.7 | 49.7 | 49.7 | 585 | 585 | 585 | 585 | 1,164 |
| Form defect | ±10 | 11.2 | 11.2 | 11.2 | 11.2 | 301 | 301 | 301 | 301 | 339 |
| Current tree class | No tolerance | 95.3 | | | | 61 | | | | 1,293 |
| Tree age | ±5 | 30.6 | 41.7 | 50.0 | 52.8 | 25 | 21 | 18 | 17 | 36 |
| Horiz dist-timberland | ±0.2 /1.0 ft | 98.2 | 99.3 | 99.5 | 99.6 | 20 | 8 | 6 | 4 | 1,118 |
| Horiz dist-woodland | ±0.2 /1.0 ft | 73.1 | 82.3 | 86.9 | 89.7 | 47 | 31 | 23 | 18 | 175 |

not include tree center, or pith; (2) tree rings are too close together or too faint to read accurately in the field; and (3) some trees are too large to reach the center. These situations are particularly prevalent in old and slow-growing trees, and they could be mitigated through better field procedures and/or processing tree cores in a dedicated tree ring laboratory that uses sandpaper, microscopes, and sometimes modeling techniques to obtain more accurate age estimates.

As more blind check information becomes available, it might become apparent that either more intensive crew training is required, or that a variable's MQO needs to be adjusted accordingly to better reflect the realistic expectation of quality for that variable. As a result, MQOs are used not only to assess the reliability of FIA measurements and their ability to meet current standards, but also to identify areas of improvement of data collection protocols and training. This ongoing process improves repeatability or may even lead to elimination of variables that prove to be unrepeatable.

# Overview of Colorado's Forests

The following sections discuss the status and trends of Colorado's forest land resources in terms of area, number of trees, volume and biomass, stand age, forest change components, growth, removals, and mortality, and stand density index (SDI) using annual data collected from 2004 through 2013. The sections "Ecoregion Provinces of Colorado," Forest Land Classification," and "Forest Land Ownership" include summaries of forest land, and non-forest lands; the remaining "Overview of Colorado's Forests" sections will focus only on the forest land base.

## Ecoregion Provinces of Colorado

Issues and events that influence forest conditions often occur across forest types, ownerships, and political boundaries. As a result, scientists, researchers, and land managers must also find a way to assess and treat these issues in a boundaryless way. Ecoregions are often used as a nonpolitical land division to help researchers study forest conditions. An ecoregion is a large landscape area that has relatively consistent patterns of topography, geology, soils, vegetation, climate, and natural processes (Shinneman et al. 2000). Many smaller ecosystems may reside within an ecoregion.

Colorado is at the confluence of seven ecoprovinces (Bailey 1995): (1) the Colorado Plateau Semi-Desert Province in the southwestern part of the State; (2) the Great Plains-Palouse Dry Steppe Province encompasses most of the eastern part of the State; (3) the Intermountain Semi-Desert Province in the northern part; (4) the Intermountain Semi-Desert and Desert Province in the west; (5) the Nevada-Utah Mountains-Semi-Desert Province in the northwest; (6) the Southern Rocky Mountain Steppe Province in the central and western part of the State; and (7) the Arizona-New Mexico Mountains Semi-Desert that occupies a very small portion in the southern region of Colorado (fig. 3).

The most prominent ecoprovince is the Southern Rocky Mountain Steppe, which contains the most forested area and greatest variety of forest types. This region is home to the Rocky Mountains, rugged glaciated mountains of over 14,000 feet. Forests in this province are characterized by vegetational zonation, controlled by a combination of altitude, latitude, direction of prevailing winds, and slope exposure. The uppermost vegetational zone is characterized by alpine tundra and the absence of trees. Directly below it is the subalpine zone, dominated in most places by Engelmann spruce and subalpine fir. Below this area lies the montane zone, characterized by ponderosa pine and Douglas-fir. Fire disturbance regimes create stands of aspen or lodgepole pine in the subalpine and montane zones. Below the montane belt is the foothill zone. Dry rocky slopes abound in this province, and

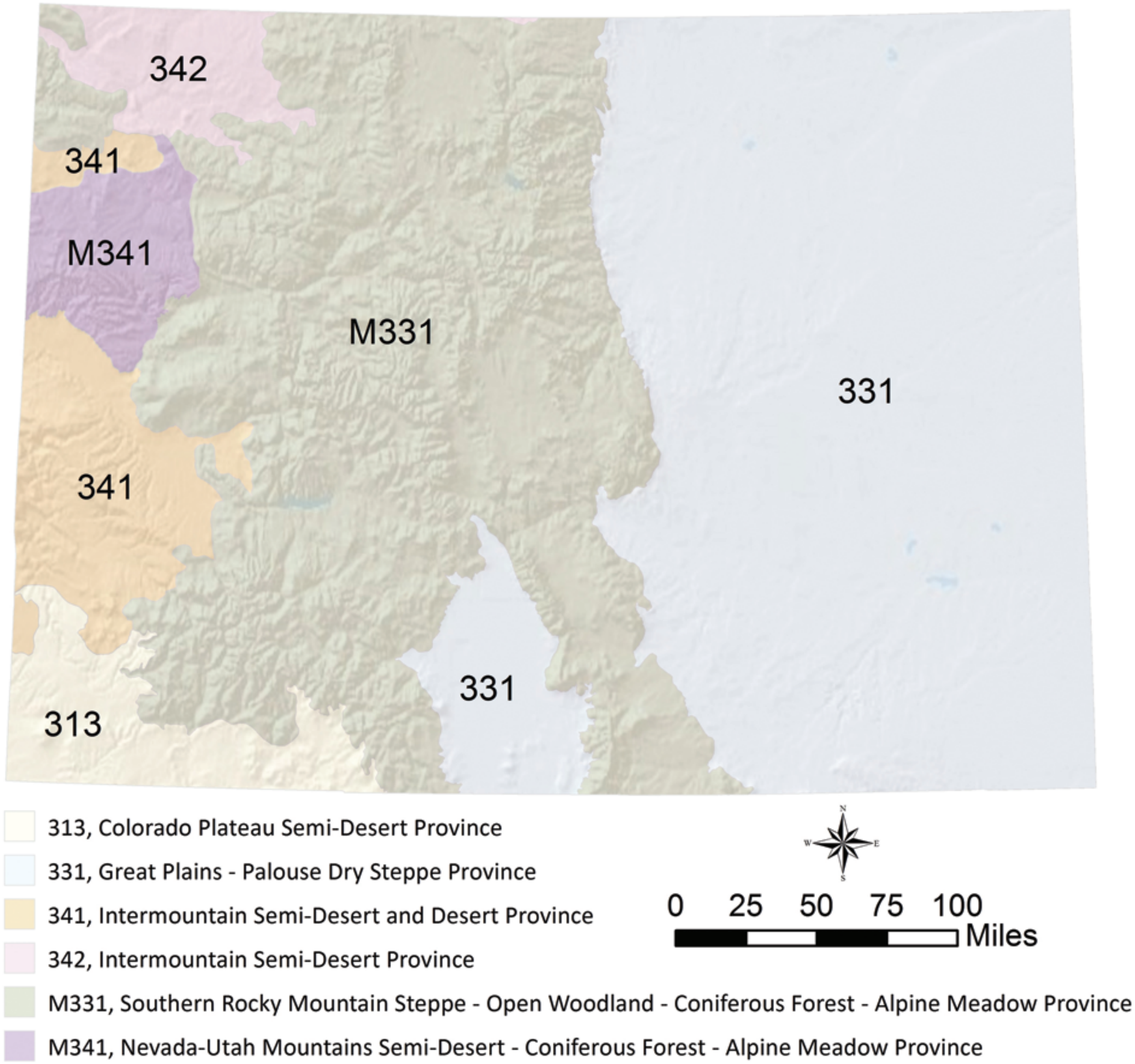


**Figure 3—**Ecoregion map of Colorado.

ponderosa pine and pinyon-juniper are the typical forest types found, depending on slope exposure.

The Great Plains-Palouse Dry Steppe Province is characterized by rolling plains and tablelands of moderate relief in a broad belt that slopes gradually eastward from an altitude of 5,500 ft (1,520 m) near the foot of the Rocky Mountains. This region, often referred to as the Great Plains grasslands, has scattered trees and shrubs, and it supports many species of grass. Forests are nearly nonexistent in this province.

The remaining four ecoregion provinces are characterized by dry rocky foothills, mesas, and plateaus. The predominate forest types in these regions are pinyon pine, juniper, or a mix of both commonly referred to as pinyon-juniper woodlands. The forests in these semi-desert regions are commonly associated with sagebrush communities.

## Forest Land Classification

Historically, FIA has used a nationally consistent standard for defining different categories of forest land. These categories were originally developed for the purpose of separating forest land deemed suitable for timber production from forest land that was either not suitable or unavailable for timber harvesting activity. The first division of forest land is unreserved forest land and reserved forest land. Unreserved forest land is considered available for harvesting activity where wood volume can be removed for wood products. Reserved forest land is considered unavailable for any type of wood utilization management practice through administrative proclamation or legislation.

Unreserved forest land is further divided into timberland and unproductive forests. Timberland is forest land capable of producing 20 cubic feet of wood per acre per year of trees designated as a timber species and not withdrawn from timber production. Unproductive forests, because of species characteristics and site conditions, are not capable of producing 20 cubic feet of wood per acre per year of trees designated as a timber species (see Appendix A for definitions).

Reserved forest land can also be divided by productivity. Some characteristics that contribute to productivity can be visibly obvious, such as the presence or absence of non-commercial species, rocky substrates, and high elevation. While these distinctions may be important to reserved area management concerns, for example their effect on visitor experience, wood production capability on reserved forest land is probably not the best way to discuss these issues.

The State of Colorado encompasses over 71.3 million acres (Appendix B, table B1). Thirty-two percent, or 22.9 million acres (Appendix B, table B2), of the area meets the definition of forest land (Appendix A). Unreserved forest land accounts for 87 percent of Colorado's total forest land with 47 percent classified as timberland and 40 percent classified as unproductive. Twelve percent of Colorado's forest land is reserved and nearly all of this reserved forest land is classified as productive (Appendix B, table B2).

## Forest Land Ownership

Colorado's largest manager of forest land is the USDA Forest Service's National Forest System (NFS), which manages 11.1 million acres of forest land (Appendix B, table B2). This represents almost 49 percent of the State's total forest land area (fig. 4). National Forest System land in Colorado consists of 10 different National Forests and two National Grasslands. Eighty-one percent of NFS forest land is classified as unreserved forest land of which the majority (84 percent) is timberland.

The other major government agency that controls a significant amount of forest land in Colorado is the Bureau of Land Management (BLM). Forest land administered by the BLM totals 5.0 million acres. The majority of BLM's forest land—about 95 percent—is classified as unreserved. Only 13 percent of BLM's forest land meets the criteria to qualify as timberland. Privately owned forest land

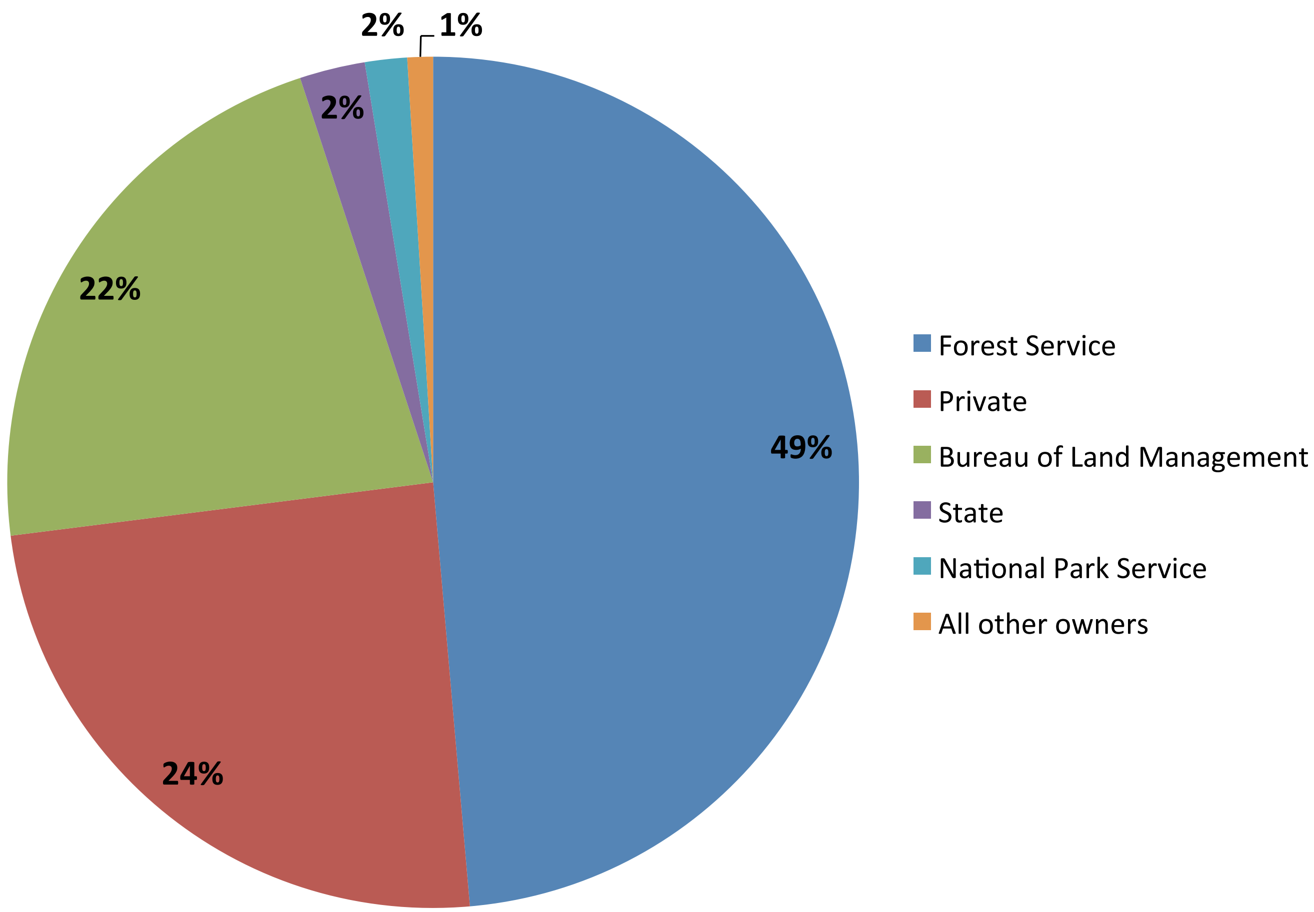


**Figure 4—**Percent distribution of forest land by owner group, Colorado 2004–2013.

totals 5.6 million acres. Private landowners are a diverse group in Colorado consisting of private individuals and corporations. All private forest land is in the unreserved owner class with 40 percent classified as timberland and 60 percent classified as unproductive. The remaining amount of forest land in Colorado is controlled by the National Park Service (NPS), State and local government, and the Department of Defense. Nearly 570,000 acres are controlled by State and local governments, another 366,000 acres are controlled by the NPS, and 103,000 acres are controlled by the Department of Defense.

## Forest Type and Forest-Type Groups

Forest type is a classification of forest land based on the species forming a plurality of basal area of living trees growing in a particular forest. Forest type names may be based on a single species or groups of species. Forest types are an important measure of diversity, structure, and successional stage. The distribution of forest types across the landscape is determined by factors such as climate, soil, elevation, aspect, and disturbance history. The loss or gain of a particular forest type over time can help assess the impact of major disturbances related to fire, weather, climate, insects, disease, and human-caused disturbances such as timber harvesting or ecosystem restoration.

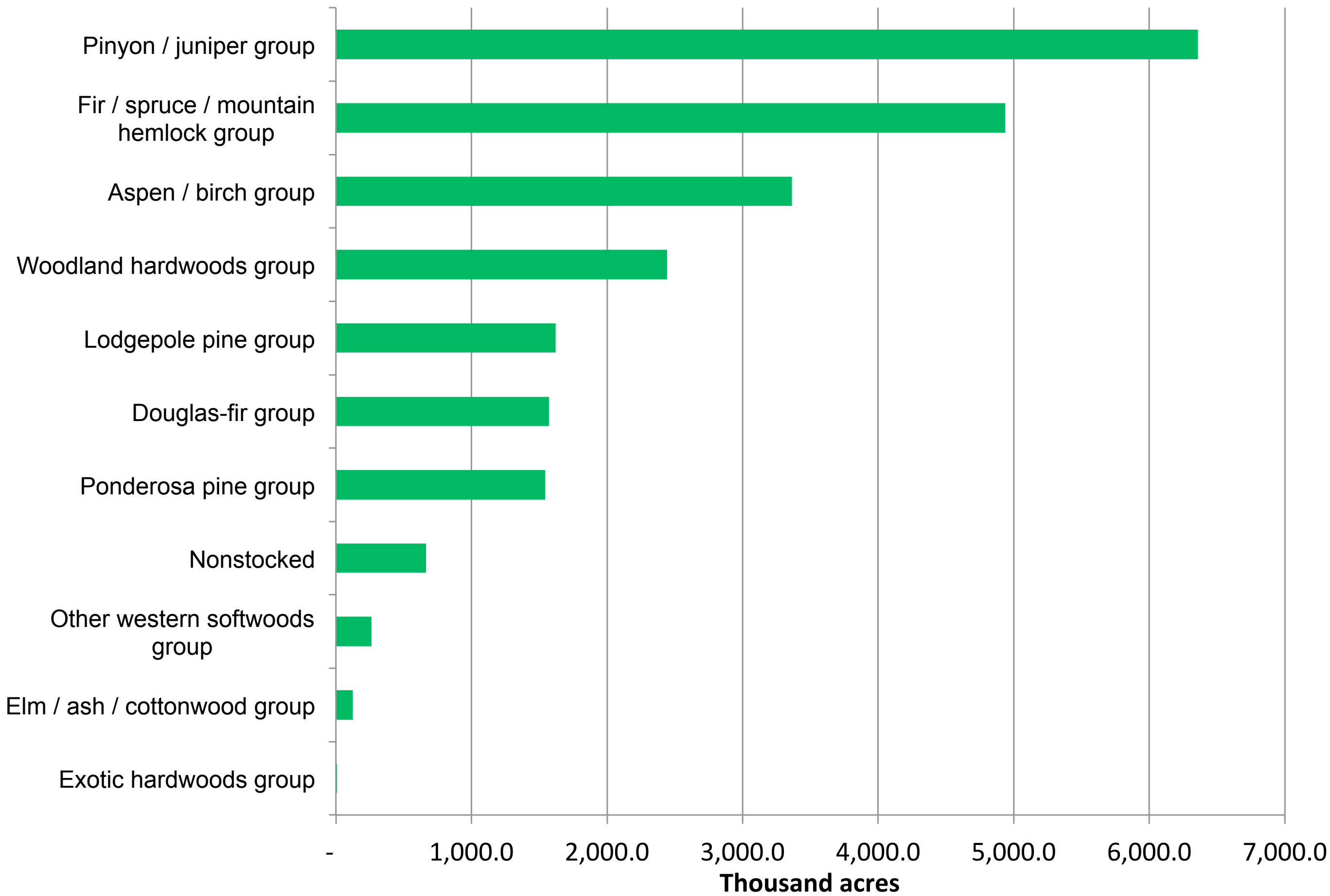


**Figure 5**—Area of forest land by forest-type group, Colorado, 2004–2013. See Appendix C for forest types and tree species included in each group.

Forest types are aggregated into forest-type groups to simplify interpretation of large-scale forest trends. Colorado's forests represent 11 forest-type groups that are further classified into distinct forest types, all of which are described in Appendix C. Some forest-type groups contain only one forest type, while other forest-type groups include several individual forest types. An example of a forest-type group with multiple forest types is the pinyon/juniper forest-type group, which consists of the Rocky Mountain juniper forest type, the pinyon/juniper forest type, and the juniper woodland forest type. As noted above, the distribution of forest types as well as individual tree species may vary among ecological provinces. Figure 5 shows the area occupied by each forest-type group in Colorado.

Colorado's most abundant forest-type group is the pinyon/juniper group, which covers 6.4 million acres and accounts for 28 percent of total forest area in the State (Appendix B, table B3). Within this forest-type group, the pinyon/juniper woodland is the most abundant (4.7 million acres), followed by the juniper woodland type (1.1 million acres) and the Rocky Mountain juniper type (0.5 million acres). Next in abundance is the fir/spruce/mountain hemlock type group, which comprises 4.9 million acres and 21 percent of the State's forest land. This diverse forest-type group consists of five forest types in Colorado where the Engelmann spruce type accounts for the majority of area at 2.1 million acres. The aspen/birch type group is third in abundance at 3.4 million acres and is entirely comprised of the aspen forest type. Fourth in abundance at 2.4 million acres, the woodland hardwoods forest-type group is mainly comprised of the deciduous woodland type—a forest type where Gambel oak is the principal species. The lodgepole pine forest type is the fifth most abundant forest type totaling 1.6 million acres. The Douglas-fir and ponderosa pine forest-type groups each occupy about 1.5 million acres. The remaining forest land in the State is classified as the nonstocked type group (0.7 million acres), other western softwoods group (0.3 million acres), and the elm/ash/cottonwood group (0.1 million acres).

## Stand Age

The age structure of forest land provides insight into prospective shifts in stand structure and composition over time. On every FIA plot that samples forest land and includes suitable trees for increment core extraction, stand age is estimated based upon the average age of only those trees that fall within the calculated stand-size category. For example, suppose an FIA plot sampled a softwood forest type where about 30 percent of the live trees were in the large diameter stand-size (trees at least 9.0 inches d.b.h. and larger) and 70 percent were in the medium diameter size class (trees between 5.0 and 9.0 inches d.b.h.). The stand would be classified as a medium diameter stand size class, and therefore only the medium size trees would be used in determining stand age.

There are limitations to collecting data for stand age computation. Repeatable measurements of increment cores are difficult to collect from certain tree species, particularly woodland species or those that may be very long-lived. Stand age may not accurately depict the age structure of uneven-aged stands, which encompass multiple age classes. Stand ages are difficult to accurately determine for stands that are predominated by small-diameter tree species such as Gambel oak trees. Stand ages are not assigned to nonstocked conditions, which are stands that contain less than 10 percent stocking of live trees because of disturbance.

Table B6 (Appendix B) shows the area of forest land, by age class and forest-type group, with 20-year intervals representing stand age classes. Over 50 percent of Colorado's forest land, or 11.5 million acres, is between 60 and 140 years of age. Stands between 80 and 100 years of age represent the largest single 20-year age class and comprise 3.5 million acres or 15 percent of Colorado's forest land. Almost 13 percent of Colorado's forest land, or 2.9 million acres, is in stands less than 20 years of age; 8 percent, or 1.8 million acres, is in stands over 200 years of age.

Considerable differences are apparent in stand age distribution among the major forest-type groups in the State (fig. 6). The pinyon/juniper and fir/spruce/mountain hemlock forest-type groups have the most even distribution of forest area across all age class groups. The pinyon/juniper forest-type group has the largest proportion (17 percent) of forest area in stands over 200 years of age and also has the smallest proportion (3 percent) of forest area in stands less than 21 years of

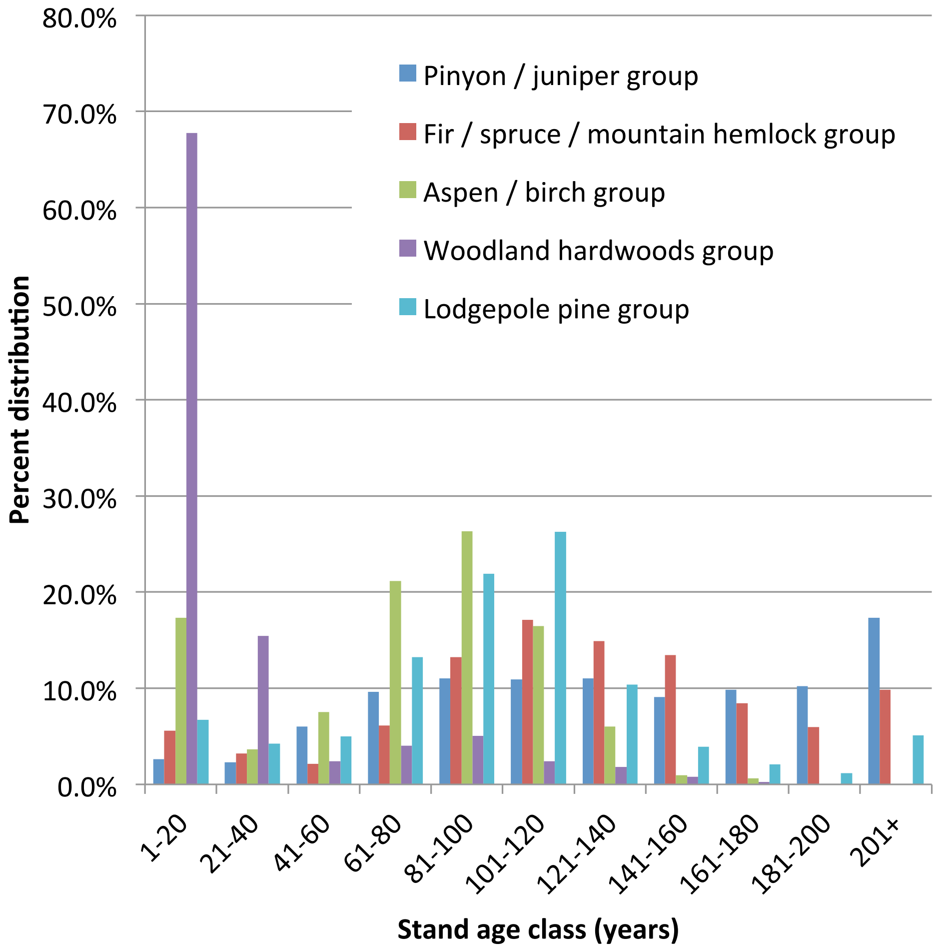


**Figure 6**—Distribution of forest land by stand-age class for major forest-type groups, Colorado, 2004-2013.

age. The lodgepole pine type group has the largest proportion (48 percent) of the State's major forest-type groups in stands between 80 and 120 years of age.

Compared to the coniferous forest-type groups, aspen forests have a slightly higher percentage (28 percent) of area that is less than 61 years of age. Seventeen percent of aspen forest types are less than 21 years of age and only 1 percent of aspen types are in stands older than 160 years. Compared to other forest-type groups, the woodland hardwood group has the greatest proportion of its area in the youngest age classes: 68 percent is younger than 20 years and another 15 percent is in the 21 to 40 year age class.

## Numbers of Trees

Estimates of the numbers of trees are beneficial to a variety of silvicultural, forest health, and habitat management applications. These estimates are typically combined with information about the size and species of trees to provide meaningful summaries of forest dynamics and stand structure. Younger forest stands usually consist of large numbers of small-diameter trees, whereas older forest stands contain small numbers of large-diameter trees. The FIA classifies individual tree species into species groups, and it also categorizes each species and species group as either softwood or hardwood (Appendix D).

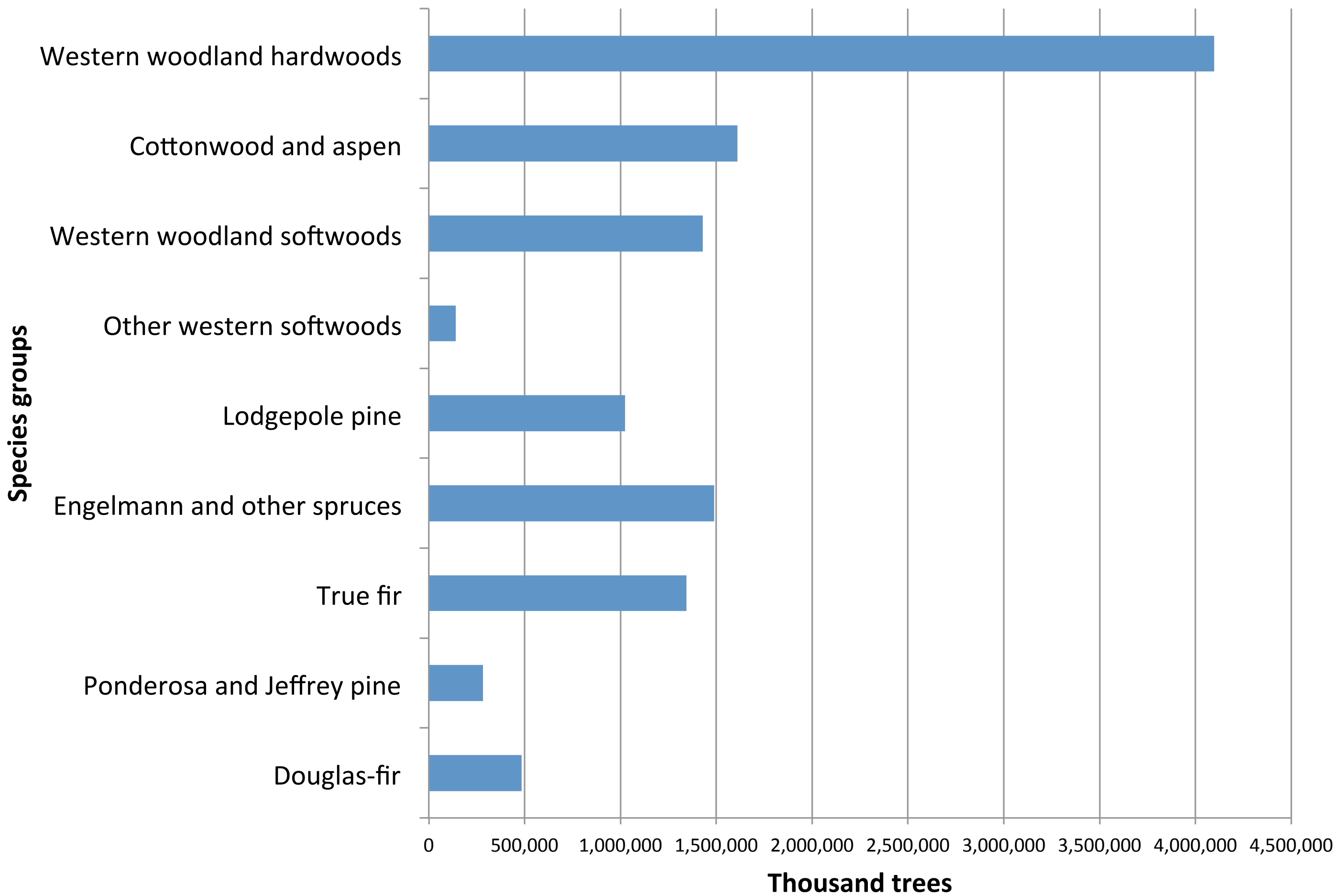


**Figure 7—**Number of live trees 1.0 inch in diameter and larger on forest land, by species group, Colorado, 2004–2013.

There is an estimated 11.9 billion live trees 1.0 inch in diameter or larger (Appendix B, table B10) on Colorado's forest land area. Softwoods species total 6.2 billion trees or 52 percent of the State's live trees. The most abundant softwood species group was the Engelmann and other spruces group, which totaled 1.5 billion trees and accounted for over 12 percent of the total number of live trees (fig. 7). Second in abundance was the western woodland softwood group, which totaled 1.4 billion trees or 12 percent of the total number of live trees. The third most abundant softwood species group was true fir, which totaled 1.3 billion trees and accounted for 11 percent of the total number of live trees. Lodgepole pine totaled over 1.0 billion trees and comprised 9 percent of all live trees in the State.

Hardwood species account for 5.7 billion trees, or 48 percent of Colorado's live trees. The vast majority of hardwood species resides in the woodland hardwood species group, which totals 4.1 billion trees. This species group, comprised mainly of Gambel oak, also makes up the majority (34 percent) of all live trees in the State. The second most abundant hardwood species group is the cottonwood and aspen species group, which consists of 1.6 billion quaking aspens and a very small amount of three cottonwood species.

Figure 8 illustrates the number of live trees by diameter class for three major species groupings—softwood, cottonwood and aspen, and western woodland

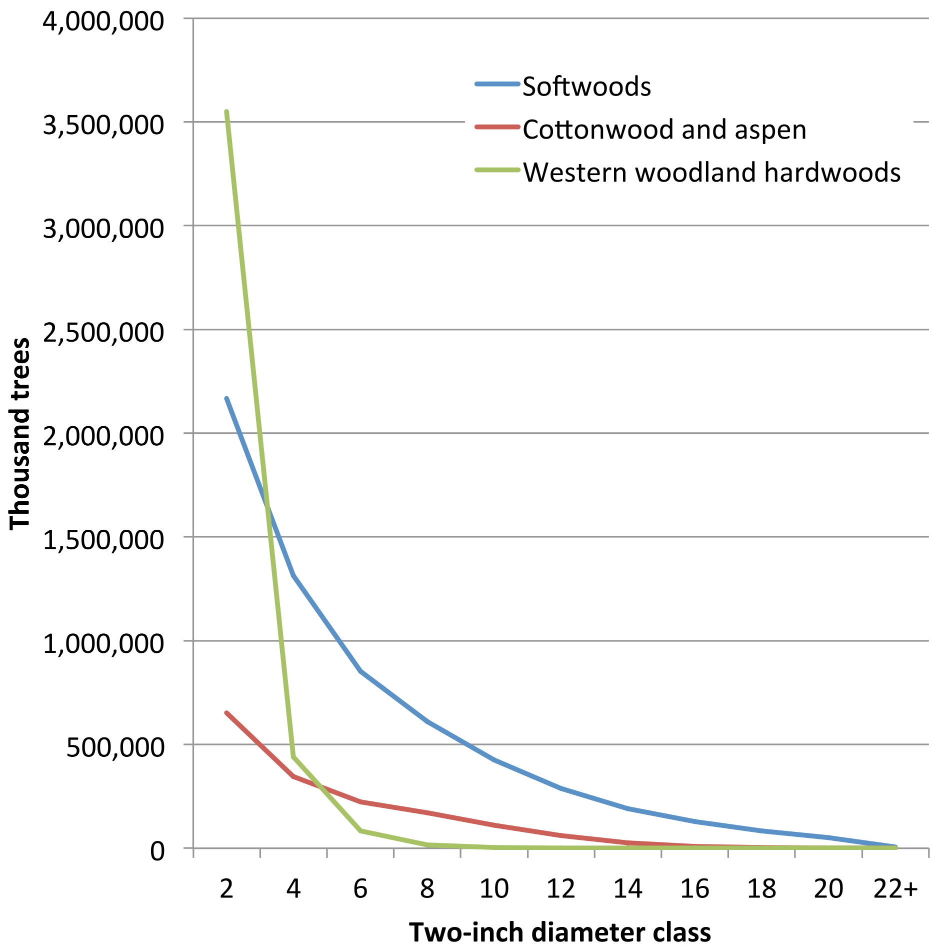


**Figure 8—**Number of live trees 1.0 inch in diameter and larger on forest land, by diameter class and major species group, Colorado, 2004–2013.

hardwoods—in Colorado. The distribution of live trees by diameter class indicates the typical inverse j-shape for softwoods and the cottonwood and aspen groups. The western woodland hardwoods species group has a very high proportion (97 percent) of live trees in the smallest diameter class (less than 5.0 inches in diameter) compared to the softwoods (57 percent) and cottonwood and aspen (62 percent).

## Tree Volume and Biomass

The amount of cubic-foot volume of wood in a forest is important for determining the sustainability of current and future wood utilization. The forest products industry and forest managers are interested in knowing the tree species composition and size distribution, as well as the geographic location and ownership status, of available wood volume. Estimates of gross and net volume include only the merchantable portion or sawlog portion (e.g., cubic-foot or board-foot) of live trees 1 inch in diameter and larger. Net volumes are computed by deducting rotten, missing, or form defects from gross volume. Net volume is reported below as net volume of all live trees, net volume of growing-stock trees, net volume of sawtimber, and net volume of sawlogs. All of these terms are defined below as well as in Appendix A. Biomass estimates are based on gross volumes and describe aboveground tree weight (oven-dry) by various components (merchantable bole and bark, tops and limbs, saplings). The sources of the equations used to estimate volume and biomass are documented in Appendix E.

Tables B12 through B16 illustrate the net volume of all live trees 5.0 inches in diameter and larger on Colorado's forest land, by various discrete categories. The net volume of all live trees on Colorado's forest land totals 35.2 billion cubic feet (Appendix B table B12). Almost 69 percent, or 24.2 billion cubic feet, is located on lands managed by the National Forest System. About 22 percent of the NFS-managed live volume exists on reserved lands and is unavailable for harvest. Privately owned forests contain 15 percent of the State's total live volume, or 5.5 billion cubic feet. Forest land controlled by the Bureau of Land Management accounts for 12 percent of total live volume, or 4.1 billion cubic feet.

The Engelmann and other spruces species groups contain the highest level of live tree volume at 11.1 billion cubic feet, or 32 percent of the total, of any species group (fig. 9). Second in abundance, the cottonwood and aspen species group accounts for 14 percent, or 5.1 billion cubic feet. The western woodland softwood, true fir, and lodgepole pine species groups account for 13, 12, and 11 percent of the total live volume, respectively.

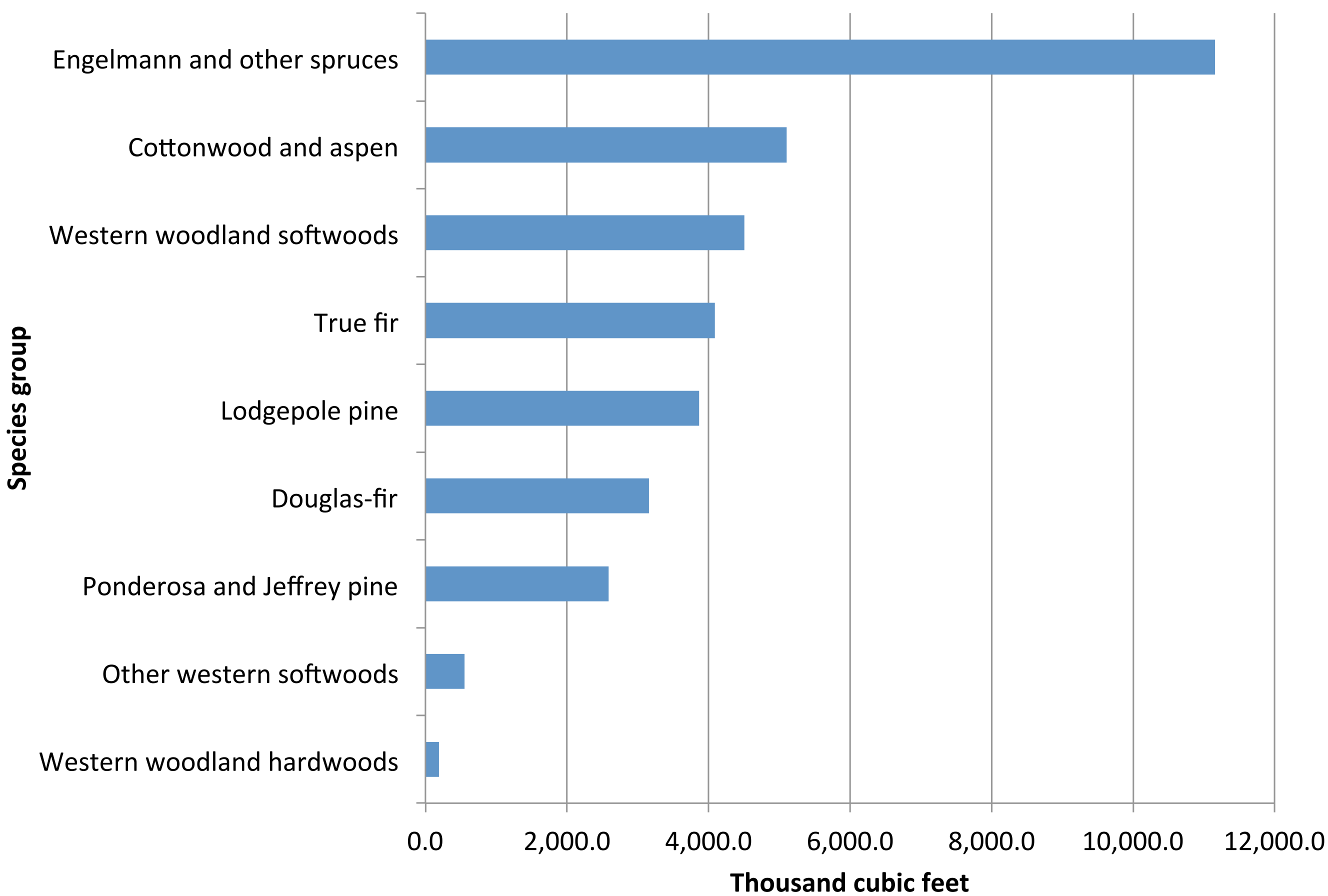


**Figure 9**—Net cubic feet volume of trees 5.0 inches in diameter or larger on forest land, by species group, Colorado, 2004–2013.

Growing-stock volume represents the live tree volume that is potentially available for harvest. The availability of timber volume for harvest is affected by three primary factors: reserved status, productivity, and merchantability. Timberland is defined as unreserved forest land capable of producing in excess of 20 cubic feet per acre per year of wood at culmination of mean annual increment. Merchantable trees are those that are 5.0 inches in diameter or larger and contain, or have the potential to produce, an 8-foot sawlog that is reasonably free of defects. Growing-stock trees are live, merchantable trees that occur on timberland. Therefore, growing-stock volume on timberland represents the amount of timber that is potentially available for harvest. The net volume of growing-stock trees on timberland in Colorado totals 22.9 billion cubic feet (Appendix B, table B17), or 65 percent of the total live volume on forest land.

The relationship between the growing stock-volume on timberland and all live volume on all forest land by species group indicates those tree species that have a higher likelihood of being harvested for timber products in Colorado. Over 87 percent, or 2.3 billion cubic feet, of the total live volume in the ponderosa and Jeffery pine species group is growing stock volume on timberland. Based on this ratio, this species group has the highest proportion of live volume available for harvest in Colorado. This same ratio was 86 percent for the cottonwood and aspen species group. Eighty percent of the Douglas-fir live volume is potentially available for harvest followed by true fir (75 percent) and lodgepole pine (74 percent). In comparison, the Engelmann and other spruces species group—the most abundant species group in terms of live volume—ratio of available to all live volume was only 67 percent. Live volume is also reported for sawtimber trees, which are defined as softwood trees 9.0 inches in diameter or larger, or hardwood trees 11.0 inches in diameter or larger (International ¼-inch rule). The net volume of sawtimber trees on timberland totals 85.5 billion board feet (Appendix B, table B19).

The total weight of oven-dry above-ground biomass on Colorado's forest land is 632 million tons. Sixty-six percent, or 418 million tons, occurs on NFS forest land. Although biomass is typically sold by green weight, the water content of wood is highly variable geographically, seasonally, and even across portions of a single tree. Therefore, live-tree inventory estimates of green biomass may be unreliable or even misleading. In contrast, oven-dry weight does not change due to fluctuations in tree water-content.

## Forest Growth and Mortality

Forest vigor, sustainability, and timber supply are often assessed by what are referred to as forest change components: growth, mortality, and removals. The relationship among these three change components quantifies the change in tree volume over time. Growth is typically expressed as net annual growth and is defined as the gross, or total, average annual growth in tree volume minus the volume lost through mortality. Mortality is the average annual net volume of trees dying over a given time period due to natural causes and excludes the volume removed through harvesting. Tree mortality often occurs at low and predictable rates due to insects and disease, suppression by overstory trees, or advanced tree age. Occasionally, highly concentrated and localized losses occur due to insect and disease epidemics, wildfire, or severe weather events. Removals represent the net volume of growing-stock trees removed from the inventory by harvesting or other cultural operations (such as timber-stand improvement), by land clearing, or by changes in land use (such as a shift to wilderness).

The three components of forest change—growth, mortality, and removals—are typically analyzed using measurements of the same plot at two points in time. It is possible, however, to also estimate growth and mortality rates based on a single inventory, as described below. In contrast, removals cannot be reliably estimated without having two measurements of the same set of plots. The Colorado inventory did not begin remeasurement until 2012, and only 20 percent remeasurement is not sufficient to provide a reliable plot-based estimate of change components. Therefore recent removals can only be estimated using information about the amount of wood cut and processed by the forest products industry. Due to this difference in analysis methods, growth and mortality are analyzed and discussed separately from removals.

In Colorado, the procedures used to estimate tree growth and mortality depended on the remeasurement status of the plot. A remeasured or paired plot refers to a plot where a periodic inventory plot was established in the previous inventory (time 1), and the field crews were able to relocate the plot and account for all trees measured during the current inventory (time 2). In most cases, the previous and current plots are co-located. As of 2013, about 20 percent of all plots that sample forest land in Colorado were remeasured, so the same trees were measured at two points in time. For trees that were alive at time 1 and time 2, growth is calculated based upon the change in volume over the time interval between plot visits. The time interval between remeasured plot visits in Colorado averaged 10 years. Mortality volume is based upon the volume of any tree that qualifies as a mortality tree over the time interval between plot visits. A tree is classified as mortality if it was alive at time 1 but dead at time 2.

A new plot is a plot established for the first time where there was no previous co-located plot to be remeasured. On new plots, annual growth is estimated from a sample of increment core measurements based on the previous 10 years of radial growth. Mortality is estimated from trees that died in the 5 years prior to the year of measurement.

The annual estimate of gross growth of all live trees 5.0 inches in diameter and greater on forest land in Colorado totaled nearly 559.0 million cubic feet. This is the sum of growth on all survivor and ingrowth trees. Survivor trees are live trees 5.0 inches and larger in diameter at time 1 and still alive at time 2 on remeasured plots, and live trees determined to be 5.0 inches and larger in diameter 10 years prior to the current measurement on new plots. Ingrowth trees are live trees 5.0 inches and larger in diameter that grew over the 5.0-inch threshold between time 1 and time 2 on remeasured plots or during the previous 10 years on new plots.

The average annual mortality of trees 5.0 inches and larger in diameter was 704.2 million cubic feet (Appendix B, table B25). The difference between the

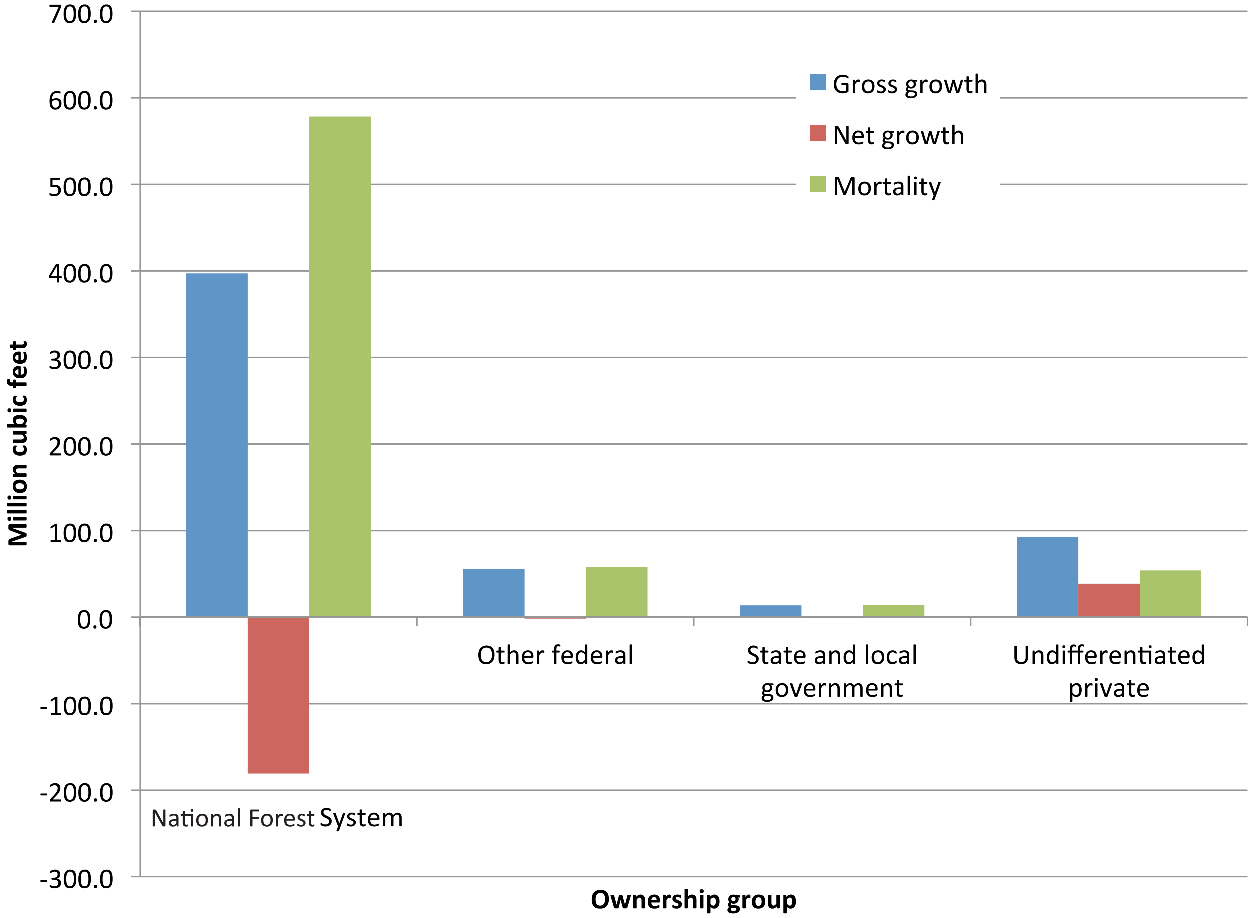


**Figure 10—**Annual gross growth, net growth, and mortality on forest land by ownership group, Colorado, 2004–2013.

live tree, or gross, growth and mortality indicates a net annual growth estimate of –145.2 million cubic feet on forest land in Colorado (see Appendix B, tables B21-B24). The –145.2 million cubic feet of net annual growth in Colorado signifies an inventory of live trees that is decreasing annually in the absence of trees removed from human-caused activities. High levels of tree mortality are offsetting gains from live tree growth.

Net annual growth varies considerably by major owner group. Figure 10 illustrates the relationship between annual gross growth, net growth, and mortality by owner group in Colorado. Annual mortality of all trees on forest lands managed by National Forest Systems totaled 578.3 million cubic feet (Appendix B, table B25) compared to –181.1 million cubic feet of net annual growth (Appendix B, table B21). In contrast, net annual growth was positive on privately owned forests: net growth totaled 38.5 million cubic feet compared to 54.1 million cubic feet of mortality.

Figure 11 illustrates the relationship between annual gross growth, net growth, and mortality for seven major inventory species in Colorado. Negative net growth was recorded for lodgepole pine, Engelmann and other spruces, and true fir species groups. Mortality was highest in the State for lodgepole pine at 257.5 million cubic feet followed by the Engelmann and other spruces species group at

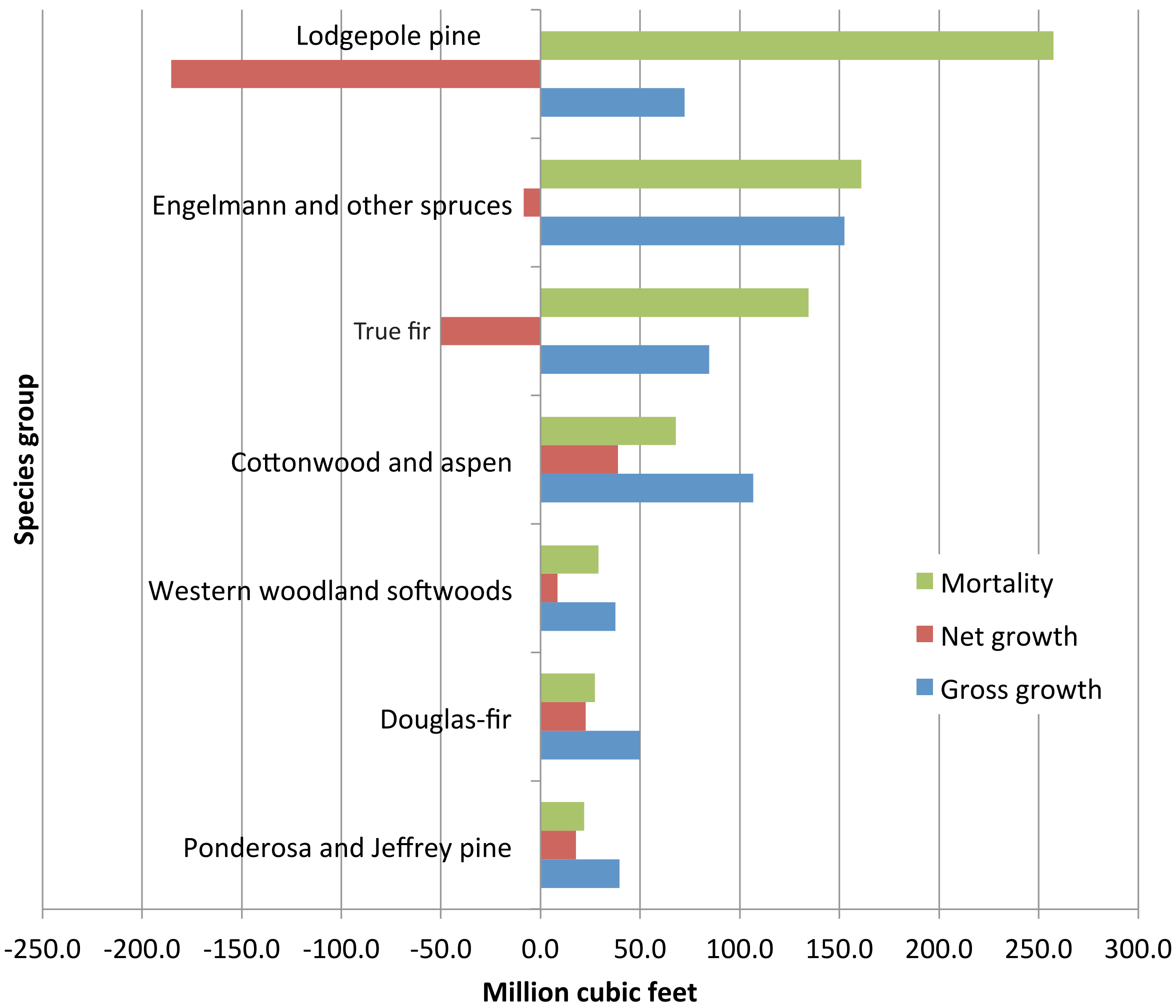


**Figure 11—**Annual gross growth, net growth, and mortality on forest land by seven major species groups, Colorado, 2004–2013.

161.0 million cubic feet. The other four major species groups recorded positive net growth with cottonwood and aspen having the highest level of net annual growth at 38.9 million cubic feet. Net growth of Douglas-fir averaged 22.7 million cubic feet compared to 27.2 million cubic feet of mortality. Net growth of the ponderosa and Jeffery pine species group averaged 17.7 million cubic feet compared to 22.0 million cubic feet of mortality.

Since high mortality is the driving force behind the large differences between gross and net growth, further examination of this change component by other resource attributes can help explain the factors behind the high level of tree volume estimated to have died. Significant differences were observed in per-acre estimates of mortality between major ownership groups and reserved statuses. Converting the state-level estimates of mortality into per-acre estimates removes the effect of differences in the amount of forest land controlled by different ownership groups. Across all ownerships, the per-acre estimate of annual mortality volume averages 30.8 cubic feet per year on forest land. Mortality on reserved forest land was significantly higher than unreserved land. Average annual mortality on reserved

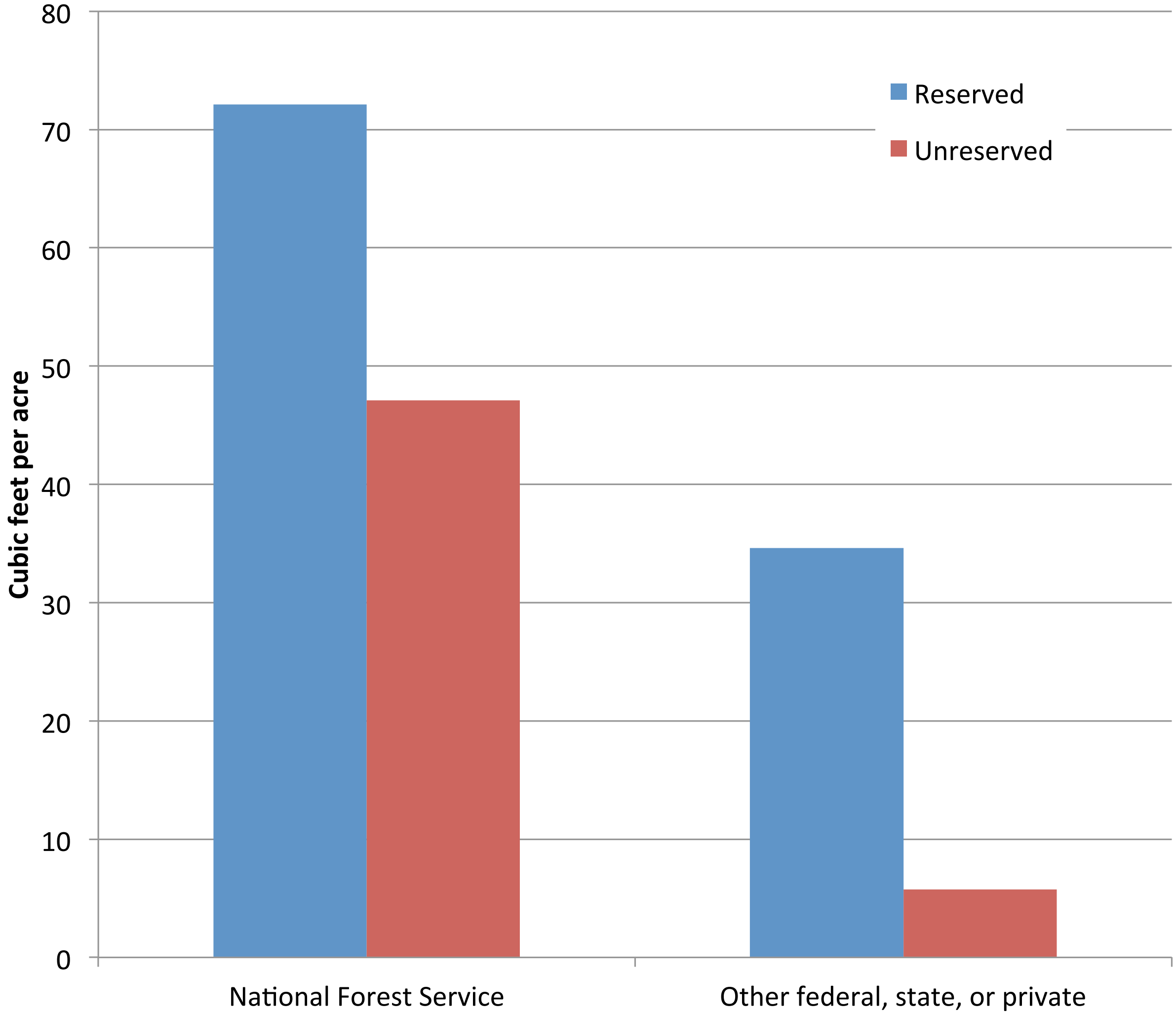


**Figure 12—**Average annual per-acre mortality on forest land by two major owner categories and reserved status, Colorado, 2004–2013.

land averaged 62.9 cubic feet per acre, compared to 31.5 cubic feet per acre on unreserved forest land. Figure 12 illustrates per-acre estimates of mortality by two major owner categories and reserved status. Reserved lands managed by the National Forest System recorded the highest average level of per-acre mortality at 72.1 cubic feet, which is over 12 times higher than the per-acre estimate recorded on unreserved land controlled by private landowners, other Federal agencies, and State agencies.

All trees classified as mortality trees are assigned a cause of death in the field. Drawing conclusions from mortality estimates by cause of death should be done with caution because the actual agent that caused a tree's death may be difficult, if not impossible, to determine. The "other" cause of death category includes trees that have died due to reasons the field crews are unable to determine. Interactions between insects and diseases are complex and make identification of causal agents difficult. Figure 13 illustrates per-acre estimates of mortality by reserved status and cause of death. Mortality due to insects accounted for the majority (66.5 percent) of total mortality. Disease was the second leading contributor to mortality,

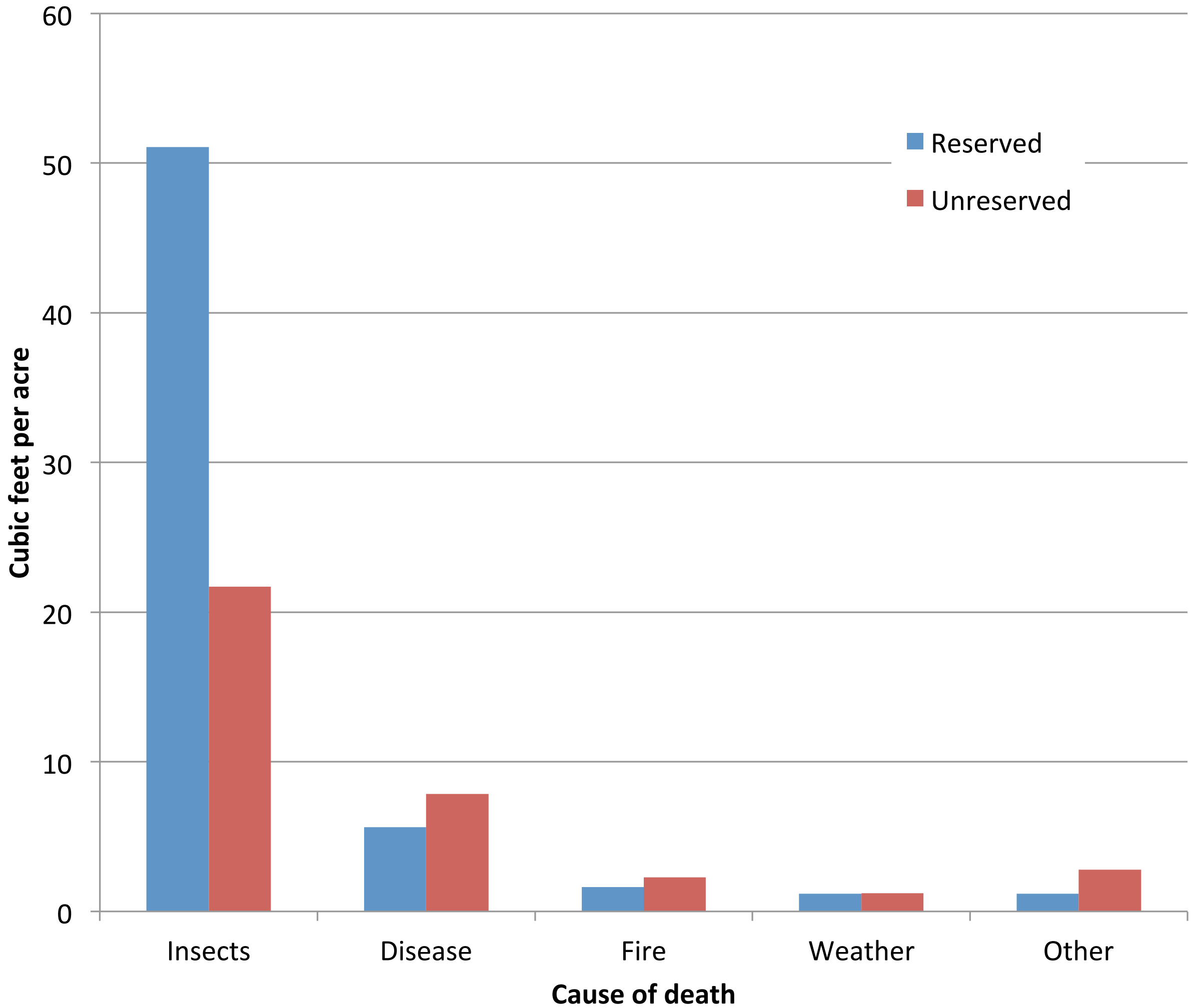


**Figure 13—**Average annual per-acre mortality on forest land by reserved status and cause of death, Colorado, 2004–2013.

accounting for 18.7 percent of total mortality. Fire accounted for 5.4 percent. The reasons behind the differences in levels of tree mortality by owner class and reserved status deserve further investigation. These differences have been observed in other State inventories (Goeking et al. 2014; Menlove et al. 2012; Witt et al. 2012), suggesting that reserved National Forest System lands have a larger share of aging forest stands that are more susceptible to insect and disease. This assumption could be verified with additional analysis of stand age, structure, density, species composition, and management regimes.

## Stand Density Index (SDI)

Stand density index (Reineke 1933) is a relative measure of stand density, based on quadratic mean diameter of the stand and the number of trees per acre. In the western States, silviculturists often use SDI as one measure of stand structure to meet diverse objectives such as ecological restoration and wildlife habitat (e.g., Lilieholm et al. 1994; Long and Shaw 2005; Shaw and Long 2007; Smith and Long 1987). Originally developed for even-aged stands, SDI can also be applied to uneven aged stands (Long and Daniel 1990; Shaw 2000). Stand structure can influence the computation of SDI, so the definition of maximum SDI must be compatible with the computation method. Stand density index was computed for each condition that sampled forest land using the summation method (Shaw 2000), and the SDI percentage was calculated using the maximum SDI for the forest type found on the condition.

Stand density index is usually presented as a percentage of a maximum SDI that is determined for each forest type. Maximum SDI is rarely, if ever, observed in nature at the stand scale because the onset of competition-induced (self-thinning) mortality occurs at about 60 percent of the maximum SDI. Within-stand variability of density results in the average stand density being well below that of the densest patches. A site is considered to be fully occupied at 35 percent of maximum SDI. Below about 25 percent of maximum SDI, individual trees are considered "free to grow." At these lower densities, individual tree growth is maximized but stand growth is below potential, while at higher densities, individual tree growth is below potential, but stand growth is maximized (Long 1985). There are several reasons why stands may have a low SDI. Stands typically have low SDI following major disturbances, such as fire, insect attack, or harvesting. These stands remain in a low-density condition until regeneration fills available growing space. Stands that are over-mature can also have a low SDI, because growing space may not be reoccupied as fast as it is released by the mortality of large, old trees. Finally, stands that occur on very thin soils or rocky sites may remain at low density indefinitely, because limitations on physical growing space do not permit full site occupancy.

There has been substantial change in Colorado's forests since annual inventory was started in 2002. Mountain pine beetle populations began to increase shortly afterward and reached epidemic levels in the late 2000s (see the *Colorado's Mountain Pine Beetle Epidemic* section in this report; Thompson 2009; Thompson et al. 2010), killing a large proportion of lodgepole pines in the State. The pinyon ips beetle also killed many common pinyon trees (Shaw et al. 2005) in the early 2000s. Drought has led to an increase in aspen mortality in some parts of the State (see the *Sudden Aspen Decline* section in this report; Worrall et al. 2008). In contrast, with a few exceptions fire has not had as proportionally great of an effect on forests of Colorado as it has in other Interior West States. Given the number of factors that result in mortality or reduced growth, we expected to find some change in relative density—in the form of overall lower SDI—in Colorado's forests.

Because SDI is a condition-level variable, computation of SDI on individual conditions is sensitive to high scaling factors that are associated with small condition proportions (that is, conditions that occupy only a small fraction of the plot footprint). For this reason, the analysis of SDI presented here only uses conditions with a condition proportion of 0.5 or greater. This subset of plots was divided by measurement year, with plots measured from 2002 to 2007 representing early- or pre-disturbance conditions (n = 2,535) and plots measured from 2008 to 2013 representing late- or post-disturbance conditions (n = 2,411).

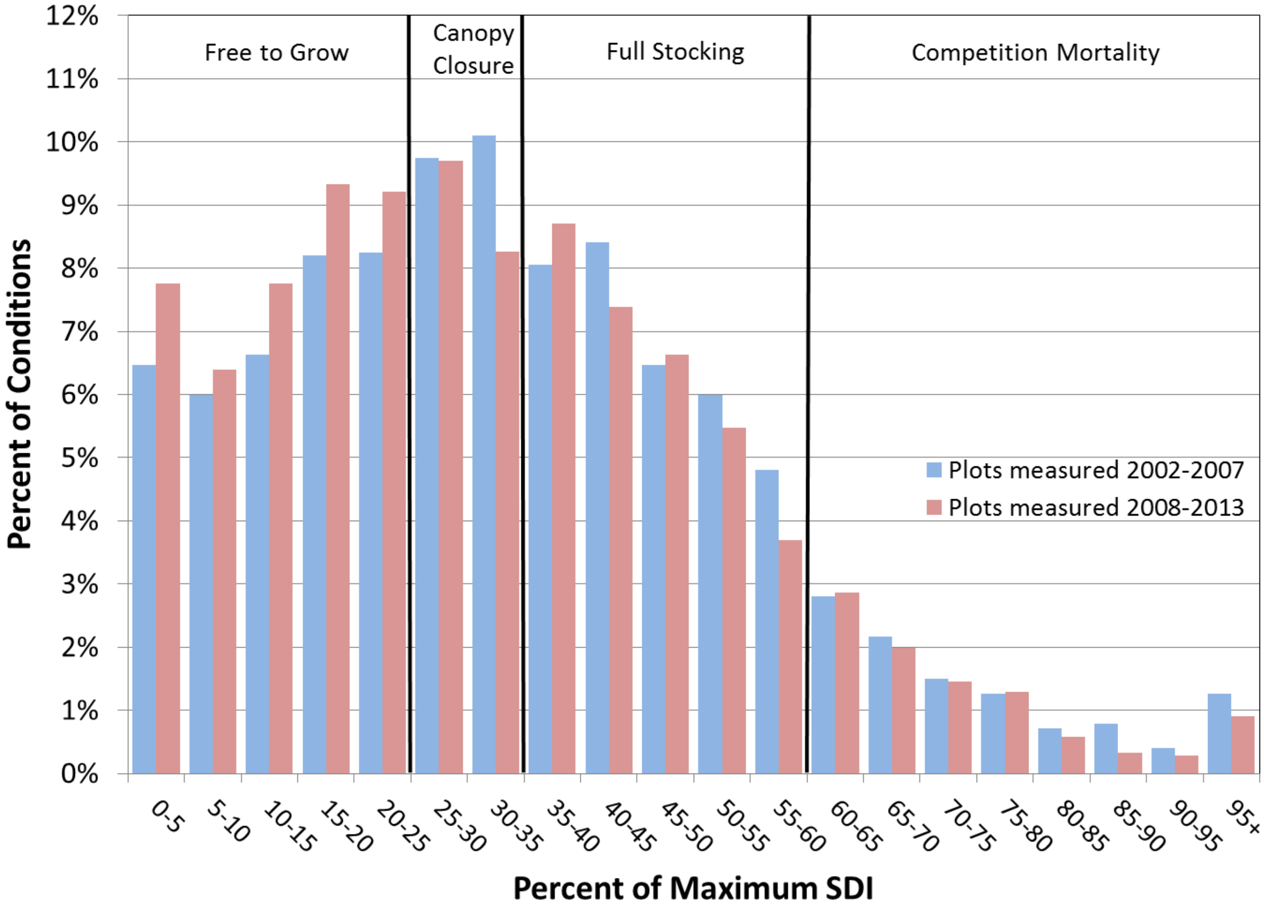


**Figure 14—**Distribution of condition-level SDI percentage in Colorado for two time periods: 2002–2007 and 2008–2013.

A statistical comparison, using a t-test, shows that the decrease in mean SDI is small (34.6 percent to 32.4 percent), but it is statistically significant ($t = 3.58$; $P < 0.001$). In the previous FIA report on Colorado's forests (Thompson et al. 2010), we noted that the SDI distribution would be "likely to skew toward lower-density stands in the coming years, because the most recent data suggests that there has been considerable mortality in conifers." The anticipated change is apparent in figure 14, where the proportions of conditions in each SDI percentage class are compared for the two measurement periods. The number of conditions by SDI class has been normalized to account for the differing numbers of conditions in the two groups in order to make the classes more comparable. There is now a higher proportion of conditions in the "free to grow" class as compared to the earlier part of the inventory period, and somewhat lower proportions of conditions in the higher density classes.

The expected trajectory over the short term is a gradual increase in stand density. In the absence of disturbance or natural senescence of stands, unoccupied growing space will gradually be filled. However, disturbance-free periods are rare, and stands are continually maturing. Therefore, the average relative density of a population always remains well below the potential relative density. The result is that there are periods of increasing average density and periods of decrease. Only about 2.4 percent of conditions have no trees present that are 1.0 inches diameter or greater—that is 0 percent of maximum SDI—although there may be seedlings present. This means the vast majority of stands have live stems remaining to immediately begin to occupy free growing space.

In cases where partial disturbance of the stands has resulted in lower relative density, and especially where the relative density is now in the "free to grow" range, the lower density can lead to higher growth rates of the remaining trees than would have occurred in the absence of disturbance. As a result, there is a compensating effect, where reduced competition causes relative density to rebound more rapidly than would be expected, based on pre-disturbance growth rates. Many residual trees in low-density stands should have increased vigor in response to lower competition, and they may be more resistant to further disturbance. Future plot measurements will record changes as residual trees and new regeneration recapture available growing space. In the absence of high rates of disturbance, relative density should begin to recover in the coming years.

# Colorado's Forest Resources

## Colorado's Primary Wood Products Industry

The University of Montana's Bureau of Business and Economic Research (BBER), in cooperation with the Interior West FIA program, conducts periodic censuses of Colorado's primary forest products industry (Hayes et al. 2012; Sorenson et al. 2015). Censuses of Colorado's primary wood products industry were conducted for calendar years 2002, 2007, and 2012, documenting the condition of the industry. Colorado's industry consisted of 58 active manufacturers in 2012 (table 3). Primary wood products manufacturers are firms that process timber into manufactured goods such as lumber and house logs, while the secondary industry further processes outputs from the primary industry into other value-added wood products, such as cabinets, doors, or furniture. The sawmill sector, manufacturing lumber and other sawn products, was the largest sector, operating 31 mills during 2012; 12 facilities produced house logs and log homes, down dramatically from 46 in 2002 and 19 in 2007. In both 2007 and 2012, there were also 15 facilities producing other primary products including excelsior, fuel pellets, posts, poles, log furniture, and biomass/energy.

Timber processors in Colorado received 89.2 million board feet (MMBF) Scribner of timber in 2012 (table 4), including 8.2 MMBF that was harvested

**Table 3—**Active Colorado primary wood products facilities by product, 2002, 2007, and 2012.

| | Lumber | House logs and log homes | Other products | Total |
|---|---|---|---|---|
| 2012 total | 31 | 12 | 15 | 58 |
| 2007 total | 30 | 19 | 15 | 64 |
| 2002 total | 50 | 46 | 37 | 133 |

**Table 4**—Timber received by Colorado primary wood products industry by ownership class and product, 2007 and 2012, MBF Scribner.

| Ownership class | Sawlogs | House logs | Other products[a] | All products |
|---|---|---|---|---|
| | ---------------------------2007--------------------------- | | | |
| Public timberland | 36,917 | 5,275 | 6,790 | 48,982 |
| Private and tribal timberland | 38,192 | 927 | 5,740 | 44,859 |
| Canada | | 30 | | 30 |
| All owners | 75,109 | 6,232 | 12,530 | 93,871 |
| | ---------------------------2012--------------------------- | | | |
| Public timberland | 43,144 | 1,492 | 18,161 | 62,797 |
| Private and tribal timberland | 18,852 | 1,637 | 5,900 | 26,389 |
| All owners | 61,996 | 3,129 | 24,061 | 89,186 |

[a]Other products include energywood logs, fiber logs, posts, poles, furniture logs, and industrial fuelwood.

outside the State. While the overall 2012 timber receipts declined by 5 percent, receipts of "other products" nearly doubled from 2007 to 2012. This coincided with decreases in sawlog and house log receipts at Colorado mills. Public lands continued to provide a larger share of total timber receipts at 70 percent (63 MMBF) in 2012, versus 52 percent (49 MMBF) in 2007 and 35 percent (29 MMBF) in 2002. While private and tribal land provided a smaller share (30 percent) of timber receipts in 2012 than in past years, 52 percent (1.6 MMBF) of house logs were sourced from private and tribal land. In 2007, just 15 percent of house logs came from private and tribal lands.

After a long period of declining output, lumber production at Colorado sawmills fell to 83 MMBF in 2002 before increasing to 116 MMBF in 2007 and declining again to 95 MMBF in 2012. The number of sawmills in Colorado dropped from 50 in 2002 to 30 in 2007 and 31 in 2012. Of the 31 sawmills in the State in 2012, the eight largest mills produced an annual average of nearly 11 MMBF of lumber, while 23 smaller sawmills produced an average of 386 MBF per mill during the year. On average, Colorado sawmills produced approximately 1.58 board feet of lumber for every board foot Scribner of timber processed, resulting in an average overrun of 58 percent in 2012. This continued the trend of increasing overrun through time, as overrun was 47 percent in 2002 and 54 percent in 2007. Improved milling technologies and increased use of smaller diameter timber both contributed to increased overrun.

Sales from Colorado's primary wood products industry during 2012 totaled nearly $87 million (table 5). Sawmill sales accounted for 45 percent ($39 million) of total sales, house log and log home manufacturers accounted for 16 percent (nearly $14 million), while other products accounted for 40 percent (over $34 million). Colorado was the leading market area for log homes, posts, poles, and log furniture, with in-state sales accounting for almost 39 percent of total sales. The North Central States were the leading market area for lumber and the second leading market area overall with 23 percent of sales from Colorado's mills going to the region. Other Rocky Mountain States and the South followed with 9 and 8 percent of total sales, respectively.

**Table 5—**Finished product sales of Colorado's primary wood products sectors, 2002, 2007, and 2012.

| Sector | 2002 | 2007 | 2012 |
|---|---|---|---|
| | ------------Thousands of 2012 dollars[a]------------ | | |
| Sawmills | 51,523 | 49,176 | 38,867 |
| House logs and log homes | 34,727 | 21,246 | 13,524 |
| Other sectors[b] | 32,901 | 40,015 | 34,465 |
| Total | 119,151 | 110,437 | 86,856 |

[a]All sales are reported f.o.b. the manufacturer's plant.
[b]Other sectors include producers of posts, poles, log furniture, fuel pellets, biomass/energy, and excelsior.

The 95 MMBF of lumber produced by Colorado's sawmills represented use of only 54 percent of the State's annual sawmill production capacity in 2012 (176 MMBF), which was a slight decline from 56 percent of capacity used in 2007. Colorado timber processors produced 108,009 bone dry units (BDU) of mill residue in 2012, with 99 percent utilized, versus 98 percent of residue utilized in 2007. Sawmills produced the majority of mill residue, resulting in 0.99 BDU per MBF of lumber in 2012, compared to 1.04 BDU per MBF of lumber in 2007.

The classification of forest industries used here follows the North American Industry Classification System (NAICS) available online via the U.S. Department of Commerce Census Bureau (USDC CB 2014). The forest industry can be found in four categories: NAICS 113—forestry and logging; NAICS 1153—forestry support activities; NAICS 321—wood product manufacturing; and NAICS 322—paper manufacturing. These categories include employees that work in both the primary and secondary wood products sectors, as defined above.

Employment in Colorado's forest industry, defined as the sum of employment in Forestry and Logging, Forestry Support, Wood Product Manufacturing, and Paper Manufacturing, has declined in recent years, though it remains an important source of jobs in many communities around the State. There were approximately 6,700 jobs in the industry in Colorado in 2012, compared to 9,100 in 2002 and 9,250 in 2007 (Bureau of Economic Analysis 2014). About 2,050 workers were employed in the "primary" industry—harvesting and processing timber or in private sector land management—during 2012, and the remaining component of the industry can be classified as secondary, employing approximately 4,650 workers in 2012. From 2007 to 2012, employment in Colorado's forest industry declined nearly 30 percent overall. However, primary forest industry employment actually increased over that period, with the employment decrease coming entirely from the secondary industry.

## Removals for Timber Products

Volume removed from forest inventory by timber harvesting, other cultural operations (such as timber-stand improvement), or land clearing is referred to as "removals." Removals are an important indicator of the sustainability of forest management. Removals that exceed growth for extended periods can indicate over-harvesting. However, growth or mortality levels that greatly exceed removals can signal a potential need for increased vegetation management to decrease risks such as insect or disease outbreaks and wildfire, which can be associated with overstocking and high tree mortality.

Removals can come from two sources: the growing-stock portion of live trees (live trees of commercial species meeting specified standards of quality or vigor), or dead trees and other non-growing stock sources. The two types of removals addressed in this section are timber products harvested for processing by mills and logging residue (i.e., volume cut or killed during harvesting operations but not utilized). Removals, as reported here, are based on a census of Colorado's primary forest products industry operating during 2012 (Sorenson et al. 2015 in preparation) and U.S. Energy Information Administration data for 2012 Colorado residential fuelwood consumption (EIA 2014).

Colorado's 2012 timber harvest for industrial wood products (which does not include residential firewood) was approximately 82 million board feet (MMBF) Scribner (Sorenson et al. 2015), or about 21.6 million cubic feet (MMCF). Dead trees accounted for about 46.2 MMBF (56 percent). The 2012 harvest was about 4.5 MMBF (5 percent) lower than the 2007 harvest (Hayes et al. 2012) but about 3 percent higher than the 2002 harvest of 79.7 MMBF (Morgan et al. 2006). A complete time series of Colorado's annual timber harvest is not available, although historic reports indicate somewhat higher harvest levels; for example the 1982 harvest was over 103 MMBF (McLain 1985).

In Colorado, removals for all timber products (including firewood) totaled 48 MMCF during 2012. Just 19 percent (9 MMCF) of removals for products came from growing stock, with over 39 MMCF coming from other sources, including dead trees and other non-growing stock sources. At 31.3 MMCF, fuelwood, including residential firewood, was the leading timber product, accounting for 65 percent of removals for products. Sawlogs, for producing lumber, accounted for 13.3 MMCF, almost 28 percent. Logs for miscellaneous products (e.g., excelsior, log homes, and log furniture) accounted for 4 percent (2 MMCF); and logs for posts and poles accounted for the remaining 3 percent of removals for timber products.

Approximately 95 percent (45.7 MMCF) of removals for products consisted of softwood species. The largest volume (1.1 MMCF) of hardwoods was used for sawlogs, with smaller quantities used for miscellaneous products and fuelwood.

Total removals in Colorado during 2012 were 50.7 MMCF. This included the 48 MMCF used for timber products and 2.7 MMCF of logging residue left in the forest as slash. Growing-stock removals were 9.4 MMCF. About 95 percent (9 MMCF) of growing-stock removals were used to produce wood products, and less than 5 percent (0.4 MMCF) were left in the forest as slash and not utilized. Sawlogs were the largest component (65 percent) of growing-stock removals, followed by fuelwood (14 percent).

One-third (3.1 MMCF) of growing-stock removals came from private and tribal timberlands, while 61 percent (5.8 MMCF) came from national forests. About 5 percent of the volume removed from growing stock was from other public lands. Ponderosa pine accounted for 25 percent (2.4 MMCF) of growing-stock

**Table 6**—Colorado total removals for products and logging residue, 2002, 2007, and 2012.

| | 2002 | 2007 | 2012 |
|---|---|---|---|
| | Million cubic feet | | |
| Sawlogs | 12.272 | 13.853 | 13.293 |
| Posts and poles | 0.0405 | 1.253 | 1.383 |
| Other products | 3.281 | 3.485 | 2.033 |
| Industrial products | 15.958 | 18.591 | 16.709 |
| Fuelwood | 18.983 | 25.776 | 31.314 |
| Total products | 34.941 | 44.367 | 48.023 |
| Logging residue | 3.624 | 2.551 | 2.713 |
| Total removals | 38.564 | 46.918 | 50.736 |

removals. Spruces also represented about 25 percent (2.3 MMCF), aspen (1.8 MMCF), lodgepole pine (1.5 MMCF), and Douglas fir (1.1 MMCF) together accounted for 47 percent of growing-stock removals.

Total removals for timber products and logging residue in Colorado were estimated to have increased about 30 percent over the past 10 years (table 6), from 38.6 MMCF in 2002 to 50.7 MMCF in 2012. However, most of this increase is attributable to increases in fuelwood consumption, rather than harvest for industrial timber products. The harvest of timber for industrial products increased less than 5 percent from 2002 to 2012, while fuelwood consumption was estimated to have increased more than 60 percent (EIA 2014).

In Colorado, growing-stock removals for products and logging residue declined over the past decade (table 7), dropping from 12.5 MMCF in 2002 to 9.4 MMCF in 2012. The annual average volume of growing-stock removals for products and associated logging residue was 10.5 MMCF for the 2002 to 2012 period.

Sustainability of Colorado's forests depends, in part, on active management of lands available for timber production, a forest products industry capable of utilizing harvested material, and harvest levels that address the needs of society while maintaining the long-term productivity of the land. But Colorado's commercial timber harvest volume has continued to decrease over the past decade; and the State's forest products industry has been facing mill closures and

**Table 7**—Colorado growing-stock removals for products and logging residue, 2002, 2007, and 2012.

| | 2002 | 2007 | 2012 | Annual average |
|---|---|---|---|---|
| | Million cubic feet | | | |
| Sawlogs | 9.086 | 5.761 | 6.191 | 7.0 |
| Posts and poles | 0.305 | 0.831 | 0.488 | 0.5 |
| Other products | 2.459 | 2.459 | 0.997 | 2.0 |
| Industrial products | 11.850 | 9.051 | 7.676 | 9.5 |
| Fuelwood | 0.001 | 0.093 | 1.323 | 0.5 |
| Total products | 11.851 | 9.144 | 9.000 | 10.0 |
| Logging residue | 0.655 | 0.500 | 0.424 | 0.5 |
| Total removals | 12.505 | 9.644 | 9.424 | 10.5 |

curtailments even as markets have begun to improve. The decline in Colorado's forest products industry has eroded the ability to actively manage forests and generate income for landowners to use towards activities like hazardous fuel reduction or forest restoration, which may not generate revenue. To ensure sustainable harvest levels for future generations, careful consideration should be given not only to growth, removals, and mortality across Colorado's available timberlands, but also to the industry infrastructure and employees that conduct management activities and utilize harvested timber.

## The Pine Nut Resource of Pinyon-Juniper Woodlands

Pinyon-juniper woodlands cover an estimated 4.7 million acres in Colorado, making it the most abundant forest type in the State by area covered. This woodland type usually consists of two-needle pinyon (*Pinus edulis*) and one or more species of juniper (*Juniperus* spp.). In Colorado, Utah juniper (*J. osteosperma*) is the most frequent cohabitant of pinyon-juniper woodlands, with Rocky Mountain juniper (*J. scopulorum*) and oneseed juniper (*J. monosperma*) occurring less often. Pinyon-juniper woodlands commonly occur in the mid-elevation belts between the lower grass/shrublands and either subalpine forests or tree line above (Lanner 1981). Trees from these woodlands have been utilized by indigenous peoples for thousands of years, providing them with building materials for basketry and clothing, hunting tools, shelter, fire wood, and medicine (Floyd and Kohler 1990; Janetski 1997). Pinyon and juniper trees continue to be used as fuel wood in many Native American communities in Colorado, making these woodlands a very important local resource for that reason alone. However, the most important utilization of pinyon-juniper woodlands has been (and continues to be) the abundant and nutritious seeds of the pinyon pine.

Pinyon pine seeds, or "pine nuts," are an extraordinary food resource very high in protein and fats and containing all 20 amino acids required for human growth (Janetski 1997). Unlike many other food items used in the past by native cultures, pine nuts were able to be stored for several years, making it a critical food in winter, times of drought, and periods of game scarcity. Pine nuts continue to be an important cultural and economic staple of contemporary tribal communities in Colorado. Each year pine nuts supplement the diets and incomes of those who know how and where to collect, process, store and sell them. Pine nut production in the U.S. is estimated to be 400 to 500 tons per year, contributing to a $100 million domestic market for the seeds (Sharashkin and Gold 2004).

Two-needle pinyon generally begins producing seeds at around 25 years of age. Although important to wildlife at this stage, the numbers of seeds produced by these young trees are not economical to harvest. Not until tree-age reaches 75 years or so do pinyon trees start producing pine nuts in sufficient quantities to harvest commercially. Two-needle pinyon trees reach maximum seed production around 160 years old and continue until roughly 300 years old, at which time production often falls off considerably (Lanner 1981). Thus, it is useful to know how many acres of pinyon-juniper are currently of sufficient age to provide a useful crop of pine nuts and how many acres are close to moving into and out of the most productive age-classes.

Forest Inventory Analysis data is used to estimate the extent and age distribution of Colorado's pinyon-juniper woodlands and relate the estimates to potential seed production. Estimates were stratified by the age-class groups that reflect the varying seed productivity levels discussed above. In addition, the portion of each age-class that will change over the next 20 years (in the absence of natural or anthropogenic disturbance) is identified. This information is useful to resource managers interested in perpetuating pinyon-juniper woodlands that have the potential to produce large quantities of pine nuts. Many other environmental factors can affect the productivity of an individual tree or stand of pinyon pine (e.g., drought, insects, site quality, and disease) and these estimates speak only to the relative potential of a stand to produce pine nuts given their age.

An estimated 42 percent of Colorado's pinyon-juniper woodlands currently reside in the 75 to 160 year age-class (fig. 15). This age-class represents fully mature trees that consistently yield harvest-worthy quantities of pine nuts. The second-most abundant age-class, at 40 percent, is 160 to 300 years. These stands have the greatest nut production of any age-class. Very few acres of Colorado's pinyon-juniper woodland are expected to move from a productive class to an unproductive one (3 percent). However, many more acres of woodland are within 20 years of moving into a more productive age-class. Barring any major disturbance, over 71 percent (466,388 acres) of the 35- to 74-year age-class will move into the 75- to 160-year age-class, with a roughly equal number of acres (498,969) moving from this category to the older 161- to 300-year age-class (fig. 16). While most age-classes show a reduction in total acres over the next 20 years, the most productive 161- to 300-year age-class will see an estimated 19 percent net increase in area during this time.

These data suggest that in the absence of a major disturbance, Colorado's pinyon-juniper woodland will potentially increase its pine nut output over the next 20 years due to a large recruitment of stands into the most productive age-classes. This analysis assumes no disturbance and thus no increase in non-stocked pinyon-juniper woodlands and no decrease in other age-classes. It also does not consider effects of climate change that might have on production over the next two decades. However, should a major disturbance convert large areas of seed-producing woodlands into zero-aged (non-stocked) sites or climate change reduce the seed output of large stands of pinyon pine, net productivity in the State could remain flat or decrease. Pinyon-juniper woodlands become more susceptible to catastrophic wildfire, disease, and insect outbreaks as they age and become more heavily stocked. So as time passes, the likelihood and amplitude of a major disturbance in these more heavily stocked woodlands increases. In addition, as these woodlands become more productive in terms of pine nut production, they often become less valuable to many wildlife species due to changes in stand structure and understory plant composition and diversity (Miller et al. 2008). Therefore, there are trade-offs that need to be considered when managing pinyon-juniper woodlands for the pine nut resource.

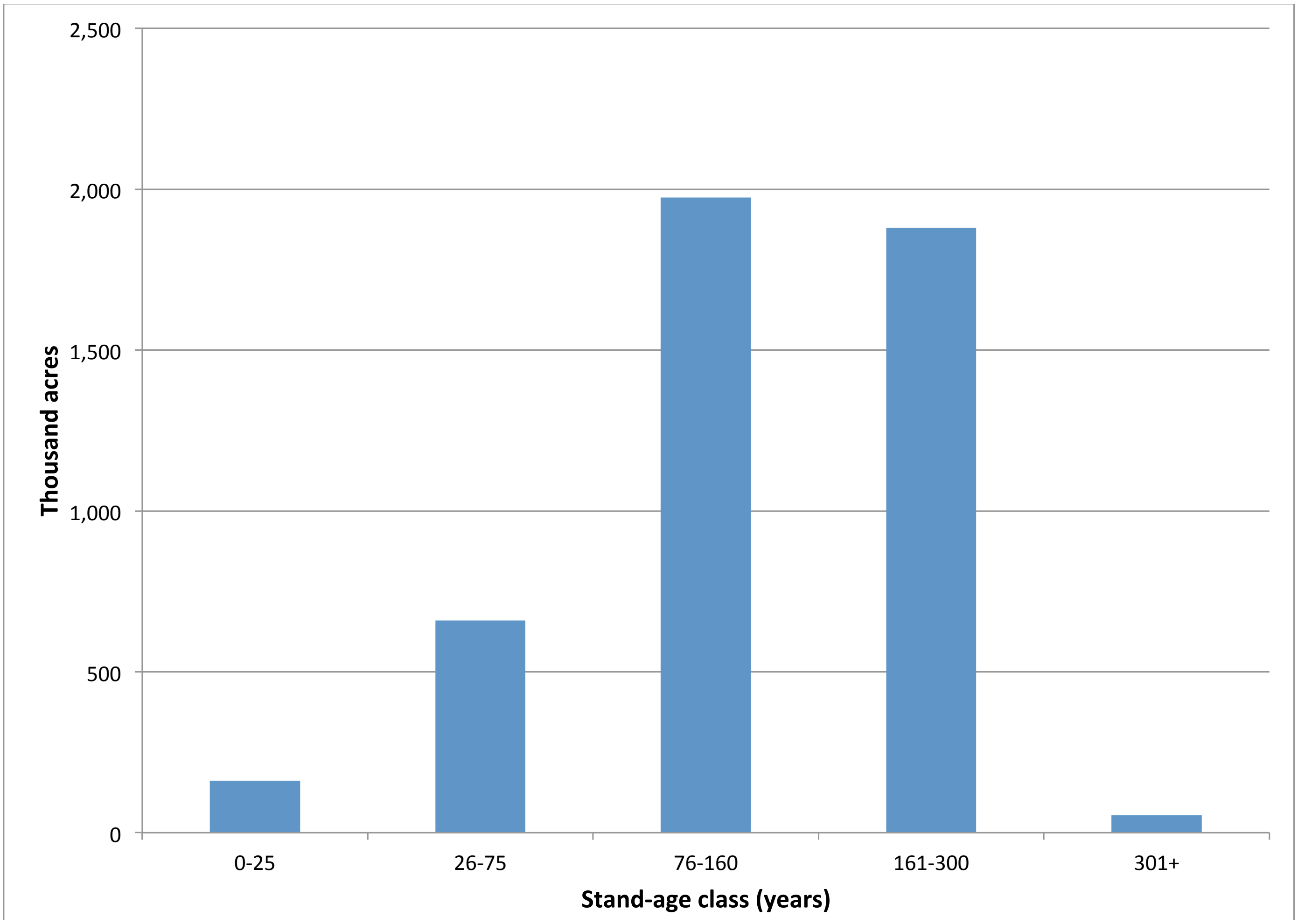


**Figure 15—**Estimated acres of pinyon-juniper woodland by age-class defined by level of pine nut productivity, Colorado, 2004–2013.

## Snags as Wildlife Habitat

Standing dead trees (snags) provide important habitat in many of the forested ecosystems of Colorado. There are many organisms that utilize snags at some point in their life history, including bacteria, fungi, insects, rodents, cavity-nesting birds, bats, raptors, mustelids, and black bears. The diameter of a snag is an important variable to species that use snags as a nesting, roosting, or den site, as larger snags tend to have a longer retention time, provide better thermal insulation, and can provide better protection from predators than smaller snags (Bull et al. 1997; Laudenslayer et al. 2002).

There is a handful of bird species that act as primary excavators of nest sites for a suite of other birds and mammals. These birds create a cavity during one breeding season but often abandon it and create a new cavity the following year (Cline et al. 1980; Conner et al. 1975). The old cavities are often occupied by secondary cavity-nesting birds. Secondary cavity nesters do not excavate their own nest sites and are dependent on primary excavators for their nest cavities. The suitability of an old cavity for a secondary cavity-nester often depends on the species of primary cavity nester that created it.

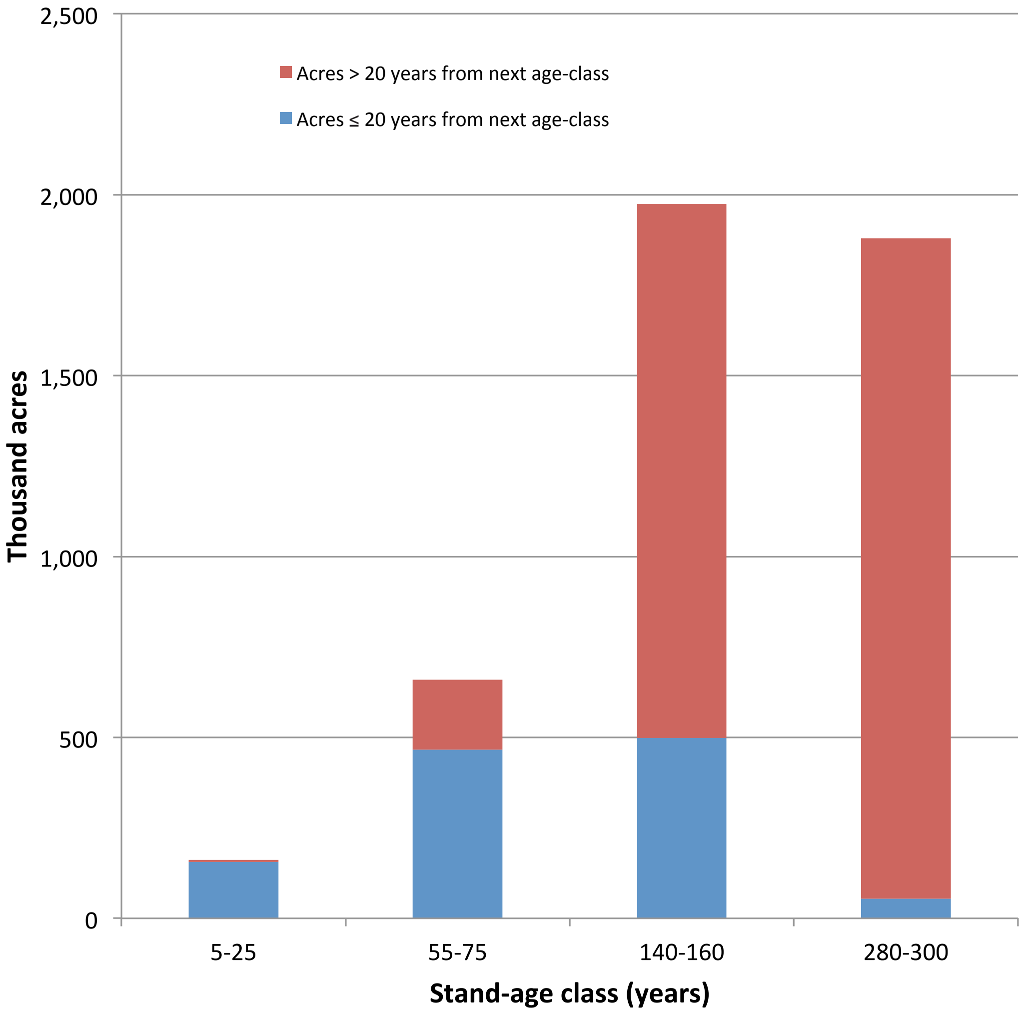


**Figure 16—**Ratio of estimated acres of pinyon-juniper woodland that is ≤20 years from moving into another age-class, Colorado, 2004–2013.

The Northern flicker (*Colaptes auratus*) and Williamson's sapsucker (*Sphyrapicus thyroideus*) create different sized openings and cavities and can be found in a variety of forest types in Colorado (Scott et al. 1980). While flickers are found in abundance in many forest types and choose to nest in snags greater than 19 inches d.b.h., Williamson's sapsuckers in Colorado prefer mid to high elevation conifer forests containing aspen, where they choose dead or dying aspen trees greater than 7 inches d.b.h. for nesting (Crockett and Hadow 1975). Since these two species provide suitable nest sites for a wide variety of secondary-nesting species over a large ecological range, the frequency of their nest site preferences can be used to assess potential nest availability of most cavity-nesting birds in Colorado.

A general estimate of suitable snags was produced for all of Colorado's primary and secondary cavity-nesting birds by estimating the number of snags meeting the size preferences for the two focal species described above. For this analysis, snags with diameters at least 20 inches d.b.h. in any forest type were used to quantify potential flicker nest sites, while aspen snags >7 inches d.b.h. found in Douglas-fir, spruce/fir, and ponderosa pine forest types were used to assess potential Williamson's sapsucker nest sites.

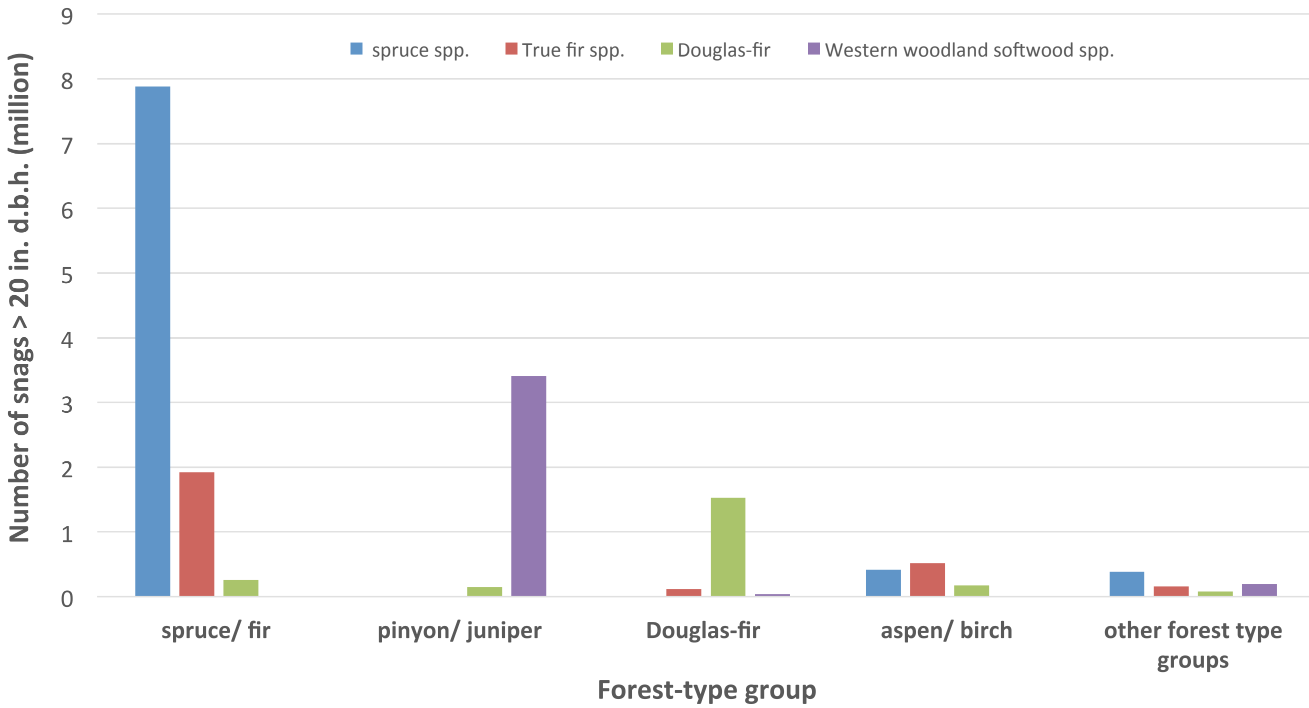


**Figure 17—**Number of snags >20 inches d.b.h. by species group within forest-type group in Colorado, 2004–2013.

There are an estimated 19.4 million snags in Colorado that meet Northern flicker diameter preferences. Figure 17 shows the estimated number of snags in Colorado that meet the minimum diameter requirements for the Northern flicker by tree species group and forest-type group. Spruce species account for 44.6 percent of the snags suitable for flicker cavities with 8.7 million snags, the most of any tree species in Colorado. The vast majority of these snags are found in the spruce/fir forest-type group; the spruce/fir forest-type group holds the most suitable flicker snags found in Colorado, with 10.5 million (54 percent) of the total. The disproportionate representation of spruce as a species and spruce/fir as a forest-type group is largely attributable to the fact that a large number of spruce attain 20 inches in diameter, and that the spruce beetle has caused a high level of mortality in the larger size classes of spruce. The Western woodland softwoods (which include pinyon pine and juniper spp.) and true fir species groups include the second and third most abundant numbers of snags, with 3.6 million and 2.7 million snags, respectively. The pinyon-juniper forest-type group is a distant second with 3.6 million snags. On a proportional basis the snag-forming species occurring within forest-type groups shows varying patterns (fig. 18). For most forest-type groups, the most abundant snags are the namesake species of the group (e.g., Engelmann spruce in the spruce/fir group, ponderosa pine in the ponderosa pine group). However, this is not always the case. Most of the snags in the Woodland hardwoods group are actually conifers—over 60 percent are ponderosa pine, while the remainder are about equal parts of Douglas-fir and woodland softwoods such as common pinyon. The Aspen/Birch group has a diversity of snag species, with aspen, Douglas-fir, Engelmann spruce, and true firs all well-represented by proportion.

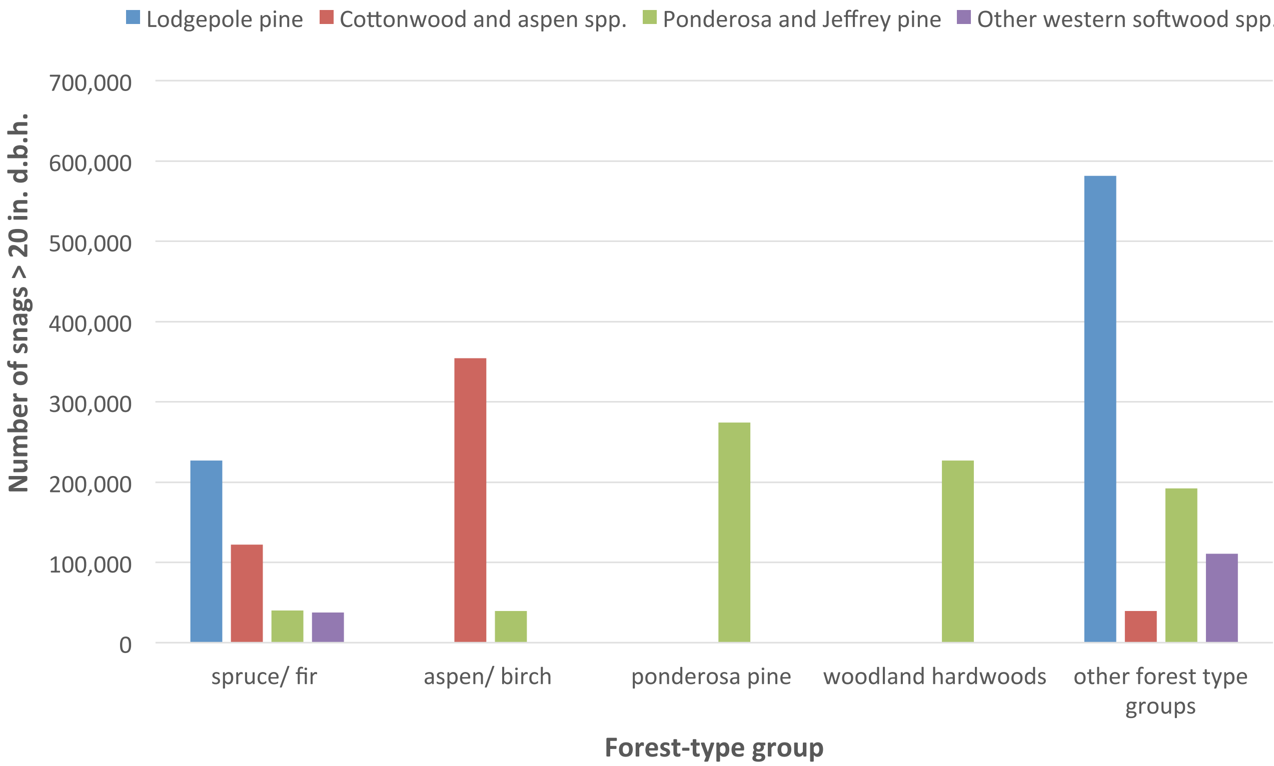


**Figure 18—**Proportions of snags >20 inches d.b.h. by species group and forest-type group in Colorado, 2004–2013.

Figure 19 displays the estimated number of aspen snags 7 inches d.b.h. or larger found in the forest types preferred by Williamson's sapsucker by stand age class. The subalpine fir forest type contains the majority of these snags (4.1 million), followed by Engelmann spruce/subalpine fir (3.4 million), and Engelmann spruce (1.7 million) respectively. In almost every case, the majority of suitable aspen snags are found in the older age classes. Only in ponderosa pine and blue spruce forests does one find more of these snags in forests younger than 100 years old.

The results of this analysis suggest that snags suitable for a large suite of cavity-nesting birds are found in a wide range of forest types and age-classes, but the majority is found in older, high elevation conifer forests. Exceptions to this general trend are the high number of snags found in the aspen/ birch and pinyon/juniper forest-type groups. Aspen forests are particularly important for some primary and secondary nesting birds because of the relationship between diseased aspen, primary excavators, and secondary nesters (Hart and Hart 2001).

Variables other than snag diameter, forest type, decay class, and stand-age need to be considered when predicting suitable wildlife habitat for forest-dwelling species. Proximity to forest edge and density of live trees is important to many cavity-nesting birds. The state of decay of a tree and its distance to foraging also plays a role in nest site suitability. Forest Inventory Analysis data can address many of these factors and there are current efforts to build predictive models for these species by using data collected by our crews. These models can be valuable tools for Federal and State land managers, as a large portion of the forests containing suitable snags occur on public lands.

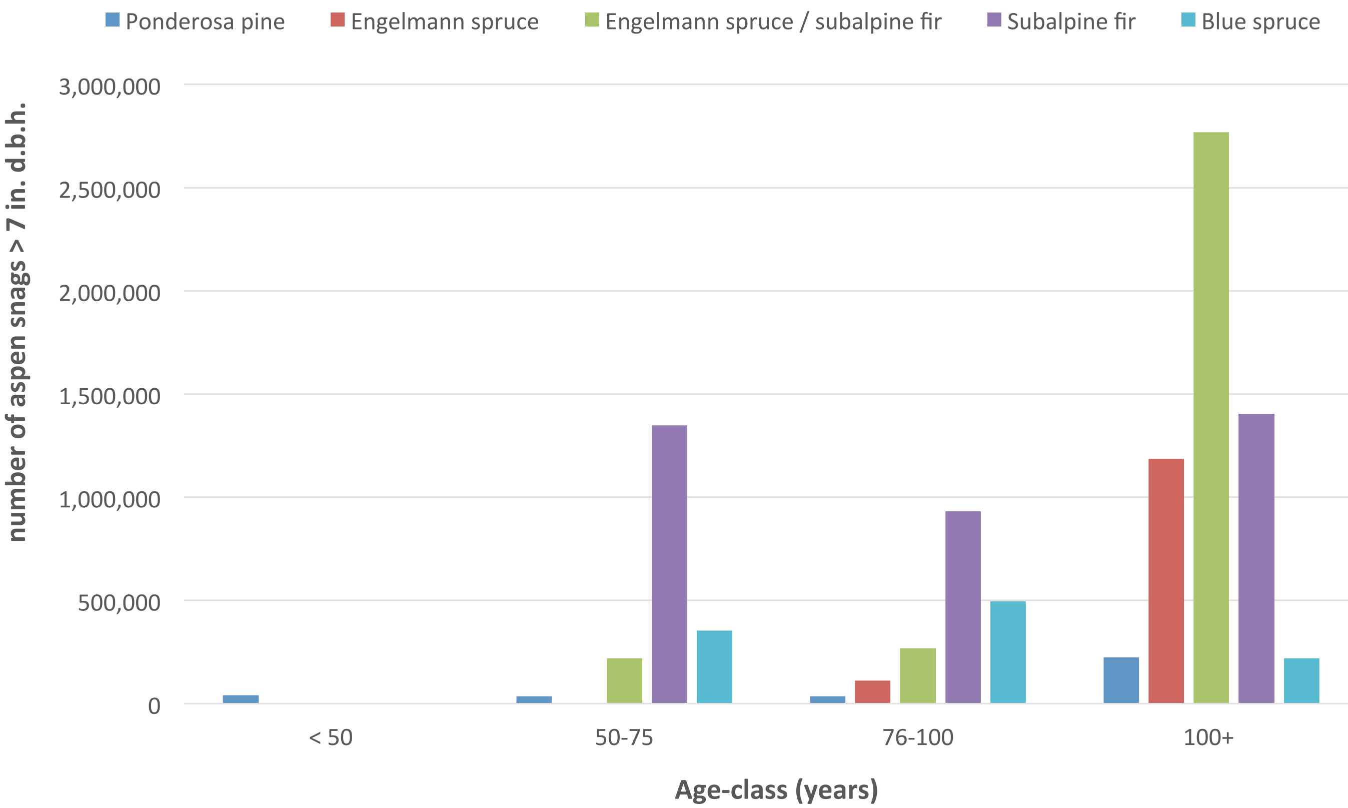


**Figure 19—**Estimated number of aspen snags >7 inches d.b.h. by forest-type and stand-age class in Colorado, 2004–2013.

## Old Forests

An important aspect of managing for ecologically sustainable and diverse ecosystems is the maintenance of forest stands representing the full range of forest succession. As forests mature, stand structure changes in ways that affect the stand's ecological and habitat function. Historically, these last stages of forest growth have been difficult to define or describe. Terminology has included primeval, pristine, primary, late seral or successional, climax, mature, overmature, and old growth, among others (Helms 2004). Standardized definitions are problematic because the final structure and age of a given forest stand depends on many biological and physical components, such as climate and geology, dominant tree species, fire regimes, and others (Kaufmann et al. 2007; Vosick et al. 2007). Therefore, the forest structural indicators used to assess old forests may differ with changes in these components. In addition, the characteristics of old growth can change with the scale of observation, from patches to stands and landscapes (Kaufmann et al. 2007). Some of the structural indicators of relatively old forests may include the size (diameter) and age of the oldest trees, the number of large and/or old trees per acre, overall stand density, canopy characteristics, and downed logs (Fiedler et al. 2007; Helms 2004).

One approach for assessing old forests using FIA data simply defines old forests as those with a stand age of 150 years or older. Based on this threshold, about 22 percent of Colorado's forest land occurs in old forests (Appendix B, table B47).

The percentage of land with a stand age of at least 150 years varies by forest-type group (fig. 20). Four forest-type groups have more than 20 percent of their total area in stands at least 150 years old. In descending order of their total area, these include the other western softwoods, pinyon/juniper, fir/spruce/mountain hemlock, and Douglas-fir forest-type groups. The group with the highest percent of old forests (48 percent) was the other western softwoods forest-type group, which consists of limber pine, bristlecone pine, and a small amount of southwestern white pine. Over 43 percent of the area covered by the pinyon/juniper forest-type group, or 2.7 million acres, occurs in stands at least 150 years old. The Douglas-fir and fir/spruce/mountain hemlock forest-type groups have percentages of stands that are 150 years old of 30 and 22 percent respectively. Although woodland hardwood forests cover more than 2.4 million acres in Colorado, less than 1 percent of their total area occurs in stands older than 150 years.

The large differences between forest-type groups illustrate the need for type-specific definitions for identifying old forests. Some tree species are longer lived, or typically grow larger, than others. Life histories of different species may affect how much area would be expected to be dominated by large, old trees of a given species. For example, a larger proportion of old forest might be expected

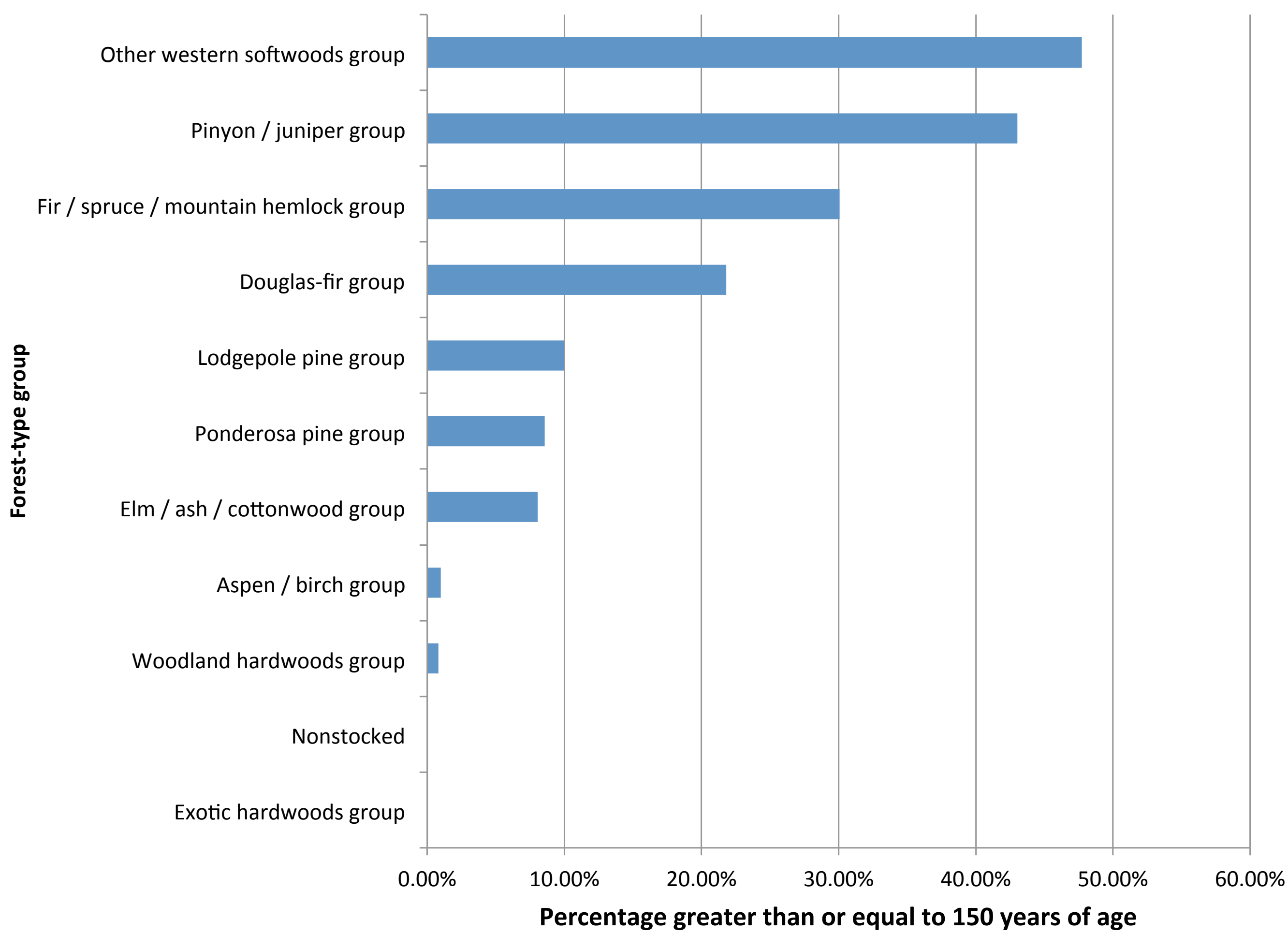


**Figure 20—**Proportion of forest area by forest-type group 150 years and older, Colorado, 2004–2013.

in limber or bristlecone pine than in aspen forest types. As noted above, the forest-type group that includes the limber and bristlecone pine forest types had the highest proportion of its area in old forests; in contrast, almost no aspen or cottonwood stands met the 150-year stand age criterion.

One caveat of this approach is that stand age does not portray the range of individual tree ages within a stand. Stand age is calculated as the mean age of trees from the stand-size class that has the plurality of stocking. This tends to diminish the significance of older trees by averaging tree ages of both old and young trees, so using stand age to identify old forests may exclude stands that include both very old and very young trees. To address this issue, other criteria have been applied to FIA data from Idaho, Montana, and Utah (respectively, Witt et al. 2012; Menlove et al. 2012; and Deblander et al. 2010), including a minimum density of trees that are at least 150 years old; minimum tree diameters; and minimum stand density (basal area per acre). These analyses found that using various criteria to identify old forests produced widely different results. Therefore, any analysis of old forests must use carefully selected criteria that represent the specific stand structure of interest. Future research may use the FIA database to validate or even help to establish surrogate measurements for defining old forest structure in different regions, by forest type, and under different site conditions.

## Understory Vegetation

Understory vegetation contributes to the diversity, productivity, and habit structure of forest ecosystems. FIA collects understory vegetation data using two distinct protocols that characterize overall vegetation structure as well as species composition. Under the vegetation structure protocol, field crews record the height class and percent cover that is occupied by each of four plant growth habits: forbs, graminoids, shrubs, and understory trees (trees), which are defined in this analysis as trees less than 5 inches d.b.h. Under the species composition protocol, height class, growth habit, and percent cover are recorded for plant species that individually occupy at least 5 percent of the ground area. If more than four species occupy more than 5 percent cover, then only the most abundant four species per life form are recorded. Note that in Colorado, the threshold for recording individual species was lowered from 5 percent to 3 percent beginning in 2012 (USDA Forest Service 2006, 2011).

Figure 21 depicts the average percent cover of each plant growth habit within Colorado's forest-type groups (the exotic hardwoods group was not included due to low sample size). Understory trees had equal or higher mean cover than other growth habits in half of the groups (pinyon/juniper, Douglas-fir, ponderosa pine, aspen/birch, and woodland hardwoods), while graminoid cover more or less equaled understory trees in three groups (pinyon/juniper, Douglas-fir, ponderosa pine) and dominated cover in three others (other western softwoods, Elm/ash/cottonwood, and Nonstocked). Shrubs supplied the highest mean cover in just two groups (fir/spruce/mountain hemlock and lodgepole pine). Forbs had

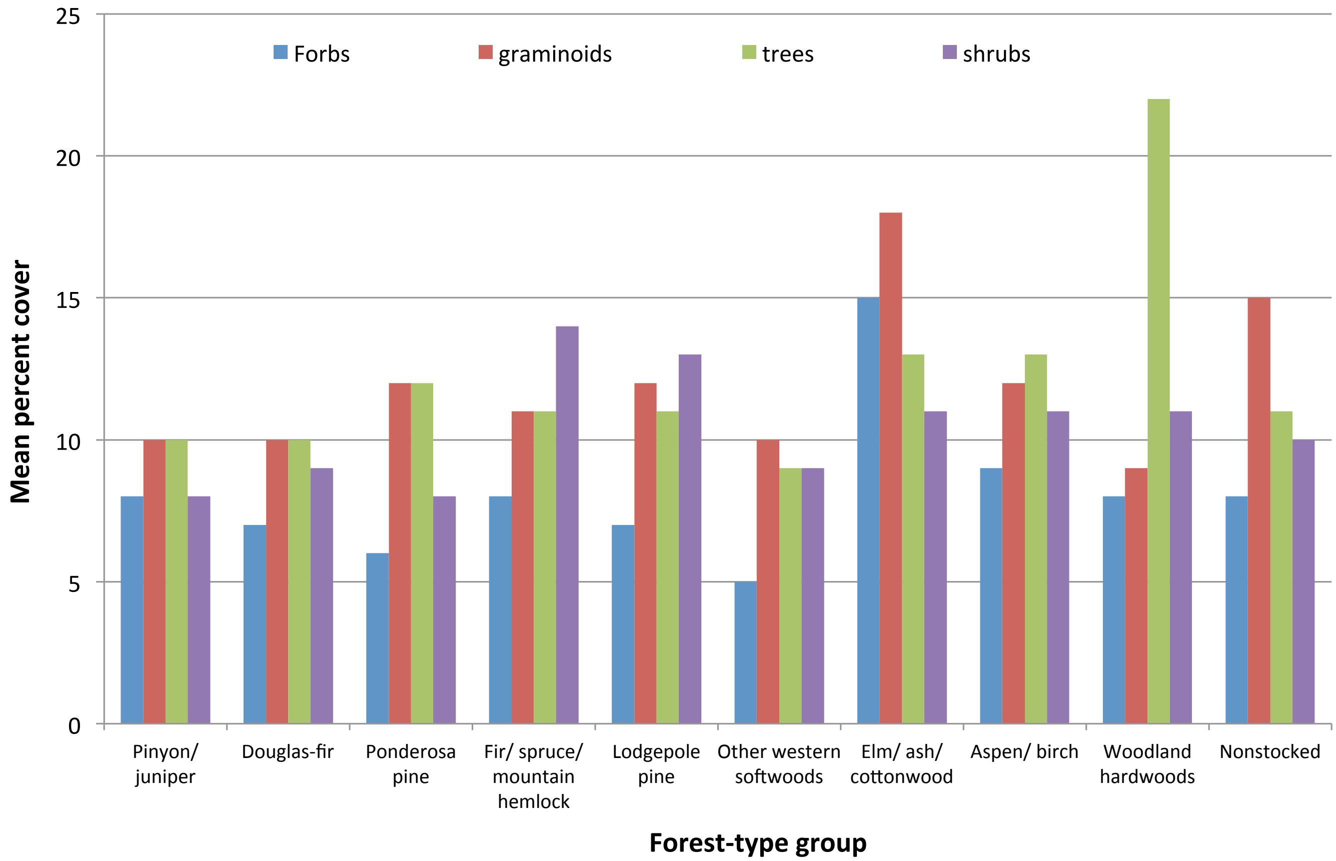


**Figure 21—**Mean percent cover of understory vegetation by growth habit and forest-type group, Colorado, 2004–2013.

consistently higher mean cover in hardwood forest groups than softwoods but did not dominate understory cover in any group.

There were 745 individual plant species recorded on Colorado's forest inventory plots. The most frequently recorded species within each growth habit are listed in table 8. Quaking aspen and Gambel oak seedlings and saplings were the most commonly encountered understory species across all growth habits, in terms of both frequency and mean percent cover. This suggests these two species are currently undergoing high regeneration and recruitment in the State. Colorado's State grass, blue grama (*Bouteloua gracilis*), was one of the five most frequently encountered graminoid species and was recorded on 286 forested plots. On average, blue grama covered 11 percent of the plots where it occurred.

## Forest Soil Resources in Colorado

Soils on the landscape are the product of five interacting soil forming factors: parent material, climate, landscape position (topography), organisms (vegetation, microbes, other soil organisms), and time (Jenny 1994). Many external forces can have a profound influence on forest soil condition and hence forest health. These include agents of change or disturbances to apparent steady-state conditions such as shifts in climate, fire, insect and disease activities, land use activities, and land management actions.

**Table 8**—The five most frequently recorded plant species in each growth habit and their average percent cover, Colorado, 2004–2013.

| Growth habit | Species | Common name | Number of plots | Mean cover |
|---|---|---|---|---|
| **Forbs** | *Arnica cordifolia* | heartleaf arnica | 402 | 31.0 |
| | *Thalictrum fendleri Engelm.* | Fendler's meadow-rue | 338 | 8.1 |
| | *Achillea millefolium* | common yarrow | 284 | 6.7 |
| | *Aster* spp. | aster | 268 | 9.2 |
| | *Fragaria virginiana* | Virginia strawberry | 268 | 6.8 |
| **Graminoids** | *Carex spp.* | sedge | 706 | 11.0 |
| | *Carex geyeri* | Geyer's sedge | 390 | 11.0 |
| | *Festuca arizonica* | Arizona fescue | 369 | 11.1 |
| | *Poa* spp. | bluegrass | 368 | 11.6 |
| | *Bouteloua gracilis* | blue grama | 286 | 11.0 |
| **Shrubs** | *Symphoricarpos oreophilus* | mountain snowberry | 793 | 13.1 |
| | *Juniperus communis* | common juniper | 676 | 8.8 |
| | *Cercocarpus montanus* | mountain mahogany | 608 | 8.7 |
| | *Artemisia tridentata* | big sagebrush | 485 | 11.1 |
| | *Vaccinium myrtillus* L. | whortleberry | 453 | 17.9 |
| **Understory trees** | *Quercus gambelii* | Gambel oak | 991 | 24.1 |
| | *Populus tremuloides* | quaking aspen | 957 | 14.2 |
| | *Pinus Engelmannii* | Engelmann spruce | 849 | 9.6 |
| | *Abies lasiocarpa* | subalpine fir | 760 | 11.3 |
| | *Pinus edulis* | two-needle pinyon | 536 | 6.8 |

The Soil Indicator of forest health was developed to assess the status and trend of forest soil resources in the United States across all ecoregions, forest types, and land ownership categories. For this report, data were analyzed and are being reported by forest-type groups. This forest type stratification not only reflects the influence of forest vegetation on soil properties, but also the interaction of parent material, climate, landscape position, and time with forest vegetation and soil organisms. A complete listing of mean soil properties in Colorado, organized by forest type, is in the Soil Indicator core tables (Appendix F, tables F3-F10). These are least-squares means generated by the SAS GLMMIX data analysis software program. There are two sets of tables—one for each soil sampling visit, and each visit corresponds to a cycle of forest health indicator plot measurement and sampling.

Most soil samples collected in the first sampling cycle in Colorado were collected in 2000 through 2004, but some plots were sampled for the first time in later years (2005 to 2010). The second sampling cycle was done in 2005 through 2013 (not yet complete), but there were not as many soil samples collected in the second cycle so some forest-type groups remain underrepresented in the resampling sequence. The total number of plots sampled for soil indicators is listed for each forest-type group in each set of tables. Some of the key soil properties were graphed by forest-type group in Colorado and are highlighted in the discussion below.

Forest soil resource data are available for eight forest-type groups in Colorado. These are the western hardwoods group (includes deciduous oak), pinyon/juniper group (includes Rocky Mountain juniper, juniper woodland, and pinyon/juniper woodland), ponderosa pine group, lodgepole pine group, Douglas-fir group, cottonwood/aspen group, spruce/fir group (includes white fir, blue spruce, Engelmann spruce, subalpine fir, and mixed Engelmann spruce/subalpine fir), and the high-elevation, 5-needle, white pine group. Most of the soil samples represent the pinyon/juniper, cottonwood/aspen, and spruce/fir groups with a smaller sampling in the other forest-type groups in Colorado. The high-elevation white pine group was represented by the smallest number of soil samples.

Generally, soil moisture tends to increase with elevation and latitude in the Interior West (associated with cooler temperatures) and forest types tend to reflect this climatic gradient. Pinyon/juniper woodlands tend to occupy drier lower-elevation sites whereas the spruce/fir group is found in wetter environments at higher elevations. Aspen forests are found at similar elevations with Douglas-fir and spruce/fir forests. There is considerable elevation overlap among the different forest-type groups and aspect also plays a key role in forest distribution and soil water content. When expressed in terms of megagrams of carbon (C) per hectare of forest area, soil C stocks also generally increase with elevation and/or soil moisture storage (fig. 22, top and fig. 23, top). There are two important exceptions to the generally observed elevation increase pattern for soil water content and soil C stocks in Colorado. Western hardwoods (deciduous oak woodlands) have higher soil water content and more soil C stocks than some other forest types found at similar to higher elevations. The high-elevation pines tend to have both lower soil water content and soil C stocks than other higher elevation forest types. Overall, soils were significantly wetter during the second visit sampling cycle than during the first, reflecting the cyclical nature of precipitation patterns in the Interior West.

The soil C stock data shown in figure 22 top, are for all plots sampled during the first cycle of plot visits from 2000 through 2010 (n = 258) and for the second cycle of plot visits from 2005 through 2013 (n = 189), although there are no forest floor total C data available for samples collected in 2013 as yet. There was no significant change in soil C storage between the first and second soil sampling visits, although variability is high since a smaller number of plots were revisited for many forest types. Carbon stocks in the forest floor component of western hardwoods and pinyon/juniper are smallest of all the stocks measured because forest canopy of these forest types tend to be more open and there is less forest floor accumulation than in wetter higher-elevation forests. Among all forest types except lodgepole pine and high-elevation white pines, most soil C is stored in the top 10-cm of mineral soil, followed by the 10 to 20 cm increment, followed by forest floor. In the lodgepole and high-elevation white pine groups, soil C stocks in forest floor are as high as or higher than those in the 10 to 20 cm mineral soil increment. Overall, the pinyon/juniper group stores the least amount of C in Colorado forest soils.

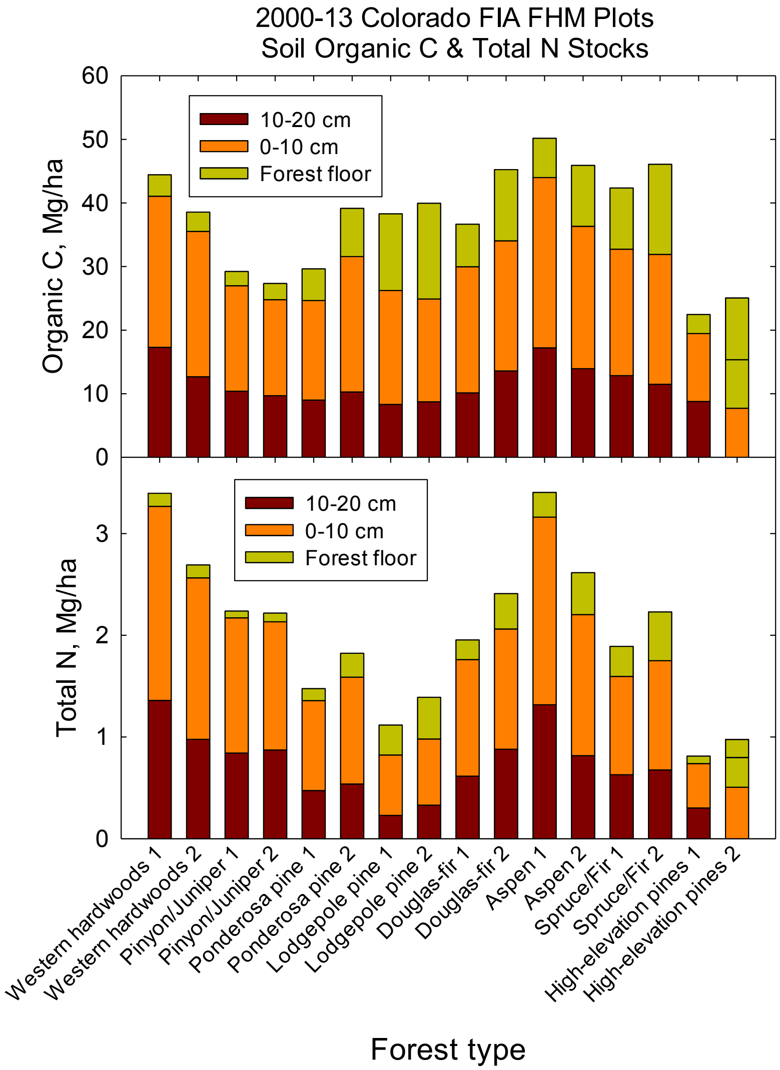


**Figure 22—**Distribution of organic carbon (top) and total nitrogen (bottom) stocks in Mg/ha in the forest floor, 0–10 cm, and 10–20 cm mineral soil depths in eight forest-type groups in Colorado. Soil samples were collected in 2000 through 2013 (1st and 2nd plot visits) from western hardwoods (includes deciduous oak woodlands), pinyon/juniper group (includes Rocky Mountain juniper, juniper woodland, and pinyon/juniper woodland), ponderosa pine, lodgepole pine, Douglas-fir, aspen, spruce/fir (includes white fir, blue spruce, subalpine fir, Engelmann spruce, and mixed Engelmann spruce/subalpine fir), and high-elevation, 5-needle white pine forest-type groups.

Soil nitrogen (N) stocks show a more mixed response to climatic gradients in Colorado than do C stocks (fig. 22, bottom). The total N data include all sampled years except 2013. Aspen and western hardwood forests tend to store more N in the mineral soil than any other forest group in Colorado (fig. 22, bottom). Aspen forests store more N than Douglas-fir or spruce/fir forests, which often intermingle with aspen as forest succession proceeds. High N levels in aspen forest floor and soils lead to lower C/N ratios than those found in forest floor and soils under spruce/fir (data not shown). Since low C/N is a good indicator of relative organic matter decomposition rate, nutrient-rich aspen leaves decompose quickly and easily compared to tree needles of the spruce/fir group. There was no significant change in soil N storage between the first and second soil sampling visits, but again, variability is high because a smaller number of plots were revisited than were sampled the first time and total N data are not yet available for 2013.

Soil bulk density (weight of soil per unit volume) influences many other soil properties including porosity and water-holding capacity. In forest soils, bulk density tends to be controlled by soil organic matter content where bulk density decreases exponentially with increasing soil organic matter (O'Neill et al. 2005). In Colorado

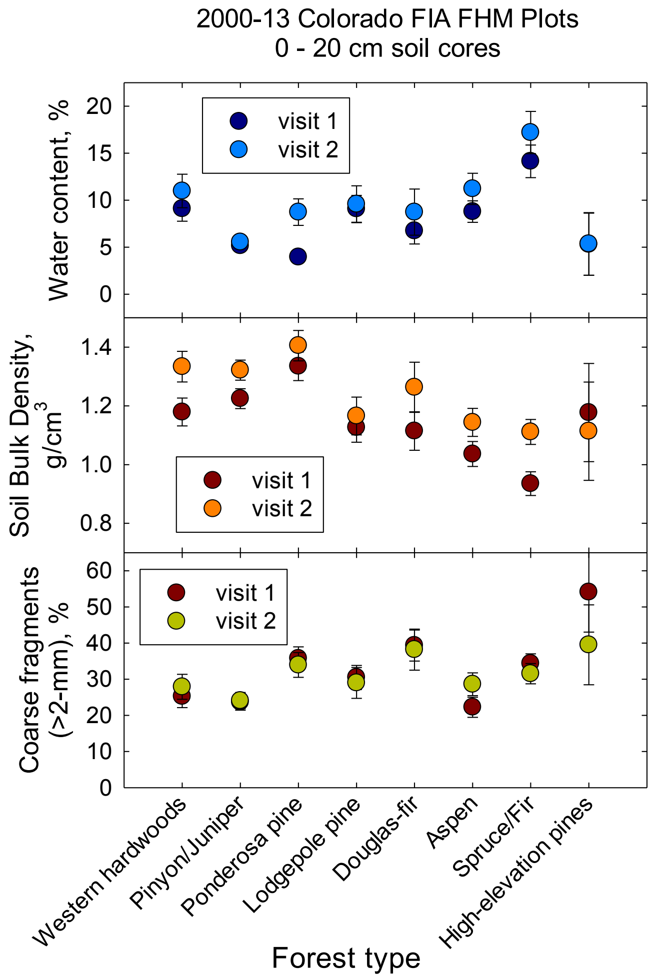


**Figure 23**—Soil water content (top), bulk density (middle), and coarse fragment (>2-mm) content (bottom) of the top 20-cm of mineral soil in eight forest type groups in Colorado.

forests, the lowest soil bulk densities tend to be found under aspen and spruce/fir forests (fig. 23, middle), and these forests have the highest organic C concentrations (fig. 23, top). Overall, soil bulk density was slightly, yet significantly, higher in the second visit samples compared to the first. The difference in visit means was about 0.1 g/cm$^3$ and is of no practical significance. It likely represents within-plot spatial variability because the same point cannot be sampled twice. High-elevation pines are often found on rockier sites with higher coarse fragment content (fig. 23, bottom). No significant difference in coarse fragment content was found between visits 1 and 2.

It is important to distinguish among forms of C in soils because the organic forms participate in a wide array of biogeochemical reactions including serving as substrate for microbial decomposition, thus contributing to atmospheric carbon dioxide ($CO_2$). Inorganic forms (stored as carbonate minerals such as calcite [$CaCO_3$]) tend to be more biologically inert but can be dissolved during physical, chemical, and biologically mediated mineral weathering reactions. In Colorado, appreciable amounts of soil C are stored in carbonate minerals under pinyon/juniper group forests (fig. 24, top). In contrast, the wetter, higher-elevation Douglas-fir, aspen, and spruce/fir forest soils store higher concentrations of organic C (fig. 24, top). Soil N concentrations tend to track organic C concentrations with more soil N found in higher-elevation forest-type groups (fig. 24, bottom) and also in western hardwoods. Ponderosa pine, lodgepole pine, and high-elevation pine soils have the lowest

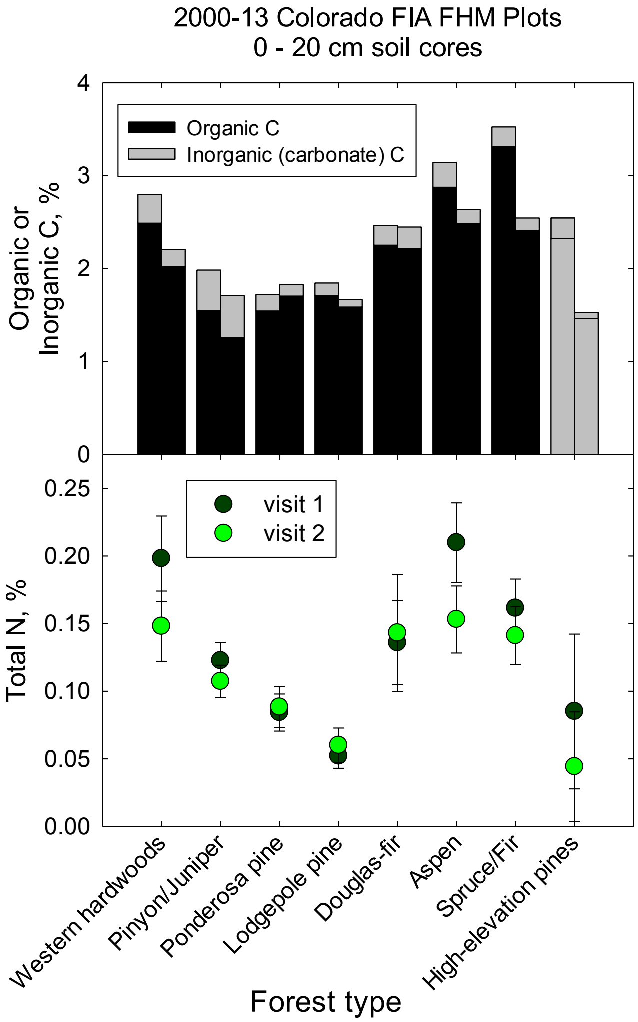


**Figure 24**—Carbon forms (organic, carbonate) (top) and total nitrogen (bottom) in the top 20 cm of mineral soil in eight forest type groups in Colorado. In the top bar graph, visit 1 stacked bars are on the left side of each forest type group tick mark, whereas visit 2 stacked bars are on the right side of each forest-type group tick mark.

concentrations of soil N (fig. 24, bottom). Although mean soil concentration of total N did not change between visits 1 and 2, mean organic C concentration was slightly higher in visit 1 samples than in visit 2 samples, which probably reflects within-plot sampling variability. This variability is of no practical significance since organic C stocks did not change between visits 1 and 2.

Soil pH is often closely related to the presence of carbonate minerals in soils. Thus, the higher pH forest soils are found under pinyon/juniper (fig. 24, top), the same forest-type group with relatively higher amounts of soil carbonates (fig. 24, top). These soils are near-neutral to alkaline. Lodgepole pine forests tend to occupy moderately acidic soils in Colorado. Higher elevation spruce/fir forests in Colorado are found on slightly acidic soils. All the forest soils in Colorado except those under lodgepole pine store appreciable amounts of exchangeable base cations as evidenced by the relatively high effective cation exchange capacities (ECEC) of these soils (fig. 25, middle). The lower-elevation, higher pH soils under western hardwoods, pinyon/juniper group, and ponderosa pine tend to have low levels of bicarbonate-extractable P (fig. 25, bottom). Bicarbonate-extractable P is used as a measure of bioavailable P for plant uptake. The pH, ECEC, and Olsen P levels of Colorado forest soils have not changed significantly between the first and second visits, suggesting that the overall nutrient status of these soils is being maintained.

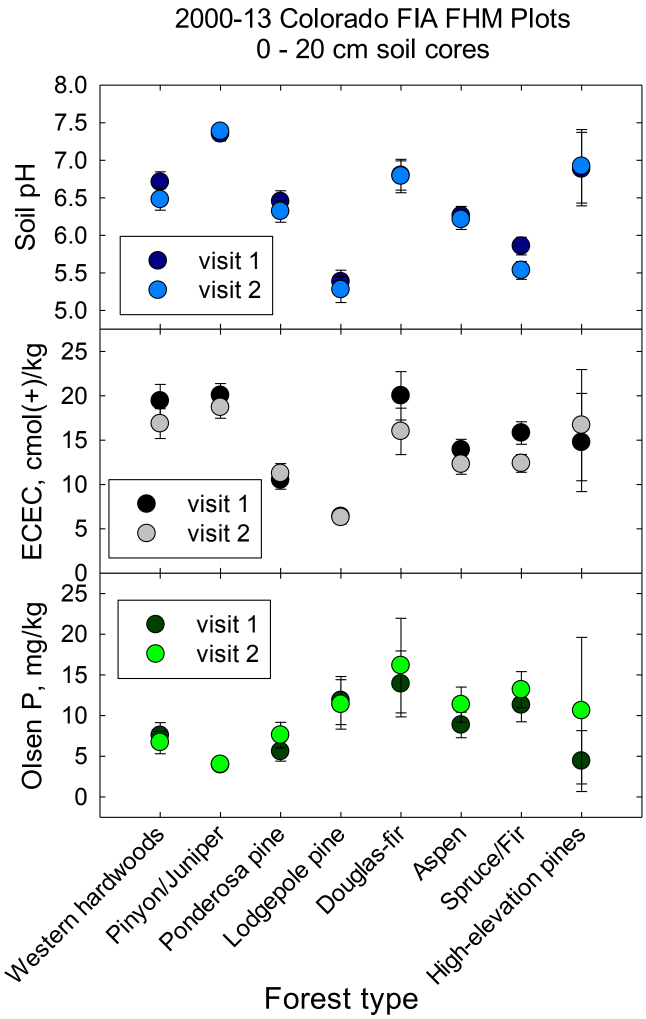


**Figure 25—**Soil pH (top), effective cation exchange capacity (ECEC) (middle), and Olsen (pH 8.5, 0.5 M NaHCO3) extractable P (bottom) in the top 20 cm of mineral soil in eight forest-type groups in Colorado.

The Soil Quality Index (SQI) concept integrates 19 measured physical and chemical properties into a single value that serves as a means of tracking overall soil quality in time and space (Amacher et al. 2007). Lower values indicate increased risk of soils-related forest health decline. Spatial changes in SQI on the landscape can be used to identify areas of higher or lower overall soil quality and trends over time can be used to track potential declines in overall soil condition and thus provide an alert to potential declines in soils-related forest health. The highest SQI forest soils in Colorado are found under western hardwoods and the higher elevation Douglas-fir, aspen, spruce/fir, and high-elevation white pine forests. This reflects the overall higher organic matter content (except white pine forests) and higher productivity (higher nutrient content) of these soils. Aspen soils tend to have the highest nutrient content (especially N and K) and have the highest SQI values. This is also closely tied to the large effect of soil moisture in controlling overall forest productivity. Pinyon/juniper and lodgepole pine forests have the lowest SQI values. Overall in Colorado, lodgepole pine tends to occupy the lower pH, lower organic matter content, and lower nutrient content (less productive) soils. There has been no detectable change in the SQI for Colorado forest soils between the first and second visits (fig. 26).

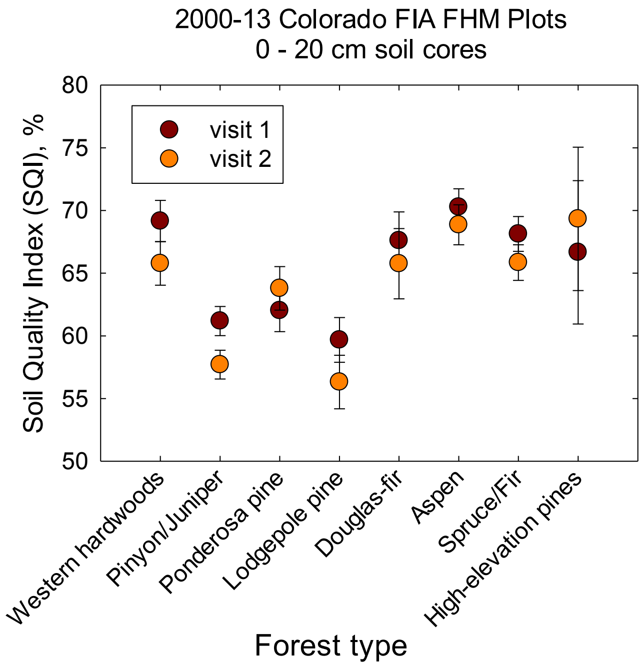


**Figure 26—**Soil quality index (SQI) in the top 20 cm of mineral soil in eight forest-type groups in Colorado.

# Current Issues in Colorado's Forests

## Colorado's Mountain Pine Beetle Epidemic

Since the beginning of Colorado's annual inventory in 2002 and the most recent annual inventory in 2013, extensive and widespread conifer mortality has occurred in Colorado (Thompson 2009). The single most significant episode occurred in lodgepole pine forests, where a mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemic caused significant mortality of this species over extensive areas in Colorado. During the peak of the epidemic, there was significant concern over the visual impact and loss of commercially valuable lodgepole pine tree volume. Furthermore, forest managers in Colorado became concerned about the long-term impacts on sustainability, structure, and composition of future lodgepole pine forests.

There are more analysis options for monitoring forest change under the annual inventory system than the periodic inventory system. One analysis option considers the fact that the annual inventory is an interpenetrating design. This may be referred to as the independent panel option. Under this approach, each annual panel is analyzed independently and estimates are produced on a yearly basis. The independent panel option is a design where the $n$ units (FIA sample plots) are divided into $k$ = 10 panels, each panel containing $m = n/k$ units. Panel 1 plots are measured in year 1, panel 2 plots are measured in year 2, and so on, such that all plots have been visited by the end of year 10. The panel cycle is repeated into perpetuity (Reams and Van Deusen 1999). The advantage of the independent panel option is that trends in inventory estimates such as tree growth and mortality, natural disturbances, and human-induced changes such as forest harvesting can be assessed almost immediately. The independent panel option does have certain limitations. Because each panel represents only about one-tenth of all plots in Colorado, the smaller number of plots results in a higher variance around the individual panel estimate. Mortality estimates, in particular, are subject to high variance because tree mortality is relatively infrequent. Tree mortality does not always occur on every plot. For situations such as insect and disease outbreaks where mortality may be spatially spotty, the signature of the event may not be adequately captured with a limited sample size. Another consideration of mortality estimates is that FIA compiles and reports tree mortality as an annual average over a measurement interval.

Independent panel estimates of live tree attributes are somewhat simpler to interpret than change estimates such as growth and mortality. An estimate of the number of live trees or live-tree volume can be generated for a specific year using only those plots measured in that year. Unlike change estimates, a live inventory estimate for a specific year is not an average—it is a valid estimate of a population total for that year. Furthermore, trends in changes of live inventory estimates can be generated for a series of individual years without the confounding effect of tracking a series of annual averages such as mortality estimates. Because of the abundance of live trees compared to mortality trees, the variance estimates are considerably lower resulting in a higher level of statistical confidence.

Lodgepole pines classified as live, ingrowth, and mortality were used in this analysis. Eleven panels representing estimates for individual measurement years were used to capture the beginning and end of the mountain pine beetle epidemic. Live lodgepole pines were classified as alive and standing at the time of the plot visit. Trees classified as ingrowth are live trees that are estimated to have grown over the 5-inch d.b.h. threshold for a given measurement year. Tree diameter growth for IWFIA plots measured for the first time is estimated from increment core measurements. For remeasured plots, plots with a visit at two points in time where the status of all trees are known at both points in time, diameter growth is obtained from the measurement of diameters at time 1 and time 2. Based on these measurements, a live tree's diameter is projected or grown back in time for 1 year to obtain an initial diameter. Therefore, any live tree that has a current diameter of 5.0 inches d.b.h. or larger and a projected initial diameter of less than 5.0 inches d.b.h. is classified as ingrowth.

Figure 27 illustrates the relationship between the average annual number of lodgepole pine trees classified as mortality and the number of ingrowth lodgepole pines by measurement year in Colorado. Beginning in 2002, the annual number of lodgepole pine mortality trees averaged 4.5 million trees compared to 10.5 million live lodgepole pines entering the 2002 inventory estimates by growing over the 5-inch d.b.h. threshold. During the years 2002–2005, the number of lodgepole pine ingrowth trees more than doubled the average number of mortality trees. In 2006, believed to be the beginning of the epidemic, lodgepole mortality began to increase rapidly peaking in 2009 at an annual average of 38 million trees. This represents a more than eightfold increase compared to the 2002 mortality estimate. After 2007, lodgepole mortality began to rapidly outpace the ingrowth estimate. With the exception of 2008, where lodgepole pine ingrowth jumped to 22 million

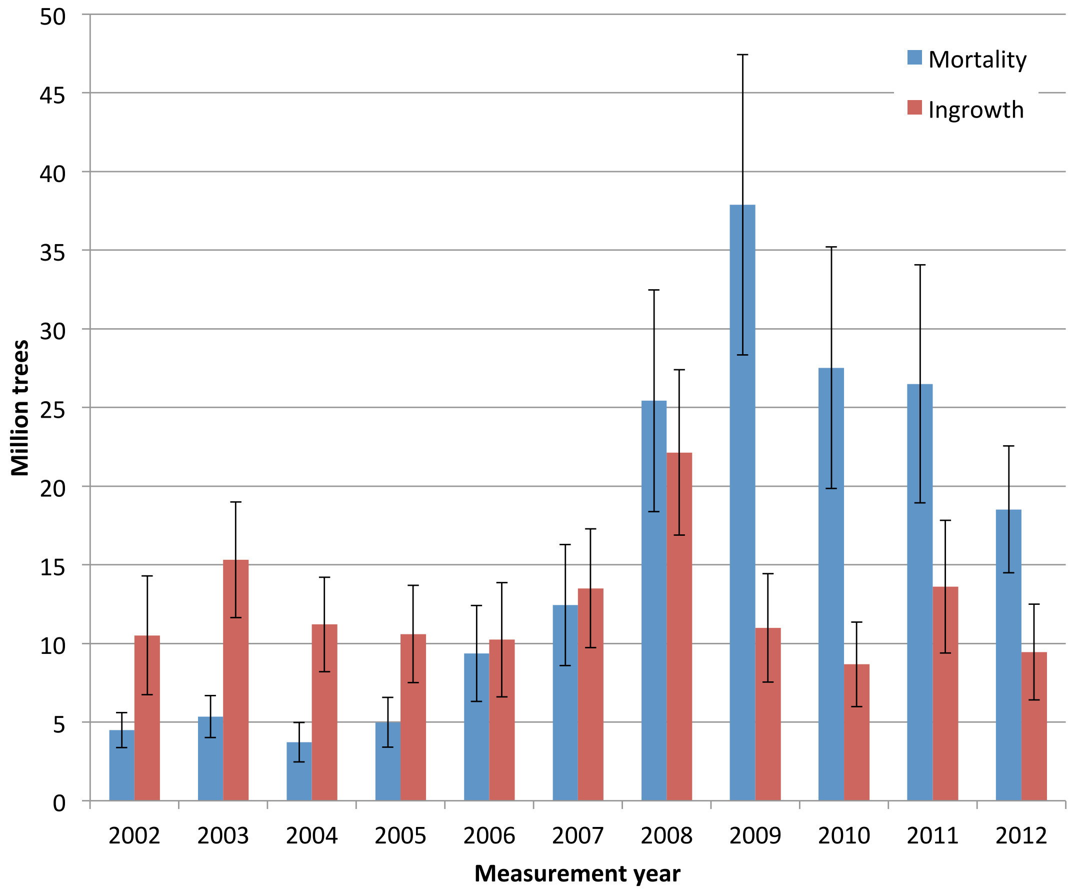


**Figure 27—**Comparison between average annual numbers of lodgepole pine mortality trees and numbers of ingrowth lodgepole pine trees by measurement year in Colorado, 2002–2012. Error bars represent the 95% confidence interval.

trees, the estimates of ingrowth over the 11 panels were relatively stable with no significant upward or downward trends noted.

Figure 28 compares trends in the number of live lodgepole pines by measurement year for two tree size classes: small diameter (5.0–8.9 inches d.b.h.) and large diameter (9.0 inches d.b.h. and larger). Small diameter lodgepole pines show fluctuation by measurement year but no significant trend over the 11 inventory panels. Numbers of large diameter lodgepole pines show a significant reduction over the time period. During the years 2003–2004, numbers of live large diameter lodgepole pines averaged about 215 million trees in Colorado. After 2009, numbers of live large diameter lodgepole pines averaged about 97 million trees.

Examination of the relationship between lodgepole pine ingrowth and annual mortality illustrates the advantage of using broad-scale inventory data to better quantify the actual net loss of trees due to a disturbance event over time. In typical non-epidemic periods with normal baseline tree mortality, losses of trees dying of natural causes are generally offset by an equal amount of tree growth. Inventories of an abundant species over a large geographic area usually remain relatively stable over time. As figure 27 illustrates, prior to the beetle epidemic, the number of new trees entering the inventory actually exceeded trees leaving the inventory

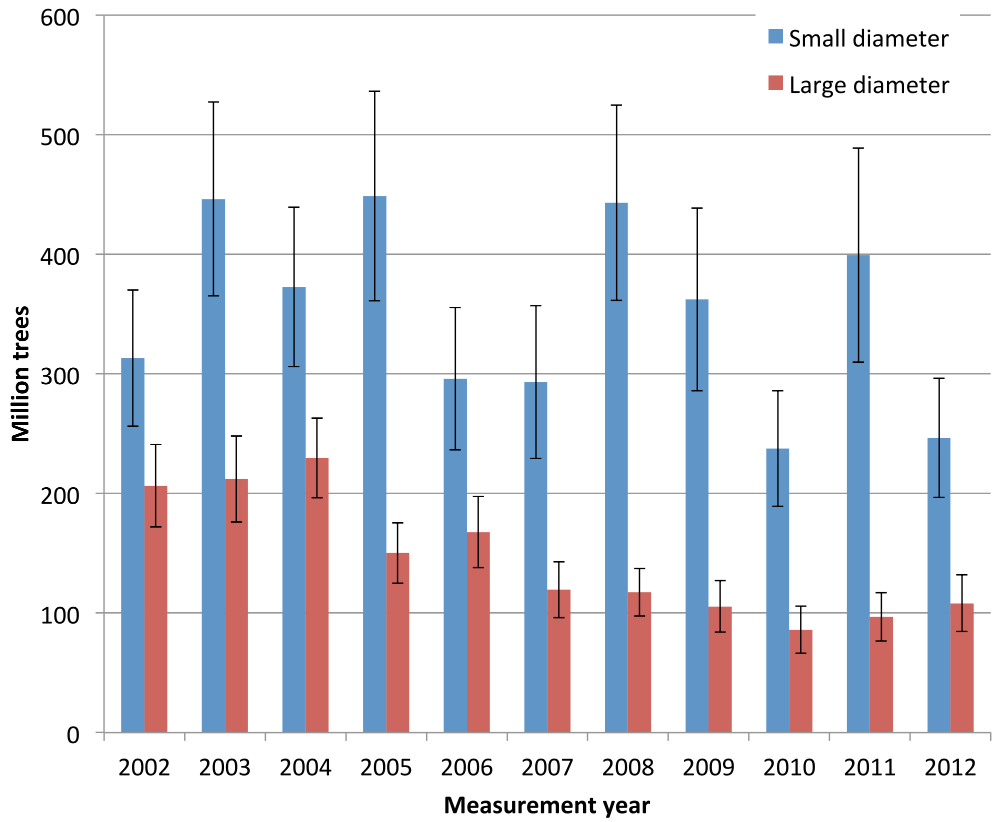


**Figure 28—**Numbers of live lodgepole pine trees 5.0 inches d.b.h. and larger by tree size class and measurement year in Colorado, 2002–2012. Error bars represent the 95% confidence interval.

due to mortality by a significant margin. Also noted is that, despite the dramatic increase in lodgepole pine mortality that peaked in 2009, the numbers of ingrowth trees remained at about the same level between 2002 and 2012.

The effect of the mountain pine beetle epidemic in Colorado on residual lodgepole pine stand structure was pronounced. The number of live large-diameter lodgepole pine trees essentially declined by over 50 percent during the 11-year study period where the number of small diameter trees remained unchanged. The impact on stand structure resulted in an altered size class distribution of lodgepole pine forests in Colorado. During the years 2003–2005, the proportion of small diameter trees averaged 63 percent of the total number of lodgepole pine trees greater than or equal to 5.0 inches d.b.h. in Colorado. During the years 2010–2012, that same proportion of small diameter trees averaged 75 percent.

## Sudden Aspen Decline

Quaking aspen is the most abundant and important hardwood species in Colorado. About 6.5 million acres in Colorado have aspen present—more acres than any other State in the western United States and almost twice as many as in Utah, which is second in aspen acreage. In Colorado, aspen is a valuable ecological component of the State's landscape, occurring in pure forests as well as growing in association with many conifer species. In addition to the tree's desirable scenic value, the diversity of understory plants that occur under the aspen canopy supplies critical wildlife habitat, valuable grazing resources, and protection for soil and water.

Scientists, forest managers, and observers in the general public began noticing rapid mortality of aspen in multiple locales in southwestern Colorado beginning in 2004 (Worrall et al. 2008). The difference between this recently observed aspen mortality and the mortality typically observed in aspen stands is the suddenness of the phenomenon and the apparent lack of regeneration occurring in stands where the overstory mortality is unusually high. Evidence to date suggests that it is a decline disease incited by acute, warm drought (Anderegg et al. 2013a). Predisposing factors include low elevation, south and southwest aspects, droughty soils, open stands, and physiological maturity. The agents that commonly kill the stressed trees include *Cytospora* canker, two bark beetle species, poplar borer, and bronze poplar borer, but it has been shown that drought alone and the depletion of trees' energy resources can kill aspen in the absence of insects and disease (Anderegg et al. 2012, 2013b).

Although aspen mortality is readily observable in some locations (e.g., Smith and Smith 2005), analysis of population trend at relatively large scales is the best way to assess whether or not the locally observed mortality occurrences are significantly affecting abundance of the overall population. Unfortunately, the early inventories of Colorado (Benson and Green 1987; Miller and Choate 1964) did not cover all aspen forests of Colorado. Therefore, the comparisons of periodic inventory results to more recent annual inventory data cannot be done for aspen as in other States, such as New Mexico (Goeking et al. 2014) and Utah (Werstak et al. 2016). In the first Colorado report based on annual inventory (Thompson et al. 2010), which was based on 50 percent of the FIA plots in the State, there appeared to be no strong trend with respect to total aspen biomass in Colorado. However, the high variance associated with a partial inventory make it difficult to make strong conclusions. In addition, the absence of a strong trend in the early 2000s does not necessarily affect the current situation, given the high annual variation of weather patterns in the Interior West. Completion of a full cycle of plots and 2 years of remeasurement improve our ability to analyze the status of aspen in Colorado.

A forest population is analogous to a bank account that accrues interest. The volume of live trees represents an account balance. Any event that removes live trees, such as insect or disease mortality, or harvesting, can be thought of as account withdrawals. New trees coming into the inventory—in the case of volume, trees becoming large enough for volume to be calculated—are "deposits." The "interest" comes in the form of growth of live trees. As opposed to a bank account, where the same interest rate applies to every dollar in the account, each tree has its own potential growth rate that is based on its size, age, the quality of the site it grows on, the presence of nearby competitors, and external factors such as temperature and precipitation. For example, it is well known that growth is lower in dry years than in wet years. Therefore, "interest" is never constant, even for a single tree. Another difference is that unlike a bank account balance, the volume of trees cannot increase indefinitely. Each site has a relatively fixed capacity, so the only way to increase the ceiling on the account balance is to add more acreage on which a species is growing. For forests this is a slow process, so we cannot observe that kind of change at the current length of the time scale of our observations. However, any loss of acreage—either by permanent land use change or a temporary reduction in acreage occupied by a species—will be reflected in the inventory almost immediately.

Using this analogy, it is possible to look at trends in the aspen population from several different aspects. In the *Forest Growth and Mortality* section, it has already been shown that the cottonwood and aspen species group, which is heavily dominated by aspen, showed positive net growth based on the last 10 years of annual inventory. In the bank account analogy, interest was greater than withdrawals. However, because the net growth calculations are based on plots collected over a period of time, they don't show any year-to-year fluctuations that occur. In other words, while the 10-year average of net growth may be positive, the most current change in population might be negative net growth.

To look at these fluctuations, we calculated alternative metrics that explore different aspects of aspen growth and mortality. In the first case, aspen mortality in each year is expressed as a percentage of the pre-mortality volume (% mortality basal area = mortality basal area / [mortality basal area + live basal area]). Each point on the annual mortality line (red) in figure 29 represents a single year of measurements, and therefore provides one of the best views of year-to-year variation. Some of the variation is undoubtedly due to chance in sampling, such as measuring a few more recently burned plots than average in a given year, but the more general trend likely captures actual fluctuation.

The second line (blue) in figure 29 is essentially a population volume calculation, for only aspen, similar to what is presented in the *Forest Growth and Mortality* section and elsewhere in this report. However, instead of presenting only the most recent 10 years of data, each point on the line includes data from years of data up to that inventory year. For example, 2013 includes years 2004–2013 (as elsewhere in this report), 2012 includes 2003–2012, etc. Because annual inventory started in Colorado in 2002, the earlier points on the line don't include a full 10 years of data. Inventory year 2004 includes years 2002–2004, inventory year 2005 includes years 2002–2005, etc. Points for 2002 and 2003–2003 are not shown due the high variability associated with using such small fractions of plots for volume estimation.

The two trend lines in figure 29, when compared, provide additional insight into recent aspen growth and mortality trends in Colorado. From 2002 to 2006, when aspen mortality averaged approximately 1.0 percent per year, it appears that there was a gradual increase in aspen volume. With the resurgence of drought conditions, mortality since 2007 has averaged closer to 1.4 percent. This increase in mortality rate appears to be coincident with the apparent decrease in aspen volume since 2006. One interpretation of these trends suggests that the "break-even" point of growth vs. mortality occurs between the two mortality levels shown in these data—perhaps close to 1.2 percent. This is a somewhat simplified view because, as mentioned above, growth rates are variable over time and the net of additions and removals

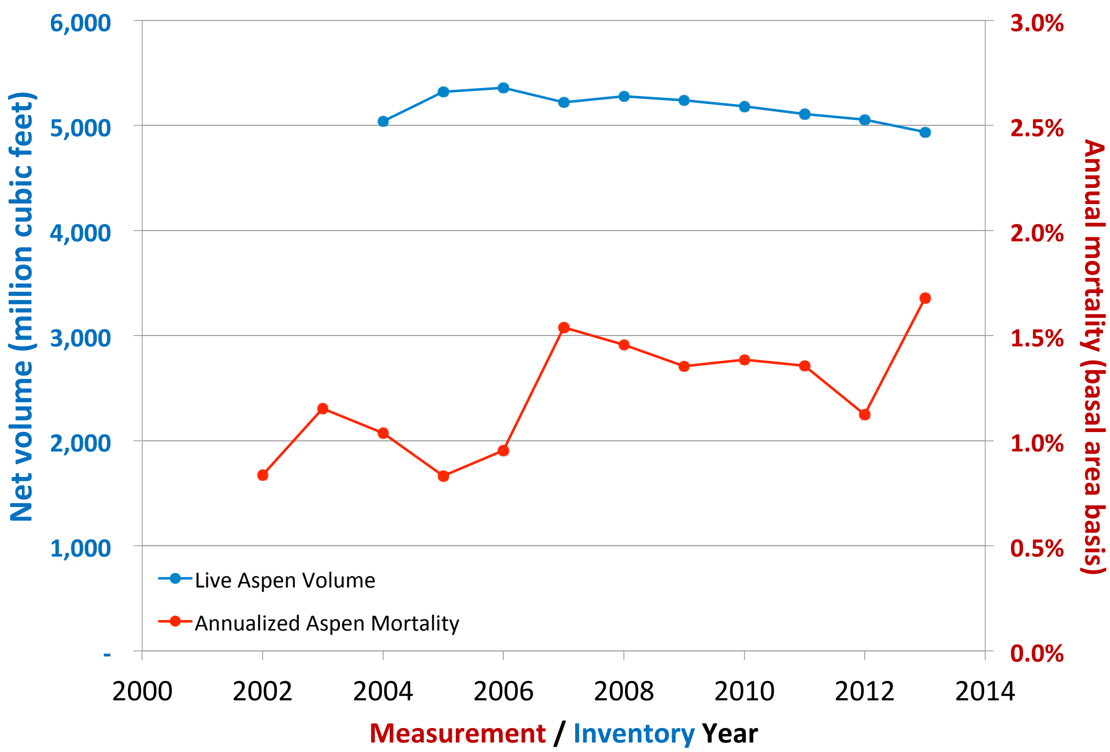


**Figure 29**—Net live volume of aspen for inventory years 2004 to 2013, and annualized mortality rate for aspen in measurement years 2002 to 2013.

from live volume is actually determined by the balance between growth and mortality—not just the rate of one or the other.

The question asked most often is: What is the long-term prospect for aspen in the Interior West? Based on the data currently available, it appears that under annual inventory (2002 to 2013), aspen transitioned from a period of positive net growth to a period of negative net growth, the latter of which is based on a steady, but gradual decline in the estimate of live volume. However, net growth remains positive, on average, for the whole time period on which the current inventory is based. If the slight decline observed in recent years were to continue at its present rate, it would take more than 50 years for the live volume of aspen in Colorado to be reduced to half of its present quantity. A steady decline for such a long period is highly unlikely as evidenced by the fact that in only 12 years of annual monitoring we have observed increases and decreases. The estimate of aspen volume in 2012 was almost identical to the estimate in 2004, which in the bank account analogy, means that the "interest" of past years has been "withdrawn" in recent years.

While it is impossible to predict future growth, some indicators suggest a possible return to positive net growth rates in the short term. Only about 30 percent of the area of Colorado was in some degree of drought by the end of water year 2014, and at the time of this writing (August 2015), only about 2 percent of Colorado is in drought conditions. Although it has been recently shown that growth does not fully rebound immediately after drought periods (Anderegg et al. 2015), favorable moisture conditions should help to reverse the most recent trends. In addition, live volume in younger stands that were regenerated during the late 1990s and early 2000s will come into the inventory soon as individual trees become large enough to compute volume. Because of the high level of interest and the value of aspen forests, the situation will continue to be analyzed in future reports.

## Spruce Beetle in Colorado

Bark beetle activity has been a significant contributor to tree mortality in the western United States over the last few decades (Werstak et al. 2016). The spruce beetle (*Dendroctonus rufipennis* Kirby) is a bark beetle native to the Engelmann spruce forests of the Interior West. At endemic population levels the spruce beetle prefers mature Engelmann spruce in stands of high density (Schmid and Frye 1977). If spruce beetles can successfully mass-attack individual spruce, their populations may increase to epidemic levels where mortality levels of greater than 90 percent are possible at scales much larger than individual stands (Schmid and Frye 1977).

Engelmann spruce mortality resulting from spruce beetle attack was noted in the previous Colorado State report (2002–2006, Thompson et al. 2010); however, considerable additional mortality has occurred in the subsequent years (2007–2013). The average annual mortality for Engelmann spruce and Engelmann spruce/subalpine fir forest types jumped from 93.1 million cubic feet for the 2002–2006 period, to 161 million cubic feet for the 2004–2013 period (Thompson et al. 2010, table B27). Ninety-six percent of this mortality has occurred on National Forest Systems land. The area of Engelmann spruce and Engelmann spruce/subalpine fir forest type affected by insects, including damage to seedling and saplings, was just under nearly 700,000 acres, which represents approximately 15 percent of the total area of these forest types in Colorado.

Mortality attributable to insects in the Engelmann spruce and Engelmann spruce/subalpine fir forest types exhibited an increasing trend over the reporting period with the largest percentage of mortality occurring from 2009 to 2013 (fig. 30). Some insect-caused mortality of subalpine fir within the Engelmann spruce/subalpine fir forest type may be attributable to the western balsam bark beetle (*Dryocoetes confuses* Swaine), but species-level records of insects that cause mortality are not currently recorded. Individual tree mortality attributable to the spruce beetle occurred relatively uniformly across the State from 2004 through approximately 2009 (fig. 31). Since 2010 the majority of the mortality has been centered on the San Juan and Rio Grande National Forests in the southwestern part of the State where there is an ongoing notable spruce beetle outbreak. Additionally, there appears to be an increase in recent Engelmann spruce mortality in the north part of the State on the Routt and Arapaho-Roosevelt National Forests.

Although the spruce beetle is thought to preferentially choose larger Engelmann spruce occurring in dense stands, this relationship breaks down during epidemics (DeRose and Long 2012; Hart et al. 2014). In Colorado, the area affected by spruce beetles occurred disproportionately higher in the 40 to 80 square foot basal area class, and lower than the overall population in the 120+ square foot class (fig. 32), confirming that stand density is probably not the limiting factor controlling spruce beetle outbreaks (Temperli et al. 2014). Interestingly, the distribution of spruce beetle-affected stands occurred uniformly across stand-age classes (fig. 33).

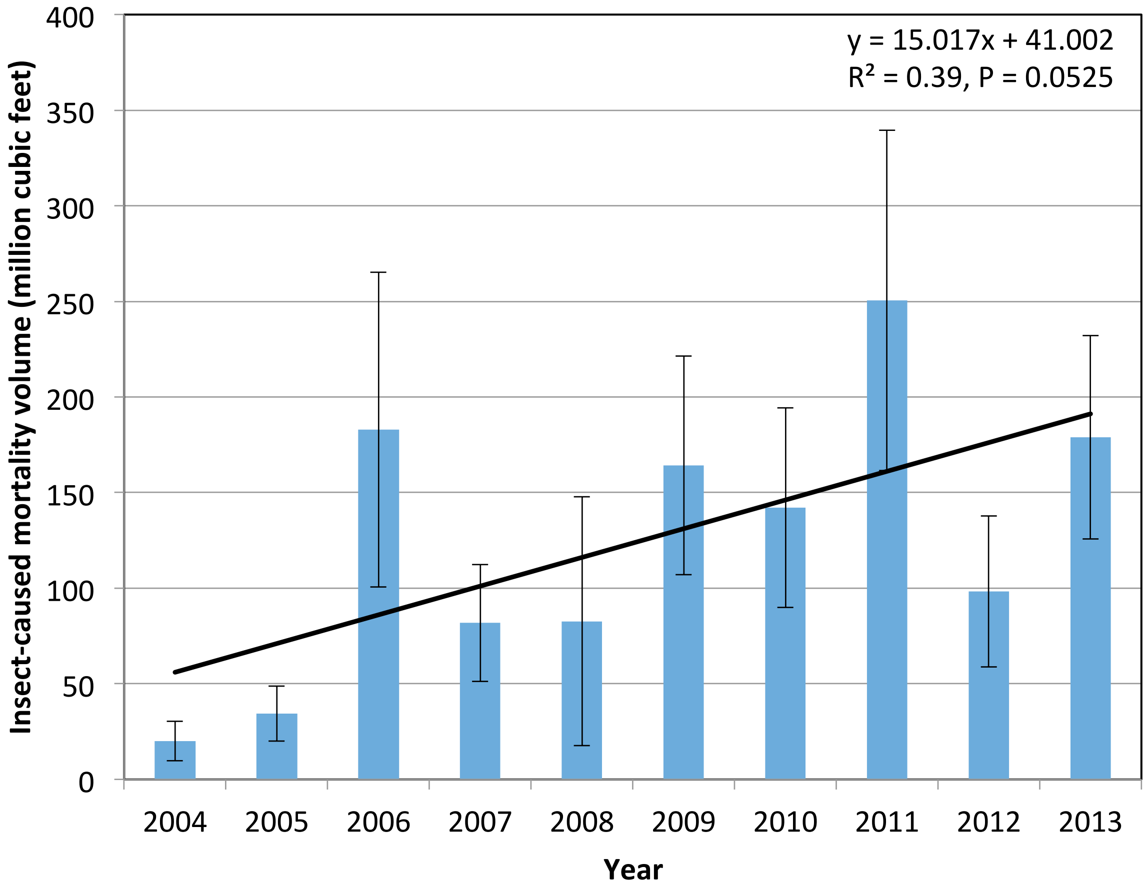


**Figure 30—**Volume of Engelmann spruce mortality by inventory year, Colorado, 2004–2013.

## Comparisons Between Colorado's Periodic and Annual Forest Inventories

One purpose of Colorado's annual forest inventory is to provide information about changes in forest attributes over time. Prior to the implementation of the annual inventory, at least three plot-based periodic inventories were conducted in Colorado. If the definitions and methods used during the periodic inventories were compatible with those used during the annual inventory, we could quantify trends over the past 30 years. However, the sampling and field procedures used during the periodic inventories were different enough from those of the annual inventory to preclude reliable trend analysis. Therefore, direct comparisons of periodic and annual inventories in their entireties are not recommended and may even produce misleading results (Goeking 2015). This section describes the primary differences between the periodic and annual inventories; presents an appropriate method for comparing periodic and annual inventory data at plots that were measured during both inventories, or co-located plots; and summarizes some changes in forest attributes that have occurred at co-located plots.

The primary differences between Colorado's periodic and annual forest inventories pertain to the operational definitions used during field data collection, plot design, estimation procedures, and sample design. Most of the periodic inventories used a variable-radius plot design with varying numbers of subplots.

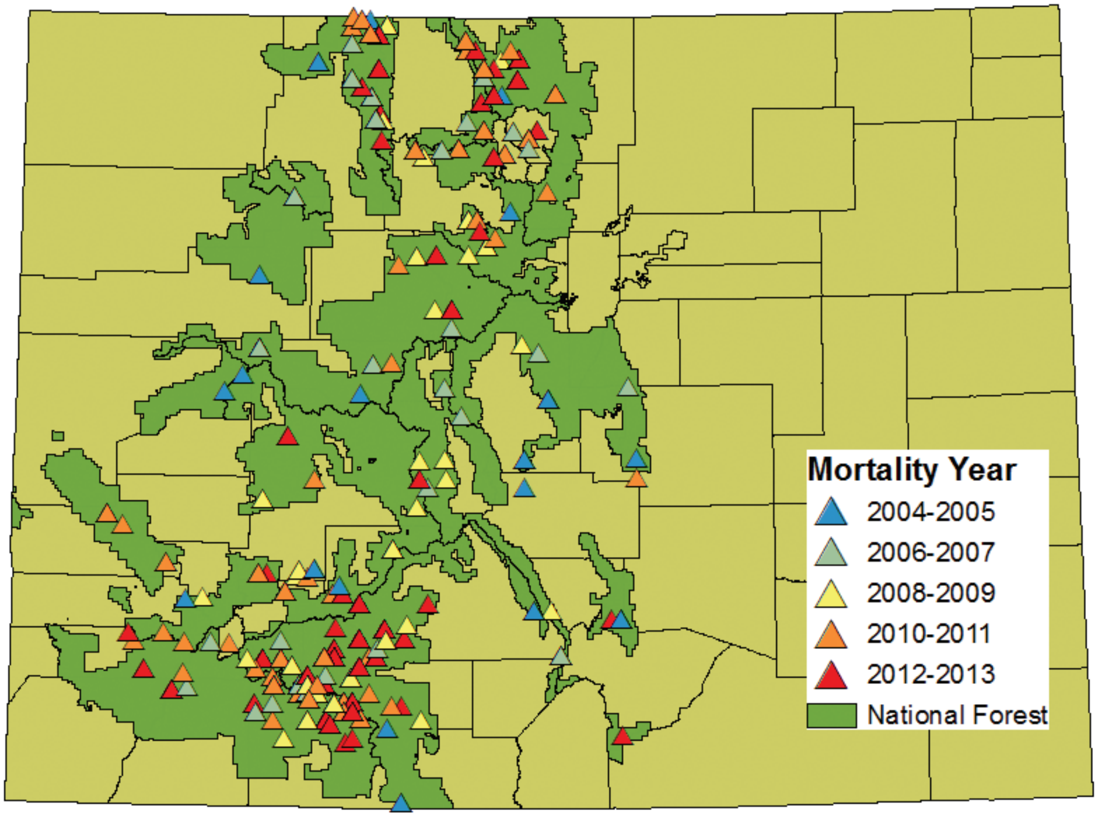


**Figure 31—**General locations of plots with spruce beetle-killed Engelmann spruce between 2004 and 2013 in Colorado.

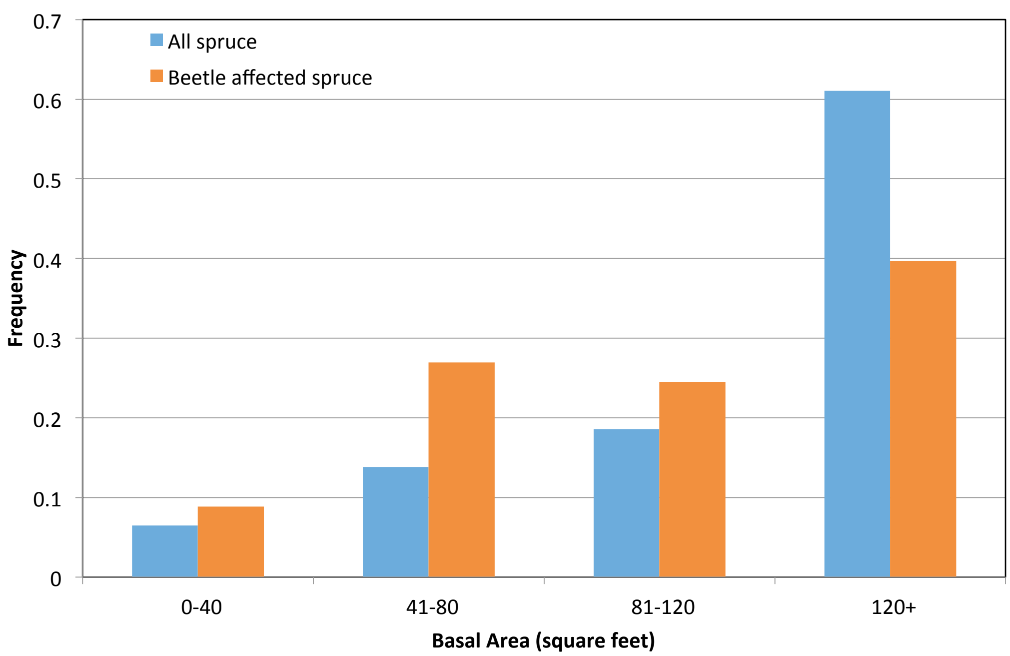


**Figure 32—**Distribution of area by basal area classes of the combined Engelmann spruce and Engelmann spruce/ subalpine fir forest types for all stands and beetle affected stands, Colorado, 2004–2013.

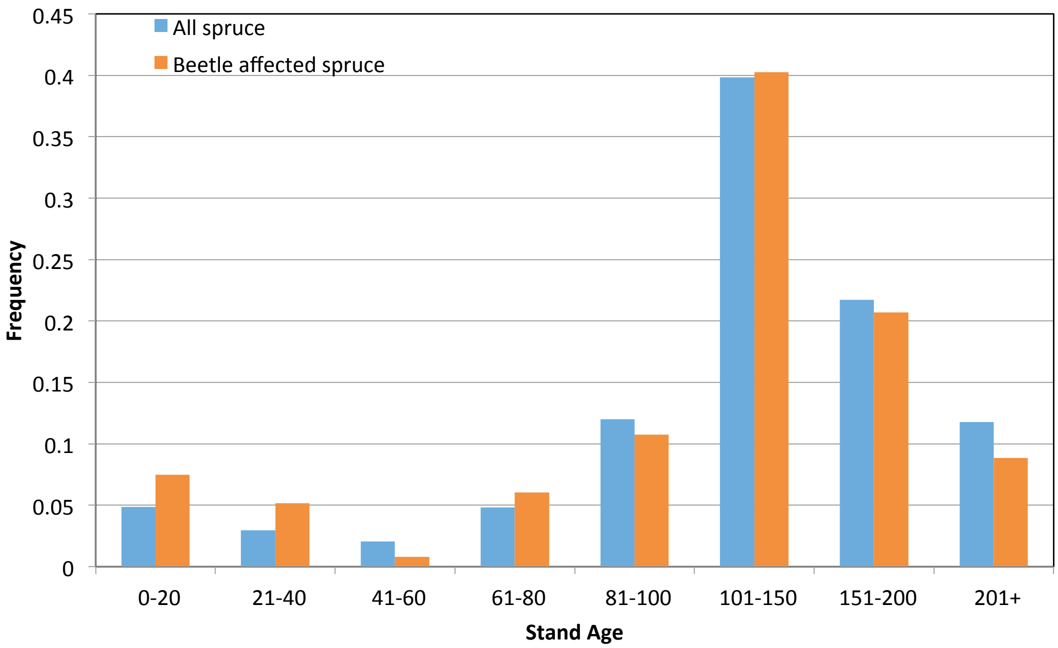


**Figure 33—**Distribution of area by stand age classes of the combined Engelmann spruce and Engelmann spruce/subalpine fir forest types for all stands and beetle affected stands, Colorado, 2004–2013.

In contrast, the plot design of the annual inventory consists of four fixed-radius subplots, as described in the *Plot Configuration* section of this report's "Inventory Methods" chapter. Colorado's periodic inventories also used an operational definition of "tree" that differentiated between tree-form and shrub-form trees. For example, pinyon pines that were less than 6 feet tall and were not expected to eventually produce a straight, 8-foot trunk section were not considered to be trees and were not measured, so they were not included in volume-based estimates such as biomass, growth, and mortality. In contrast, the annual inventory identifies trees strictly by their species, regardless of growth form. Therefore, trees on many woodland plots in the current annual inventory would not have been measured under previous definitions.

Estimation procedures also changed from using a combination of plot data and maps to using plot data almost exclusively, with maps being used only for post-stratification (Bechtold and Patterson 2005). For example, the first published statewide inventory of Colorado (Miller and Choate 1964) included area estimates that were based on delineation of stands on aerial photographs, while volume estimates were based on just over 2,000 ground plots. Sample designs also changed appreciably from samples that typically targeted specific ownership groups and varied in sample intensity to a spatially representative plot grid with consistent sample intensity across all forest types and management categories. For example, when the second periodic inventory was conducted between 1979 and 1984, sample plots were located almost exclusively on privately owned lands. The private plot data, on the other hand, were combined with information provided by individual National Forests and other Federal land management agencies to produce the estimates published by Benson and Green (1987; Thompson et al. 2010). In contrast, during the third periodic inventory in 1997, plots were measured only on the Grand Mesa, Uncompahgre, and Gunnison (GMUG) National Forests of west-central Colorado.

Due to these differences in forest inventories over time, users of FIA data should be aware of appropriate methods of evaluating trends and avoid inappropriate methods. Examples of inappropriate comparisons between periodic and annual inventories range from comparing the statewide tree volume within a specific forest type to directly comparing the total area of forest land. Instead, an appropriate method of quantifying trends is to first identify forest plots that were measured during both periodic and annual inventories, and then assess trends at only those plots. FIA refers to such plot locations as co-located plots. Although different plot designs were used during the periodic and annual measurements of co-located plots, each plot design allows estimation of volume, growth, and mortality per acre as well as stand-level variables such as forest type. However, this approach also assumes that the information collected on forest plots was consistent among the two time periods being compared, so operational definitions must be consistent between the inventories. If this assumption is met, comparisons of multiple measurements at co-located plots are useful for quantifying trends in attributes on a per-acre basis, such as volume, mortality, growth, biomass, and number of trees per acre. This assumption can be met for the periodic inventory of the 1990s, but not for the earlier 1980s inventory. Therefore, valid comparisons of periodic versus annual plot data should include only the 1997 inventory of the GMUG National Forests.

Changes between Colorado's most recent periodic inventory and the annual inventory have been presented by Goeking (2015) and are summarized here. The first measurements of co-located plots occurred in 1997, and the second measurements occurred between 2003 and 2012. Figure 34 shows the distribution of all plots in the 1997 periodic inventory, all plots in the annual inventory, and the 336 co-located plots that were measured during both inventories. By comparing the proportional representation of each forest type during the periodic versus annual inventories in their entireties, Goeking (2015) determined that the 1997 inventory of the GMUG National Forests underrepresented pinyon/juniper forest types and, to a lesser extent, ponderosa pine and Douglas-fir types. Conversely, it overrepresented the following timber forest-type groups: aspen/birch, fir/spruce/mountain hemlock, and lodgepole pine. As a result of these biases among forest types, the 1997 estimates of volume per acre of both live and dead trees were much higher, on average, than those produced by the annual inventory.

Mean total and live volume per acre at co-located plots decreased by 3 and 5 percent, respectively, between 1997 and the annual measurements, and these decreases were statistically significant (Goeking 2015). In contrast, mean dead volume per acre increased by 14 percent. Mean mortality and net growth volumes, which are both expressed as cubic-foot volume per acre per year, showed contrasting but complementary changes. Mean net growth volume decreased 60 percent from 32.8 to 13.2 cubic-feet per acre per year, while mean mortality volume increased by 78 percent from 12.8 to 22.8 cubic-feet per acre per year over the same period (77.6 percent; Goeking 2015). Because net growth equals gross growth minus mortality, part of the change in net growth reflects the large increase in mortality accompanied by an increase in gross growth. In contrast to the results from co-located plots, a comparison of all plots in both inventories indicated no change in either dead net volume or mortality (Goeking 2015), thus demonstrating that comparing periodic to annual inventories in their entireties may produce misleading results.

To investigate changes for individual tree species, we conducted additional analyses to quantify the mean annual mortality, mean annual net growth, live basal area, and dead basal area for several species. This analysis focused on co-located plots that were measured in 1997 and again during the most recent full cycle of Colorado's annual inventory (2004–2013). Here we present the results for the five species that are most abundant, in terms of numbers of trees, in Colorado. In decreasing order of statewide abundance, these are Engelmann spruce, quaking aspen, subalpine fir, lodgepole pine, and Gambel oak.

Figure 35 shows that all major species except for subalpine fir showed positive net growth during both inventory periods, and all major species showed lower rates of net growth in the annual inventory than in 1997. Decreases in net growth appear to be at least partially attributable to increased mortality over this period; all species showed increased mortality between 1997 and the annual inventory. At the most recent measurements, all major species had less live basal area per acre, and more dead basal area per acre, than in 1997 (fig. 36). Given the recent negative net growth of subalpine fir (fig. 35), we could expect that subalpine fir will have less live basal area and more dead basal area during the second cycle of Colorado's annual inventory.

The caveat of the co-located plot analysis presented here is that results cannot be scaled to the entire State and cannot overcome the limitations of the periodic sample design. For example, if the periodic inventory under-sampled a particular forest type, an analysis of co-located plots will still underrepresent that forest type and will instead exhibit trends that occurred on forest types that were sampled more representatively. Further, these results cannot be extrapolated beyond the GMUG National Forests. Nonetheless, this type of analysis provides the best information available on the direction of change in Colorado's forests. As Colorado's forest inventory continues into its second cycle and plots are remeasured at a consistent 10-year interval, FIA's ability to quantify trends in forest attributes will expand from analyses of co-located periodic plots to robust Statewide estimates of change based on the spatially representative annual plot grid.

## Fires in Colorado

Fire is an important disturbance that influences the structure and dynamics of Colorado's forests. In some forest types, such as ponderosa pine, fire can maintain open stands and stimulate the growth of grasses and forbs in the understory. Throughout the Interior West, a century of fire suppression has led to a buildup of fuels and stand densification, which may lead to uncharacteristically intense fires (Reinhardt et al. 2008). Areas that burn intensely may experience slow regeneration, but others may recover relatively quickly. For example, the area inside the boundary of the large 1910 fires in Idaho and Montana (Cohen and Miller 1978;

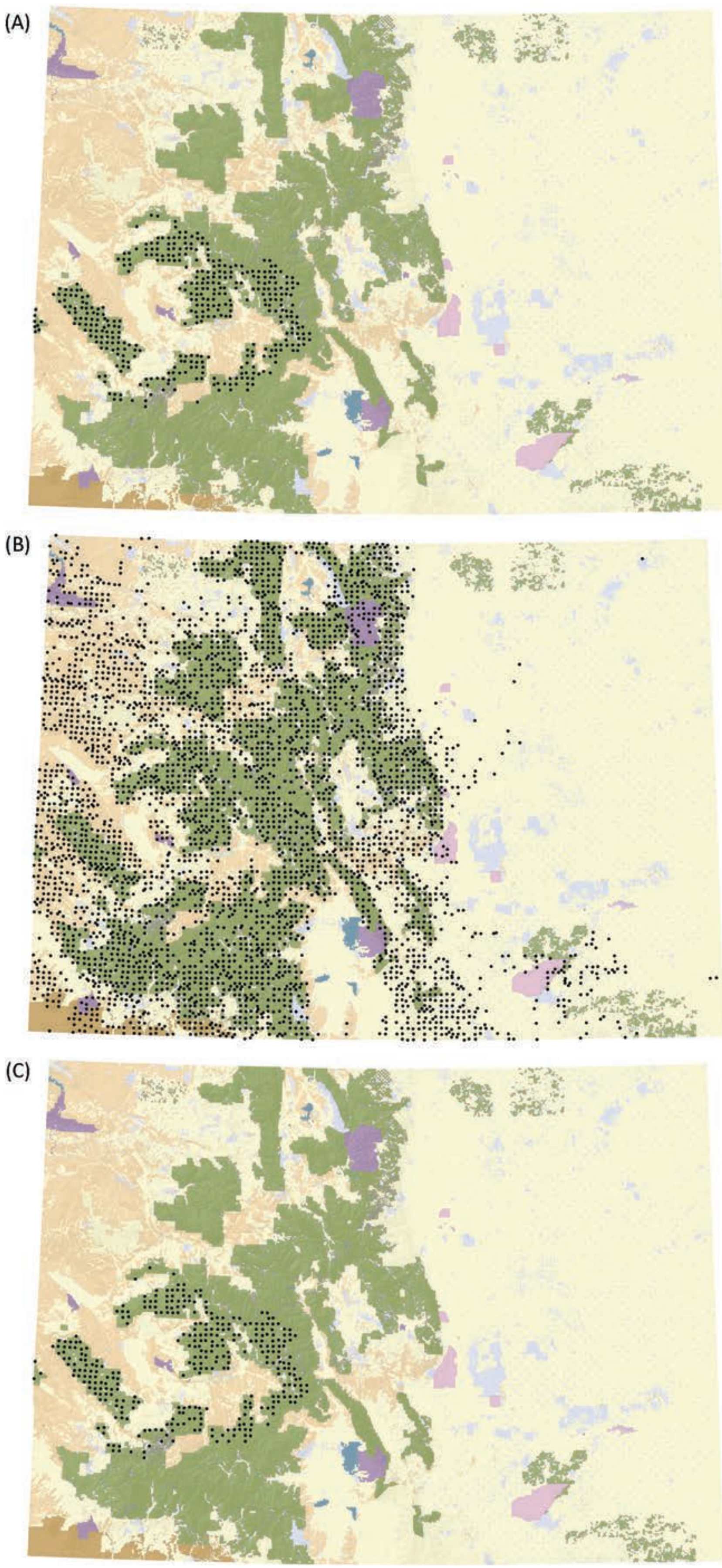


**Figure 34—**Approximate locations of forested plots in (A) the 1997 periodic inventory; (B) a full cycle of the annual inventory; and (C) co-located plots measured during 1997 and again during the annual inventory.

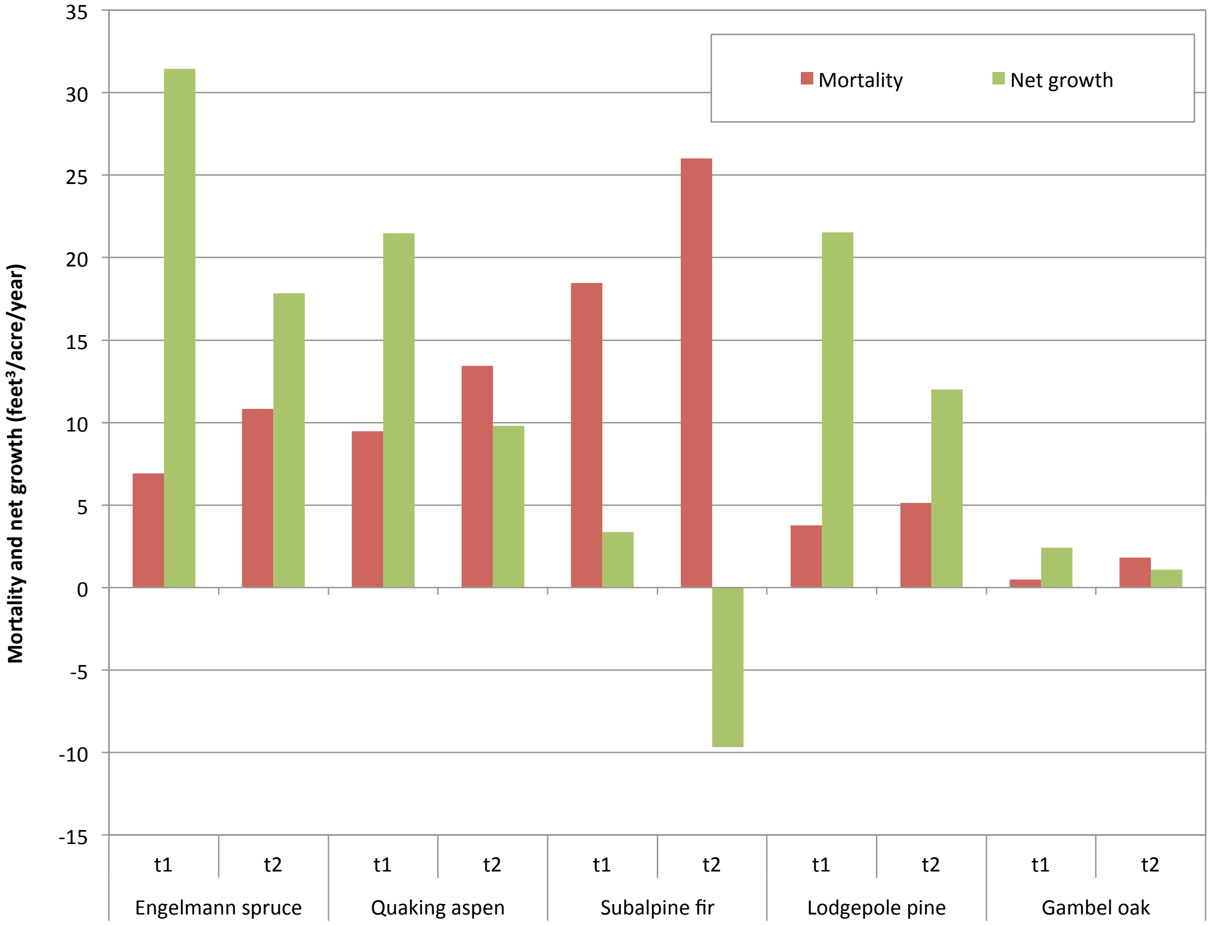


**Figure 35**—Mean annual mortality and mean annual net growth for the most abundant tree species of Colorado, as measured at co-located plots that were measured during the 1997 inventory (t1) and again between 2004 and 2013 (t2).

Egan 2009; Pyne 2008) now carries about the same amount of live tree volume per acre as areas outside the fires. The mean stand age, however, is somewhat lower and the volume is generally distributed among smaller trees (Wilson et al. 2010).

During the period covered by this report there were numerous fires in Colorado. Some FIA plots within fire boundaries were measured before the fires occurred, and some were measured after. As a result, some fire perimeters contain both prefire and postfire plots, while others may contain only prefire or only postfire plots. Prefire plots represent the original conditions in areas that later burned, while only postfire plots provide insight into the short-term effects of fire. This means that normal data compilation methods cannot be used without introducing some element of temporal bias. These limitations on analysis will be reduced as more remeasurement data are acquired. However, there are some general analyses that can be conducted with the current data.

We used data from the Monitoring Trends in Burn Severity (MTBS) project, which is an interagency effort being conducted and maintained by the USDA Forest Service Remote Sensing Applications Center and the U.S. Geological Survey National Center for Earth Resources Observation and Science. The purpose of the MTBS project is to map the perimeters and severities of large wildland

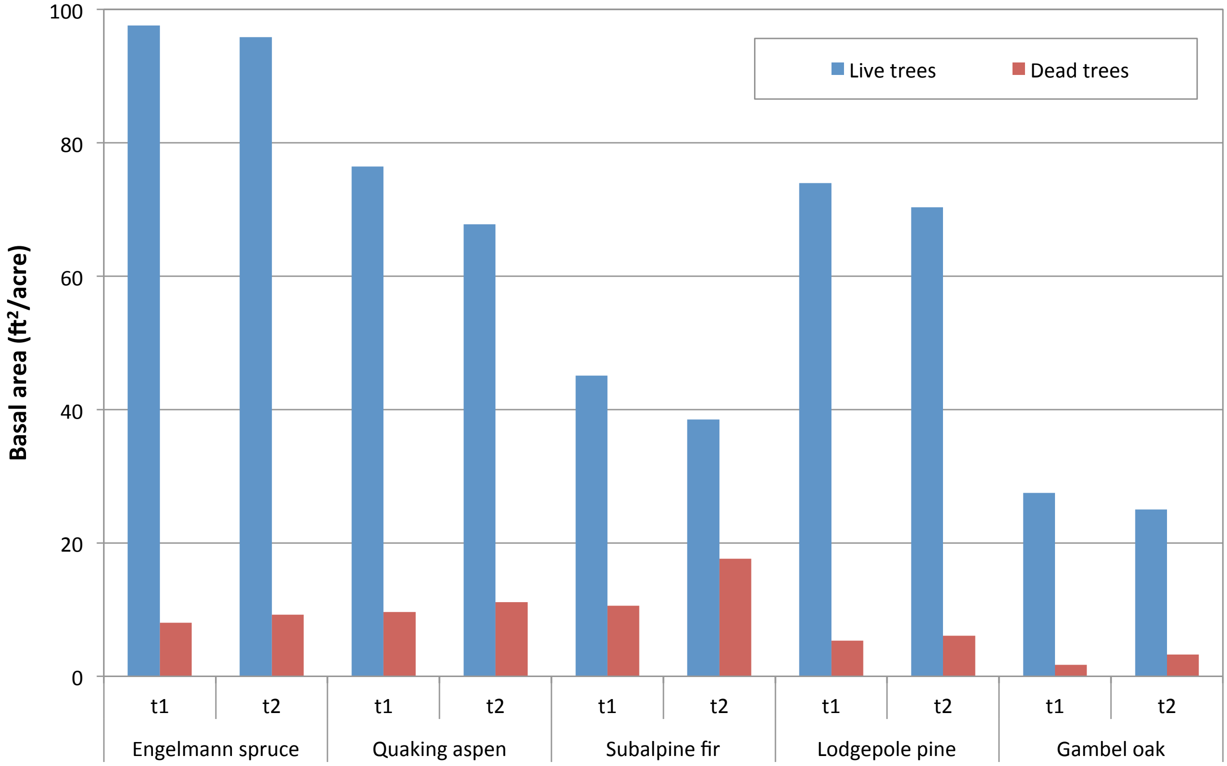


**Figure 36**—Mean basal area for major tree species of Colorado, as measured at co-located plots that were measured during the 1997 inventory (t1) and again between 2004 and 2013 (t2).

fires (including wildfire, wildland fire use, and prescribed fire) across all lands of the United States. In western States, the project maps all fires larger than 1,000 acres (Eidenshink et al. 2007). The analysis presented here is based on fire perimeters identified by the MTBS program between 1984 and 2012 and FIA plot data collected between 2002 and 2013 in Colorado (Shaw et al. 2017).

The MTBS program delineated 336 fire perimeters from 289 different fires that burned just over 1.52 million acres in Colorado between 1984 and 2012. For fires overlapping State boundaries, we report only the portion occurring in Colorado. This acreage represents the sum of all burned areas, but about 4 percent of this area burned more than once. The unique burned area is just over 1.46 million acres. This is in contrast to other States and the Interior West in general, where approximately 20 percent of the area within MTBS boundaries burned more than once. These fires ranged in size from the minimum MTBS mapped area to 129,000 acres (Hayman Fire), with an average size of about 5,000 acres. This average excludes the many smaller fires that occurred in Colorado, but which were below the MTBS minimum mapping threshold. In addition to the Hayman Fire, other large fires include the High Park Fire (90,769 acres), the Missionary Ridge Fire (68,919 acres), and the West Fork Complex (53,216 acres).

These fire perimeters include 2 percent (211) of all the FIA plots in Colorado (10,813 plots) (fig. 37). Just over 64 percent of the plots within these fire perimeters are forest plots and about 36 percent are nonforest plots (table 9). Of the total land area burned by these fires, the largest proportion was on Federal land managed by the USDA Forest Service at 34 percent and accounts for nearly 50 percent of the burned forest land. The second highest proportion of total land area burned was held by private landowners at 28 percent and accounts for nearly 20 percent of the burned forest land. The third highest proportion of total land area burned was on Federal land managed by the Bureau of Land Management at 20 percent, representing nearly 21 percent of the burned forest land (table 9).

Time since fire for the postfire forest plots ranged from almost immediately postfire to 26 years in Colorado (fig. 38). About 90 percent of plot visits occurred within 15 years of the most recent fire. Figure 39 shows the distribution of the total number and average number of acres burned by fire in Colorado between 1984 and 2012 (MTBS 2014).

Figure 40 shows the distribution of average live basal area for postfire plots at time of measurement. Live basal area calculations include all live trees at least 5 inches in diameter and larger. Nearly one-half of the plots (47 percent) measured after the occurrence of fire had no live basal area. The remaining plots (53 percent) show a wide range of postfire live basal area. Because of the slow growth of most tree species sampled and the 5-inch minimum diameter used to calculate basal area, the amount of postfire basal area is influenced very little by new tree growth and therefore mostly reflects postfire residual trees.

The prefire and postfire average basal area for live trees and standing dead trees in Colorado clearly indicates that while fire kills some trees, it does not kill all trees (fig. 41). Further, the increase in standing dead basal area after fire indicates that trees are not completely consumed by fire. Another interesting observation is that the live basal area at burned plots was about 36 percent of the live basal area at unburned plots. This difference between live basal area at burned plots compared to unburned plots may be related to the forest type and stand structure in Colorado, which is dominated by pinyon/juniper woodlands. Because this comparison of burned and unburned plots used a space-for-time substitution, rather than remeasurement data from the same plots before and after fire, these results may be due to higher initial basal area at the burned plots. We do not yet have enough data to analyze whether prefire, high-density stands are more likely to be represented in our sample than low-density stands.

The analyses in this section should be considered only a first approximation of fire effects on Colorado's forests. Although the results are generally consistent with expectations, the magnitude of fire-related mortality cannot yet be stated precisely. Nonetheless, the data confirm that within fire boundaries there has been only partial mortality. Additional data and analysis will be required to determine whether, for example, mortality is more or less evenly distributed among plots within the burned areas or if mortality tends to be all-or-none at the plot scale. Regeneration of seedling and sapling densities after fire loosely resembles what would be expected, but inconsistencies in the data still remain. Remeasurement data will be necessary to confirm fire related tree mortality and seedling and sapling regeneration.

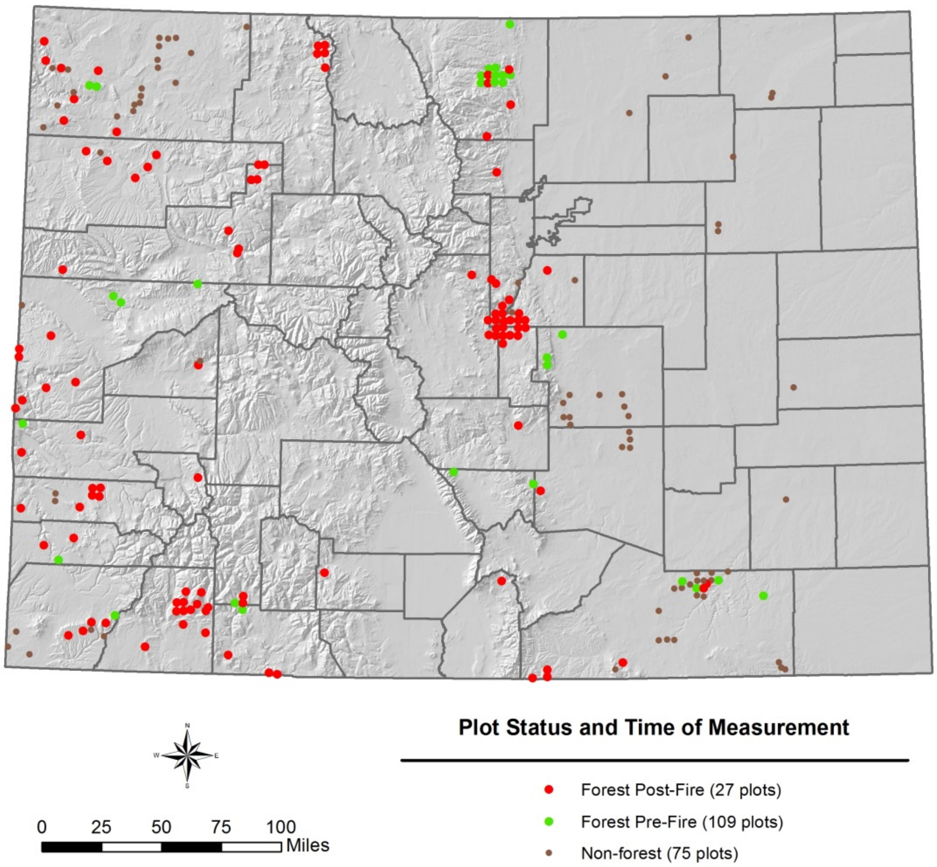


**Figure 37—**Distribution of FIA plots within MTBS burn perimeters, Colorado, 2004–2013.

**Table 9—**Proportions of total land area, forest area, and nonforest area burned by fire, by ownership, Colorado, 2004–2013.

| Owner code | Ownership | Forest | Nonforest | All lands |
|---|---|---|---|---|
| 11 | Forest Service | 49.5 | 6.1 | 33.9 |
| 21 | NPS | 33.0 | 3.9 | 3.3 |
| 22 | BLM | 20.5 | 17.5 | 19.4 |
| 24 | DOD/DOE | 4.8 | 19.0 | 9.9 |
| 31 | State | 2.4 | 11.5 | 5.7 |
| 40 | Private | 19.8 | 41.9 | 27.8 |
| Total | | 100% | 100% | 100% |

## Conclusions and Future Analysis

Colorado's 23 million acres of forest land are one of the more complex ecosystems of the Interior West, with a diverse mix of coniferous and deciduous tree species. The major forest-type groups in Colorado are the pinyon/juniper, fir/spruce/mountain hemlock, aspen/birch, woodland hardwood, and lodgepole pine. Also comprising significant areas of forest land are Gambel oak, Douglas-fir, and ponderosa pine. The reason for this diversity is a physical landscape that ranges from flat plains and high plateaus to steep mountains and deep canyons. Within this landscape, a wide range of topographic, soil, and moisture regimes exist.

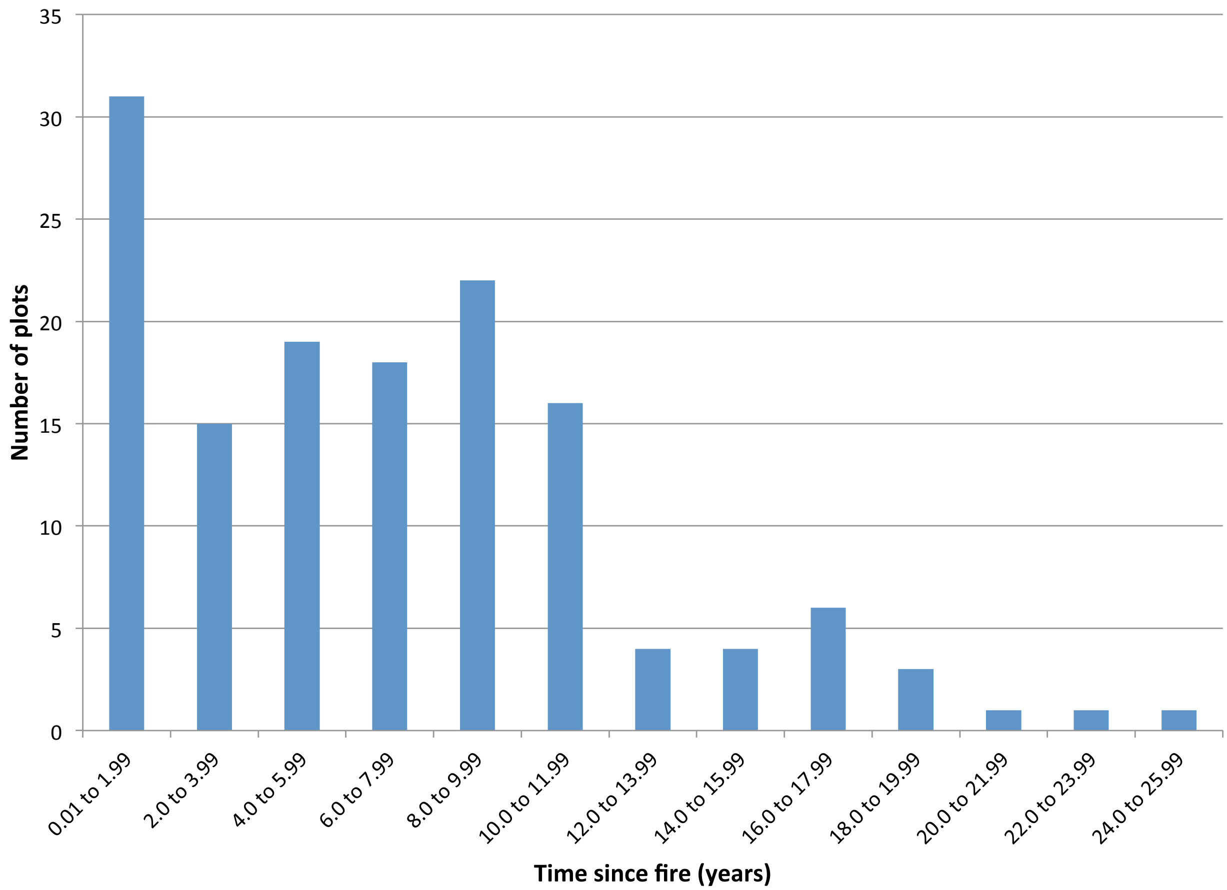


**Figure 38—**Number of years between fire and plot visit for postfire plots, Colorado, 2004–2013 and, MTBS, 1984–2012.

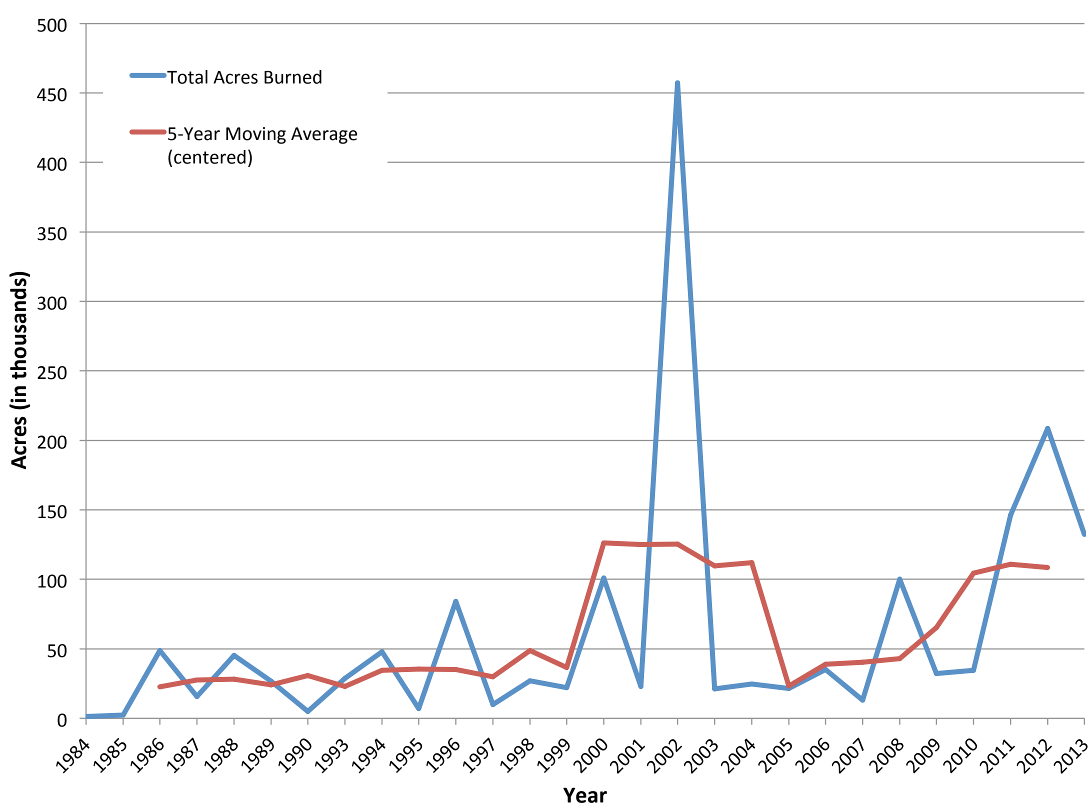


**Figure 39—**Total number and average number of acres burned by fire at 5-year intervals, Colorado, 1984–2012.

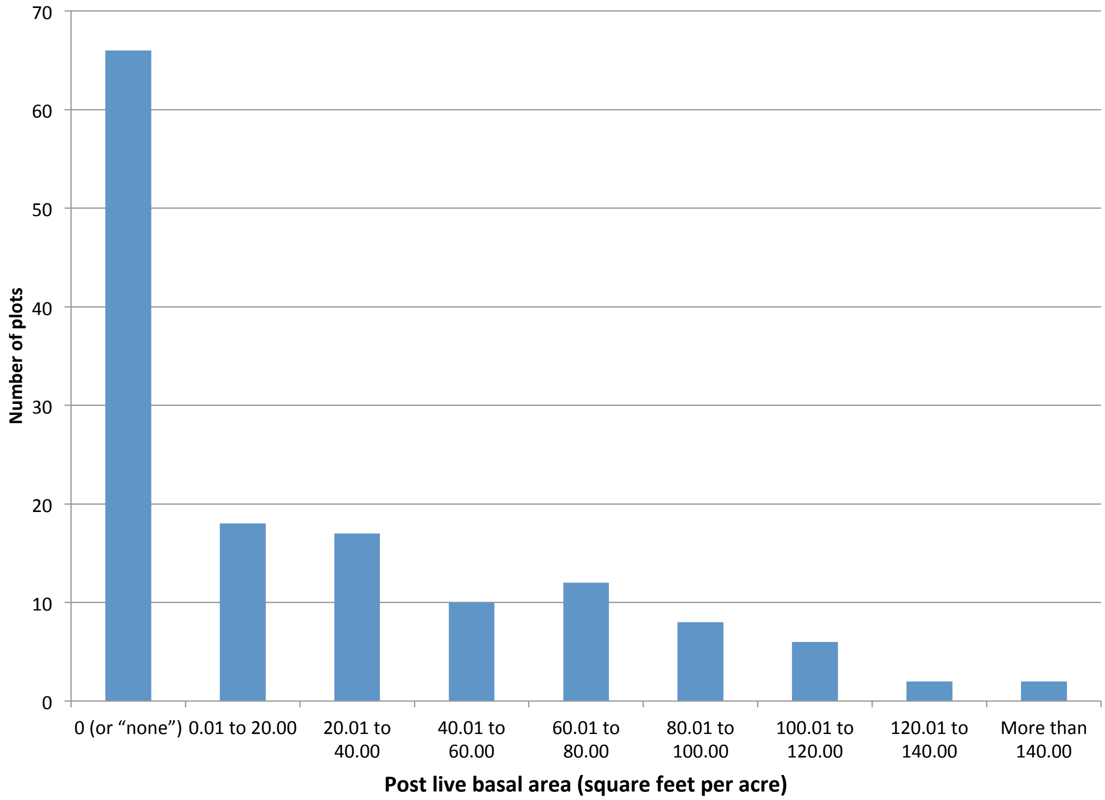


**Figure 40—**Distribution of average live basal area for postfire plots at time of measurement, Colorado, 2004–2013 and, MTBS, 1984–2012.

Most of Colorado's forests are controlled by public agencies. Nearly half of all forest land is controlled by National Forest Systems and 24 percent is controlled by private landowners. The significant amount of public land points to a forest resource that must meet the diverse needs of people. These needs include shelter for people and wildlife, water quality, recreation, pollution control, and timber products that furnish jobs and strengthen local economies. The population of Colorado has been growing at a tremendous rate since 1990 in many of the mountain counties (Forstall 1995). This "mountain sprawl" has placed many homeowners very close to forest land. Naturally, people living in these settings are going to be concerned about anything that might endanger these forests and their homes, such as wildfire, insects, and disease.

The most significant estimates in Colorado's forest inventory include high rates of mortality that are causing reductions in net growth in some of the major tree species in the State. Negative net growth was recorded for the lodgepole pine, Engelmann and other spruces, and true fir species groups. However, net growth was positive for most of the other major species groups in Colorado, including aspen. Insects and disease are the major contributing factors to the elevated levels of mortality that are likely related to multi-year weather patterns such as drought. Mortality was higher on National Forest lands than any other ownership category and mortality exceeds gross growth on National Forest lands in Colorado. Colorado's commercial timber harvest volume has continued to decrease over the past decade; and the State's forest products industry has been facing mill closures

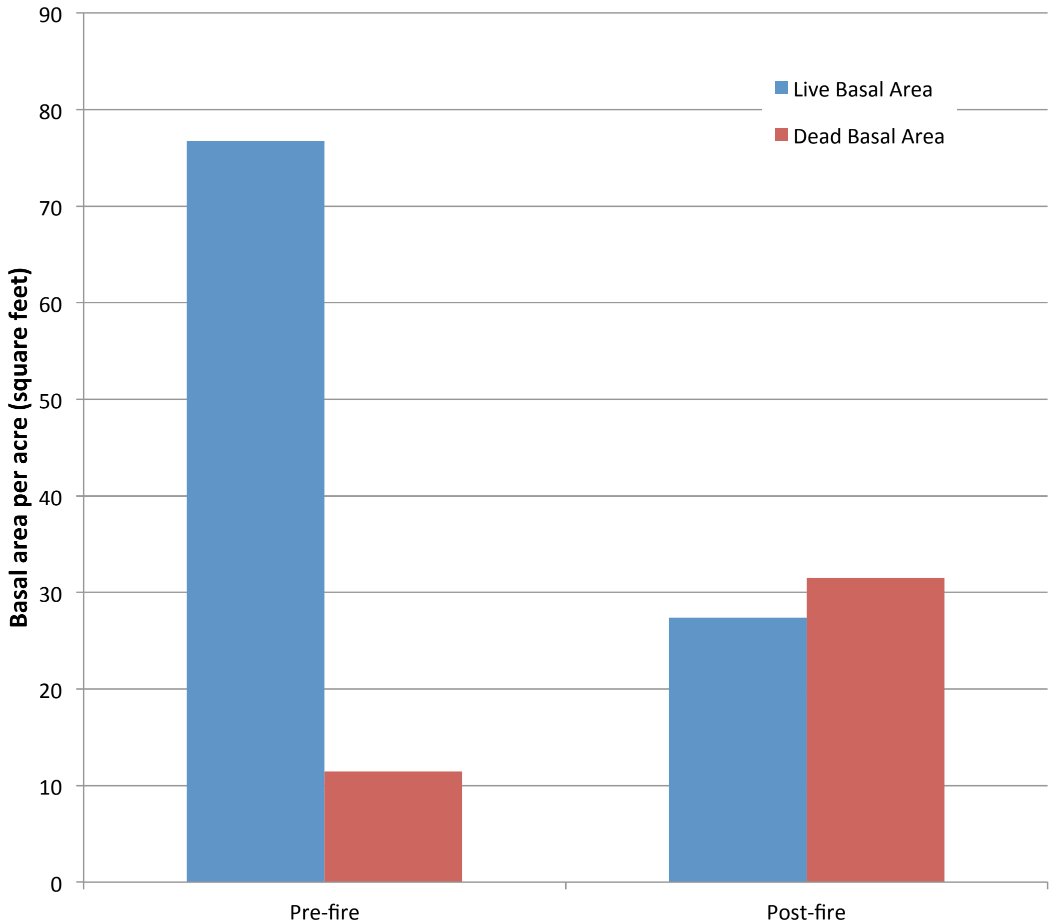


**Figure 41—**Estimates of prefire and postfire, live and dead average basal area per acre, Colorado, 2004–2013 and, MTBS, 1984–2012.

and curtailments even as markets have begun to improve. The decline in Colorado's forest products industry has eroded the ability to actively manage forests and generate income for landowners to use towards activities such as hazardous fuel reduction or forest restoration, which may reduce future statewide mortality losses. To ensure sustainable harvest levels for future generations, careful consideration should be given not only to growth, removals, and mortality across Colorado's available timberlands, but also to the industry infrastructure and employees that conduct management activities and utilize harvested timber.

The mountain pine beetle epidemic that occurred during the timespan this report covers in Colorado was considered to be catastrophic and unprecedented. The infestation peaked between 2004 and 2008 and is now considered to have ended. Forest managers have had serious concerns about the future of lodgepole pine, the primary affected species. However, comparing annual levels of lodgepole pine ingrowth against annual mortality as a metric for sustainability of the lodgepole resource indicates net mortality losses may not be as severe as initially thought. Nevertheless, the epidemic had an immediate effect on the structure and composition of lodgepole pine forests in Colorado. Beetles concentrated the attacks on older stands with large-diameter trees. The mortality associated with the epidemic resulted in reshaping the lodgepole resource to a higher proportion of younger lodgepole pine forests comprised of smaller-diameter trees.

Also of concern is the relatively recent rapid mortality of aspen occurring in certain locales in Colorado—referred to as Sudden Aspen Decline. Based on the State's annual inventory, aspen transitioned from a period of positive to negative net growth during the 2004 to 2013 inventory period. However, across the entire time period, average aspen net growth remained positive. No significant detectable reduction in aspen inventory occurred statewide although we acknowledge that certain regions in Colorado have experienced significant losses of aspen due to elevated mortality rates. Because there is so much interest and value of the aspen resource in Colorado, the situation will continue to be monitored in future inventories.

The information presented in this report points to opportunities for further analysis, investigation, and studies. The systematic interpenetrating panel design of the annual inventory presents opportunities to assess trends in inventory estimates never before possible with periodic inventories. Quantitative inferences about temporal trends require consideration of independent estimates of the population status each year, each of which uses completely different sample plots from different panels. Various time-series model-based estimation techniques have been explored (Czaplewski and Thompson 2009). These model-based estimators cannot only be used to track mortality events, they can lead to better monitoring of forest growth, live tree inventory, and tree harvest activity. Once the annual inventory effort extends into the second measurement cycle in Colorado, the power to detect significant effects related to tree mortality and other parameters of interest will increase substantially with estimates derived from the remeasured (paired) plots that will be available. What is clear is the need for accurate, consistent, long-term monitoring procedures for managers and researchers to study relationships between forest attributes and changing climate patterns.

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# Appendix A. Standard Forest Inventory and Analysis Terminology

**Average annual mortality**—The average annual volume of trees 5.0 inches d.b.h./d.r.c. and larger that died from natural causes.

**Average net annual growth**—Average annual net change in volume of trees 5.0 inches diameter at breast height (d.b.h.)/diameter at root collar (d.r.c). and larger in the absence of cutting (average annual gross growth minus average annual mortality).

**Basal area (BA)**—The cross-sectional area of a tree stem/bole (trunk) at the point where diameter is measured, inclusive of bark. BA is calculated for trees 1.0 inch and larger in diameter and is expressed in square feet. For timber species, the calculation is based on d.b.h.; for woodland species, it is based on d.r.c.

**Biomass**—The quantity of wood fiber, for trees 1.0-inch d.b.h./d.r.c. and larger, expressed in terms of oven-dry weight. It includes above-ground portions of trees: bole/stem (trunk), bark, and branches. Biomass estimates can be computed for live and/or dead trees.

**Board-foot volume**—A unit of measure indicating the amount of wood contained in an unfinished board 1 foot wide, 1 foot long, and 1 inch thick**.** Board-foot volume is computed for the sawlog portion of a sawtimber-size tree; the sawlog portion includes the part of the bole on sawtimber-size tree from a 1-foot stump to a minimum sawlog top of 7 inches in diameter outside bark (d.o.b.) for softwoods, or 9 inches d.o.b. for hardwoods. **Net board-foot volume** is calculated as the gross board-foot volume in the sawlog portion of a sawtimber-size tree, less deductions for cull (note: board-foot cull deductions are limited to rotten/missing material and form defect—referred to as the **merchantability factor—board-foot**). Board-foot volume estimates are computed in both Scribner and International ¼-inch rule and can be calculated for live and/or dead (standing or down) trees.

**Census water**—Streams, sloughs, estuaries, canals, and other moving bodies of water 200 feet wide and greater, and lakes, reservoirs, ponds, and other permanent bodies of water 4.5 acres in area and greater.

**Coarse woody debris**—Down pieces of wood leaning more than 45 degrees from vertical with a diameter of at least 3.0 inches and a length of at least 3.0 feet.

**Condition class**—The combination of discrete landscape and forest attributers that identify, define, and stratify the area associated with a plot. Such attributes include reserved status, owner group, forest type, stand size class, stand origin, and tree density.

**Crown class**—A classification of trees based on dominance in relation to adjacent trees in the stand as indicated by crown development and amount of sunlight received from above and the sides.

**Crown cover (canopy cover)**—The percentage of the ground surface area covered by a vertical projection of plant crowns. Tree crown cover for a sample site includes the combined cover of timber and woodland trees 1.0 inch d.b.h./d.r.c. and larger. Maximum crown cover for a site is 100 percent; overlapping cover is not double counted.

**Cubic-foot volume (merchantable)**—A unit of measure indicating the amount of wood contained in a cube 1-by-1-by-1 foot. Cubic-foot volume is computed for the merchantable portion of timber and woodland species; the merchantable portion for timber species includes that part of a bole from a 1-foot stump to a minimum 4-inch top d.o.b, or above the place(s) of diameter measurement for any woodland tree with a single 5.0-inch stem or larger or a cumulative (calculated) d.r.c. of at least 5.0 inches to the 1.5-inch ends of all branches. **Net cubic-foot volume** is calculated as the gross cubic-foot volume in the merchantable portion of a tree, less deductions for cull.

**Diameter at breast height (d.b.h.)**—The diameter of a tree bole/stem (trunk) measured at breast height (4.5 feet above ground), measured outside the bark. The point of diameter measurement may vary for abnormally formed trees.

**Diameter at root collar (d.r.c.)**—The diameter of a tree stem(s) measured at root collar or at the point nearest the ground line (whichever is higher) that represents the basal area of the tree, measured outside the bark. For multi-stemmed trees, d.r.c. is calculated from an equation that incorporates the individual stem diameter measurements. The point of diameter measurement may vary for woodland trees with stems that are abnormally formed. With the exception of seedlings, woodland stems qualifying for measurement must be at least 1.0 inch in diameter or larger and at least 1.0 foot in length.

**Diameter class**—A grouping of tree diameters (d.b.h. or d.r.c.) into classes of a specified range. For some diameter classes, the number referenced (e.g., 4”, 6”, 8”) is designated as the midpoint of an individual class range. For example, if 2-inch classes are specified (the range for an individual class) and even numbers are referenced, the 6-inch class would include trees 5.0 to 6.9 inches in diameter.

**Diameter outside bark (d.o.b.)**—Tree diameter measurement inclusive of the outside perimeter of the tree bark. The d.o.b. measurement may be taken at various points on a tree (e.g., breast height, tree top) or log, and is sometimes estimated.

**Field plot/location**—A reference to the sample site or plot; an area containing the field location center (LC) and all sample points. A field location consists of four subplots and four microplots.

- **Subplot**—A 1/24-acre fixed-radius area (24-foot horizontal radius) used to sample trees 5.0-inches d.b.h./d.r.c. and larger and understory vegetation.
- **Microplot**—A 1/300-acre fixed-radius plot (6.8-foot radius), located at the center of each subplot, used to inventory seedlings and saplings.

**Fixed-radius plot**—A circular sample plot of a specified horizontal radius: 1/300 acre = 6.8-foot radius (microplot); 1/24 acre = 24.0-foot radius (subplot).

**Forest industry land**—Land owned by a company or an individual(s) operating a primary wood-processing plant.

**Forest land**—Land that has at least 10 percent cover of live tally tree species of any size, or land formerly having such tree cover, and not currently developed for a nonforest use. The minimum area for classification as forest land is 1 acre. Roadside, streamside, and shelterbelt strips of trees must be at least 120 feet wide to qualify as forest land. Unimproved roads and trails, streams and other bodies of water, or natural clearings in forested areas are classified as forest if less than 120 feet in width or 1 acre in size. Grazed woodlands, reverting fields, and pastures that are not actively maintained are included if the above qualifications are satisfied.

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

**Gross growth**—The annual increase in volume of trees 5.0 inches d.b.h. and larger in absence of cutting and mortality. Gross growth includes survivor growth, ingrowth, growth on ingrowth, growth on removals before removal, and growth on mortality prior to death.

**Growing-stock trees**—A live timber species, 5.0 inches d.b.h. or larger, with less than 2/3 (67 percent) of the merchantable volume cull, and containing at least one solid 8-foot section, now or prospectively, reasonably free of form defect, on the merchantable portion of the tree.

**Growing-stock volume**—The cubic-foot volume of sound wood in growing-stock trees at least 5.0 inches d.b.h. from a 1-foot stump to a minimum 4-inch top d.o.b. to the central stem.

**Hardwoods**—Dicotyledonous trees, usually broadleaf and deciduous.

**Hexagonal grid (Hex)**—A hexagonal grid formed from equilateral triangles for the purpose of tessellating the FIA inventory sample. Each hexagon in the base grid has an area of 5,937 acres (2,403.6 ha) and contains one inventory plot. The base grid can be subdivided into smaller hexagons to intensify the sample.

**Indian Trust lands**—American Indian lands held in fee, or trust, by the Federal Government, but administered for tribal groups or as individual trust allotments.

**Inventory year**—The year in which a plot was scheduled to be completed. Within each subpanel, all plots have the same inventory year. Inventory year may differ from measurement year.

**Land use**—The classification of a land condition by use or type.

**Litter**—The uppermost layer of organic debris on a forest floor; that is, essentially the freshly fallen, or only slightly decomposed material, mainly foliage, but also bark fragments, twigs, flowers, fruits, and so forth. Humus is the organic layer, unrecognizable as to origin, immediately beneath the litter layer from which it is derived. Litter and humus together are often termed duff.

**Logging residue/products—**

- **Bolt**—A short piece of pulpwood; a short log.
- **Industrial wood**—All commercial roundwood products, excluding fuelwood.
- **Logging residue**—The unused sections within the merchantable portions of sound (growing-stock) trees cut or killed during logging operations.
- **Mill or plant residue**—Wood material from mills or other primary manufacturing plants that is not used for the mill's or plant's primary products. Mill or plant residue includes bark, slabs, edgings, trimmings, miscuts, sawdust, and shavings. Much of the mill and plant residue is used as fuel and as the raw material for such products as pulp, palletized fuel, fiberwood, mulch, and animal bedding. Mill or plant residue includes bark and the following components:
- **Coarse residue**—Wood material suitable for chipping, such as slabs, edgings, and trim.
- **Fine residue**—Wood material unsuitable for chipping, such as sawdust and shavings.
- **Pulpwood**—Roundwood, whole-tree chips, or wood residues that are used for the production of wood pulp.
- **Roundwood**—Logs, bolts, or other round sections cut from trees.

**Mapped-plot design**—A sampling technique that identifies (maps) and separately classifies distinct "conditions" on the field location sample area. Each condition must meet minimum size requirements. At the most basic level, condition class delineations include forest land, nonforest land, and water. Forest land conditions can be further subdivided into separate condition classes if there are distinct variations in forest type, stand size class, stand origin, and stand density, given that each distinct area meets minimum size requirements.

**Measurement year**—The year in which a plot was completed. Measurement year may differ from inventory year.

**Merchantable portion**—For trees measured at d.b.h. and 5.0 inches d.b.h. and larger, the merchantable portion (or "merchantable bole") includes the part of the tree bole from a 1-foot stump to a 4.0-inch top (d.o.b.). For trees measured at d.r.c., the merchantable portion includes all qualifying segments above the place(s) of diameter measurement for any tree with a single 5.0-inch stem or larger or a cumulative (calculated) d.r.c. of at least 5.0 inches to the 1.5-inch ends of all branches; sections below the place(s) of diameter measurement are not included. Qualifying segments are stems or branches that are a minimum of 1 foot in length and at least 1.0 inch in diameter; portions of stems or branches smaller than 1.0 inch in diameter, such as branch tips, are not included in the merchantable portion of the tree.

**Mortality tree**—All standing or down dead trees 5.0 inches d.b.h./d.r.c. and larger that were alive within the previous five years (in most States); for the 2008 to

2012 New Mexico inventory, this includes trees that were alive within the previous 10 years.

**National Forest System (NFS) lands**—Public lands administered by the Forest Service, U.S. Department of Agriculture, such as National Forests, National Grasslands, and some National Recreation Areas.

**National Park lands**—Public lands administered by the Park Service, U.S. Department of the Interior, such as National Parks, National Monuments, National Historic Sites (such as National Memorials and National Battlefields), and some National Recreation Areas.

**Noncensus water**—Portions of rivers, streams, sloughs, estuaries, and canals that are 30 to 200 feet wide and at least 1 acre in size; and lakes, reservoirs, and ponds 1 to 4.5 acres in size. Portions of rivers and streams not meeting the criteria for census water, but at least 30 feet wide and 1 acre in size, are considered noncensus water. Portions of braided streams not meeting the criteria for census water, but at least 30 feet in width and 1 acre in size, and more than 50 percent water at normal high-water level are also considered noncensus water.

**Nonforest land**—Land that does not support, or has never supported, forests, and lands formerly forested where tree regeneration is precluded by development for other uses. Includes areas used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining rights-of-way, power line clearings of any width, and noncensus water. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., more than 1 acre in size, to qualify as nonforest land.

**Nonindustrial private lands**—Privately owned land excluding forest industry land.

**Nonstocked stand**—A formerly stocked stand that currently has less than 10 percent stocking but has the potential to again become 10 percent stocked. For example, recently harvested, burned, or windthrow-damaged areas.

**Other Federal lands**—Public lands administered by Federal agencies other than the Forest Service, U.S. Department of Agriculture, or the Bureau of Land Management, U.S. Department of the Interior.

**Other private lands**—Privately owned lands other than forest industry or Indian Trust.

**Other public lands**—Public lands administered by agencies other than the Forest Service, U.S. Department of Agriculture. Includes lands administered by other Federal, State, county, and local government agencies, including lands leased by these agencies for more than 50 years.

**Poletimber-size trees**—For trees measured at d.b.h, softwoods 5.0 to 8.9 inches d.b.h. and hardwoods 5.0 to 10.9 inches d.b.h. For trees measured at d.r.c., all live trees 5.0 to 8.9 inches d.r.c.

**Primary wood-processing plants**—An industrial plant that processes roundwood products, such as sawlogs, pulpwood bolts, or veneer logs.

**Private lands**—All lands not owned or managed by a Federal, State, or other public entity, including lands owned by corporations, trusts, or individuals, as well as Tribal lands.

**Productive forest land**—Forest land capable of producing 20 cubic feet per acre per year of wood from trees classified as a timber species (see Appendix D) on forest land classified as a timber forest type (see Appendix C).

**Productivity**—The potential yield capability of a stand calculated as a function of site index (expressed in terms of cubic-foot growth per acre per year at age of culmination of MAI). Productivity values for forest land provide an indication of biological potential. Timberland stands are classified by the potential net annual growth attainable in fully stocked natural stands. For FIA reporting, Productivity Class is a variable that groups stand productivity values into categories of a specified range. Productivity is sometimes referred to as "Yield" or "Mean annual increment (MAI)."

**Removals**—The net volume of sound (growing-stock) trees removed from the inventory by harvesting or other cultural operations (such as timber-stand improvement), by land clearing, or by changes in land use (such as a shift to wilderness).

**Reserved land**—Land withdrawn from management for production of wood products through statute or administrative designation; examples include Wilderness areas and National Parks and Monuments.

**Sampling error**—A statistical term used to describe the accuracy of the inventory estimates. Expressed on a percentage basis in order to enable comparisons between the precision of different estimates, sampling errors are computed by dividing the estimate into the square root of its variance.

**Sapling**—A live tree 1.0 to 4.9 inches d.b.h./d.r.c.

**Sawlog portion**—The part of the bole of sawtimber-size trees between a 1-foot stump and the sawlog top.

**Sawlog top**—The point on the bole of sawtimber-size trees above which a sawlog cannot be produced. The minimum sawlog top is 7 inches d.o.b. for softwoods and 9 inches d.o.b. for hardwoods.

**Sawtimber-size trees**—Softwoods 9.0 inches d.b.h. and larger and hardwoods 11.0 inches and larger.

**Sawtimber volume**—The growing-stock volume in the sawlog portion of sawtimber-size trees in board feet.

**Seedlings**—Live trees less than 1.0 inch d.b.h./d.r.c.

**Site index**—A measure of forest productivity for a timberland tree/stand. Expressed in terms of the expected height (in feet) of trees on the site at an index age of 50 (or 80 years for aspen and cottonwood). Calculated from height-to-age equations.

**Site tree**—A tree used to provide an index of site quality. Timber species selected for site index calculations must meet specified criteria with regards to age, diameter, crown class, and damage.

**Snag**—A standing-dead tree.

**Softwood trees**—Coniferous trees, usually evergreen, having needle- or scale-like leaves.

**Stand**—A community of trees that can be distinguished from adjacent communities due to similarities and uniformity in tree and site characteristics, such as age-class distribution, species composition, spatial arrangement, structure, etc.

**Stand density**—A relative measure that quantifies the relationship between trees per acre, stand basal area, average stand diameter, and stocking of a forested stand.

**Stand density index (SDI)**—A widely used measure developed by Reineke (1933) and is an index that expresses relative stand density based on a comparison of measured stand values with some standard conditions; **relative stand density** is the ratio, proportion, or percent of absolute stand density to a reference level defined by some standard level of competition. For FIA reporting, the SDI for a site is usually presented as a percentage of the maximum SDI for the forest type. Site SDI values are sometimes grouped into SDI classes of a specified percentage range. Maximum SDI values vary by species and region.

**Standing tree**—To qualify as a standing dead tally tree, dead trees must be at least 5.0 inches in diameter, have a bole that has an unbroken actual length of at least 4.5 feet, and lean less than 45 degrees from vertical as measured from the base of the tree to 4.5 feet. Portions of boles on dead trees that are separated greater than 50 percent (either above or below 4.5 feet) are considered severed and are included in Down Woody Material (DWM) if they otherwise meet DWM tally criteria. For western woodland species with multiple stems, a tree is considered down if more than 2/3 of the volume is no longer attached or upright; cut and removed volume are not considered. For western woodland species with single stems to qualify as a standing dead tally tree, dead trees must be at least 5.0 inches in diameter, be at least 1.0 foot in unbroken actual length, and lean less than 45 degrees from vertical.

**Stand-size class**—A classification of forest land based on the predominant diameter size of live trees presently forming the plurality of live-tree stocking. Classes are defined as follows:

- **Sawtimber stand (large-tree stand)**—A stand at least 10 percent stocked with live trees, in which half or more of the total stocking is from live trees 5.0 inches or larger in diameter, and with sawtimber (large tree) stocking equal to or greater than poletimber (medium tree) stocking.
- **Poletimber stand (medium-tree stand)**—A stand at least 10 percent stocked with live trees, in which half or more of the total stocking is from live trees

5.0 inches or larger in diameter, and with poletimber (medium tree) stocking exceeding sawtimber (large tree) stocking.

- **Sapling/seedling stand**—A stand at least 10 percent stocked with live trees, in which half or more of the total stocking is from live trees less than 5.0 inches in diameter.
- **Nonstocked stand**—A formerly stocked stand that currently has less than 10 percent stocking but has the potential to again become 10 percent stocked. For example, recently harvested, burned, or windthrow-damaged areas.

**Stockability (stockability factor)**—An estimate of the stocking potential of a given site; for example, a stockability factor of 0.8 for a given site indicates that the site is capable of supporting only about 80 percent of "normal" stocking as indicated by yield tables. Stockability factors (maximum site value of 1.0) are assigned to sites based on habitat type/plant associations.

**Stocking**—An expression of the extent to which growing space is effectively utilized by live trees.

**Timber species**—Tally tree species traditionally used for industrial wood products. These include all species of conifers, except pinyon and juniper. Timber species are measured at d.b.h.

**Timber stand improvement**—A term comprising all intermediate cuttings or treatments, such as thinning, pruning, release cutting, girdling, weeding, or poisoning, made to improve the composition, health, and growth of the remaining trees in the stand.

**Timberland**—Unreserved forest land capable of producing 20 cubic feet per acre per year of wood from trees classified as a timber species (see Appendix D) on forest land designated as a timber forest type (see Appendix C).

**Unproductive forest land**—Forest land not capable of producing 20 cubic feet per acre per year of wood from trees classified as a timber species (see Appendix D) on forest land designated as a timber forest type and all forest lands designated as a woodland forest type (see Appendix C).

**Unreserved forest land**—Forest land not withdrawn from management for production of wood products through statute or administrative designation.

**Wilderness area**—An area of undeveloped land currently included in the Wilderness System, managed to preserve its natural conditions and retain its primeval character and influence.

**Woodland species**—Tally tree species that are not usually converted into industrial wood products. Common uses of woodland trees are fuelwood, fenceposts, and Christmas trees. These species include pinyon, juniper, mesquite, locust, mountain-mahogany (*Cercocarpus* spp.), Rocky Mountain maple, bigtooth maple, desert ironwood, and most oaks (note: bur oak and chinkapin oak are classified as timber species). Because most woodland trees are extremely variable in form, diameter is measured at d.r.c.

# Appendix B. Standard Forest Resource Tables

Table B32—Area of forest land, in thousand acres, by inventory unit, county, ownership group, and forest-land status, Colorado, 2004–2013.

Table B33—Area of timberland, in thousand acres, by inventory unit, county, and stand-size class, Colorado, 2004–2013.

Table B34—Area of timberland, in thousand acres, by inventory unit, county, and stocking class, Colorado, 2004–2013.

Table B35—Net volume of growing-stock trees (at least 5 inches d.b.h.), in million cubic feet, and sawtimber trees, in million board feet (International 1/4 inch rule), on timberland by inventory unit, county, and major species group, Colorado, 2004–2013.

Table B36—Average annual net growth of growing-stock trees (at least 5 inches d.b.h.), in million cubic feet, and sawtimber trees, in million board feet (International 1/4 inch rule), on timberland by inventory unit, county, and major species group, Colorado, 2004–2013.

Table B37—Sampling errors (in percent) by inventory unit and county for area of timberland, volume, average annual net growth, average annual removals, and average annual mortality on timberland, Colorado, 2004–2013.

**Table B1**—Percentage of plot area by land status, Colorado, 2004–2013.

| Land status | Percentage of sample |
|---|---|
| **Accessible forest land** | |
| Unreserved forest land | |
| Timberland | 15.1 |
| Unproductive | 12.9 |
| Total unreserved forest land | 28.0 |
| Reserved forest land | |
| Productive | 3.3 |
| Unproductive | 0.8 |
| Total reserved forest land | 4.1 |
| **Total accessible forest land** | **32.1** |
| **Nonforest and other areas** | |
| Nonforest land | 63.5 |
| Water | 0.5 |
| Census | 0.3 |
| Non-Census | 0.2 |
| **Total nonforest and other areas** | **64.0** |
| **Nonsampled land** | |
| Access denied | 3.2 |
| Hazardous conditions | 0.7 |
| Other | 0.0 |
| **Total nonsampled land** | **3.9** |
| **All land** | **100.0** |

All table cells without observations in the inventory sample are indicated by—.
Table value of 0.0 indicates the percentage rounds to less
than 0.1 percent. Columns and rows may not add to their totals due to rounding.

**Table B2**—Area of accessible forest land, in thousand acres, by owner class and forest land status, Colorado, 2004–2013.

| Owner class | | Unreserved forests | | | Reserved forests | | | All forest land |
|---|---|---|---|---|---|---|---|---|
| | | Timberland | Unproductive | Total | Productive | Unproductive | Total | |
| **Forest Service** | | | | | | | | |
| | National Forest | 7,532 | 1,434 | 8,966 | 2,025 | 140 | 2,165 | **11,130** |
| | National Grassland | — | 25.7 | 25.7 | — | — | — | **25.7** |
| **Other Federal** | | | | | | | | |
| | National Park Service | — | — | — | 203.9 | 161.9 | 365.8 | **365.8** |
| | Bureau of Land Management | 671.9 | 4,083.2 | 4,755.1 | 36.6 | 231.9 | 268.6 | **5,023.6** |
| | Departments of Defense and Energy | 11.2 | 91.4 | 102.6 | — | — | — | **102.6** |
| **State and local government** | | | | | | | | |
| | State | 199.7 | 294.0 | 493.7 | 74.5 | 1.5 | 75.9 | **569.6** |
| | County and Municipal | 82.0 | 11.8 | 93.9 | — | — | — | **93.9** |
| **Private** | | | | | | | | |
| | Undifferentiated private | 2,248.6 | 3,331.2 | 5,579.8 | — | — | — | **5,579.8** |
| **All owners** | **Total** | **10,745.2** | **9,271.2** | **20,016.3** | **2,340.0** | **535.0** | **2,875.0** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B3**—Area of accessible forest land, in thousand acres, by forest-type group and productivity class, Colorado, 2004–2013.

| Forest-type group | Site-productivity class (cubic feet/acre/year) | | | | | | | Total all classes |
|---|---|---|---|---|---|---|---|---|
| | 0-19 | 20-49 | 50-84 | 85-119 | 120-164 | 165-224 | 225+ | |
| Pinyon / juniper group | 6,357.1 | — | — | — | — | — | — | 6,357.1 |
| Douglas-fir group | 14.7 | 1,349.6 | 206.2 | — | — | — | — | 1,570.5 |
| Ponderosa pine group | 19.0 | 1,387.7 | 136.8 | — | — | — | — | 1,543.5 |
| Fir / spruce / mountain hemlock group | 38.5 | 2,419.0 | 2,147.5 | 325.1 | 6.0 | — | — | 4,936.1 |
| Lodgepole pine group | 183.4 | 1,332.6 | 105.4 | — | — | — | — | 1,621.4 |
| Other western softwoods group | 79.7 | 176.2 | 6.2 | — | — | — | — | 262.0 |
| Elm / ash / cottonwood group | 9.5 | 81.5 | 27.0 | 6.0 | — | — | — | 123.9 |
| Aspen / birch group | 361.6 | 2,158.8 | 809.6 | 34.3 | — | — | — | 3,364.2 |
| Woodland hardwoods group | 2,442.0 | — | — | — | — | — | — | 2,442.0 |
| Exotic hardwoods group | — | 4.4 | — | — | — | — | — | 4.4 |
| Nonstocked | 300.6 | 321.8 | 43.8 | — | — | — | — | 666.2 |
| **All forest-type groups** | **9,806.1** | **9,231.4** | **3,482.4** | **365.3** | **6.0** | **—** | **—** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B4**—Area of accessible forest land, in thousand acres, by forest-type group, ownership group, and land status, Colorado, 2004–2013.

| | Forest Service | | Other Federal | | State and local government | | Undifferentiated private | | |
|---|---|---|---|---|---|---|---|---|---|
| **Forest-type group** | **Timber-land** | **Other forest land** | **Timber-land** | **Other forest land** | **Timber-land** | **Other forest land** | **Timber-land** | **Other forest land** | **All forest land** |
| Pinyon / juniper group | — | 452.5 | — | 3,760.9 | — | 160.4 | — | 1,983.3 | 6,357.1 |
| Douglas-fir group | 770.9 | 130.0 | 204.8 | 4.6 | 73.8 | 1.7 | 378.1 | 6.6 | 1,570.5 |
| Ponderosa pine group | 668.4 | 38.0 | 105.1 | 20.7 | 50.1 | 7.8 | 647.0 | 6.4 | 1,543.5 |
| Fir / spruce / mountain hemlock group | 2,794.4 | 1,418.6 | 153.9 | 106.2 | 51.4 | 25.8 | 385.8 | — | 4,936.1 |
| Lodgepole pine group | 938.0 | 341.6 | 48.8 | 69.4 | 13.4 | 31.6 | 147.6 | 31.0 | 1,621.4 |
| Other western softwoods group | 124.5 | 78.5 | 7.6 | 17.4 | — | 4.8 | 22.3 | 6.9 | 262.0 |
| Elm / ash / cottonwood group | 3.1 | — | 1.7 | 3.4 | 23.1 | 3.5 | 86.6 | 2.6 | 123.9 |
| Aspen / birch group | 2,061.3 | 413.4 | 142.6 | 69.7 | 60.8 | 26.1 | 495.1 | 95.3 | 3,364.2 |
| Woodland hardwoods group | — | 642.7 | — | 565.6 | — | 113.8 | — | 1,119.8 | 2,442.0 |
| Exotic hardwoods group | — | — | — | — | 4.4 | — | — | — | 4.4 |
| Nonstocked | 171.1 | 109.1 | 18.7 | 190.9 | 4.6 | 6.3 | 86.2 | 79.3 | 666.2 |
| **All forest-type groups** | **7,531.8** | **3,624.2** | **683.1** | **4,808.9** | **281.7** | **381.8** | **2,248.6** | **3,331.2** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B5**—Area of accessible forest land, in thousand acres, by forest-type group and stand-size class, Colorado, 2004–2013.

| | Stand-size class | | | | |
|---|---|---|---|---|---|
| **Forest-type group** | **Large diameter** | **Medium diameter** | **Small diameter** | **Nonstocked** | **All size classes** |
| Pinyon / juniper group | 5,622.0 | 499.4 | 235.7 | — | 6,357.1 |
| Douglas-fir group | 1,292.6 | 225.5 | 52.4 | — | 1,570.5 |
| Ponderosa pine group | 1,380.7 | 74.6 | 88.2 | — | 1,543.5 |
| Fir / spruce / mountain hemlock group | 3,664.3 | 811.1 | 460.7 | — | 4,936.1 |
| Lodgepole pine group | 580.2 | 775.5 | 265.6 | — | 1,621.4 |
| Other western softwoods group | 210.1 | 30.6 | 21.4 | — | 262.0 |
| Elm / ash / cottonwood group | 104.2 | 13.5 | 6.3 | — | 123.9 |
| Aspen / birch group | 822.7 | 1,818.3 | 723.2 | — | 3,364.2 |
| Woodland hardwoods group | 102.0 | 272.6 | 2,067.3 | — | 2,442.0 |
| Exotic hardwoods group | — | — | 4.4 | — | 4.4 |
| Nonstocked | — | — | — | 666.2 | 666.2 |
| **All forest-type groups** | **13,778.9** | **4,521.0** | **3,925.3** | **666.2** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B6**—Area of forest land, in thousand acres, by forest-type group and stand-age class, Colorado, 2004–2013.

| | Non- | Stand-age class (years) | | | | | | | | | | | All |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forest-type group | stocked | 1-20 | 21-40 | 41-60 | 61-80 | 81-100 | 101-120 | 121-140 | 141-160 | 161-180 | 181-200 | 201+ | classes |
| Pinyon / juniper group | — | 165.6 | 145.6 | 382.1 | 611.4 | 699.8 | 695.4 | 700.9 | 578.9 | 626.0 | 650.6 | 1,100.9 | 6,357.1 |
| Douglas-fir group | — | 46.2 | 7.8 | 39.9 | 174.5 | 371.9 | 273.5 | 231.9 | 146.5 | 132.8 | 56.5 | 89.0 | 1,570.5 |
| Ponderosa pine group | — | 72.7 | 27.9 | 75.7 | 202.8 | 383.5 | 395.0 | 199.0 | 93.2 | 29.5 | 28.8 | 35.5 | 1,543.5 |
| Fir / spruce / mountain hemlock group | — | 274.9 | 158.5 | 105.2 | 303.3 | 653.8 | 844.5 | 735.3 | 663.7 | 417.1 | 293.4 | 486.4 | 4,936.1 |
| Lodgepole pine group | — | 109.2 | 68.9 | 80.9 | 214.2 | 355.3 | 426.1 | 168.2 | 63.2 | 33.7 | 18.6 | 83.1 | 1,621.4 |
| Other western softwoods group | — | 5.8 | 4.4 | 6.2 | 17.5 | 32.3 | 17.2 | 40.8 | 37.7 | 37.9 | 32.1 | 30.3 | 262.0 |
| Elm / ash / cottonwood group | — | 5.1 | 1.2 | 19.1 | 37.7 | 26.2 | 20.9 | 3.8 | — | 1.6 | 5.8 | 2.6 | 123.9 |
| Aspen / birch group | — | 582.7 | 122.2 | 253.0 | 711.3 | 886.2 | 553.7 | 202.3 | 32.2 | 20.5 | — | — | 3,364.2 |
| Woodland hardwoods group | — | 1,654.9 | 377.0 | 58.7 | 98.1 | 123.4 | 59.3 | 44.4 | 19.4 | 6.6 | — | — | 2,442.0 |
| Exotic hardwoods group | — | 4.4 | — | — | — | — | — | — | — | — | — | — | 4.4 |
| Nonstocked | 666.2 | — | — | — | — | — | — | — | — | — | — | — | 666.2 |
| **All forest-type groups** | **666.2** | **2,921.6** | **913.4** | **1,020.7** | **2,370.8** | **3,532.5** | **3,285.6** | **2,326.6** | **1,634.8** | **1,305.6** | **1,085.6** | **1,827.8** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B7**—Area of forest land, in thousand acres, by forest-type group and stand origin, Colorado, 2004–2013.

| | Stand origin | | |
|---|---|---|---|
| Forest-type group | Natural stands | Artificial regeneration | All forest land |
| Pinyon / juniper group | 6,350.5 | 6.6 | 6,357.1 |
| Douglas-fir group | 1,570.5 | — | 1,570.5 |
| Ponderosa pine group | 1,536.9 | 6.6 | 1,543.5 |
| Fir / spruce / mountain hemlock group | 4,930.0 | 6.0 | 4,936.1 |
| Lodgepole pine group | 1,621.4 | — | 1,621.4 |
| Other western softwoods group | 262.0 | — | 262.0 |
| Elm / ash / cottonwood group | 123.9 | — | 123.9 |
| Aspen / birch group | 3,364.2 | — | 3,364.2 |
| Woodland hardwoods group | 2,442.0 | — | 2,442.0 |
| Exotic hardwoods group | 4.4 | — | 4.4 |
| Nonstocked | 659.5 | 6.6 | 666.2 |
| **All forest-type groups** | **22,865.3** | **25.9** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B8**—Area of forest land. In thousand acres, by forest-type group and primary disturbance class, Colorado, 2004–2013.

| | Disturbance class | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forest-type group | None | Insects | Disease | Fire | Wild animals | Domestic animals | Weather | Vegetation | Other | Human | Geological | All forest land |
| Pinyon / juniper group | 5,723.6 | 370.1 | 100.8 | 31.2 | 37.5 | 30.3 | 36.6 | — | — | 11.3 | 15.8 | 6,357.1 |
| Douglas-fir group | 1,375.3 | 125.3 | 37.6 | 11.6 | — | 3.4 | 4.6 | — | 6.8 | 6.0 | — | 1,570.5 |
| Ponderosa pine group | 1,329.5 | 78.4 | 52.7 | 74.9 | — | 1.5 | 6.5 | — | — | — | — | 1,543.5 |
| Fir / spruce / mountain hemlock group | 3,891.5 | 810.5 | 159.6 | 6.5 | — | 5.6 | 31.0 | — | — | — | 31.5 | 4,936.1 |
| Lodgepole pine group | 1,055.0 | 404.2 | 125.4 | 11.7 | 6.2 | — | 5.5 | 6.0 | — | — | 7.4 | 1,621.4 |
| Other western softwoods group | 241.3 | 19.5 | — | — | — | — | — | — | — | — | 1.3 | 262.0 |
| Elm / ash / cottonwood group | 103.8 | — | 7.2 | — | — | 6.8 | 6.1 | — | — | — | - - | 123.9 |
| Aspen / birch group | 2,519.4 | 263.6 | 378.8 | 43.6 | 68.3 | 57.3 | 19.2 | — | 6.4 | — | 7.6 | 3,364.2 |
| Woodland hardwoods group | 2,214.1 | 25.6 | 43.6 | 63.0 | — | 53.9 | 29.5 | — | 6.4 | 5.8 | — | 2,442.0 |
| Exotic hardwoods group | 4.4 | — | — | — | — | — | — | — | — | — | — | 4.4 |
| Nonstocked | 493.3 | 51.2 | 1.6 | 110.8 | 1.6 | — | — | 6.0 | — | — | 1.7 | 666.2 |
| **All forest-type groups** | **18,951.0** | **2,148.5** | **907.2** | **353.3** | **113.6** | **158.8** | **139.1** | **12.0** | **19.6** | **23.1** | **65.1** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B9**—Area of timberland, in thousand acres, by forest-type group and stand-size class, Colorado, 2004–2013.

| | Stand-size class | | | | |
|---|---|---|---|---|---|
| Forest-type group | Large diameter | Medium diameter | Small diameter | Nonstocked | All size classes |
| Douglas-fir group | 1,176.7 | 209.0 | 41.8 | — | 1,427.6 |
| Ponderosa pine group | 1,307.9 | 74.6 | 88.2 | — | 1,470.6 |
| Fir / spruce / mountain hemlock group | 2,532.9 | 614.1 | 238.4 | — | 3,385.4 |
| Lodgepole pine group | 397.4 | 559.0 | 191.4 | — | 1,147.8 |
| Other western softwoods group | 132.5 | 16.0 | 5.9 | — | 154.4 |
| Elm / ash / cottonwood group | 98.1 | 13.5 | 2.9 | — | 114.5 |
| Aspen / birch group | 753.8 | 1,444.2 | 561.8 | — | 2,759.7 |
| Exotic hardwoods group | — | — | 4.4 | — | 4.4 |
| Nonstocked | — | — | — | 280.7 | 280.7 |
| **All forest-type groups** | **6,399.3** | **2,930.3** | **1,134.9** | **280.7** | **10,745.2** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres.
Columns and rows may not add to their totals due to rounding.

**Table B10**—Number of live trees (at least 1 inch d.b.h./d.r.c.), in thousand trees, on forest land by species group and diameter class, Colorado, 2004–2013.

| | Diameter class (inches) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species group | 1.0-2.9 | 3.0-4.9 | 5.0-6.9 | 7.0-8.9 | 9.0-10.9 | 11.0-12.9 | 13.0-14.9 | 15.0-16.9 | 17.0-18.9 | 19.0-20.9 | 21.0-24.9 | 25.0-28.9 | 29.0-32.9 | 33.0-36.9 | 37.0+ | All classes |
| **Softwood species groups** | | | | | | | | | | | | | | | | |
| **Western softwood species groups** | | | | | | | | | | | | | | | | |
| Douglas-fir | 154,435 | 93,186 | 68,680 | 55,473 | 39,474 | 27,456 | 15,820 | 12,075 | 8,301 | 4,450 | 4,004 | 941 | 734 | 185 | 36 | 485,249 |
| Ponderosa and Jeffrey pine | 63,828 | 43,206 | 36,113 | 33,755 | 33,887 | 26,221 | 18,683 | 11,115 | 6,225 | 4,412 | 4,121 | 1,533 | 308 | 204 | 40 | 283,651 |
| True fir | 663,800 | 291,537 | 152,560 | 95,088 | 59,682 | 34,747 | 20,962 | 10,643 | 6,470 | 3,525 | 2,704 | 978 | 392 | 39 | 37 | 1,343,163 |
| Engelmann and other spruces | 516,608 | 308,289 | 195,629 | 145,709 | 104,558 | 74,013 | 50,790 | 35,700 | 24,459 | 13,021 | 13,711 | 3,988 | 1,031 | 464 | — | 1,487,970 |
| Lodgepole pine | 279,488 | 284,136 | 204,528 | 128,937 | 70,790 | 32,218 | 15,233 | 5,632 | 1,973 | 631 | 112 | — | — | — | — | 1,023,677 |
| Other western softwoods | 39,514 | 35,637 | 21,067 | 14,674 | 11,784 | 6,934 | 4,232 | 2,225 | 1,459 | 831 | 958 | 310 | 36 | — | — | 139,663 |
| **Other** | | | | | | | | | | | | | | | | |
| Western woodland softwoods | 449,580 | 256,996 | 173,019 | 136,435 | 104,994 | 87,750 | 63,982 | 51,397 | 35,750 | 25,475 | 26,300 | 10,646 | 4,358 | 1,464 | 976 | 1,429,122 |
| **All softwoods** | 2,167,252 | 1,312,987 | 851,596 | 610,071 | 425,169 | 289,339 | 189,702 | 128,786 | 84,636 | 52,346 | 51,910 | 18,396 | 6,859 | 2,356 | 1,089 | 6,192,494 |
| **Hardwood species groups** | | | | | | | | | | | | | | | | |
| **Western hardwood species groups** | | | | | | | | | | | | | | | | |
| Cottonwood and aspen | 652,063 | 346,764 | 224,397 | 171,713 | 112,258 | 59,949 | 26,843 | 9,558 | 4,261 | 1,183 | 900 | 329 | 80 | 78 | — | 1,610,378 |
| Other western hardwoods | 2,051 | 3,550 | 840 | 165 | 205 | 167 | 284 | 80 | 39 | — | — | — | — | — | — | 7,381 |
| **Other** | | | | | | | | | | | | | | | | |
| Western woodland hardwoods | 3,551,063 | 441,238 | 83,519 | 15,478 | 4,279 | 1,712 | 433 | 157 | 39 | 37 | — | — | — | — | — | 4,097,953 |
| **All hardwoods** | 4,205,177 | 791,553 | 308,756 | 187,357 | 116,742 | 61,828 | 27,560 | 9,795 | 4,338 | 1,220 | 900 | 329 | 80 | 78 | — | 5,715,713 |
| **All species groups** | **6,372,429** | **2,104,539** | **1,160,352** | **797,427** | **541,911** | **351,167** | **217,262** | **138,581** | **88,975** | **53,566** | **52,811** | **18,725** | **6,939** | **2,434** | **1,089** | **11,908,207** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0 indicates the number of trees rounds to less than 1 thousand trees. Columns and rows may not add to their totals due to rounding.

**Table B11**—Number of growing stock trees (at least 5 inches d.b.h.), in thousand trees, on timberland by species group and diameter class, Colorado, 2004–2013.

| | Diameter class (inches) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species group | 5.0-6.9 | 7.0-8.9 | 9.0-10.9 | 11.0-12.9 | 13.0-14.9 | 15.0-16.9 | 17.0-18.9 | 19.0-20.9 | 21.0-24.9 | 25.0-28.9 | 29.0-32.9 | 33.0-36.9 | 37.0+ | All classes |
| **Softwood species groups** | | | | | | | | | | | | | | |
| **Western softwood species groups** | | | | | | | | | | | | | | |
| Douglas-fir | 56,584 | 46,574 | 32,035 | 22,271 | 13,245 | 9,909 | 6,447 | 3,404 | 2,882 | 598 | 692 | 143 | 36 | 1,426,212 |
| Ponderosa and Jeffrey pine | 28,181 | 26,923 | 27,987 | 21,720 | 15,333 | 9,252 | 5,169 | 3,818 | 3,773 | 1,377 | 308 | 204 | 40 | 194,820 |
| True fir | 108,553 | 68,913 | 43,873 | 25,604 | 15,901 | 7,956 | 4,996 | 2,754 | 2,156 | 744 | 237 | 39 | — | 144,084 |
| Engelmann and other spruces | 129,262 | 97,357 | 69,624 | 49,063 | 33,919 | 24,090 | 16,371 | 8,316 | 8,715 | 2,273 | 492 | 308 | — | 281,725 |
| Lodgepole pine | 142,241 | 93,368 | 52,191 | 23,763 | 10,652 | 4,078 | 1,602 | 403 | 73 | — | — | — | — | 439,790 |
| Other western softwoods | 12,231 | 8,551 | 7,783 | 3,595 | 2,479 | 1,040 | 852 | 381 | 392 | 119 | — | — | — | 328,371 |
| **All softwoods** | 477,053 | 341,685 | 233,493 | 146,015 | 91,528 | 56,324 | 35,437 | 19,077 | 17,992 | 5,110 | 1,729 | 694 | 76 | 37,421 |
| **Hardwood species groups** | | | | | | | | | | | | | | |
| **Western hardwood species groups** | | | | | | | | | | | | | | |
| Cottonwood and aspen | 153,372 | 130,908 | 92,787 | 50,815 | 23,347 | 8,412 | 3,347 | 884 | 685 | 221 | 40 | 78 | — | 464,894 |
| Other western hardwoods | 193 | — | 43 | — | 39 | 40 | — | — | — | — | — | — | — | 314 |
| **All hardwoods** | 153,565 | 130,908 | 92,830 | 50,815 | 23,385 | 8,451 | 3,347 | 884 | 685 | 221 | 40 | 78 | — | 465,208 |
| **All species groups** | **630,618** | **472,593** | **326,323** | **196,830** | **114,913** | **64,775** | **38,784** | **19,961** | **18,676** | **5,331** | **1,769** | **772** | **76** | **1,891,420** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0 indicates the number of trees rounds to less than 1 thousand trees. Columns and rows may not add to their totals due to rounding.

**Table B12**—Net volume of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, by owner class and forest land status,Colorado, 2004–2013.

| | Unreserved forests | | | Reserved forests | | | All |
|---|---|---|---|---|---|---|---|
| Owner class | Timberland | Unproductive | Total | Productive | Unproductive | Total | forest land |
| **Forest Service** | | | | | | | |
| National Forest | 17,904.5 | 920.2 | 18,824.8 | 5,330.7 | 107.7 | 5,438.4 | 24,263.2 |
| National Grassland | — | 14.7 | 14.7 | — | — | — | 14.7 |
| **Other Federal** | | | | | | | |
| National Park Service | — | — | — | 503.5 | 82.2 | 585.8 | 585.8 |
| Bureau of Land Management | 1,225.1 | 2,693.9 | 3,919.0 | 66.6 | 151.8 | 218.3 | 4,137.4 |
| Departments of Defense and Energy | 9.4 | 42.0 | 51.4 | — | — | — | 51.4 |
| **State and local government** | | | | | | | |
| State | 337.1 | 148.4 | 485.5 | 118.6 | 0.4 | 119.0 | 604.5 |
| County and Municipal | 107.0 | 2.9 | 109.8 | — | — | — | 109.8 |
| **Private** | | | | | | | |
| Undifferentiated private | 3,777.3 | 1,679.6 | 5,456.9 | — | — | — | 5,456.9 |
| **All owners** | **23,360.3** | **5,501.8** | **28,862.1** | **6,019.5** | **342.0** | **6,361.5** | **35,223.6** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B13**—Net volume of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand-size class, Colorado, 2004–2013.

| | Stand-size class | | | | |
|---|---|---|---|---|---|
| Forest-type group | Large diameter | Medium diameter | Small diameter | Nonstocked | All size classes |
| Pinyon / juniper group | 4,424.8 | 165.2 | 21.0 | — | 4,611.0 |
| Douglas-fir group | 2,528.6 | 276.2 | 29.3 | — | 2,834.1 |
| Ponderosa pine group | 2,140.1 | 55.9 | 36.5 | — | 2,232.4 |
| Fir / spruce / mountain hemlock group | 13,225.2 | 1,450.4 | 188.0 | — | 14,863.7 |
| Lodgepole pine group | 1,716.0 | 1,594.2 | 132.0 | — | 3,442.2 |
| Other western softwoods group | 353.8 | 18.6 | 4.1 | — | 376.4 |
| Elm / ash / cottonwood group | 199.8 | 4.3 | 0.4 | — | 204.5 |
| Aspen / birch group | 2,638.2 | 3,229.5 | 265.8 | — | 6,133.5 |
| Woodland hardwoods group | 90.5 | 114.8 | 287.0 | — | 492.3 |
| Nonstocked | — | — | — | 33.5 | 33.5 |
| **All forest-type groups** | **27,316.9** | **6,909.1** | **964.1** | **33.5** | **35,223.6** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B14**—Net volume of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by species group and ownership group, Colorado, 2004–2013.

| | Ownership group | | | | |
|---|---|---|---|---|---|
| Species group | Forest Service | Other Federal | State and local government | Undifferentiated private | All owners |
| **Softwood species groups** | | | | | |
| **Western softwood species groups** | | | | | |
| Douglas-fir | 1,973.1 | 413.3 | 102.5 | 668.5 | 3,157.4 |
| Ponderosa and Jeffrey pine | 1,277.1 | 134.1 | 96.5 | 1,080.2 | 2,588.0 |
| True fir | 3,523.1 | 154.5 | 60.8 | 352.8 | 4,091.4 |
| Engelmann and other spruces | 9,699.0 | 670.8 | 90.0 | 694.1 | 11,153.9 |
| Lodgepole pine | 3,113.6 | 288.9 | 83.3 | 379.3 | 3,865.1 |
| Other western softwoods | 453.3 | 32.8 | 6.0 | 62.3 | 554.4 |
| **Other** | | | | | |
| Western woodland softwoods | 298.4 | 2,842.1 | 105.0 | 1,263.5 | 4,508.9 |
| **All softwoods** | 20,337.7 | 4,536.4 | 544.1 | 4,500.8 | 29,919.0 |
| **Hardwood species groups** | | | | | |
| **Western hardwood species groups** | | | | | |
| Cottonwood and aspen | 3,883.2 | 216.8 | 160.2 | 845.9 | 5,106.1 |
| Other western hardwoods | 0.8 | 2.5 | 4.8 | 1.9 | 9.9 |
| **Other** | | | | | |
| Western woodland hardwoods | 56.2 | 18.8 | 5.2 | 108.3 | 188.5 |
| **All hardwoods** | 3,940.2 | 238.1 | 170.2 | 956.1 | 5,304.6 |
| **All species groups** | **24,277.9** | **4,774.5** | **714.3** | **5,456.9** | **35,223.6** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B15**—Net volume of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by species group and diameter class, Colorado, 2004–2013.

| | Diameter class (inches) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species group | 5.0-6.9 | 7.0-8.9 | 9.0-10.9 | 11.0-12.9 | 13.0-14.9 | 15.0-16.9 | 17.0-18.9 | 19.0-20.9 | 21.0-24.9 | 25.0-28.9 | 29.0-32.9 | 33.0-36.9 | 37.0+ | All classes |
| **Softwood species groups** | | | | | | | | | | | | | | |
| **Western softwood species groups** | | | | | | | | | | | | | | |
| Douglas-fir | 119 | 264 | 370 | 425 | 365 | 403 | 379 | 264 | 305 | 107 | 113 | 36 | 8 | 3,157 |
| Ponderosa and Jeffrey pine | 59 | 143 | 269 | 347 | 380 | 324 | 248 | 226 | 294 | 190 | 52 | 43 | 12 | 2,588 |
| True fir | 319 | 541 | 653 | 629 | 578 | 404 | 331 | 232 | 211 | 113 | 61 | 8 | 12 | 4,091 |
| Engelmann and other spruces | 418 | 824 | 1,169 | 1,394 | 1,457 | 1,513 | 1,378 | 926 | 1,295 | 517 | 166 | 96 | — | 11,154 |
| Lodgepole pine | 575 | 908 | 933 | 659 | 430 | 214 | 99 | 40 | 8 | — | — | — | — | 3,865 |
| Other western softwoods | 31 | 63 | 95 | 85 | 79 | 52 | 49 | 30 | 47 | 20 | 3 | — | — | 554 |
| **Other** | | | | | | | | | | | | | | |
| Western woodland softwoods | 194 | 317 | 420 | 519 | 529 | 541 | 470 | 410 | 526 | 297 | 163 | 66 | 57 | 4,509 |
| **All softwoods** | 1,715 | 3,059 | 3,909 | 4,059 | 3,818 | 3,450 | 2,954 | 2,128 | 2,687 | 1,244 | 558 | 249 | 89 | 29,919 |
| **Hardwood species groups** | | | | | | | | | | | | | | |
| **Western hardwood species groups** | | | | | | | | | | | | | | |
| Cottonwood and aspen | 453 | 962 | 1,236 | 1,075 | 704 | 321 | 179 | 62 | 68 | 28 | 7 | 13 | — | 5,106 |
| Other western hardwoods | 1 | 0 | 1 | 2 | 4 | 1 | 1 | — | — | — | — | — | — | 10 |
| **Other** | | | | | | | | | | | | | | |
| Western woodland hardwoods | 102 | 44 | 21 | 14 | 5 | 2 | 0 | 1 | — | — | — | — | — | 189 |
| **All hardwoods** | 556 | 1,007 | 1,258 | 1,091 | 712 | 324 | 180 | 62 | 68 | 28 | 7 | 13 | — | 5,305 |
| **All species groups** | **2,271** | **4,066** | **5,167** | **5,150** | **4,530** | **3,775** | **3,133** | **2,190** | **2,755** | **1,272** | **565** | **261** | **89** | **35,224** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0 indicates the volume rounds to less than 1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B16**—Net volume of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand origin, Colorado, 2004–2013.

| | Stand origin | | |
|---|---|---|---|
| Forest-type group | Natural stands | Artificial regeneration | All forest land |
| Pinyon / juniper group | 4,607.0 | 4.0 | 4,611.0 |
| Douglas-fir group | 2,834.1 | — | 2,834.1 |
| Ponderosa pine group | 2,218.8 | 13.7 | 2,232.4 |
| Fir / spruce / mountain hemlock group | 14,863.7 | — | 14,863.7 |
| Lodgepole pine group | 3,442.2 | — | 3,442.2 |
| Other western softwoods group | 376.4 | — | 376.4 |
| Elm / ash / cottonwood group | 204.5 | — | 204.5 |
| Aspen / birch group | 6,133.5 | — | 6,133.5 |
| Woodland hardwoods group | 492.3 | — | 492.3 |
| Nonstocked | 33.5 | — | 33.5 |
| **All forest-type groups** | **35,205.9** | **17.6** | **35,223.6** |

All table cells without observations in the inventory sample are indicated by —.
Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet.
Columns and rows may not add to their totals due to rounding.

**Table B17**—Net volume of growing stock trees (at least 5 inches d.b.h.), in million cubic feet, on timberland by species group and diameter class, Colorado, 2004–2013.

| Species group | Diameter class (inches) | | | | | | | | | | | | All |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.0-6.9 | 7.0-8.9 | 9.0-10.9 | 11.0-12.9 | 13.0-14.9 | 15.0-16.9 | 17.0-18.9 | 19.0-20.9 | 21.0-24.9 | 25.0-28.9 | 29.0-32.9 | 33.0-36.9 | 37.0+ | classes |
| **Softwood species groups** | | | | | | | | | | | | | | |
| **Western softwood species groups** | | | | | | | | | | | | | | |
| Douglas-fir | 100 | 225 | 302 | 348 | 312 | 332 | 298 | 204 | 218 | 64 | 105 | 25 | 8 | 2,540 |
| Ponderosa and Jeffrey pine | 48 | 119 | 229 | 299 | 322 | 279 | 213 | 198 | 271 | 174 | 52 | 43 | 12 | 2,260 |
| True fir | 231 | 394 | 486 | 465 | 443 | 309 | 260 | 186 | 171 | 92 | 43 | 8 | — | 3,087 |
| Engelmann and other spruces | 286 | 567 | 797 | 953 | 991 | 1,051 | 943 | 599 | 832 | 298 | 78 | 69 | — | 7,464 |
| Lodgepole pine | 415 | 674 | 705 | 499 | 310 | 161 | 81 | 27 | 5 | — | — | — | — | 2,878 |
| Other western softwoods | 19 | 39 | 66 | 47 | 49 | 25 | 30 | 16 | 22 | 8 | — | — | — | 323 |
| **All softwoods** | 1,099 | 2,016 | 2,587 | 2,612 | 2,427 | 2,157 | 1,825 | 1,230 | 1,520 | 636 | 278 | 145 | 20 | 18,552 |
| **Hardwood species groups** | | | | | | | | | | | | | | |
| **Western hardwood species groups** | | | | | | | | | | | | | | |
| Cottonwood and aspen | 336 | 783 | 1,070 | 955 | 633 | 299 | 153 | 51 | 53 | 18 | 5 | 13 | — | 4,369 |
| Other western hardwoods | 0 | — | 0 | — | 1 | 1 | — | — | — | — | — | — | — | 2 |
| **All hardwoods** | 337 | 783 | 1,071 | 955 | 633 | 300 | 153 | 51 | 53 | 18 | 5 | 13 | — | 4,371 |
| **All species groups** | **1,436** | **2,800** | **3,657** | **3,567** | **3,060** | **2,457** | **1,978** | **1,281** | **1,572** | **654** | **283** | **158** | **20** | **22,923** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0 indicates the volume rounds to less than 1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B18**—Net volume of growing stock trees (at least 5 inches d.b.h.), in million cubic feet, on timberland by species group and ownership group, Colorado, 2004–2013.

| Species group | Ownership group | | | | |
|---|---|---|---|---|---|
| | Forest Service | Other Federal | State and local government | Undifferentiated private | All owners |
| **Softwood species groups** | | | | | |
| **Western softwood species groups** | | | | | |
| Douglas-fir | 1,526.7 | 330.1 | 84.1 | 599.3 | 2,540.1 |
| Ponderosa and Jeffrey pine | 1,162.2 | 97.0 | 74.5 | 926.3 | 2,259.9 |
| True fir | 2,592.4 | 107.1 | 46.6 | 341.4 | 3,087.4 |
| Engelmann and other spruces | 6,323.4 | 385.7 | 65.9 | 688.8 | 7,463.8 |
| Lodgepole pine | 2,398.2 | 106.8 | 25.1 | 347.4 | 2,877.5 |
| Other western softwoods | 261.0 | 13.8 | 3.4 | 45.1 | 323.2 |
| **All softwoods** | 14,263.8 | 1,040.4 | 299.6 | 2,948.3 | 18,552.1 |
| **Hardwood species groups** | | | | | |
| **Western hardwood species groups** | | | | | |
| Cottonwood and aspen | 3,346.5 | 148.4 | 134.6 | 739.4 | 4,368.9 |
| Other western hardwoods | 0.8 | 0.6 | 0.0 | 0.5 | 1.9 |
| **All hardwoods** | 3,347.3 | 149.0 | 134.6 | 739.9 | 4,370.8 |
| **All species groups** | **17,611.0** | **1,189.4** | **434.2** | **3,688.2** | **22,922.9** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B19**—Net volume of sawtimber trees, in million board feet (International 1/4 inch rule), on timberland by species group and diameter class, Colorado, 2004–2013.

| | Diameter class (inches) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species group** | **9.0-10.9** | **11.0-12.9** | **13.0-14.9** | **15.0-16.9** | **17.0-18.9** | **19.0-20.9** | **21.0-24.9** | **25.0-28.9** | **29.0-32.9** | **33.0-36.9** | **37.0+** | **All classes** |
| **Softwood species groups** | | | | | | | | | | | | |
| **Western softwood species groups** | | | | | | | | | | | | |
| Douglas-fir | 1,086 | 1,527 | 1,486 | 1,670 | 1,519 | 1,066 | 1,153 | 353 | 580 | 143 | 37 | 10,620 |
| Ponderosa and Jeffrey pine | 701 | 1,206 | 1,467 | 1,368 | 1,068 | 1,036 | 1,440 | 956 | 295 | 230 | 63 | 9,829 |
| True fir | 1,926 | 2,146 | 2,205 | 1,571 | 1,350 | 979 | 933 | 517 | 230 | 43 | — | 11,900 |
| Engelmann and other spruces | 3,240 | 4,559 | 5,087 | 5,596 | 5,135 | 3,326 | 4,830 | 1,753 | 458 | 413 | — | 34,395 |
| Lodgepole pine | 2,588 | 2,144 | 1,465 | 794 | 418 | 135 | 27 | — | — | — | — | 7,570 |
| Other western softwoods | 175 | 156 | 192 | 105 | 139 | 72 | 104 | 36 | — | — | — | 979 |
| **All softwoods** | 9,716 | 11,738 | 11,901 | 11,104 | 9,629 | 6,614 | 8,485 | 3,615 | 1,563 | 828 | 100 | 75,293 |
| **Hardwood species groups** | | | | | | | | | | | | |
| **Western hardwood species groups** | | | | | | | | | | | | |
| Cottonwood and aspen | — | 4,312 | 3,036 | 1,467 | 770 | 249 | 258 | 71 | 19 | 41 | — | 10,224 |
| Other western hardwoods | — | — | 1 | 3 | — | — | — | — | — | — | — | 4 |
| **All hardwoods** | — | 4,312 | 3,038 | 1,469 | 770 | 249 | 258 | 71 | 19 | 41 | — | 10,228 |
| **All species groups** | **9,716** | **16,050** | **14,939** | **12,573** | **10,399** | **6,863** | **8,743** | **3,686** | **1,582** | **869** | **100** | **85,520** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0 indicates the volume rounds to less than 1 million board feet.
Columns and rows may not add to their totals due to rounding.

**Table B20**—Net volume of sawlog portion of sawtimber trees, in million cubic feet, on timberland by species group and ownership group, Colorado, 2004–2013.

| | Ownership group | | | | |
|---|---|---|---|---|---|
| Species group | Forest Service | Other Federal | State and local government | Undifferentiated private | All owners |
| **Softwood species groups** | | | | | |
| **Western softwood species groups** | | | | | |
| Douglas-fir | 1,210.0 | 250.6 | 58.2 | 451.0 | 1,969.8 |
| Ponderosa and Jeffrey pine | 966.9 | 79.9 | 59.4 | 741.5 | 1,847.7 |
| True fir | 1,824.2 | 71.6 | 32.6 | 236.7 | 2,165.1 |
| Engelmann and other spruces | 4,974.8 | 308.3 | 46.8 | 518.1 | 5,848.0 |
| Lodgepole pine | 1,402.4 | 36.7 | 15.1 | 175.0 | 1,629.2 |
| Other western softwoods | 200.5 | 9.2 | 2.4 | 33.3 | 245.5 |
| **All softwoods** | 10,578.8 | 756.3 | 214.6 | 2,155.7 | 13,705.3 |
| **Hardwood species groups** | | | | | |
| **Western hardwood species groups** | | | | | |
| Cottonwood and aspen | 1,246.9 | 44.3 | 64.7 | 269.7 | 1,625.6 |
| Other western hardwoods | 0.6 | 0.5 | — | — | 1.1 |
| **All hardwoods** | 1,247.5 | 44.8 | 64.7 | 269.7 | 1,626.7 |
| **All species groups** | **11,826.3** | **801.1** | **279.2** | **2,425.4** | **15,332.0** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B21**—Average annual net growth of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, by owner class and forest land status, Colorado, 2004–2013.

| | Unreserved forests | | | Reserved forests | | | All |
|---|---|---|---|---|---|---|---|
| Owner class | Timberland | Unproductive | Total | Productive | Unproductive | Total | forest land |
| **Forest Service** | | | | | | | |
| National Forest | -103.2 | -1.4 | -104.6 | -74.7 | -1.9 | -76.5 | -181.1 |
| National Grassland | — | 0.1 | 0.1 | — | — | — | 0.1 |
| **Other Federal** | | | | | | | |
| National Park Service | — | — | — | -8.2 | 0.4 | -7.8 | -7.8 |
| Bureau of Land Management | -3.7 | 8.7 | 5.0 | 0.7 | 0.2 | 0.8 | 5.8 |
| Departments of Defense and Energy | 0.1 | -0.2 | -0.1 | — | — | — | -0.1 |
| **State and local government** | | | | | | | |
| State | 4.1 | -1.7 | 2.4 | -4.4 | 0.0 | -4.4 | -2.0 |
| County and Municipal | 1.5 | -0.1 | 1.4 | — | — | — | 1.4 |
| **Private** | | | | | | | |
| Undifferentiated private | 26.9 | 11.5 | 38.5 | — | — | — | 38.5 |
| **All owners** | **-74.1** | **16.8** | **-57.3** | **-86.6** | **-1.3** | **-87.9** | **-145.2** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B22**—Average annual net growth of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand-size class, Colorado, 2004–2013.

| | Stand-size class | | | | |
|---|---|---|---|---|---|
| Forest-type group | Large diameter | Medium diameter | Small diameter | Nonstocked | All size classes |
| Pinyon / juniper group | 13.0 | 2.5 | 0.5 | — | 15.9 |
| Douglas-fir group | 17.0 | 2.3 | 0.4 | — | 19.7 |
| Ponderosa pine group | 18.3 | 1.6 | 0.8 | — | 20.6 |
| Fir / spruce / mountain hemlock group | -44.0 | -28.7 | -54.7 | — | -127.4 |
| Lodgepole pine group | -1.4 | -26.5 | -35.1 | — | -63.0 |
| Other western softwoods group | 1.1 | 0.3 | -1.1 | — | 0.3 |
| Elm / ash / cottonwood group | 1.7 | 0.2 | 0.0 | — | 1.8 |
| Aspen / birch group | 8.4 | 13.1 | -9.5 | — | 12.0 |
| Woodland hardwoods group | 1.4 | 3.7 | 0.3 | — | 5.3 |
| Nonstocked | — | — | — | -30.7 | -30.7 |
| **All forest-type groups** | **15.4** | **-31.5** | **-98.5** | **-30.7** | **-145.2** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B23**—Average annual net growth of all live trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by species group and ownership group, Colorado, 2004–2013.

| | Ownership group | | | | |
|---|---|---|---|---|---|
| Species group | Forest Service | Other Federal | State and local government | Undifferentiated private | All owners |
| **Softwood species groups** | | | | | |
| **Western softwood species groups** | | | | | |
| Douglas-fir | 8.9 | 3.9 | 2.0 | 8.0 | 22.7 |
| Ponderosa and Jeffrey pine | 6.2 | -0.5 | -0.7 | 12.6 | 17.7 |
| True fir | -50.0 | -0.2 | 0.9 | -0.5 | -49.9 |
| Engelmann and other spruces | -22.9 | 4.9 | 0.8 | 8.7 | -8.5 |
| Lodgepole pine | -159.0 | -18.3 | -5.5 | -2.5 | -185.3 |
| Other western softwoods | 3.3 | -0.8 | 0.0 | 0.7 | 3.1 |
| **Other** | | | | | |
| Western woodland softwoods | -1.7 | 7.3 | 0.0 | 3.0 | 8.6 |
| **All softwoods** | -215.3 | -3.7 | -2.6 | 30.0 | -191.6 |
| **Hardwood species groups** | | | | | |
| **Western hardwood species groups** | | | | | |
| Cottonwood and aspen | 32.3 | 0.3 | 1.8 | 4.6 | 38.9 |
| Other western hardwoods | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 |
| **Other** | | | | | |
| Western woodland hardwoods | 2.0 | 1.3 | 0.2 | 3.8 | 7.3 |
| **All hardwoods** | 34.3 | 1.6 | 2.1 | 8.5 | 46.4 |
| **All species groups** | **-181.1** | **-2.1** | **-0.6** | **38.5** | **-145.2** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B24**—Average annual net growth of growing stock trees (at least 5 inches d.b.h.), in million cubic feet, on timberland by species group and ownership group, Colorado, 2004–2013.

| | Ownership group | | | | |
|---|---|---|---|---|---|
| Species group | Forest Service | Other Federal | State and local government | Undifferentiated private | All owners |
| **Softwood species groups** | | | | | |
| **Western softwood species groups** | | | | | |
| Douglas-fir | 5.7 | 2.8 | 1.8 | 6.4 | 16.8 |
| Ponderosa and Jeffrey pine | 5.7 | -1.0 | 0.8 | 9.8 | 15.4 |
| True fir | -39.3 | -1.0 | 0.6 | -0.9 | -40.5 |
| Engelmann and other spruces | 9.9 | 3.3 | 0.6 | 8.6 | 22.4 |
| Lodgepole pine | -115.8 | -8.5 | 0.1 | -2.8 | -126.9 |
| **All softwoods** | -131.8 | -4.1 | 3.9 | 21.7 | -110.3 |
| **Hardwood species groups** | | | | | |
| **Western hardwood species groups** | | | | | |
| Cottonwood and aspen | 25.8 | -0.3 | 1.4 | 3.8 | 30.7 |
| Other western hardwoods | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **All hardwoods** | 25.8 | -0.3 | 1.4 | 3.8 | 30.8 |
| **All species groups** | **-106.0** | **-4.5** | **5.4** | **25.5** | **-79.6** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B25**—Average annual mortality of trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by owner class and forest land status, Colorado, 2004–2013.

| | Unreserved forests | | | Reserved forests | | | All |
|---|---|---|---|---|---|---|---|
| Owner class | Timberland | Unproductive | Total | Productive | Unproductive | Total | forest land |
| **Forest Service** | | | | | | | |
| National Forest | 404.8 | 17.3 | 422.2 | 152.4 | 3.8 | 156.2 | 578.3 |
| **Other Federal** | | | | | | | |
| National Park Service | — | — | — | 15.9 | 0.2 | 16.1 | 16.1 |
| Bureau of Land Management | 24.8 | 14.9 | 39.6 | 0.5 | 0.8 | 1.3 | 41.0 |
| Departments of Defense and Energy | 0.0 | 0.5 | 0.5 | — | — | — | 0.5 |
| **State and local government** | | | | | | | |
| State | 2.7 | 3.6 | 6.3 | 7.2 | — | 7.2 | 13.5 |
| County and Municipal | 0.6 | 0.2 | 0.7 | — | — | — | 0.7 |
| **Private** | | | | | | | |
| Undifferentiated private | 41.9 | 12.2 | 54.1 | — | — | — | 54.1 |
| **All owners** | **474.8** | **48.7** | **523.4** | **175.9** | **4.8** | **180.7** | **704.2** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B26**—Average annual mortality of trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand-size class,Colorado, 2004–2013.

| | Stand-size class | | | | |
|---|---|---|---|---|---|
| Forest-type group | Large diameter | Medium diameter | Small diameter | Nonstocked | All size classes |
| Pinyon / juniper group | 22.5 | 1.4 | 0.1 | — | 24.0 |
| Douglas-fir group | 19.4 | 4.2 | 0.3 | — | 23.9 |
| Ponderosa pine group | 14.7 | 0.1 | 0.0 | — | 14.9 |
| Fir / spruce / mountain hemlock group | 225.7 | 61.9 | 60.4 | — | 348.0 |
| Lodgepole pine group | 24.6 | 65.7 | 40.4 | — | 130.7 |
| Other western softwoods group | 3.0 | 0.1 | 1.2 | — | 4.3 |
| Elm / ash / cottonwood group | 1.5 | 0.0 | — | — | 1.5 |
| Aspen / birch group | 34.9 | 64.3 | 16.7 | — | 116.0 |
| Woodland hardwoods group | 0.3 | 0.5 | 8.4 | — | 9.2 |
| Nonstocked | — | — | — | 31.7 | 31.7 |
| **All forest-type groups** | **346.7** | **198.2** | **127.6** | **31.7** | **704.2** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B27**—Average annual mortality of trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by species group and ownership group, Colorado, 2004–2013.

| | Ownership group | | | | |
|---|---|---|---|---|---|
| Species group | Forest Service | Other Federal | State and local government | Undifferentiated private | All owners |
| **Softwood species groups** | | | | | |
| **Western softwood species groups** | | | | | |
| Douglas-fir | 20.7 | 2.6 | 0.5 | 3.5 | 27.2 |
| Ponderosa and Jeffrey pine | 11.9 | 2.6 | 2.3 | 5.3 | 22.0 |
| True fir | 121.1 | 3.6 | 0.6 | 9.1 | 134.5 |
| Engelmann and other spruces | 154.9 | 3.2 | 0.9 | 2.0 | 161.0 |
| Lodgepole pine | 214.9 | 25.2 | 7.3 | 10.1 | 257.5 |
| Other western softwoods | 2.5 | 1.4 | 0.2 | 0.2 | 4.2 |
| **Other** | | | | | |
| Western woodland softwoods | 4.2 | 14.2 | 1.0 | 9.6 | 29.0 |
| **All softwoods** | 530.1 | 52.7 | 12.7 | 39.8 | 635.3 |
| **Hardwood species groups** | | | | | |
| **Western hardwood species groups** | | | | | |
| Cottonwood and aspen | 47.8 | 4.8 | 1.5 | 13.9 | 67.9 |
| Other western hardwoods | — | — | 0.0 | 0.0 | 0.0 |
| **Other** | | | | | |
| Western woodland hardwoods | 0.4 | 0.1 | 0.0 | 0.4 | 1.0 |
| **All hardwoods** | 48.2 | 4.9 | 1.6 | 14.3 | 68.9 |
| **All species groups** | **578.3** | **57.6** | **14.2** | **54.1** | **704.2** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B28**—Average annual mortality of growing stock trees (at least 5 inches d.b.h.), in million cubic feet, on timberland by species group and ownership group, Colorado, 2004–2013.

| | Ownership group | | | | |
|---|---|---|---|---|---|
| Species group | Forest Service | Other Federal | State and local government | Undifferentiated private | All owners |
| **Softwood species groups** | | | | | |
| **Western softwood species groups** | | | | | |
| Douglas-fir | 17.4 | 2.1 | 0.2 | 3.5 | 23.2 |
| Ponderosa and Jeffrey pine | 10.2 | 2.4 | 0.4 | 4.8 | 17.8 |
| True fir | 92.2 | 3.2 | 0.3 | 9.1 | 104.9 |
| Engelmann and other spruces | 79.9 | 1.1 | 0.4 | 2.0 | 83.4 |
| Lodgepole pine | 159.3 | 11.9 | 0.6 | 9.7 | 181.5 |
| Other western softwoods | 1.6 | 0.0 | 0.2 | 0.2 | 1.9 |
| **All softwoods** | 360.7 | 20.8 | 2.1 | 29.2 | 412.8 |
| **Hardwood species groups** | | | | | |
| **Western hardwood species groups** | | | | | |
| Cottonwood and aspen | 40.6 | 3.9 | 1.3 | 12.1 | 57.8 |
| **All hardwoods** | 40.6 | 3.9 | 1.3 | 12.1 | 57.8 |
| **All species groups** | **401.3** | **24.7** | **3.3** | **41.3** | **470.6** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic feet. Columns and rows may not add to their totals due to rounding.

**Table B29** —Aboveground dry weight of all live trees (at least 1 inch d.b.h./d.r.c.), in thousand dry short tons, by owner class and forest land status, Colorado, 2004–2013.

| | Unreserved forests | | | Reserved forests | | | All |
|---|---|---|---|---|---|---|---|
| **Owner class** | **Timberland** | **Unproductive** | **Total** | **Productive** | **Unproductive** | **Total** | **forest land** |
| **Forest Service** | | | | | | | |
| National Forest | 308,015 | 21,551 | 329,566 | 86,228 | 2,265 | 88,493 | 418,059 |
| National Grassland | — | 204 | 204 | — | — | — | 204 |
| **Other Federal** | | | | | | | |
| National Park Service | — | — | — | 8,405 | 1,872 | 10,277 | 10,277 |
| Bureau of Land Management | 22,357 | 54,772 | 77,129 | 1,212 | 3,076 | 4,287 | 81,416 |
| Departments of Defense and Energy | 168 | 696 | 863 | — | — | — | 863 |
| **State and local government** | | | | | | | |
| State | 6,161 | 3,281 | 9,442 | 2,177 | 19 | 2,196 | 11,638 |
| County and Municipal | 1,974 | 166 | 2,140 | — | — | — | 2,140 |
| **Private** | | | | | | | |
| Undifferentiated private | 68,946 | 38,494 | 107,440 | — | — | — | 107,440 |
| **All owners** | **407,621** | **119,163** | **526,784** | **98,021** | **7,231** | **105,252** | **632,036** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0 indicates the aboveground tree biomass rounds to less than 1 thousand dry tons. Columns and rows may not add to their totals due to rounding.

**Table B30**—Aboveground dry weight of all live trees (at least 1 inch d.b.h./d.r.c.), in thousand dry short tons, on forest land by species group and diameter class, Colorado, 2004–2013.

| | Diameter class (inches) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species group | 1.0-2.9 | 3.0-4.9 | 5.0-6.9 | 7.0-8.9 | 9.0-10.9 | 11.0-12.9 | 13.0-14.9 | 15.0-16.9 | 17.0-18.9 | 19.0-20.9 | 21.0-22.9 | 23.0-24.9 | 25.0-26.9 | 27.0-28.9 | 29.0+ | All classes |
| **Softwood species groups** | | | | | | | | | | | | | | | | |
| **Western softwood species groups** | | | | | | | | | | | | | | | | |
| Douglas-fir | 417 | 1,485 | 2,503 | 5,443 | 7,509 | 8,569 | 7,301 | 8,011 | 7,509 | 5,206 | 3,700 | 2,308 | 1,173 | 915 | 3,063 | 65,113 |
| Ponderosa and Jeffrey pine | 105 | 416 | 1,101 | 2,625 | 4,877 | 6,240 | 6,776 | 5,748 | 4,385 | 3,993 | 3,442 | 1,731 | 1,890 | 1,433 | 1,878 | 46,640 |
| True fir | 1,545 | 4,121 | 4,749 | 7,919 | 9,473 | 9,048 | 8,273 | 5,776 | 4,793 | 3,348 | 2,048 | 1,070 | 1,153 | 586 | 1,230 | 65,131 |
| Engelmann and other spruces | 1,216 | 3,748 | 6,494 | 12,523 | 17,525 | 20,706 | 21,493 | 22,194 | 20,114 | 13,489 | 11,660 | 7,159 | 4,754 | 2,722 | 3,772 | 169,568 |
| Lodgepole pine | 1,109 | 5,620 | 9,516 | 14,706 | 14,912 | 10,439 | 6,760 | 3,347 | 1,538 | 620 | 105 | 25 | — | — | — | 68,698 |
| Other western softwoods | 77 | 389 | 573 | 1,115 | 1,683 | 1,486 | 1,387 | 913 | 850 | 524 | 365 | 454 | 259 | 87 | 46 | 10,208 |
| **Other** | | | | | | | | | | | | | | | | |
| Western woodland softwoods | 1,084 | 2,209 | 3,113 | 5,139 | 6,936 | 8,814 | 9,110 | 9,593 | 8,453 | 7,430 | 5,707 | 4,111 | 3,119 | 2,529 | 5,388 | 82,734 |
| **All softwoods** | 5,554 | 17,987 | 28,048 | 49,471 | 62,914 | 65,303 | 61,099 | 55,582 | 47,641 | 34,610 | 27,026 | 16,859 | 12,348 | 8,272 | 15,378 | 508,092 |
| **Hardwood species groups** | | | | | | | | | | | | | | | | |
| **Western hardwood species groups** | | | | | | | | | | | | | | | | |
| Cottonwood and aspen | 2,329 | 6,669 | 9,137 | 18,066 | 22,206 | 18,719 | 12,002 | 5,387 | 2,995 | 1,017 | 486 | 632 | 427 | 45 | 311 | 100,428 |
| Other western hardwoods | 7 | 113 | 21 | 7 | 24 | 29 | 75 | 22 | 17 | — | — | — | — | — | — | 315 |
| **Other** | | | | | | | | | | | | | | | | |
| Western woodland hardwoods | 12,731 | 6,872 | 1,955 | 847 | 397 | 261 | 85 | 41 | 5 | 9 | — | — | — | — | — | 23,202 |
| **All hardwoods** | 15,068 | 13,654 | 11,113 | 18,919 | 22,628 | 19,009 | 12,162 | 5,449 | 3,017 | 1,026 | 486 | 632 | 427 | 45 | 311 | 123,944 |
| **All species groups** | **20,622** | **31,640** | **39,161** | **68,390** | **85,542** | **84,312** | **73,261** | **61,031** | **50,658** | **35,636** | **27,511** | **17,491** | **12,774** | **8,318** | **15,688** | **632,036** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0 indicates the aboveground tree biomass rounds to less than 1 thousand dry tons.
Columns and rows may not add to their totals due to rounding.

**Table B31**—Area of accessible forest land, in thousand acres, by inventory unit, county and forest land status, Colorado, 2004–2013.

| | Unreserved forests | | | Reserved forests | | | All |
|---|---|---|---|---|---|---|---|
| Inventory unit and county | Timberland | Unproductive | Total | Productive | Unproductive | Total | forest land |
| **Northern Front Range** | | | | | | | |
| Boulder | 190.9 | 14.3 | 205.2 | 35.7 | — | 35.7 | 240.9 |
| Clear Creek | 108.5 | 22.3 | 130.9 | 25.3 | 5.6 | 30.8 | 161.7 |
| Douglas | 154.7 | 63.3 | 218.0 | — | 1.5 | 1.5 | 219.5 |
| Elbert | 31.4 | 2.6 | 34.0 | — | — | — | 34.0 |
| El Paso | 176.4 | 56.8 | 233.2 | — | — | — | 233.2 |
| Gilpin | 51.8 | 28.0 | 79.8 | 14.8 | — | 14.8 | 94.6 |
| Jefferson | 251.5 | 28.6 | 280.1 | 13.6 | — | 13.6 | 293.7 |
| Lake | 85.0 | 18.6 | 103.6 | 19.0 | — | 19.0 | 122.6 |
| Larimer | 536.4 | 96.1 | 632.5 | 238.8 | 12.4 | 251.2 | 883.8 |
| Park | 500.7 | 70.2 | 570.9 | 95.9 | 32.8 | 128.7 | 699.6 |
| Teller | 242.7 | 27.5 | 270.2 | 6.9 | — | 6.9 | 277.1 |
| **Total** | 2,330.0 | 428.4 | 2,758.4 | 450.0 | 52.2 | 502.2 | 3,260.7 |
| **Southern Front Range** | | | | | | | |
| Chaffee | 248.2 | 148.8 | 397.0 | 20.3 | — | 20.3 | 417.3 |
| Costilla | 187.1 | 110.1 | 297.1 | — | — | — | 297.1 |
| Custer | 162.2 | 38.6 | 200.8 | 37.1 | — | 37.1 | 237.9 |
| Fremont | 183.6 | 485.2 | 668.8 | 27.4 | 6.8 | 34.2 | 703.0 |
| Huerfano | 134.5 | 266.7 | 401.3 | 36.6 | — | 36.6 | 437.9 |
| Las Animas | 197.0 | 727.6 | 924.6 | 6.8 | — | 6.8 | 931.3 |
| Pueblo | 26.4 | 156.3 | 182.7 | 7.2 | — | 7.2 | 189.9 |
| **Total** | 1,139.0 | 1,933.3 | 3,072.3 | 135.4 | 6.8 | 142.3 | 3,214.5 |
| **West Central** | | | | | | | |
| Alamosa | — | 12.0 | 12.0 | 10.5 | 6.0 | 16.5 | 28.6 |
| Conejos | 200.5 | 35.1 | 235.6 | 41.0 | — | 41.0 | 276.6 |
| Eagle | 344.0 | 290.5 | 634.5 | 107.3 | 12.0 | 119.2 | 753.7 |
| Grand | 567.2 | 48.1 | 615.3 | 147.0 | 3.3 | 150.3 | 765.6 |
| Gunnison | 783.3 | 146.1 | 929.4 | 247.1 | 51.1 | 298.2 | 1,227.6 |
| Hinsdale | 201.7 | 30.8 | 232.5 | 178.6 | — | 178.6 | 411.1 |
| Jackson | 281.3 | 12.4 | 293.7 | 130.1 | — | 130.1 | 423.7 |
| Mineral | 245.3 | 1.5 | 246.8 | 138.4 | 6.2 | 144.6 | 391.4 |
| Pitkin | 184.1 | 68.7 | 252.8 | 144.5 | — | 144.5 | 397.3 |
| Rio Grande | 198.9 | 54.1 | 253.0 | — | — | — | 253.0 |
| Routt | 624.3 | 161.7 | 786.0 | 100.3 | 6.4 | 106.7 | 892.7 |
| Saguache | 637.2 | 205.2 | 842.4 | 95.2 | 5.8 | 101.0 | 943.4 |
| San Juan | 85.1 | — | 85.1 | 20.7 | — | 20.7 | 105.8 |
| Summit | 148.7 | 3.4 | 152.1 | 65.2 | — | 65.2 | 217.3 |
| **Total** | 4,501.6 | 1,069.7 | 5,571.3 | 1,426.0 | 90.8 | 1,516.7 | 7,088.0 |
| **Western** | | | | | | | |
| Archuleta | 366.8 | 283.5 | 650.3 | 66.5 | — | 66.5 | 716.8 |
| Delta | 143.4 | 186.3 | 329.8 | — | 11.3 | 11.3 | 341.1 |
| Dolores | 216.8 | 168.6 | 385.5 | 10.9 | 6.2 | 17.1 | 402.5 |
| Garfield | 406.6 | 723.7 | 1,130.3 | 121.3 | — | 121.3 | 1,251.6 |
| La Plata | 342.7 | 361.0 | 703.7 | 52.7 | — | 52.7 | 756.4 |
| Mesa | 321.8 | 880.3 | 1,202.1 | — | 90.9 | 90.9 | 1,293.0 |
| Moffat | 69.4 | 619.5 | 688.9 | — | 87.7 | 87.7 | 776.6 |
| Montezuma | 229.8 | 331.1 | 560.9 | — | 149.2 | 149.2 | 710.1 |
| Montrose | 163.0 | 762.3 | 925.2 | — | 33.0 | 33.0 | 958.2 |
| Ouray | 101.9 | 109.2 | 211.1 | 23.2 | — | 23.2 | 234.3 |
| Rio Blanco | 275.1 | 956.0 | 1,231.1 | 40.7 | 6.8 | 47.5 | 1,278.6 |
| San Miguel | 109.5 | 368.5 | 478.1 | 13.4 | — | 13.4 | 491.4 |
| **Total** | 2,746.9 | 5,750.1 | 8,497.0 | 328.7 | 385.1 | 713.8 | 9,210.8 |
| **Eastern** | | | | | | | |
| Adams | 1.5 | — | 1,452.0 | — | — | — | 1.5 |
| Arapahoe | 5.7 | — | 5,728.0 | — | — | — | 5.7 |
| Baca | 7.5 | 23.9 | 31,357.0 | — | — | — | 31.4 |
| Bent | — | 30.2 | 30,226.0 | — | — | — | 30.2 |
| Denver | 4.1 | — | 4,113.0 | — | — | — | 4.1 |
| Logan | 6.1 | — | 6,118.0 | — | — | — | 6.1 |
| Morgan | 2.9 | — | 2,855.0 | — | — | — | 2.9 |
| Otero | — | 35.5 | 35,498.0 | — | — | — | 35.5 |
| **Total** | 27.7 | 89.6 | 117,346.0 | — | — | — | 117.3 |
| **All counties** | **10,745.2** | **9,271.2** | **20,016.3** | **2,340.0** | **535.0** | **2,875.0** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres.
Columns and rows may not add to their totals due to rounding.

**Table B32**—Area of accessible forest land, in thousand acres, by survey unit, county, ownership group and forest land status, Colorado, 2004–2013.

| | Forest Service | | Other Federal | | State and local government | | Undifferentiated private | | |
|---|---|---|---|---|---|---|---|---|---|
| Inventory unit and county | Timber-land | Other forest land | Timber-land | Other forest land | Timber-land | Other forest land | Timber-land | Other forest land | All forest land |
| **Northern Front Range** | | | | | | | | | |
| Boulder | 107.2 | 28.6 | 7.1 | 7.1 | 6.4 | 7.1 | 70.2 | 7.1 | 240.9 |
| Clear Creek | 60.4 | 47.6 | — | — | 16.0 | — | 32.1 | 5.6 | 161.7 |
| Douglas | 134.4 | 1.5 | — | — | 4.8 | 1.5 | 15.6 | 61.8 | 219.5 |
| Elbert | — | — | — | — | 6.0 | — | 25.4 | 2.6 | 34.0 |
| El Paso | 84.9 | 9.4 | 11.2 | 16.4 | 17.7 | 12.1 | 62.7 | 18.9 | 233.2 |
| Gilpin | 29.6 | 22.2 | — | — | — | 7.4 | 22.2 | 13.2 | 94.6 |
| Jefferson | 87.4 | 6.8 | — | — | 47.7 | 17.9 | 116.4 | 17.5 | 293.7 |
| Lake | 36.7 | 30.4 | 10.1 | 3.5 | — | — | 38.2 | 3.8 | 122.6 |
| Larimer | 345.5 | 224.0 | 6.2 | 92.8 | 16.2 | 14.5 | 168.6 | 16.0 | 883.8 |
| Park | 370.0 | 173.9 | 35.9 | — | 1.5 | 4.5 | 93.4 | 20.4 | 699.6 |
| Teller | 120.2 | 13.8 | 25.8 | 13.8 | 6.9 | — | 89.8 | 6.9 | 277.1 |
| **Total** | 1,376.1 | 558.1 | 96.4 | 133.6 | 123.0 | 65.0 | 734.5 | 173.9 | 3,260.7 |
| **Southern Front Range** | | | | | | | | | |
| Chaffee | 218.5 | 85.0 | 1.6 | 58.5 | 6.3 | 6.3 | 21.8 | 19.3 | 417.3 |
| Costilla | — | — | — | — | — | — | 187.1 | 110.1 | 297.1 |
| Custer | 91.3 | 48.0 | — | — | 6.2 | 6.2 | 64.6 | 21.6 | 237.9 |
| Fremont | 32.5 | 51.4 | 71.9 | 333.2 | 15.2 | 20.7 | 63.9 | 114.3 | 703.0 |
| Huerfano | 66.9 | 54.2 | 19.1 | 47.3 | — | 11.1 | 48.5 | 190.7 | 437.9 |
| Las Animas | 6.8 | 20.2 | — | 50.4 | 4.3 | 52.4 | 185.9 | 611.4 | 931.3 |
| Pueblo | 14.3 | 14.3 | — | 25.4 | — | 18.0 | 12.1 | 105.7 | 189.9 |
| **Total** | 430.4 | 273.0 | 92.6 | 514.7 | 32.0 | 114.7 | 584.0 | 1,173.1 | 3,214.5 |
| **West Central** | | | | | | | | | |
| Alamosa | — | 16.5 | — | 12.0 | — | — | — | — | 28.6 |
| Conejos | 180.8 | 41.0 | 6.3 | 25.7 | 13.4 | 6.3 | — | 3.0 | 276.6 |
| Eagle | 295.8 | 188.0 | 18.9 | 149.1 | — | 12.0 | 29.3 | 60.6 | 753.7 |
| Grand | 423.1 | 96.4 | 38.1 | 83.8 | 11.8 | — | 94.1 | 18.3 | 765.6 |
| Gunnison | 614.1 | 329.3 | 56.9 | 52.5 | — | 12.2 | 112.3 | 50.4 | 1,227.6 |
| Hinsdale | 152.0 | 188.5 | 35.7 | 14.4 | 6.0 | — | 8.1 | 6.5 | 411.1 |
| Jackson | 203.6 | 88.6 | 23.5 | — | 5.5 | 52.5 | 48.7 | 1.4 | 423.7 |
| Mineral | 243.0 | 146.1 | — | — | — | — | 2.3 | — | 391.4 |
| Pitkin | 157.7 | 182.0 | — | 12.5 | 6.2 | — | 20.1 | 18.7 | 397.3 |
| Rio Grande | 186.5 | 35.0 | 5.8 | 5.8 | — | 5.8 | 6.6 | 7.5 | 253.0 |
| Routt | 443.7 | 130.7 | 32.1 | 24.6 | 29.0 | 16.2 | 119.5 | 96.9 | 892.7 |
| Saguache | 545.6 | 174.8 | 74.4 | 96.5 | 1.6 | 1.6 | 15.6 | 33.3 | 943.4 |
| San Juan | 71.3 | 20.7 | 13.8 | — | — | — | — | — | 105.8 |
| Summit | 114.5 | 65.2 | — | — | 6.4 | — | 27.9 | 3.4 | 217.3 |
| **Total** | 3,631.7 | 1,703.0 | 305.5 | 476.8 | 79.8 | 106.5 | 484.6 | 300.1 | 7,088.0 |
| **Western** | | | | | | | | | |
| Archuleta | 264.2 | 145.4 | — | 6.6 | — | — | 102.6 | 197.9 | 716.8 |
| Delta | 123.5 | 17.8 | — | 84.7 | — | 5.7 | 20.0 | 89.4 | 341.1 |
| Dolores | 206.0 | 88.5 | 10.9 | 58.1 | — | 1.6 | — | 37.5 | 402.5 |
| Garfield | 202.4 | 159.4 | 115.5 | 494.1 | 6.4 | — | 82.3 | 191.5 | 1,251.6 |
| La Plata | 295.4 | 93.3 | — | — | 6.9 | 27.8 | 40.3 | 292.7 | 756.4 |
| Mesa | 276.5 | 182.6 | — | 652.9 | — | — | 45.3 | 135.8 | 1,293.0 |
| Moffat | 27.2 | 1.8 | 14.5 | 610.5 | 6.1 | 6.1 | 21.7 | 88.8 | 776.6 |
| Montezuma | 190.4 | 41.5 | 6.5 | 155.8 | 6.5 | 34.1 | 26.3 | 249.1 | 710.1 |
| Montrose | 143.2 | 189.3 | — | 530.6 | 1.6 | 3.3 | 18.1 | 72.0 | 958.2 |
| Ouray | 52.1 | 40.3 | 14.3 | 34.6 | — | — | 35.5 | 57.4 | 234.3 |
| Rio Blanco | 235.5 | 67.7 | 25.3 | 804.0 | 3.3 | 2.8 | 11.0 | 129.1 | 1,278.6 |
| San Miguel | 77.2 | 43.4 | 1.7 | 251.9 | — | 8.3 | 30.7 | 78.2 | 491.4 |
| **Total** | 2,093.6 | 1,071.0 | 188.7 | 3,683.9 | 30.9 | 89.6 | 433.8 | 1,619.5 | 9,210.8 |
| **Eastern** | | | | | | | | | |
| Adams | — | — | — | — | — | — | 1.5 | — | 1.5 |
| Arapahoe | — | — | — | — | 5.7 | — | — | — | 5.7 |
| Baca | — | 6.0 | — | — | — | 6.0 | 7.5 | 11.9 | 31.4 |
| Bent | — | — | — | — | — | — | — | 30.2 | 30.2 |
| Denver | — | — | — | — | 4.1 | — | — | — | 4.1 |
| Logan | — | — | — | — | 6.1 | — | — | — | 6.1 |
| Morgan | — | — | — | — | — | — | 2.9 | — | 2.9 |
| Otero | — | 13.1 | — | — | — | — | — | 22.4 | 35.5 |
| **Total** | — | 19.0 | — | — | 16.0 | 6.0 | 11.8 | 64.6 | 117.3 |
| **All counties** | **7,531.8** | **3,624.2** | **683.1** | **4,808.9** | **281.7** | **381.8** | **2,248.6** | **3,331.2** | **22,891.3** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres.
Columns and rows may not add to their totals due to rounding.

**Table B33**—Area of timberland, in thousand acres, by inventory unit, county and stand-size class, Colorado, 2004–2013.

| Inventory unit and county | | Stand-size class: Large diameter | Medium diameter | Small diameter | Nonstocked | All size classes |
|---|---|---|---|---|---|---|
| **Northern Front Range** | | | | | | |
| | Boulder | 105.7 | 60.3 | 17.8 | 7.1 | 190.9 |
| | Clear Creek | 60.4 | 43.3 | 4.8 | — | 108.5 |
| | Douglas | 129.3 | 11.7 | 5.8 | 7.9 | 154.7 |
| | Elbert | 28.4 | — | 3.0 | — | 31.4 |
| | El Paso | 148.5 | 14.1 | 10.5 | 3.3 | 176.4 |
| | Gilpin | 14.8 | 37.0 | — | — | 51.8 |
| | Jefferson | 160.6 | 24.9 | 28.4 | 37.5 | 251.5 |
| | Lake | 55.9 | 20.2 | 8.9 | — | 85.0 |
| | Larimer | 301.2 | 158.0 | 37.7 | 39.6 | 536.4 |
| | Park | 265.7 | 113.8 | 91.3 | 29.9 | 500.7 |
| | Teller | 193.8 | 19.7 | 18.9 | 10.3 | 242.7 |
| | **Total** | 1,464.1 | 503.1 | 227.1 | 135.7 | 2,330.0 |
| **Southern Front Range** | | | | | | |
| | Chaffee | 148.9 | 56.6 | 30.6 | 12.1 | 248.2 |
| | Costilla | 126.3 | 35.4 | 25.4 | — | 187.1 |
| | Custer | 108.0 | 18.6 | 27.9 | 7.7 | 162.2 |
| | Fremont | 111.7 | 46.2 | 25.7 | — | 183.6 |
| | Huerfano | 81.7 | 35.0 | 9.7 | 8.1 | 134.5 |
| | Las Animas | 137.9 | 59.1 | — | — | 197.0 |
| | Pueblo | 19.3 | — | — | 7.2 | 26.4 |
| | **Total** | 733.8 | 250.9 | 119.2 | 35.1 | 1,139.0 |
| **West Central** | | | | | | |
| | Conejos | 112.4 | 72.6 | 10.8 | 4.7 | 200.5 |
| | Eagle | 190.7 | 92.3 | 47.9 | 13.1 | 344.0 |
| | Grand | 201.8 | 210.0 | 137.5 | 17.9 | 567.2 |
| | Gunnison | 495.1 | 221.4 | 53.4 | 13.4 | 783.3 |
| | Hinsdale | 143.8 | 37.3 | 18.9 | 1.6 | 201.7 |
| | Jackson | 62.0 | 139.9 | 76.7 | 2.8 | 281.3 |
| | Mineral | 124.4 | 65.5 | 55.4 | — | 245.3 |
| | Pitkin | 97.7 | 53.8 | 32.6 | — | 184.1 |
| | Rio Grande | 122.6 | 54.5 | 21.9 | — | 198.9 |
| | Routt | 236.2 | 314.8 | 54.3 | 19.0 | 624.3 |
| | Saguache | 291.2 | 263.9 | 71.4 | 10.7 | 637.2 |
| | San Juan | 56.7 | 17.4 | 5.5 | 5.5 | 85.1 |
| | Summit | 81.1 | 37.4 | 23.8 | 6.4 | 148.7 |
| | **Total** | 2,215.6 | 1,580.6 | 610.2 | 95.2 | 4,501.6 |
| **Western** | | | | | | |
| | Archuleta | 331.9 | 29.9 | 5.0 | — | 366.8 |
| | Delta | 81.6 | 50.5 | 11.3 | — | 143.4 |
| | Dolores | 178.4 | 18.2 | 20.2 | — | 216.8 |
| | Garfield | 299.4 | 68.5 | 33.9 | 4.8 | 406.6 |
| | La Plata | 250.5 | 72.8 | 19.4 | — | 342.7 |
| | Mesa | 189.2 | 89.0 | 43.7 | — | 321.8 |
| | Moffat | 47.0 | 20.6 | 1.8 | — | 69.4 |
| | Montezuma | 161.8 | 63.0 | 4.9 | — | 229.8 |
| | Montrose | 115.2 | 34.6 | 13.2 | — | 163.0 |
| | Ouray | 80.8 | 17.6 | 3.6 | — | 101.9 |
| | Rio Blanco | 168.0 | 98.7 | 4.2 | 4.2 | 275.1 |
| | San Miguel | 60.1 | 32.2 | 17.3 | — | 109.5 |
| | **Total** | 1,963.9 | 595.6 | 178.4 | 8.9 | 2,746.9 |
| **Eastern** | | | | | | |
| | Adams | — | — | — | 1.5 | 1.5 |
| | Arapahoe | 5.7 | — | — | — | 5.7 |
| | Baca | 6.0 | — | — | 1.5 | 7.5 |
| | Denver | 4.1 | — | — | — | 4.1 |
| | Logan | 6.1 | — | — | — | 6.1 |
| | Morgan | — | — | — | 2.9 | 2.9 |
| | **Total** | 21.9 | — | — | 5.8 | 27.7 |
| **All counties** | | **6,399.3** | **2,930.3** | **1,134.9** | **280.7** | **10,745.2** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres. Columns and rows may not add to their totals due to rounding.

**Table B34**—Area of timberland, in thousand acres, by inventory unit, county and stocking class, Colorado, 2004–2013.

| | | Stocking class of growing-stock trees | | | | | |
|---|---|---|---|---|---|---|---|
| Inventory unit and county | | Nonstocked | Poorly stocked | Moderately stocked | Fully stocked | Over-stocked | All classes |
| **Northern Front Range** | | | | | | | |
| | Boulder | 12.5 | 72.0 | 67.1 | 32.2 | 7.1 | 190.9 |
| | Clear Creek | — | 20.0 | 51.6 | 25.7 | 11.2 | 108.5 |
| | Douglas | 7.9 | 47.5 | 64.3 | 35.1 | — | 154.7 |
| | Elbert | — | 12.0 | 15.0 | 4.5 | — | 31.4 |
| | El Paso | 3.3 | 76.1 | 71.9 | 25.2 | — | 176.4 |
| | Gilpin | — | — | 14.8 | 37.0 | — | 51.8 |
| | Jefferson | 45.5 | 93.6 | 100.5 | 10.2 | 1.7 | 251.5 |
| | Lake | — | 16.7 | 34.2 | 19.0 | 15.1 | 85.0 |
| | Larimer | 40.4 | 189.9 | 166.3 | 130.0 | 9.9 | 536.4 |
| | Park | 29.9 | 142.4 | 191.1 | 134.7 | 2.6 | 500.7 |
| | Teller | 15.5 | 113.9 | 89.3 | 22.3 | 1.7 | 242.7 |
| | **Total** | 155.0 | 784.1 | 865.9 | 475.8 | 49.3 | 2,330.0 |
| **Southern Front Range** | | | | | | | |
| | Chaffee | 12.1 | 52.4 | 64.3 | 110.1 | 9.4 | 248.2 |
| | Costilla | — | 18.5 | 68.3 | 97.2 | 3.1 | 187.1 |
| | Custer | 7.7 | 39.9 | 63.5 | 31.0 | 20.1 | 162.2 |
| | Fremont | — | 86.0 | 63.3 | 34.2 | — | 183.6 |
| | Huerfano | 8.1 | 46.7 | 20.7 | 49.4 | 9.7 | 134.5 |
| | Las Animas | 8.4 | 47.1 | 94.2 | 47.3 | — | 197.0 |
| | Pueblo | 7.2 | 14.3 | — | 4.9 | — | 26.4 |
| | **Total** | 43.4 | 304.9 | 374.3 | 374.1 | 42.3 | 1,139.0 |
| **West Central** | | | | | | | |
| | Conejos | 4.7 | 36.1 | 61.8 | 59.8 | 38.1 | 200.5 |
| | Eagle | 19.1 | 72.3 | 79.2 | 145.8 | 27.6 | 344.0 |
| | Grand | 17.9 | 126.5 | 234.5 | 170.7 | 17.5 | 567.2 |
| | Gunnison | 15.9 | 198.4 | 232.9 | 274.3 | 61.8 | 783.3 |
| | Hinsdale | 1.6 | 16.0 | 90.8 | 80.4 | 13.0 | 201.7 |
| | Jackson | 2.8 | 52.8 | 122.3 | 93.7 | 9.7 | 281.3 |
| | Mineral | 3.1 | 36.3 | 98.5 | 92.1 | 15.4 | 245.3 |
| | Pitkin | — | 37.3 | 37.5 | 84.3 | 25.0 | 184.1 |
| | Rio Grande | — | 41.0 | 63.2 | 61.2 | 33.5 | 198.9 |
| | Routt | 19.0 | 124.7 | 259.8 | 188.8 | 32.1 | 624.3 |
| | Saguache | 20.9 | 158.9 | 177.3 | 248.4 | 31.8 | 637.2 |
| | San Juan | 5.5 | 9.7 | 24.9 | 33.2 | 11.8 | 85.1 |
| | Summit | 6.4 | 15.2 | 52.5 | 69.9 | 4.8 | 148.7 |
| | **Total** | 116.8 | 925.1 | 1,535.1 | 1,602.6 | 322.1 | 4,501.6 |
| **Western** | | | | | | | |
| | Archuleta | — | 85.3 | 156.9 | 116.3 | 8.3 | 366.8 |
| | Delta | — | 33.5 | 22.6 | 81.0 | 6.4 | 143.4 |
| | Dolores | 4.7 | 45.6 | 74.9 | 79.2 | 12.4 | 216.8 |
| | Garfield | 16.1 | 152.7 | 139.0 | 78.3 | 20.5 | 406.6 |
| | La Plata | — | 81.4 | 123.4 | 110.1 | 27.8 | 342.7 |
| | Mesa | 3.0 | 75.4 | 74.0 | 136.2 | 33.2 | 321.8 |
| | Moffat | — | 31.5 | 14.9 | 15.9 | 7.2 | 69.4 |
| | Montezuma | — | 72.3 | 63.2 | 84.6 | 9.8 | 229.8 |
| | Montrose | — | 37.9 | 50.9 | 72.5 | 1.6 | 163.0 |
| | Ouray | — | 27.1 | 26.6 | 40.8 | 7.4 | 101.9 |
| | Rio Blanco | 4.2 | 40.4 | 114.4 | 111.0 | 5.1 | 275.1 |
| | San Miguel | — | 14.2 | 34.0 | 46.7 | 14.6 | 109.5 |
| | **Total** | 28.0 | 697.3 | 894.8 | 972.5 | 154.3 | 2,746.9 |
| **Eastern** | | | | | | | |
| | Adams | 1.5 | — | — | — | — | 1.5 |
| | Arapahoe | — | 5.7 | — | — | — | 5.7 |
| | Baca | 1.5 | — | 6.0 | — | — | 7.5 |
| | Denver | — | — | — | 4.1 | — | 4.1 |
| | Logan | — | — | 6.1 | — | — | 6.1 |
| | Morgan | 2.9 | — | — | — | — | 2.9 |
| | **Total** | 5.8 | 5.7 | 12.1 | 4.1 | — | 27.7 |
| **All counties** | | **349.0** | **2,717.1** | **3,682.1** | **3,429.1** | **568.0** | **10,745.2** |

All table cells without observations in the inventory sample are indicated by—. Table value of 0.0 indicates the acres round to less than 0.1 thousand acres.
Columns and rows may not add to their totals due to rounding.

**Table B35**—Net volume of growing stock trees (at least 5 inches d.b.h.), in million cubic feet, and sawtimber trees, in million board feet (International 1/4 inch rule), on timberland by inventory unit, county, and major species group, Colorado, 2004–2013.

| Inventory unit | Growing stock | | | | | Sawtimber | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Major species group | | | | | Major species group | | | | |
| and county | Pine | Other softwoods | Soft hardwoods | Hard hardwoods | All species | Pine | Other softwoods | Soft hardwoods | Hard hardwoods | All species |
| | (In million cubic feet) | | | | | (In million board feet) | | | | |
| **Northern Front Range** | | | | | | | | | | |
| Boulder | 149.9 | 101.1 | 3.1 | — | 254.0 | 488.9 | 293.6 | 1.8 | — | 784.3 |
| Clear Creek | 101.7 | 147.5 | 6.8 | — | 256.1 | 232.8 | 589.2 | 5.7 | — | 827.7 |
| Douglas | 105.9 | 169.2 | 2.1 | — | 277.1 | 371.2 | 728.4 | 5.6 | — | 1,105.2 |
| Elbert | 52.8 | — | — | — | 52.8 | 247.9 | — | — | — | 247.9 |
| El Paso | 127.0 | 129.1 | 3.1 | — | 259.3 | 477.6 | 542.9 | — | — | 1,020.5 |
| Gilpin | 73.2 | 42.0 | 7.8 | — | 123.0 | 124.9 | 152.7 | — | — | 277.6 |
| Jefferson | 165.6 | 86.0 | 11.2 | — | 262.9 | 648.3 | 342.4 | 24.5 | — | 1,015.2 |
| Lake | 68.8 | 114.1 | 15.7 | — | 198.7 | 189.3 | 440.5 | 2.0 | — | 631.8 |
| Larimer | 522.2 | 207.7 | 17.5 | — | 747.4 | 1,397.5 | 696.1 | 10.1 | — | 2,103.7 |
| Park | 257.0 | 331.6 | 23.0 | — | 611.6 | 822.6 | 1,215.0 | 7.7 | — | 2,045.3 |
| Teller | 99.9 | 163.4 | 5.3 | — | 268.6 | 375.5 | 672.8 | 3.5 | — | 1,051.8 |
| **Total** | 1,724.2 | 1,491.7 | 95.7 | — | 3,311.5 | 5,376.5 | 5,673.7 | 60.8 | — | 11,111.0 |
| **Southern Front Range** | | | | | | | | | | |
| Chaffee | 159.1 | 356.0 | 32.5 | — | 547.6 | 496.8 | 1,490.8 | 78.1 | — | 2,065.7 |
| Costilla | 67.1 | 265.6 | 32.2 | — | 364.9 | 224.4 | 1,061.3 | 37.6 | — | 1,323.3 |
| Custer | 72.0 | 179.0 | 49.7 | — | 300.8 | 264.0 | 700.9 | 87.6 | — | 1,052.5 |
| Fremont | 66.7 | 164.0 | 7.9 | — | 238.6 | 264.2 | 612.1 | 3.3 | — | 879.6 |
| Huerfano | 59.8 | 116.3 | 45.1 | — | 221.2 | 167.2 | 486.3 | 103.5 | — | 757.0 |
| Las Animas | 103.0 | 170.4 | 33.2 | — | 306.7 | 314.4 | 590.6 | 71.5 | — | 976.5 |
| Pueblo | 15.0 | 10.5 | 0.5 | — | 26.0 | 63.2 | 38.8 | 1.6 | — | 103.5 |
| **Total** | 542.8 | 1,261.8 | 201.1 | — | 2,005.7 | 1,794.2 | 4,980.7 | 383.1 | — | 7,158.0 |
| **West Central** | | | | | | | | | | |
| Conejos | 24.3 | 410.2 | 101.1 | — | 535.6 | 96.1 | 1,870.2 | 130.2 | — | 2,096.5 |
| Eagle | 259.7 | 481.9 | 167.1 | — | 908.7 | 952.4 | 1,997.2 | 344.2 | — | 3,293.8 |
| Grand | 276.8 | 588.9 | 111.5 | — | 977.3 | 586.5 | 2,389.4 | 199.8 | — | 3,175.8 |
| Gunnison | 458.2 | 1,292.9 | 378.7 | — | 2,129.8 | 1,364.2 | 5,825.8 | 841.9 | — | 8,031.9 |
| Hinsdale | 12.8 | 483.0 | 75.7 | — | 571.5 | 55.4 | 2,259.0 | 161.1 | — | 2,475.4 |
| Jackson | 159.1 | 195.8 | 107.4 | — | 462.2 | 342.7 | 755.6 | 132.0 | — | 1,230.3 |
| Mineral | 21.5 | 399.3 | 125.8 | — | 546.6 | 71.6 | 1,765.9 | 242.4 | — | 2,079.9 |
| Pitkin | 84.1 | 301.8 | 104.6 | — | 490.6 | 243.6 | 1,342.7 | 290.9 | — | 1,877.2 |
| Rio Grande | 19.3 | 334.5 | 75.4 | — | 429.2 | 86.4 | 1,386.9 | 153.2 | — | 1,626.5 |
| Routt | 287.6 | 635.4 | 465.6 | — | 1,388.6 | 906.5 | 2,766.9 | 966.9 | — | 4,640.2 |
| Saguache | 340.1 | 572.4 | 213.4 | — | 1,125.9 | 874.1 | 2,155.0 | 249.2 | — | 3,278.3 |
| San Juan | 0.0 | 207.9 | 45.5 | — | 253.4 | — | 949.1 | 74.9 | — | 1,024.0 |
| Summit | 151.5 | 262.8 | 12.9 | — | 427.3 | 383.8 | 1,210.3 | 12.8 | — | 1,606.9 |
| **Total** | 2,095.0 | 6,166.7 | 1,984.9 | — | 10,246.6 | 5,963.1 | 26,674.1 | 3,799.5 | — | 36,436.7 |
| **Western** | | | | | | | | | | |
| Archuleta | 237.2 | 638.0 | 186.6 | — | 1,061.8 | 1,149.1 | 3,056.3 | 548.1 | — | 4,753.4 |
| Delta | — | 303.6 | 134.5 | — | 438.1 | — | 1,476.4 | 341.4 | — | 1,817.8 |
| Dolores | 98.1 | 517.6 | 134.9 | — | 750.5 | 455.4 | 2,562.7 | 540.3 | — | 3,558.4 |
| Garfield | 6.3 | 639.0 | 170.6 | — | 815.8 | 30.7 | 2,801.0 | 457.8 | — | 3,289.5 |
| La Plata | 278.7 | 499.5 | 212.9 | 0.3 | 991.3 | 1,401.0 | 2,540.9 | 513.9 | 1.3 | 4,457.1 |
| Mesa | 50.3 | 398.4 | 344.0 | 2.4 | 795.1 | 249.1 | 1,825.7 | 981.5 | 9.1 | 3,065.3 |
| Moffat | 28.5 | 53.1 | 66.6 | 9.9 | 158.0 | 50.5 | 230.6 | 164.3 | 39.6 | 485.1 |
| Montezuma | 232.0 | 243.9 | 111.2 | — | 587.1 | 1,137.1 | 1,203.3 | 197.7 | — | 2,538.1 |
| Montrose | 58.0 | 142.3 | 201.5 | — | 401.8 | 270.9 | 641.4 | 668.7 | — | 1,581.1 |
| Ouray | — | 230.4 | 64.6 | — | 295.0 | — | 1,143.6 | 194.8 | — | 1,338.4 |
| Rio Blanco | 66.5 | 334.9 | 305.2 | 0.2 | 706.8 | 298.3 | 1,400.0 | 881.8 | — | 2,580.1 |
| San Miguel | 43.1 | 170.7 | 98.4 | — | 312.3 | 201.8 | 704.6 | 289.8 | — | 1,196.1 |
| **Total** | 1,098.7 | 4,171.2 | 2,030.9 | 12.8 | 7,313.7 | 5,243.8 | 19,586.4 | 5,780.0 | 50.1 | 30,660.2 |
| **Eastern** | | | | | | | | | | |
| Arapahoe | — | — | 3.7 | — | 3.7 | — | — | 16.8 | — | 16.8 |
| Baca | — | — | 15.4 | — | 15.4 | — | — | 47.6 | — | 47.6 |
| Denver | — | — | 17.4 | — | 17.4 | — | — | 60.3 | — | 60.3 |
| Logan | — | — | 9.0 | — | 9.0 | — | — | 29.7 | — | 29.7 |
| **Total** | — | — | 45.4 | — | 45.4 | — | — | 154.3 | — | 154.3 |
| **All counties** | **5,460.7** | **13,091.4** | **4,357.9** | **12.8** | **22,922.9** | **18,377.6** | **56,914.9** | **10,177.7** | **50.1** | **85,520.3** |

All table cells without observations in the inventory sample are indicated by --. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic or board feet. Columns and rows may not add to their totals due to rounding.

**Table B36**—Average annual net growth of growing stock trees (at least 5 inches d.b.h.), in million cubic feet, and sawtimber trees, in million board feet (International 1/4 inch rule), on timberland by inventory unit, county, and major species group, Colorado, 2004–2013.

| Inventory unit and county | Growing stock | | | | | Sawtimber | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Major species group | | | | | Major species group | | | | |
| | Pine | Other softwoods | Soft hardwoods | Hard hardwoods | All species | Pine | Other softwoods | Soft hardwoods | Hard hardwoods | All species |
| | (In million cubic feet) | | | | | (In million board feet) | | | | |
| **Northern Front Range** | | | | | | | | | | |
| Boulder | 0.3 | 2.0 | 0.2 | — | 2.5 | 8.2 | 7.8 | 0.1 | — | 16.0 |
| Clear Creek | 0.5 | 1.2 | 0.2 | — | 1.9 | 2.0 | 6.8 | 0.1 | — | 8.9 |
| Douglas | 0.0 | 1.5 | -0.3 | — | 1.2 | 0.0 | 9.2 | -1.1 | — | 8.0 |
| Elbert | 0.7 | — | — | — | 0.7 | 3.6 | — | — | — | 3.6 |
| El Paso | 1.8 | 2.0 | 0.1 | — | 3.9 | 9.7 | 11.9 | -0.1 | — | 21.5 |
| Gilpin | 0.8 | 0.2 | 0.2 | — | 1.2 | 5.3 | 2.1 | — | — | 7.5 |
| Jefferson | -0.2 | 1.5 | 0.2 | — | 1.5 | 2.3 | 8.5 | 0.5 | — | 11.3 |
| Lake | 1.1 | 1.5 | 0.3 | — | 2.8 | 9.3 | 7.4 | 0.1 | — | 16.8 |
| Larimer | 0.8 | 1.0 | 0.0 | — | 1.8 | 5.0 | 5.1 | 1.4 | — | 11.5 |
| Park | 2.8 | 4.3 | -0.2 | — | 6.9 | 14.9 | 22.0 | 0.1 | — | 37.0 |
| Teller | -1.1 | 0.5 | 0.0 | — | -0.6 | -5.2 | 6.6 | 0.0 | — | 1.5 |
| **Total** | 7.5 | 15.7 | 0.6 | — | 23.7 | 55.2 | 87.4 | 1.0 | — | 143.6 |
| **Southern Front Range** | | | | | | | | | | |
| Chaffee | 2.3 | 2.7 | 0.0 | — | 5.0 | 14.8 | 18.4 | 5.1 | — | 38.3 |
| Costilla | 0.7 | 3.2 | 0.6 | — | 4.5 | 5.4 | 22.4 | 0.6 | — | 28.4 |
| Custer | 0.8 | 1.6 | 0.1 | — | 2.5 | 3.6 | 8.0 | 3.8 | — | 15.4 |
| Fremont | 1.0 | 1.9 | 0.0 | — | 2.8 | 5.0 | 12.5 | 0.1 | — | 17.5 |
| Huerfano | -0.6 | 2.1 | -0.7 | — | 0.7 | 0.3 | 12.2 | -1.3 | — | 11.2 |
| Las Animas | 1.3 | 2.2 | 0.4 | — | 4.0 | 7.8 | 12.7 | 3.4 | — | 23.9 |
| Pueblo | 0.2 | -1.7 | 0.0 | — | -1.4 | 1.3 | -8.0 | 0.1 | — | -6.6 |
| **Total** | 5.7 | 12.0 | 0.4 | — | 18.2 | 38.0 | 78.4 | 11.8 | — | 128.1 |
| **West Central** | | | | | | | | | | |
| Conejos | 0.4 | 0.8 | 2.0 | — | 3.1 | 2.6 | 16.4 | 6.1 | — | 25.1 |
| Eagle | -3.3 | -2.7 | 1.4 | — | -4.6 | -11.4 | 7.6 | 18.7 | — | 14.8 |
| Grand | -75.7 | -4.4 | 0.1 | — | -79.9 | -275.8 | -11.1 | 5.8 | — | -281.1 |
| Gunnison | 4.9 | 2.9 | 3.6 | — | 11.4 | 31.2 | 34.1 | 34.7 | — | 100.0 |
| Hinsdale | 0.0 | 1.6 | 1.2 | — | 2.8 | 0.1 | 9.3 | 13.4 | — | 22.8 |
| Jackson | -33.4 | -4.1 | 0.9 | — | -36.6 | -113.4 | -19.9 | 2.8 | — | -130.4 |
| Mineral | 0.4 | -19.2 | 2.0 | — | -16.8 | 3.2 | -82.4 | 14.3 | — | -64.9 |
| Pitkin | -0.3 | -4.7 | 1.2 | — | -3.7 | 0.8 | -20.4 | 6.6 | — | -13.0 |
| Rio Grande | 0.2 | 1.6 | 0.3 | — | 2.1 | 0.8 | 22.8 | 5.0 | — | 28.6 |
| Routt | -21.8 | 0.2 | 1.8 | — | -19.8 | -87.9 | 9.4 | 42.4 | — | -36.2 |
| Saguache | 3.4 | 3.9 | 3.3 | — | 10.6 | 10.2 | 29.5 | 12.0 | — | 51.7 |
| San Juan | 0.0 | 0.8 | 0.8 | — | 1.6 | - - | 8.7 | 1.2 | — | 9.9 |
| Summit | -7.4 | 2.1 | 0.1 | — | -5.2 | -33.5 | 10.9 | -0.3 | — | -22.9 |
| **Total** | -132.7 | -21.1 | 18.6 | — | -135.2 | -473.1 | 14.9 | 162.6 | — | -295.5 |
| **Western** | | | | | | | | | | |
| Archuleta | 2.7 | -3.8 | -0.1 | — | -1.2 | 16.7 | -3.5 | 15.7 | — | 28.9 |
| Delta | — | -3.7 | 0.3 | — | -3.4 | — | -11.4 | 2.0 | — | -9.4 |
| Dolores | 1.7 | 0.9 | 1.8 | — | 4.3 | 9.9 | 12.5 | 5.3 | — | 27.7 |
| Garfield | 0.0 | 3.1 | 0.0 | — | 3.2 | 0.1 | 23.1 | 17.3 | — | 40.5 |
| La Plata | 2.6 | -3.9 | 0.3 | 0.0 | -0.9 | 18.8 | -14.5 | 25.1 | 1.4 | 30.7 |
| Mesa | 0.7 | -2.1 | 0.0 | 0.0 | -1.5 | 3.3 | -3.6 | 27.8 | 0.0 | 27.5 |
| Moffat | -0.7 | 1.4 | 0.6 | 0.2 | 1.5 | -6.4 | 8.3 | 1.2 | 1.0 | 4.1 |
| Montezuma | 3.8 | -0.9 | 2.7 | — | 5.6 | 26.7 | 1.8 | 23.8 | — | 52.2 |
| Montrose | 0.7 | -1.4 | 1.4 | — | 0.7 | 4.8 | -2.1 | 22.6 | — | 25.3 |
| Ouray | — | 0.1 | 0.1 | — | 0.2 | — | 8.1 | 3.4 | — | 11.5 |
| Rio Blanco | -1.5 | 2.0 | 3.2 | -0.1 | 3.6 | -8.0 | 14.1 | 34.7 | — | 40.9 |
| San Miguel | 0.5 | 0.4 | 0.1 | — | 1.0 | 2.2 | 0.8 | 5.6 | — | 8.6 |
| **Total** | 10.5 | -7.9 | 10.5 | 0.2 | 13.2 | 68.1 | 33.5 | 184.5 | 2.4 | 288.4 |
| **Eastern** | | | | | | | | | | |
| Adams | — | — | -0.2 | — | -0.2 | — | — | -0.5 | — | -0.5 |
| Arapahoe | — | — | 0.1 | — | 0.1 | — | — | 0.8 | — | 0.8 |
| Baca | — | — | 0.5 | — | 0.5 | — | — | 7.9 | — | 7.9 |
| Denver | — | — | 0.1 | — | 0.1 | — | — | 0.5 | 0.0 | 0.5 |
| Logan | — | — | 0.0 | — | 0.0 | — | — | -0.3 | — | -0.3 |
| **Total** | — | — | 0.5 | — | 0.5 | — | — | 8.3 | 0.0 | 8.4 |
| **All counties** | **-109.0** | **-1.4** | **30.6** | **0.2** | **-79.6** | **-311.9** | **214.2** | **368.3** | **2.4** | **273.0** |

All table cells without observations in the inventory sample are indicated by —. Table value of 0.0 indicates the volume rounds to less than 0.1 million cubic or board feet. Columns and rows may not add to their totals due to rounding.

**Table B37**—Sampling errors (in percent) by inventory unit and county for area of timberland, volume, average annual net growth, average annual removals, and average annual mortality on timberland, Colorado, 2004–2013.

| Inventory unit and county | Forest area | Timberland area | Growing stock (on timberland) Volume | Growth | Removals | Mortality | Sawtimber (on timberland) Volume | Growth | Removals | Mortality |
|---|---|---|---|---|---|---|---|---|---|---|
| **Northern Front Range** | | | | | | | | | | |
| Boulder | 4.44 | 9.16 | 16.22 | 52.48 | — | 37.49 | 18.24 | 38.58 | — | 46.01 |
| Clear Creek | 8.14 | 15.22 | 22.26 | 50.92 | — | 39.26 | 27.68 | 49.95 | — | 47.24 |
| Douglas | 8.18 | 12.51 | 17.91 | 100.00 | — | 72.05 | 20.46 | 100.00 | — | 76.18 |
| Elbert | 38.79 | 41.28 | 53.75 | 47.71 | — | - - | 57.12 | 50.19 | — | — |
| El Paso | 7.75 | 10.48 | 13.11 | 15.66 | — | 43.85 | 14.44 | 16.20 | — | 50.77 |
| Gilpin | 1.65 | 26.73 | 31.17 | 58.06 | — | 48.57 | 45.10 | 44.64 | — | 72.38 |
| Jefferson | 6.61 | 8.59 | 12.62 | 100.00 | — | 44.84 | 13.65 | 76.88 | — | 52.66 |
| Lake | 9.79 | 17.33 | 27.97 | 20.88 | — | 83.29 | 35.92 | 30.76 | — | — |
| Larimer | 3.02 | 7.28 | 10.80 | 100.00 | — | 24.19 | 12.90 | 100.00 | — | 25.92 |
| Park | 4.18 | 7.22 | 10.68 | 23.84 | — | 36.32 | 11.55 | 17.68 | — | 50.35 |
| Teller | 7.09 | 9.11 | 13.43 | 100.00 | — | 48.51 | 14.10 | 100.00 | — | 50.19 |
| **Total** | 1.84 | 3.23 | 4.97 | 24.62 | — | 14.85 | 5.72 | 18.53 | — | 17.33 |
| **Southern Front Range** | | | | | | | | | | |
| Chaffee | 4.61 | 10.45 | 16.40 | 26.92 | — | 36.34 | 19.86 | 24.58 | — | 48.34 |
| Costilla | 7.07 | 12.47 | 16.30 | 22.08 | — | 38.70 | 17.47 | 25.61 | — | 53.03 |
| Custer | 5.98 | 12.00 | 19.55 | 40.29 | — | 38.48 | 20.58 | 34.65 | — | 47.75 |
| Fremont | 3.53 | 15.75 | 20.52 | 20.35 | — | 41.68 | 22.33 | 23.68 | — | 54.33 |
| Huerfano | 5.86 | 18.21 | 24.64 | 100.00 | — | 48.65 | 30.04 | 68.05 | — | 56.95 |
| Las Animas | 4.93 | 15.50 | 18.91 | 24.50 | — | 36.01 | 21.00 | 24.96 | — | 51.04 |
| Pueblo | 12.52 | 46.13 | 61.33 | 100.00 | — | 94.38 | 64.82 | 100.00 | — | 95.53 |
| **Total** | 2.19 | 5.63 | 7.73 | 18.53 | — | 20.52 | 8.90 | 14.96 | — | 27.12 |
| **West Central** | | | | | | | | | | |
| Alamosa | 43.79 | — | — | — | — | — — | — | — | — | — |
| Conejos | 7.81 | 10.80 | 16.95 | 65.97 | — | 35.71 | 20.18 | 43.44 | — | 41.12 |
| Eagle | 3.83 | 9.88 | 13.06 | 100.00 | — | 25.16 | 14.37 | 100.00 | — | 25.70 |
| Grand | 2.84 | 5.66 | 9.90 | -17.72 | — | 14.18 | 13.17 | -18.71 | — | 14.38 |
| Gunnison | 3.06 | 5.79 | 8.99 | 29.93 | — | 16.66 | 10.73 | 24.50 | — | 23.21 |
| Hinsdale | 5.73 | 13.44 | 18.28 | 64.52 | — | 32.68 | 19.97 | 64.85 | — | 37.77 |
| Jackson | 4.00 | 9.25 | 13.71 | -26.91 | — | 21.13 | 18.40 | -30.82 | — | 23.75 |
| Mineral | 4.61 | 10.44 | 15.97 | -39.36 | — | 26.09 | 18.05 | -45.26 | — | 26.12 |
| Pitkin | 3.92 | 14.42 | 21.57 | 100.00 | — | 69.77 | 24.77 | 100.00 | — | 77.83 |
| Rio Grande | 7.01 | 9.42 | 15.18 | 76.11 | — | 26.83 | 17.18 | 35.64 | — | 31.36 |
| Routt | 3.62 | 5.94 | 9.75 | -45.52 | — | 18.46 | 12.41 | 100.00 | — | 22.57 |
| Saguache | 3.37 | 6.02 | 9.04 | 26.36 | — | 23.31 | 10.53 | 26.32 | — | 28.71 |
| San Juan | 9.77 | 15.95 | 20.38 | 79.56 | — | 40.42 | 22.23 | 83.19 | — | 47.71 |
| Summit | 6.61 | 12.80 | 18.56 | -71.94 | — | 34.16 | 23.88 | -73.05 | — | 35.58 |
| **Total** | 1.22 | 2.35 | 3.70 | -17.54 | — | 7.61 | 4.51 | -35.56 | — | 8.48 |
| **Western** | | | | | | | | | | |
| Archuleta | 2.90 | 9.84 | 12.84 | 100.00 | — | 26.10 | 13.48 | 85.11 | — | 30.41 |
| Delta | 5.98 | 16.57 | 19.95 | -78.79 | — | 31.77 | 22.82 | 100.00 | — | 35.89 |
| Dolores | 5.55 | 12.70 | 17.36 | 52.79 | — | 36.33 | 18.39 | 46.38 | — | 40.45 |
| Garfield | 3.21 | 10.02 | 14.41 | 100.00 | — | 32.09 | 15.92 | 54.25 | — | 36.76 |
| La Plata | 4.09 | 10.42 | 13.71 | 100.00 | — | 25.52 | 15.00 | 66.56 | — | 29.36 |
| Mesa | 2.95 | 11.92 | 16.17 | 100.00 | — | 24.04 | 18.09 | 45.25 | — | 30.72 |
| Moffat | 6.50 | 28.43 | 37.68 | 100.00 | — | 51.71 | 35.46 | 100.00 | — | 67.50 |
| Montezuma | 4.28 | 13.57 | 16.69 | 42.37 | — | 44.86 | 18.37 | 29.09 | — | 49.76 |
| Montrose | 3.35 | 18.14 | 21.91 | 100.00 | — | 36.19 | 23.89 | 51.14 | — | 48.73 |
| Ouray | 7.53 | 19.84 | 25.13 | 100.00 | — | 39.30 | 27.16 | 48.97 | — | 44.08 |
| Rio Blanco | 3.80 | 13.08 | 15.89 | 75.89 | — | 28.14 | 17.87 | 45.80 | — | 34.85 |
| San Miguel | 6.27 | 22.05 | 25.97 | 100.00 | — | 43.23 | 25.52 | 53.42 | — | 45.58 |
| **Total** | 1.26 | 3.91 | 5.07 | 71.79 | — | 9.54 | 5.52 | 18.71 | — | 11.34 |
| **Eastern** | | | | | | | | | | |
| Adams | 100.00 | 100.00 | — | 100.00 | — | 100.00 | — | 100.00 | — | 100.00 |
| Arapahoe | 100.00 | 100.00 | 100.00 | 100.00 | — | — | 100.00 | 100.00 | — | — |
| Baca | 42.51 | 82.39 | 100.00 | 100.00 | — | 100.00 | 100.00 | 100.00 | — | — |
| Bent | 43.11 | — | — | — | — | — | — | — | — | — |
| Denver | 100.00 | 100.00 | 100.00 | 100.00 | — | — | 100.00 | 100.00 | — | — |
| Logan | 100.00 | 100.00 | 100.00 | 100.00 | — | 100.00 | 100.00 | 100.00 | — | 100.00 |
| Morgan | 100.00 | 100.00 | — | — | — | — | — | — | — | — |
| Otero | 38.65 | — | — | — | — | — | — | — | — | — |
| **Total** | 21.44 | 41.94 | 55.38 | 95.58 | — | 62.75 | 54.44 | 95.31 | — | 72.72 |
| **All counties** | 0.76 | 1.68 | 2.52 | -33.22 | — | 5.66 | 2.95 | 44.99 | — | 6.42 |

All table cells without observations in the inventory sample are indicated by—. Sampling errors that exceed 100% are reported as 100%.

# Appendix C: Colorado Forest-Type Groups and Forest Types, with Descriptions and Timber (T) or Woodland (W) Designations

Forest-type groups and forest types are usually named for the predominant species (or group of species) on the condition. In order to determine the forest type, the stocking (site occupancy) of trees is estimated by softwoods and hardwoods. If softwoods predominate, then the forest type will be one of the softwood types and if hardwoods predominate, then the forest type will be one of the hardwood types. Some other special stocking rules apply to individual forest types, and are described below.

Associate species are defined as those that regularly form the majority of the non-predominant species stocking of mixed-species conditions. These descriptions are applicable to the current inventory; species importance, including predominance in some cases, will vary for other States or inventory years. When species are listed, they are in decreasing order of overall forest type stocking.

**ASPEN/BIRCH GROUP (T)**

**Aspen**

Predominant species: quaking aspen

Associate species: Engelmann spruce, subalpine fir, lodgepole pine, Douglas-fir, white fir, Gambel oak, ponderosa pine

Other species: blue spruce, Rocky Mountain bristlecone pine, limber pine, corkbark fir, Rocky Mountain juniper, Fremont cottonwood, narrowleaf cottonwood, water birch, Utah juniper, common or two-needle pinyon, southwestern white pine

**DOUGLAS-FIR GROUP (T)**

**Douglas-fir**

Predominant species: Douglas-fir

Associate species: quaking aspen, ponderosa pine, limber pine, Engelmann spruce, white fir, Rocky Mountain juniper, lodgepole pine, Gambel oak, subalpine fir

Other species: Rocky Mountain bristlecone pine, blue spruce, common or two-needle pinyon, corkbark fir, southwestern white pine, boxelder, narrowleaf cottonwood, Utah juniper, oneseed juniper

**ELM/ASH/COTTONWOOD GROUP (T)**

**Cottonwood**

Predominant species: narrowleaf cottonwood, plains cottonwood, Fremont cottonwood, eastern cottonwood

Associate species: blue spruce, quaking aspen, ponderosa pine

Other species: Utah juniper, white fir, Engelmann spruce, Rocky Mountain juniper, Douglas-fir, honeylocust, common or two-needle pinyon, boxelder, Gambel oak, subalpine fir

Special rules: Stocking of cottonwoods must be at least 50 percent of total stocking.

**Cottonwood/willow**

Predominant species: narrowleaf cottonwood, Gambel oak

Associate species: none identified

Other species: ponderosa pine, blue spruce, quaking aspen

Special rules: Stocking of cottonwoods stocking is less than 50 percent, but predominant. In order to meet 50 percent hardwood stocking, other hardwoods must be present.

**Sugarberry/hackberry/elm/green ash**

Predominant species: boxelder

Associate species: none identified

Other species: narrowleaf cottonwood, Rocky Mountain juniper

Special rules: Several species, mostly Eastern, are evaluated for this type. The only one of these species found in Colorado's current inventory is boxelder.

**EXOTIC HARDWOODS GROUP (T)**

**Other exotic hardwoods**

Predominant species: Siberian elm.

Associate species: none

Other species: none

Special rules: A "catch-all" type for non-native hardwood species.

**FIR/SPRUCE/MOUNTAIN HEMLOCK GROUP (T)**

**Blue spruce**

Predominant species: blue spruce

Associate species: quaking aspen, Douglas-fir, ponderosa pine, narrowleaf cottonwood, Engelmann spruce

Other species: subalpine fir, lodgepole pine, white fir, Gambel oak, Rocky Mountain juniper, Rocky Mountain bristlecone pine, limber pine

**Engelmann spruce**

Predominant species: Engelmann spruce

Associate species: subalpine fir, quaking aspen, lodgepole pine, Rocky Mountain bristlecone pine, Douglas-fir, corkbark fir

Other species: limber pine, blue spruce, white fir, ponderosa pine, narrowleaf cottonwood, water birch

Special rules: In order to use Engelmann spruce stocking predominance, subalpine fir and/or corkbark fir stocking must be less than 5 percent of the total. If subalpine fir and/or corkbark fir stocking is 5 percent or more, Engelmann spruce stocking must be at least 75 percent of total.

**Engelmann spruce/subalpine fir**

Predominant species: Engelmann spruce, subalpine fir, corkbark fir

Associate species: quaking aspen, lodgepole pine, Douglas-fir, limber pine

Other species: Rocky Mountain bristlecone pine, blue spruce, white fir

Special rules: The combined stocking of Engelmann spruce with subalpine fir and/or corkbark fir is predominant. Stocking of both Engelmann spruce and subalpine fir/corkbark fir must each be between 5 and 74 percent of the total.

### Subalpine fir

Predominant species: subalpine fir

Associate species: quaking aspen, Engelmann spruce, lodgepole pine, Douglas-fir

Other species: blue spruce, Rocky Mountain juniper, limber pine, ponderosa pine, Gambel oak

Special rules: Both subalpine fir and corkbark fir are evaluated as subalpine fir. In order to use subalpine fir stocking predominance, Engelmann spruce stocking must be less than 5 percent of the total. If Engelmann spruce stocking is 5 percent or more, subalpine fir/corkbark fir stocking must be at least 75 percent of total stocking.

### White fir

Predominant species: white fir

Associate species: Douglas-fir, quaking aspen, ponderosa pine, Engelmann spruce

Other species: Rocky Mountain juniper, limber pine, lodgepole pine, boxelder, subalpine fir, Gambel oak, southwestern white pine, blue spruce

## LODGEPOLE PINE

### Lodgepole pine

Predominant species: lodgepole pine

Associate species: quaking aspen, Engelmann spruce, subalpine fir, Douglas-fir

Other species: limber pine, ponderosa pine, white fir, blue spruce, corkbark fir, Rocky Mountain bristlecone pine, Rocky Mountain juniper

## NONSTOCKED

### Nonstocked

Predominant species: various, most commonly ponderosa pine, but many nonstocked conditions have no live-tree stocking.

Associate species: various, seldom more than two species on a condition

Other species: Complete species list: ponderosa pine, common or two-needle pinyon, Utah juniper, quaking aspen, lodgepole pine, Douglas-fir, Engelmann spruce, Gambel oak, subalpine fir, Rocky Mountain bristlecone pine, Fremont cottonwood, Rocky Mountain juniper

Special rules: Used when all live stocking is less than 10 percent. Implies disturbance, but may be used for sparse stands with no disturbance, especially with woodland species.

## OTHER WESTERN SOFWOODS GROUP (T)

### Foxtail pine/bristlecone pine

Predominant species: Rocky Mountain bristlecone pine

Associate species: quaking aspen, Engelmann spruce

Other species: limber pine, Douglas-fir, ponderosa pine, common or two-needle pinyon, lodgepole pine

Special rules: This is mostly an "either/or" forest type. Rocky Mountain bristlecone pine is the only applicable species that occurs in Colorado.

### Limber pine

Predominant species: limber pine

Associate species: Engelmann spruce, quaking aspen, Douglas-fir, lodgepole pine, ponderosa pine

Other species: white fir, Rocky Mountain bristlecone pine, subalpine fir, Rocky Mountain juniper

### Southwestern white pine

Predominant species: southwestern white pine

Associate species: ponderosa pine

Other species: Douglas-fir, quaking aspen, Gambel oak

## PINYON/JUNIPER GROUP (W)

### Juniper woodland

Predominant species: Utah juniper, oneseed juniper

Associate species: none identified

Other species: Rocky Mountain juniper, Gambel oak, Douglas-fir, ponderosa pine, eastern cottonwood

Special rules: Predominance of any combination of junipers other than Rocky Mountain juniper, and live pinyons are NOT present.

### Pinyon/juniper woodland

Predominant species: Utah juniper, common or two-needle pinyon, oneseed juniper

Associate species: Rocky Mountain juniper, Gambel oak

Other species: ponderosa pine, Douglas-fir, curlleaf mountain-mahogany, limber pine, narrowleaf cottonwood, white fir, Fremont cottonwood, Rocky Mountain bristlecone pine, quaking aspen

Special rules: Any combination of pinyons and junipers other than Rocky Mountain juniper predominate. Pinyons must be present.

### Rocky Mountain juniper

Predominant species: Rocky Mountain juniper

Associate species: common or two-needle pinyon, ponderosa pine, Gambel oak, Douglas-fir, oneseed juniper, Utah juniper

Other species: white fir, quaking aspen, narrowleaf cottonwood, blue spruce, plains cottonwood, limber pine

## PONDEROSA PINE GROUP (T)

### Ponderosa pine

Predominant species: ponderosa pine

Associate species: Douglas-fir, Gambel oak, Rocky Mountain juniper, quaking aspen, common or two-needle pinyon

Other species: white fir, lodgepole pine, limber pine, Engelmann spruce, Rocky Mountain bristlecone pine, narrowleaf cottonwood, blue spruce, oneseed juniper, southwestern white pine, subalpine fir

## WOODLAND HARDWOODS GROUP (W)

### Cercocarpus woodland

Predominant species: curlleaf mountain-mahogany

Associate species: Gambel oak

Other species: Rocky Mountain juniper, common or two-needle pinyon, Utah juniper, Douglas-fir

### Deciduous oak woodland

Predominant species: Gambel oak

Associate species: ponderosa pine, common or two-needle pinyon, Rocky Mountain juniper, Douglas-fir, quaking aspen, Utah juniper

Other species:  white fir, oneseed juniper, narrowleaf cottonwood, limber pine, Rocky Mountain bristlecone pine, curlleaf mountain-mahogany, Engelmann spruce, subalpine fir, plains cottonwood

# Appendix D: Tree Species Groups and Tree Species Measured in Colorado's Annual Inventory with Common Name, Scientific Name, and Timber (T) or Woodland (W) Designation

**HARDWOODS**

**Cottonwood and aspen group (T)**

Eastern cottonwood (*Populus deltoides*)
Fremont cottonwood (*Populus fremontii*)
Narrowleaf cottonwood (*Populus angustifolia*)
Plains cottonwood (*Populus deltoides* ssp. *monilifera*)
Quaking aspen (*Populus tremuloides*)

**Other western hardwoods group (T)**

Boxelder (*Acer negundo*)
Honeylocust (*Gleditsia tricanthos*)
Water birch (*Betula occidentalis*)

**Woodland hardwoods group (W)**

Gambel oak (*Quercus gambelii*)
Curlleaf mountain-mahogany (*Cercocarpus ledifolia*)

**SOFTWOODS**

**Douglas-fir group (T)**

Douglas-fir (*Pseudotsuga menziesii*)

**Engelmann and other spruces group (T)**

Blue spruce (*Picea pungens*)
Engelmann spruce (*Picea engelmannii*)

**Lodgepole pine (T)**

Lodgepole pine (*Pinus contorta*)

**Other western softwoods group (T)**

Limber pine (*Pinus flexilis*)
Rocky Mountain bristlecone pine (*Pinus aristata*)
Southwestern white pine (*Pinus strobiformis*)

**Ponderosa and Jeffrey pines group (T)**

Ponderosa pine (*Pinus ponderosa*)

**True fir group (T)**

Corkbark fir (*Abies lasiocarpa* var. *arizonica*)
Subalpine fir (*Abies lasiocarpa*)
White fir (*Abies concolor*)

**Woodland softwoods group (W)**

Common or two-needle pinyon (*Pinus edulis*)
Oneseed juniper (*Juniperus monosperma*)
Rocky Mountain juniper (*Juniperus scopulorum*)
Utah juniper (*Juniperus osteosperma*)

# Appendix E: Volume, Biomass, and Site Index Equation Sources

**Volume**

Chojnacky (1985) was used for bigtooth maple, curlleaf mountain-mahogany, Gambel oak, and singleleaf pinyon pine volume estimation.

Chojnacky (1994) was used for common or two-needle pinyon pine, Rocky Mountain juniper, and Utah juniper volume estimation.

Edminster et al. (1980) was used for ponderosa pine volume estimation in northeastern Utah.

Edminister et al. (1982) was used for aspen volume estimation in northeastern Utah.

Hann and Bare (1978) was used for aspen, blue spruce, Douglas-fir, Engelmann spruce, Great Basin bristlecone pine, limber pine, lodgepole pine, ponderosa pine, subalpine fir, and white fir volume estimation in southwestern Utah.

Kemp (1956) was used for Fremont and narrowleaf cottonwood volume estimation.

Myers (1964) was used for limber and lodgepole pine volume estimation in northeastern Utah.

Myers and Edminister (1972) was used for blue spruce, Douglas-fir, Engelmann spruce, subalpine fir, and white fir volume estimation in northeastern Utah.

**Biomass**

Chojnacky (1984) was used for curlleaf mountain mahogany biomass estimation.

Chojnacky (1992) was used for bigtooth maple and Gambel oak biomass estimation.

Chojnacky and Moisen (1993) was used for all juniper and pinyon species biomass estimation.

Van Hooser and Chojnacky (1983) was used for all timber (T) species biomass estimation.

**Site Index**

Brickell (1970) was used for blue spruce, Douglas-fir, Engelmann spruce, Great Basin bristlecone pine, limber pine, lodgepole pine, ponderosa pine, and subalpine fir site index estimation.

Edminster et al. (1985) was used for aspen and Fremont and narrowleaf cottonwood site index estimation.

Stage (1966) was used for white fir site index estimation. (Original equations were reformulated by J. Shaw; documentation on file at U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Inventory Monitoring, Ogden, UT.)

# Appendix F: Colorado Timber Products Output Tables and Colorado Soils Indicator Tables

**Table F1**—Total roundwood output (in thousand cubic feet) by product, species group, and source of material, Colorado, 2012.

| | Source of material | | | |
|---|---|---|---|---|
| | Growing-stock trees | | | |
| Product and species group | Sawtimber | Poletimber | Other sources | All sources |
| **Sawlogs** | | | | |
| Softwood | 4,509 | 591 | 7,040 | 12,140 |
| Hardwood | 965 | 126 | 62 | 1,153 |
| Total | 5,474 | 717 | 7,102 | 13,293 |
| **Veneer logs** | | | | |
| Softwood | 0 | 0 | 0 | 0 |
| Hardwood | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 |
| **Pulpwood** | | | | |
| Softwood | 0 | 0 | 0 | 0 |
| Hardwood | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 |
| **Composite panels** | | | | |
| Softwood | 0 | 0 | 0 | 0 |
| Hardwood | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 |
| **Poles and posts** | | | | |
| Softwood | 5 | 477 | 895 | 1,377 |
| Hardwood | 0 | 6 | 0 | 6 |
| Total | 5 | 483 | 895 | 1,383 |
| **Other miscellaneous** | | | | |
| Softwood | 344 | 45 | 771 | 1,160 |
| Hardwood | 538 | 70 | 264 | 873 |
| Total | 882 | 116 | 1,035 | 2,033 |
| **Total industrial products** | | | | |
| Softwood | 4,858 | 1,113 | 8,706 | 14,677 |
| Hardwood | 1,503 | 203 | 326 | 2,032 |
| Total | 6,361 | 1,316 | 9,032 | 16,709 |
| **Fuelwood (including residential)[a]** | | | | |
| Softwood | 1,164 | 152 | 29,691 | 31,007 |
| Hardwood | 6 | 1 | 300 | 307 |
| Total | 1,170 | 153 | 29,991 | 31,314 |
| **All products** | | | | |
| Softwood | 6,022 | 1,266 | 38,397 | 45,685 |
| Hardwood | 1,508 | 204 | 626 | 2,338 |
| Total | 7,531 | 1,469 | 39,023 | 48,023 |

[a] Includes residential fuelwood consumption reported by U.S. Energy Information Administration http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US#Consumption.

**Table F2—**Volume of timber removals (in thousand cubic feet) by source of material, species group, and removal type, Colorado, 2012.

| | Source of material | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Growing stock | | | Other sources | | | All sources | | |
| Removal type | Softwoods | Hardwoods | Total | Softwoods | Hardwoods | Total | Softwoods | Hardwoods | Total |
| Roundwood products | | | | | | | | | |
| Saw logs | 5,100 | 1,091 | 6,161 | 7,040 | 62 | 7,102 | 12,140 | 1,153 | 13,293 |
| Veneer logs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pulpwood | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Composite products | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fuelwood (including residential)[a] | 1,317 | 6 | 1,323 | 29,691 | 300 | 29,991 | 31,007 | 307 | 31,314 |
| Posts, poles, and pilings | 482 | 6 | 488 | 895 | 0 | 895 | 1,377 | 6 | 1,383 |
| Miscellaneous products | 389 | 608 | 997 | 771 | 264 | 1,035 | 1,160 | 873 | 2,033 |
| Total roundwood products | 7,288 | 1,712 | 9,000 | 38,397 | 626 | 39,023 | 45,685 | 2,338 | 48,023 |
| Logging residues | 330 | 94 | 424 | 1,992 | 298 | 2,289 | 2,322 | 392 | 2,713 |
| Total timber removals | 7,618 | 1,806 | 9,424 | 40,389 | 924 | 41,313 | 48,006 | 2,730 | 50,736 |

[a] Includes residential fuelwood consumption reported by U.S. Energy Information Administration http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US#Consumption.

**Table F3**—Mean water, carbon, and nitrogen contents of forest floor and soil cores by forest type, Colorado, visit 1, 2000–2010.

| Forest type | Soil layer cm | Number of plots | Water content[a] % | Organic carbon % | Inorganic carbon % | Total nitrogen % | C/N ratio | Forest floor mass[a] Mg/ha | Organic carbon Mg/ha | Total nitrogen Mg/ha |
|---|---|---|---|---|---|---|---|---|---|---|
| Western hardwoods group[b] | Forest floor | 31 | 17.21 | 29.55 | — | 1.127 | 26.7 | 11.17 | 3.361 | 0.129 |
| | 0–10 | 22 | 8.36 | 3.09 | 0.33 | 0.244 | 12.6 | — | 23.746 | 1.908 |
| | 10–20 | 22 | 9.56 | 2.00 | 0.29 | 0.157 | 12.9 | — | 17.314 | 1.360 |
| Pinyon/Juniper group[c] | Forest floor | 61 | 8.32 | 25.29 | — | 0.731 | 35.8 | 8.71 | 2.226 | 0.066 |
| | 0–10 | 49 | 5.00 | 1.95 | 0.41 | 0.156 | 12.5 | — | 16.588 | 1.328 |
| | 10–20 | 39 | 5.65 | 1.18 | 0.47 | 0.095 | 12.5 | — | 10.403 | 0.843 |
| Ponderosa pine | Forest floor | 27 | 12.50 | 33.99 | — | 0.770 | 44.6 | 14.86 | 4.974 | 0.117 |
| | 0–10 | 23 | 4.40 | 2.20 | 0.21 | 0.125 | 17.7 | — | 15.647 | 0.884 |
| | 10–20 | 20 | 3.94 | 1.08 | 0.14 | 0.057 | 19.0 | — | 9.015 | 0.474 |
| Lodgepole pine | Forest floor | 24 | 47.90 | 37.99 | — | 0.939 | 41.2 | 31.47 | 12.062 | 0.293 |
| | 0–10 | 20 | 11.98 | 3.07 | 0.17 | 0.102 | 30.4 | — | 17.902 | 0.594 |
| | 10–20 | 20 | 7.34 | 0.95 | 0.11 | 0.026 | 36.1 | — | 8.327 | 0.230 |
| Douglas-fir | Forest floor | 15 | 19.33 | 30.53 | — | 0.869 | 37.0 | 21.69 | 6.679 | 0.192 |
| | 0–10 | 13 | 5.83 | 3.51 | 0.20 | 0.206 | 17.4 | — | 19.844 | 1.146 |
| | 10–20 | 10 | 6.93 | 1.40 | 0.22 | 0.088 | 16.6 | — | 10.137 | 0.616 |
| Cottonwood/aspen group | Forest floor | 37 | 27.19 | 29.57 | — | 1.145 | 26.0 | 20.93 | 6.172 | 0.242 |
| | 0–10 | 29 | 10.51 | 4.05 | 0.31 | 0.275 | 14.9 | — | 26.781 | 1.846 |
| | 10–20 | 28 | 7.83 | 2.11 | 0.23 | 0.159 | 13.1 | — | 17.214 | 1.317 |
| Spruce/fir group[d] | Forest floor | 52 | 36.99 | 33.99 | — | 1.038 | 34.1 | 27.87 | 9.611 | 0.295 |
| | 0–10 | 36 | 16.24 | 4.99 | 0.25 | 0.237 | 20.7 | — | 19.888 | 0.967 |
| | 10–20 | 24 | 12.21 | 2.24 | 0.19 | 0.109 | 20.3 | — | 12.848 | 0.630 |
| High-elevation white pine group | Forest floor | 3 | 9.25 | 24.36 | — | 0.618 | 41.7 | 10.55 | 2.987 | 0.072 |
| | 0–10 | 2 | 5.04 | 2.96 | 0.34 | 0.119 | 25.0 | — | 10.680 | 0.437 |
| | 10–20 | 2 | 4.92 | 1.91 | 0.15 | 0.065 | 29.6 | — | 8.783 | 0.303 |

[a] Water content and forest floor mass are reported on an oven-dry weight basis (105 degrees C).

[b] Western hardwoods group includes deciduous oak woodland.

[c] Pinyon/juniper group includes Rocky Mountain juniper, juniper woodland, and pinyon/juniper woodland.

[d] Spruce/fir group includes white fir, blue spruce, Engelmann spruce, subalpine fir, and mixed Engelmann spruce/subalpine fir.

**Table F4—**Mean physical and chemical properties of soil cores by forest type, Colorado, visit 1, 2000-2010.

| Forest type | Soil layer cm | Number of plots | SQI % | Bulk density g/cm3 | Coarse fragments % | pH H2O | pH CaCl2 | Bray 1 extractable phosphorus mg/kg | Olsen extractable phosphorus mg/kg |
|---|---|---|---|---|---|---|---|---|---|
| Western hardwood group | 0–10 | 22 | 72 | 1.07 | 23.92 | 6.73 | 6.28 | 18.3 | 11.5 |
| | 10–20 | 22 | 66 | 1.29 | 26.61 | 6.68 | 6.16 | 10.3 | 5.0 |
| Pinyon/juniper group | 0–10 | 49 | 64 | 1.15 | 20.09 | 7.30 | 6.83 | 6.4 | 6.7 |
| | 10–20 | 39 | 58 | 1.30 | 27.25 | 7.40 | 6.87 | 3.5 | 2.3 |
| Ponderosa pine | 0–10 | 23 | 67 | 1.19 | 31.90 | 6.36 | 5.76 | 19.4 | 8.6 |
| | 10–20 | 20 | 57 | 1.48 | 39.62 | 6.54 | 5.84 | 11.1 | 3.6 |
| Lodgepole pine | 0–10 | 20 | 63 | 0.91 | 27.18 | 5.30 | 4.71 | 19.0 | 13.6 |
| | 10–20 | 20 | 56 | 1.35 | 33.78 | 5.47 | 4.77 | 22.4 | 10.3 |
| Douglas-fir | 0–10 | 13 | 71 | 0.97 | 36.46 | 6.80 | 6.35 | 28.4 | 16.8 |
| | 10–20 | 10 | 64 | 1.26 | 42.19 | 6.80 | 6.26 | 22.5 | 11.5 |
| Cottonwood/aspen group | 0–10 | 29 | 72 | 0.91 | 20.58 | 6.25 | 5.73 | 19.4 | 9.1 |
| | 10–20 | 28 | 68 | 1.16 | 23.91 | 6.28 | 5.70 | 15.3 | 8.6 |
| Spruce/fir group | 0–10 | 36 | 72 | 0.75 | 30.97 | 5.93 | 5.39 | 18.6 | 16.3 |
| | 10–20 | 24 | 64 | 1.12 | 37.74 | 5.79 | 5.20 | 14.5 | 7.9 |
| High-elevation white pine group | 0–10 | 2 | 69 | 1.08 | 51.88 | 7.12 | 6.59 | 10.8 | 4.0 |
| | 10–20 | 2 | 65 | 1.28 | 56.31 | 6.65 | 6.18 | 9.2 | 4.9 |

SQI = Soil Quality Index

**Table F5—**Mean exchangeable cation concentrations in soil cores by forest type, Colorado, visit 1, 2000–2010.

| Forest type | Soil layer cm | Number of plots | 1 M NH4Cl Exchangeable cations (mg/kg) Na | K | Mg | Ca | Al | ECEC cmolc/kg |
|---|---|---|---|---|---|---|---|---|
| Western hardwood group | 0–10 | 22 | 16 | 279 | 290 | 3266 | 0 | 20.13 |
| | 10–20 | 22 | 26 | 229 | 272 | 3056 | 3 | 18.74 |
| Pinyon/juniper group | 0–10 | 49 | 14 | 201 | 194 | 3517 | 2 | 20.19 |
| | 10–20 | 39 | 24 | 148 | 200 | 3493 | 1 | 19.92 |
| Ponderosa pine | 0–10 | 23 | 10 | 167 | 209 | 1945 | 2 | 11.96 |
| | 10–20 | 20 | 14 | 107 | 158 | 1493 | 8 | 9.22 |
| Lodgepole pine | 0–10 | 20 | 17 | 161 | 118 | 1020 | 64 | 7.58 |
| | 10–20 | 20 | 16 | 108 | 85 | 672 | 78 | 5.40 |
| Douglas-fir | 0–10 | 13 | 4 | 255 | 289 | 3416 | -1 | 20.58 |
| | 10–20 | 10 | 88 | 217 | 361 | 3054 | 6 | 19.44 |
| Cottonwood/aspen group | 0–10 | 29 | 8 | 324 | 254 | 2591 | 4 | 16.02 |
| | 10–20 | 28 | 14 | 253 | 184 | 1927 | 4 | 12.08 |
| Spruce/fir group | 0–10 | 36 | 30 | 290 | 274 | 2666 | 61 | 18.14 |
| | 10–20 | 24 | 29 | 178 | 228 | 1718 | 73 | 13.77 |
| High-elevation white pine group | 0–10 | 2 | 21 | 401 | 186 | 2475 | 1 | 15.27 |
| | 10–20 | 2 | 14 | 427 | 212 | 2259 | 0 | 14.23 |

**Table F6—**Mean extractable trace element concentrations in soil cores by forest type, Colorado, visit 1, 2000-2010.

| | | | 1 M NH4Cl extractable | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soil layer | Number of plots | Mn | Fe | Ni | Cu | Zn | Cd | Pb | S |
| Forest type | cm | | mg/kg | | | | | | | |
| Western hardwood group | 0–10 | 22 | 5.2 | 0.01 | 0.05 | 0.00 | 0.02 | 0.09 | 0.05 | 511.1 |
| | 10–20 | 22 | 6.0 | 0.32 | 0.03 | 0.04 | 0.07 | 0.04 | 0.14 | 489.8 |
| Pinyon/juniper group | 0–10 | 49 | 4.9 | 0.18 | 0.06 | 0.00 | 1.85 | 0.15 | 0.26 | 166.3 |
| | 10–20 | 39 | 3.4 | 0.07 | 0.01 | 0.05 | 0.03 | 0.02 | 0.20 | 129.7 |
| Ponderosa pine | 0–10 | 23 | 24.0 | 0.04 | 0.04 | 0.00 | 0.41 | 0.12 | 0.14 | 7.1 |
| | 10–20 | 20 | 10.2 | 0.14 | 0.03 | 0.04 | 0.26 | 0.06 | 0.11 | 6.3 |
| Lodgepole pine | 0–10 | 20 | 47.0 | 7.01 | 0.06 | 0.00 | 1.25 | 0.10 | 0.46 | 9.8 |
| | 10–20 | 20 | 8.9 | 6.14 | 0.02 | 0.03 | 1.44 | 0.05 | 0.47 | 6.4 |
| Douglas-fir | 0–10 | 13 | 13.4 | 0.22 | 0.02 | 0.00 | 0.16 | 0.12 | 0.21 | 16.2 |
| | 10–20 | 10 | 5.9 | 0.01 | 0.06 | 0.01 | 0.02 | 0.02 | 0.14 | 44.8 |
| Cottonwood/aspen group | 0–10 | 29 | 13.9 | 0.18 | 0.12 | 0.00 | 0.09 | 0.08 | 0.15 | 9.5 |
| | 10–20 | 28 | 9.7 | 0.41 | 0.01 | 0.00 | 0.16 | 0.03 | 0.15 | 17.6 |
| Spruce/fir group | 0–10 | 36 | 33.0 | 3.10 | 0.06 | 0.00 | 0.66 | 0.12 | 0.22 | 8.1 |
| | 10–20 | 24 | 13.3 | 2.57 | 0.06 | 0.03 | 0.93 | 0.07 | 0.38 | 27.8 |
| High-elevation white pine group | 0–10 | 2 | 7.8 | 0.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 7.6 |
| | 10–20 | 2 | 6.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.09 | 22.8 |

**Table F7—**Mean water, carbon, and nitrogen contents of forest floor and soil cores by forest type, Colorado, visit 2, 2005–2013.

| Forest type | Soil layer (cm) | Number of plots | Water content[a] (%) | Organic carbon (%) | Inorganic carbon (%) | Total nitrogen (%) | C/N ratio | Forest floor mass[a] (Mg/ha) | Organic carbon (Mg/ha) | Total nitrogen (Mg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Western hardwoods group[b] | Forest floor | 21 | 21.99 | 22.56 | — | 0.189 | 13.9 | 13.77 | 24.25 | 1.644 |
| | 0–10 | 20 | 11.32 | 2.62 | 0.18 | 0.116 | 12.2 | — | 12.75 | 0.973 |
| | 10–20 | 18 | 11.57 | 1.52 | 0.18 | 0.127 | 12.6 | — | 14.88 | 1.202 |
| Pinyon/juniper group[c] | Forest floor | 49 | 8.70 | 25.12 | — | 0.091 | 11.4 | 10.44 | 9.66 | 0.852 |
| | 0–10 | 47 | 5.13 | 1.55 | 0.38 | 0.124 | 19.8 | — | 22.01 | 1.098 |
| | 10–20 | 44 | 6.17 | 1.01 | 0.53 | 0.063 | 18.6 | — | 10.39 | 0.550 |
| Ponderosa pine | Forest floor | 20 | 18.93 | 28.41 | — | 0.081 | 26.8 | 25.55 | 16.84 | 0.645 |
| | 0–10 | 20 | 9.31 | 2.52 | 0.15 | 0.045 | 26.3 | — | 8.91 | 0.342 |
| | 10–20 | 20 | 8.13 | 1.19 | 0.10 | 0.185 | 15.9 | — | 21.62 | 1.235 |
| Lodgepole pine | Forest floor | 13 | 43.59 | 35.99 | — | 0.111 | 16.5 | 42.65 | 13.66 | 0.885 |
| | 0–10 | 13 | 14.09 | 2.14 | 0.08 | 0.224 | 15.2 | — | 24.28 | 1.555 |
| | 10–20 | 11 | 6.20 | 1.19 | 0.09 | 0.105 | 15.5 | — | 14.14 | 0.835 |
| Douglas-fir | Forest floor | 9 | 28.37 | 28.79 | — | 0.196 | 19.3 | 40.57 | 21.57 | 1.165 |
| | 0–10 | 7 | 8.66 | 2.96 | 0.26 | 0.102 | 17.8 | — | 11.74 | 0.675 |
| | 10–20 | 7 | 7.37 | 1.72 | 0.21 | 0.041 | 18.7 | — | 9.46 | 0.315 |
| Cottonwood/aspen group | Forest floor | 25 | 37.62 | 27.22 | — | 0.047 | 13.2 | 34.55 | 8.83 | 0.483 |
| | 0–10 | 24 | 12.39 | 3.34 | 0.17 | 0.189 | 13.9 | — | 24.25 | 1.644 |
| | 10–20 | 21 | 9.47 | 1.77 | 0.13 | 0.116 | 12.2 | — | 12.75 | 0.973 |
| Spruce/fir groupd | Forest floor | 28 | 53.65 | 27.36 | — | 0.127 | 12.6 | 48.77 | 14.88 | 1.202 |
| | 0–10 | 30 | 18.99 | 3.43 | 0.17 | 0.091 | 11.4 | — | 9.66 | 0.852 |
| | 10–20 | 28 | 14.15 | 1.66 | 0.10 | 0.124 | 19.8 | — | 22.01 | 1.098 |
| High-elevations white pine group | Forest floor | 1 | 7.31 | 43.33 | — | 0.063 | 18.6 | 26.04 | 10.39 | 0.550 |
| | 0–10 | 2 | 4.55 | 1.69 | 0.07 | 0.081 | 26.8 | — | 16.84 | 0.645 |
| | 10–20 | 2 | 5.88 | 1.33 | 0.06 | 0.045 | 26.3 | — | 8.91 | 0.342 |

[a] Water content and forest floor mass are reported on an oven-dry weight basis (105 degrees C).

[b] Western hardwoods group includes deciduous oak woodland.

[c] Pinyon/juniper group includes Rocky Mountain juniper, juniper woodland, and pinyon/juniper woodland.

[d] Spruce/fir group includes white fir, blue spruce, Engelmann spruce, subalpine fir, and mixed Engelmann spruce/subalpine fir.

**Table F8—**Mean physical and chemical properties of soil cores by forest type, Colorado, visit 2, 2005–2013.

| Forest type | Soil layer | Number of plots | SQI | Bulk density | Coarse fragments | pH | | Bray 1 extractable phosphorus | Olsen extractable phosphorus |
|---|---|---|---|---|---|---|---|---|---|
| | cm | | % | $g/cm^3$ | % | $H_2O$ | $CaCl_2$ | mg/kg | mg/kg |
| Western hardwood group | 0–10 | 20 | 71 | 1.22 | 22.87 | 6.42 | 5.94 | 24.2 | 9.7 |
| | 10–20 | 18 | 61 | 1.45 | 32.94 | 6.53 | 5.97 | 10.7 | 4.6 |
| Pinyon/juniper group | 0–10 | 47 | 61 | 1.23 | 19.77 | 7.35 | 6.91 | 7.8 | 5.7 |
| | 10–20 | 44 | 55 | 1.41 | 28.39 | 7.42 | 6.93 | 1.8 | 2.8 |
| Ponderosa pine | 0–10 | 20 | 69 | 1.29 | 28.50 | 6.26 | 5.71 | 18.6 | 9.7 |
| | 10–20 | 20 | 59 | 1.52 | 39.37 | 6.38 | 5.78 | 12.6 | 6.0 |
| Lodgepole pine | 0–10 | 13 | 59 | 1.07 | 23.78 | 5.23 | 4.67 | 18.7 | 11.0 |
| | 10–20 | 11 | 54 | 1.26 | 34.18 | 5.33 | 4.73 | 19.1 | 11.7 |
| Douglas-fir | 0–10 | 7 | 70 | 1.14 | 37.80 | 6.75 | 6.32 | 41.8 | 19.4 |
| | 10–20 | 7 | 62 | 1.38 | 38.60 | 6.83 | 6.35 | 27.1 | 13.4 |
| Cottonwood/aspen group | 0–10 | 24 | 72 | 1.03 | 26.72 | 6.17 | 5.76 | 28.0 | 15.0 |
| | 10–20 | 21 | 66 | 1.26 | 30.51 | 6.25 | 5.76 | 16.6 | 8.6 |
| Spruce/fir group | 0–10 | 30 | 70 | 0.95 | 27.25 | 5.54 | 5.13 | 22.1 | 16.5 |
| | 10–20 | 28 | 62 | 1.27 | 35.82 | 5.52 | 4.98 | 13.8 | 10.5 |
| High-elevation white pine group | 0–10 | 2 | 66 | 0.98 | 37.59 | 7.01 | 6.40 | 18.0 | 10.1 |
| | 10–20 | 2 | 73 | 1.25 | 41.45 | 6.84 | 6.37 | 14.9 | 11.2 |

SQI = Soil Quality Index

**Table F9—**Mean exchangeable cation concentrations in soil cores by forest type, Colorado, visit 2, 2005–2013.

| Forest type | Soil layer | Number of plots | 1 M NH4Cl exchangeable cations | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Mg | Ca | Al | ECEC |
| | cm | | | | | mg/kg | | cmolc/kg |
| Western hardwood group | 0–10 | 20 | 40 | 248 | 307 | 2670 | 0 | 17.34 |
| | 10–20 | 18 | 32 | 194 | 290 | 2533 | 3 | 16.40 |
| Pinyon/juniper group | 0–10 | 47 | 45 | 165 | 171 | 3187 | 0 | 18.50 |
| | 10–20 | 44 | 48 | 134 | 168 | 3293 | 1 | 18.91 |
| Ponderosa pine | 0–10 | 20 | 12 | 181 | 221 | 1887 | 1 | 11.89 |
| | 10–20 | 20 | 20 | 140 | 187 | 1702 | 2 | 10.62 |
| Lodgepole pine | 0–10 | 13 | 39 | 109 | 115 | 882 | 74 | 7.03 |
| | 10–20 | 11 | 37 | 49 | 92 | 625 | 89 | 5.64 |
| Douglas-fir | 0–10 | 7 | 13 | 354 | 242 | 2823 | 2 | 16.92 |
| | 10–20 | 7 | 18 | 204 | 201 | 2522 | 1 | 15.12 |
| Cottonwood/aspen group | 0–10 | 24 | 33 | 264 | 214 | 2078 | 4 | 13.58 |
| | 10–20 | 21 | 38 | 237 | 167 | 1724 | 2 | 11.13 |
| Spruce/fir group | 0–10 | 30 | 35 | 176 | 216 | 2127 | 30 | 14.04 |
| | 10–20 | 28 | 57 | 140 | 188 | 1475 | 45 | 10.93 |
| High-elevation white pine group | 0–10 | 2 | 15 | 483 | 242 | 2329 | 0 | 15.22 |
| | 10–20 | 2 | 34 | 692 | 340 | 2669 | 0 | 18.31 |

**Table F10—**Mean extractable trace element concentrations in soil cores by forest type, Colorado, visit 2, 2005-2013.

| Forest type | Soil layer (cm) | Number of plots | Mn | Fe | Ni | Cu | Zn | Cd | Pb | S |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 M NH4Cl extractable (mg/kg) | | | | | | | |
| Western hardwood group | 0–10 | 20 | 7.7 | 0.36 | 0.02 | 0.00 | 0.02 | 0.04 | 0.12 | 476.7 |
| | 10–20 | 18 | 6.0 | 0.18 | 0.05 | 0.00 | –0.02 | 0.03 | 0.16 | 443.0 |
| Pinyon/juniper group | 0–10 | 47 | 2.4 | 0.17 | –0.01 | 0.00 | 1.43 | 0.07 | 0.08 | 289.3 |
| | 10–20 | 44 | 1.9 | 0.10 | 0.00 | 0.01 | –0.10 | 0.01 | 0.11 | 507.8 |
| Ponderosa pine | 0–10 | 20 | 13.3 | 0.38 | 0.00 | 0.00 | 0.22 | 0.08 | 0.08 | 2.6 |
| | 10–20 | 20 | 12.0 | 0.40 | 0.04 | 0.01 | –0.01 | 0.03 | 0.15 | 2.5 |
| Lodgepole pine | 0–10 | 13 | 22.2 | 11.17 | 0.02 | 0.00 | 0.40 | 0.04 | 0.76 | 4.3 |
| | 10–20 | 11 | 10.3 | 11.98 | 0.00 | -0.01 | –0.51 | 0.01 | 0.41 | 2.6 |
| Douglas-fir | 0–10 | 7 | 12.1 | 0.23 | 0.00 | 0.00 | 0.12 | 0.06 | 0.10 | –3.6 |
| | 10–20 | 7 | 4.6 | 0.02 | 0.00 | 0.00 | 0.02 | 0.03 | 0.05 | –22.0 |
| Cottonwood/aspen group | 0–10 | 24 | 16.7 | 0.59 | 0.03 | 0.00 | 0.18 | 0.06 | 0.19 | 16.2 |
| | 10–20 | 21 | 9.8 | 0.04 | 0.00 | 0.00 | –0.05 | 0.03 | 0.09 | 12.5 |
| Spruce/fir group | 0–10 | 30 | 54.1 | 5.59 | 0.04 | 0.00 | 0.43 | 0.11 | 1.76 | 17.6 |
| | 10–20 | 28 | 18.4 | 4.96 | 0.09 | 0.01 | 0.05 | 0.06 | 0.16 | 19.3 |
| High-elevation white pine group | 0–10 | 2 | 6.3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 8.8 |
| | 10–20 | 2 | 7.2 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 9.2 |

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