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Utah's Forest Resources, 2003–2012

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Abstract

This report presents a summary of the most recent inventory of Utah's forests based on field data collected from 2003 through 2012. The report includes descriptive highlights and tables of area, numbers of trees, biomass, 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 Utah's forest land area totals 18.3 million acres. Fifteen percent (2.8 million acres) of this forest land is privately owned, and another 35 percent (6.3 million acres) is administered by the United States Department of Agriculture (USDA) Forest Service. The pinyon/juniper forest-type group which, is comprised of juniper woodland, pinyon/juniper woodland, and Rocky Mountain juniper forest types, is the most predominant group covering more than 10.7 million acres and accounts for 59 percent of the forest land in Utah. The State's most predominant forest type is pinyon/juniper woodland covering nearly 8 million acres and accounts for 44 percent of the forest land in Utah. Gambel oak is the most abundant tree species by number of trees, and Utah juniper is the most abundant by volume or biomass. Utah's forests contain 15.3 billion cubic feet of net volume in trees 5.0 inches in diameter and larger. Gross growth of all live trees 5.0 inches in diameter and larger averaged 207.2 million cubic feet per year. Average annual mortality totaled 256.7 million cubic feet per year, resulting in a negative net growth of –49.5 million cubic feet per year.

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Report Highlights

Forest Area

- Utah's forest land area totals 18.3 million acres.
- Unreserved forest land accounts for most of the forest land area in Utah (89 percent) and totals 16.3 million acres.
- Twenty-one percent of Utah's unreserved forest land is classified as timberland and 69 percent is classified as unproductive forest land.
- Nearly 35 percent of Utah's total forest land area, about 6.3 million acres, is administered by the USDA Forest Service.
- The pinyon/juniper forest-type group which, is comprised of juniper woodland, pinyon/juniper woodland, and Rocky Mountain juniper forest types, is the most predominant group covering more than 10.7 million acres and accounts for 59 percent of the total forest land area in Utah.
- The woodland hardwoods, aspen/birch, and fir/spruce/mountain hemlock forest-type groups are the next three most predominant groups in Utah covering nearly 2.5, 1.6, and 1.5 million acres respectively.
- The State's most predominant forest type is pinyon/juniper woodland covering nearly 8 million acres and accounts for 44 percent of the total forest land area in Utah.

Numbers of Trees, Volume, and Biomass

- There are an estimated 7.6 billion live trees in Utah.
- Softwood species total 3.4 billion trees or 45 percent of all live trees.
- The total number of trees in the woodland hardwoods species group is 3.4 billion making this group the most predominant in Utah.
- The total number of Gambel oak trees, which are part of the woodlands hardwoods species group, is more than 2.7 billion, making this species the single most abundant in Utah.
- The net volume of live trees on forest land in Utah is 15.3 billion cubic feet.
- Growing-stock volume on timberland in Utah is 6.4 billion cubic feet, or 42 percent of the total live volume on forest land.
- Softwoods constitute 75 percent of the growing-stock volume in Utah.
- Net volume of sawtimber trees on timberland in Utah is 24.5 billion board feet (International ¼-inch rule).
- The aboveground biomass weight (oven-dry) of live trees on forest land in Utah is 298 million tons.

Forest Growth, Mortality, and Removals

- Estimated gross annual growth of all live trees 5.0 inches in diameter and larger on forest land in Utah was nearly 207.2 million cubic feet.
- Estimated annual mortality of trees 5.0 inches in diameter and larger on forest land in Utah was 256.7 million cubic feet. Net annual growth totaled –49.5 million cubic feet.

- Negative net growth was recorded for six of Utah's eight major tree species. The only major tree species with positive net growth were quaking aspen and Utah juniper.
- Total removals from Utah's forests during 2007 were just over 16.0 million cubic feet.
- Utah's timber harvest in 2012 was 19.4 million board feet Scribner rule, just one-third of what it was in 1992. In 2007, Utah's timber harvest was about one-half of the 1992 level; in 2002 it was about two-thirds of the 1992 level. These decreases in harvest volume were largely the result of harvest reductions from national forests.

Current Issues in Utah's Forests

- Mortality of pinyons in Utah during the 2000s appears to be lower than the average percentage of mortality of pinyons in all Interior West States combined, which was about 4 to 5 percent of the total basal area.
- For the current inventory, there are just over 1.6 million acres of the aspen forest type in Utah, as compared to 1.4 million acres found during the 1993 inventory.
- Woodland species accounted for 35,471 of the tallied trees and 78 percent of these trees had no damage. Form defect was the most frequently recorded damage agent group occurring in about 12 percent of these woodland species.
- Timber species accounted for 23,572 of the tallied trees, and 52 percent had no damage. Like the woodland species, form defect was the most frequently recorded damage group (at about 35 percent).
- Monitoring Trends in Burn Severity program showed that 292 fire perimeters from 224 different fires burned just over 2 million acres in Utah between 2003 and 2012.
- Canada thistle (*Cirsium arvense*) and nodding plumeless thistle (*Carduus nutans*) were the most common noxious weed species. These two species accounted for 77 percent of the noxious weed occurrences on Utah's forest lands.

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Introduction

Utah encompasses a wide variety of environments and forest types that are valued for their scenic beauty, wood products, wildlife habitat, and ecological functions. This report contains highlights of the status of Utah's forest resources, with discussions of pertinent issues based on 10 years of inventory under the United States Department of Agriculture (USDA) Forest Service's Forest Inventory and Analysis (FIA) annual data-collection system (Gillespie 1999).

The most recent annual report for Utah (DeBlander and others 2010) was based on inventory data from 2000 through 2005. With this current annual report for Utah, 13 years of annual inventory data were available (2000 through 2012) and were used for certain trend analyses. However, the most recent 10 years of data (2003 through 2012) were used for current status.

This chapter briefly describes the implementation of the national FIA sample design in Utah, as well as some basic differences between this inventory and previous inventories of Utah's forests. The following chapters describe specific inventory methods; an overview of traditional forest attributes measured by the FIA program, such as forest land area and timber volume; descriptions of selected resources that Utah's forests provide; and, current issues and events affecting Utah's forests.The appendices contain supplemental information including: a glossary of terms used in this report; descriptions of forest types and forest-type groups; lists of tree species and tree species groups; and, documentation for the equations used to produce estimates of tree volume and site index.

Utah's Annual Forest Inventory

The annual inventory of Utah's forests follows sampling procedures specified by federal legislation and the national 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 every 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 terms and definitions). The year in which each plot was actually surveyed is recorded as its measurement year. In most States, inventory year and measurement year are the same for almost all field plots.

This report is based on aggregated data from a complete inventory of 10 subpanels collected in the period 2003–2012. The aggregated dataset consists of 8,853 plots, where 3,176 plots contained at least one forested condition, and 5,677 plots were entirely nonforest.

Accessing Utah's Forest Inventory Data

The national FIA database contains data from the 1993 periodic inventory of Utah as well as annual forest inventory data, which is updated each year as additional measurements are collected. Although collected over a span of several years, the periodic inventory is assigned an inventory year of 1993. Data collected as part of the annual inventory are assigned an inventory year that corresponds to the year in which the plot was scheduled for measurement on the 10-year remeasurement cycle. Groups of inventory years that can be used to make forest population estimates are called evaluations. The FIA database currently supports seven annual evaluation groups: 2000–2008 (nine subpanels), 2000–2009, 2001–2010, 2002–2011, 2003–2012, 2004-2013, and 2005-2014.

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 Phase 3 data. Tables B1 through B39g in Appendix B summarize annual forest inventory data collected in Utah between 2003 and 2012 in terms of traditional FIA attributes. These tables present statistics for land area, numbers of trees, wood volume, biomass (oven-dry weight), growth, mortality, sampling errors, and mean forest soil properties. 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 (scheduled to be visited but not sampled due to inaccessibility, denied access, or other reasons). All other tables exclude nonforest land and therefore include only accessible forest land or timberland (see Appendix A for standard FIA terms and definitions). Table B37 shows sampling errors for area, volume, net growth, and mortality on timberland as a percentage of the estimate.

This report also contains supplemental tables within the body of the report. To avoid confusion between supplemental tables found in the report chapters and the standard forest resource tables in Appendix B, supplemental tables in the report chapters are labeled consecutively as they appear, beginning with table 1. Standard forest resource tables will be referred to beginning with the appendix letter followed by the table number (e.g., table B1)

Inventory Methods

This chapter briefly describes five key aspects of the Forest Inventory and Analysis (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 Utah.

Plot Configuration

The national FIA plot design consists of four 24-foot-radius subplots configured as a central subplot and three peripheral subplots (USDA FS 2011; 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 5.0 inches and 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. or d.r.c. from 1.0 inch to 4.9 inches is also measured.

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 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

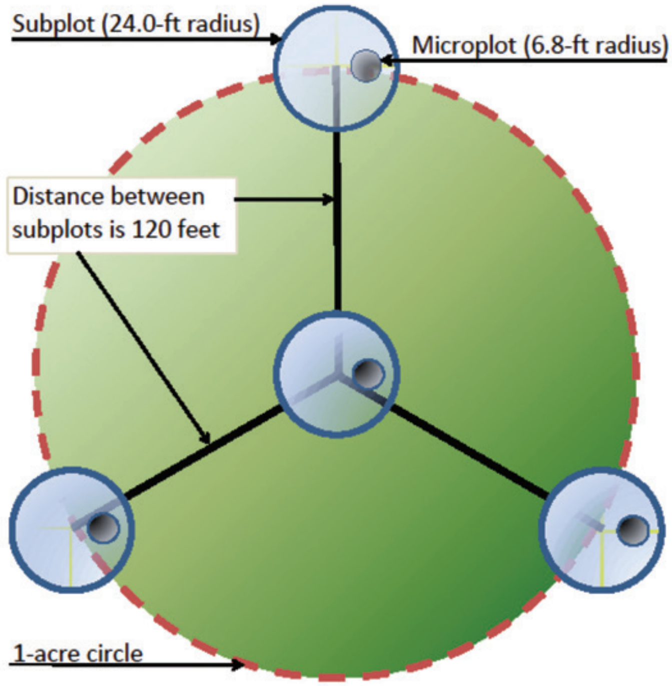


Figure 1—Plot configuration used by the Forest Inventory and Analysis program. Each plot consists of four subplots with a 24-foot radius. The three outer subplots are located 120 feet from the central subplot's center at azimuths of 360 (0), 120, and 240 degrees. Microplots with radii of 6.8 feet are located on each subplot, and the microplot centers are located 12 feet from the subplot center at an azimuth of 90 degrees.

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 or stand size, or both; 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 historical 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 by using procedures designed to preserve existing plot locations from previous inventories. These sample plots, designated as the federal base sample, were divided into 5 spatially interpenetrating panels and 10 subpanels, where each panel consists of 2 subpanels. In the eastern United States, two subpanels are measured each year such that the inventory cycle is on a 5-year rotation. In the western United States, including Utah, 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

Inventories are conducted 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 standard FIA terms and 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 and others 2008). Calibration data in Utah 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 before 2004. In Utah, 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 land owners 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, such as sheer cliffs, or temporary hazards, such as 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 and others 2012). The overall nonresponse rate in Utah's forest inventory was relatively low at less than 4 percent. However, nonresponse occurs at a higher rate in the forest stratum (6 percent) than in the nonforest stratum (2 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.

Estimates are made 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 made up of groups of counties, and smaller estimation units that represent individual counties. Utah consists of five survey units and 29 estimation units denoted as g, each containing n_g ground plots. The area of each estimation unit is divided into strata of known size by using the State's stratification map, which assigns each 250-meter 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 Utah 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 stratum h in estimation unit g

n_{hg} = total number of Phase 2 plots that have at least one sampled condition

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 pre-field interpretation, and it was historically considered part of Phase 1 because both pre-field interpretation and Phase 1 relied on remote sensing data. However, Phase 1 delineation of forest and nonforest strata occurs independently of current pre-field interpretation of the Phase 2 grid. Therefore, pre-field 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 pre-field 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 for standard FIA terms and definitions). 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 cannot obtain permission to reach the plot. 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 shows the total percentage of Phase 2 plot areas that represent forest, nonforest, and non-sampled conditions.

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 productivity class, forest disturbance history, silvicultural treatment, slope, aspect, and physiographic class. Some of these area attributes are measured or observed (such as regeneration status), some are assigned by definition (for example, ownership group), and some are computed from tree data (for example, 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 Utah's forest inventory are described in detail in the FIA field guide (USDA FS 2011). 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.

Understory vegetation and down woody materials data are typically collected as part of FIA's national Phase 3 protocols. However, Interior West FIA collects these data on all Phase 2 plots. In Utah, understory vegetation data have been collected since implementation of the annual inventory in 2000, and down woody materials data have been collected since 2006.

Phase 3—The third phase of the enhanced FIA program focuses on forest and ecosystem health. The Phase 3 sample consists of a one-sixteenth subset of the Phase 2 plots, which equates to one Phase 3 plot for approximately every 96,000 acres. In the Interior West, Phase 3 plots include all the measurements collected on Phase 2 plots, plus an extended suite of ecological data pertaining to soil samples, lichen communities, and tree crowns. 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. In 2011, FIA made the decision to discontinue the national Phase 3 data collection effort, although some Phase 3 variables continued to be collected after 2011. Starting in 2015, the Phase 3 sample of soil properties will be replaced with a new soils grid within the Phase 2 sample.

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 2003–2012 FIA inventory of Utah is based on a sample of 8,853 plots (not including 318 nonresponse plots) systematically located across the State. The total area of Utah is 54.3 million acres, so the sampling rate is approximately one plot for every 6,134 acres.

The statistical estimation procedures used to estimate 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 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.

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:

$$SE_s = SE_t \frac{\sqrt{X_t}}{\sqrt{X_s}}$$

where

SE_s = sampling error for subdivision of State total

SE_t = sampling error for State total

X_s = sum of values for the variable of interest (for example, area, volume, or biomass) for subdivision of State total

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 (such as 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. 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

To ensure the quality of all collected data, FIA uses a quality assurance (QA) program. The goal of the program is to provide 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 quality control process operates via data quality inspectors, who assess individual field crews during hot checks and cold checks and then provide timely feedback to improve the crews' performance. During a hot check, an inspector accompanies field crewmembers 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.

The second facet of FIA's QA program is quality assessment, which evaluates the overall precision of field measurements by comparing two independent measurements of the same plot. Specific measurement quality objectives (MQOs) for precision are designed to provide a performance objective that FIA strives to achieve for every field measurement. 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. The practicality of these MQOs, as well as the measurement uncertainty associated with a given field measurement, can be tested by comparing data from blind check plots. Blind check data consist of paired observations where, in addition to the field measurements of the standard FIA crew, a second QA measurement of the plot is taken by a crew without knowledge of the first crew's results (Pollard and others 2006). Therefore, for many FIA variables, the data quality is measured by the repeatability of two independent measurements.

Quality assessment data for Utah's current inventory were collected between 2001 and 2012. Each year about 3 percent of all forest plots were visited by a blind check crew. 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. Tolerances define the acceptable range of variability between two independent observations. Each variable and its associated 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 times out of the total records the data fell outside the tolerance. For example, table 2 shows that there were 913 paired records for the variable "DBH" (diameter at breast height). At the 1× tolerance level, about 90 percent of those records fell within plus or minus 0.1 inch of each other, for each 20.0 inches of d.b.h. observed. This percentage is referred to as the observed compliance rate. Each variable's MQOs consist of two parts: a compliance standard, which is compared to the observed compliance rate, and a measurement tolerance.

Table 1—Results of quality assessment for condition-level variables, Utah, 2001-2012.

		Percentage of data within tolerance				Number of times data exceeded tolerance				
Variable	Tolerance	@1x	@2x	@3x	@4x	@1x	@2x	@3x	@4x	Records
National Variables										
Condition Status	No Tolerance	97.6%				3				126
Reserve Status	No Tolerance	98.4%				2				126
Owner Group	No Tolerance	96.0%				5				126
Owner Class	No Tolerance	95.2%				6				126
Owner Status	No Tolerance	87.5%				1				8
Forest Type	No Tolerance	90.5%				10				105
Stand Size	No Tolerance	87.6%				13				105
Regeneration Status	No Tolerance	99.0%				1				105
Tree Density	No Tolerance	100.0%				0				105
Disturbance 1	No Tolerance	81.0%				20				105
Disturbance Year 1	±1 yr	88.9%	100.0%	100.0%	100.0%	1	0	0	0	9
Disturbance 2	No Tolerance	98.1%				2				105
Disturbance Year 2	±1 yr	100.0%				0				1
Disturbance 3	No Tolerance	99.0%				1				105
Disturbance Year 3	±1 yr	100.0%				0				1
Treatment 1	No Tolerance	100.0%				0				105
Treatment Year 1	±1 yr									
Treatment 2	No Tolerance	100.0%				0				105
Treatment Year 2	±1 yr									
Treatment 3	No Tolerance	100.0%				0				105
Treatment Year 3	±1 yr									
Physiographic Class	No Tolerance	62.9%				39				105
Present Nonforest Use	No Tolerance	100.0%				0				16
Regional Variables										
Percent Crown Cover	±10 %	90.5%	98.1%	100.0%		10	2	0		105
Percent Bare Ground	±10 %	78.1%	90.5%	94.3%	96.2%	23	10	6	4	105
Habitat Type 1	No Tolerance	71.4%				30				105
Habitat Type 2	No Tolerance	65.7%				36				105

Table 2—Results of quality assessment for tree-level variables, Utah, 2001-2012.

Variable	Tolerance	Percentage of data within tolerance				Number of times data exceeded tolerance				Records
		@1x	@2x	@3x	@4x	@1x	@2x	@3x	@4x	
National Variables										
DBH	±0.1 /20 in.	89.8%	96.2%	97.9%	98.4%	93	35	19	15	913
DRC using IW MQO	±0.2 in*#stems	85.4%	93.2%	95.7%	96.5%	316	147	94	76	2,168
Azimuth	±10 °	97.1%	98.6%	98.8%	98.9%	68	32	28	26	2,339
Horizontal Distance	±0.2 /1.0 ft	77.0%	89.8%	94.9%	96.6%	537	239	120	79	2,339
Species	No Tolerance	99.0%				32				3,081
Tree Status	No Tolerance	99.6%				4				1,109
Rotten/Missing Cull	±10 %	96.1%	98.8%	99.3%	99.7%	106	33	19	8	2,722
Total Length	±10 %	77.3%	94.2%	97.9%	98.9%	698	180	66	34	3,081
Actual Length	±10 %	78.4%	94.8%	98.3%	99.1%	625	151	48	27	2,891
Compacted Crown Ratio	±10 %	100.0%	100.0%	100.0%	100.0%	0	0	0	0	2,629
Uncompacted Crown Ratio (P3)	±10 %	93.1%	98.4%	99.7%	99.9%	160	38	8	2	2,315
Crown Class	No Tolerance	11.6%				2323				2,629
Decay Class	±1 class	100.0%				0				446
Cause of Death	No Tolerance	73.5%				40				151
Mortality Year	±2 yr	83.4%	94.7%	98.0%	100.0%	25	8	3	0	151
Condition Class	No Tolerance	99.9%				4				3,081
Regional Variables										
Mistletoe	±1 class	98.6%	99.2%	99.4%	99.7%	38	22	15	8	2,629
Number of Stems	±1 stem	98.2%	98.8%	99.3%	99.7%	38	25	15	6	2,168
Percent Missing Top	±10 %	98.6%	98.8%	98.9%	99.0%	37	34	31	27	2,722
Sound Dead	±10 %	65.1%	69.7%	71.6%	72.7%	949	825	772	742	2,722
Form Defect	±10 %	61.6%	73.5%	82.0%	86.4%	175	121	82	62	456
Current Tree Class	No Tolerance	98.0%				61				3,081
Tree Age	±5 %	23.2%	40.5%	55.9%	68.0%	235	182	135	98	306
Horiz Dist-timberland	±0.2 /1.0 ft	97.2%	98.7%	99.2%	99.5%	26	12	7	5	913
Horiz Dist-woodland	±0.2 /1.0 ft	75.0%	88.4%	93.9%	95.9%	541	251	132	89	2,168

The information in tables 1 and 2 shows variables with varying degrees of repeatability. For example, one condition-level regional variable with high repeatability is "percent crown cover." At the 1× tolerance level, its observed compliance rate was about 91 percent for 105 paired observations that were within plus or minus 10 percent of each other. In contrast, the compliance rate for "habitat type 1," which has no tolerance variability, was only 71 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 rate for habitat types would be higher if we could consider habitat-type groups (or groups of very similar types) in our QA 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 "tree species" was 99 percent. The variables "d.b.h." and "d.r.c." (diameter at root collar) represent the respective diameters of timber and woodland tree species (see Appendix D). Whereas timber species are measured at breast height (4.5 feet above ground level), woodland species are measured near ground level at root collar. The tolerance for d.r.c. is plus or minus 0.2 inch per stem, which allows for larger tolerances on multi-stemmed woodland trees. The 1× compliance rate for d.b.h. was almost 90 percent based on the 0.1-inch tolerance. The 1× compliance rate for d.r.c. was lower, at 85 percent based on the tolerance of 0.2 inch per stem for the whole tree. 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 1× level were about 77 percent and 78 percent, respectively. Tree age was the least repeatable tree-level variable, with a 1× compliance rate of only 23 percent. This low compliance rate probably reflects the difficulty of obtaining accurate tree ages. Several factors that might contribute to inconsistency among recorded tree ages are (1) tree too large to reach the center, (2) rings too close or too faint to read accurately, and (3) variation in age estimation when cores do not include tree center, or pith. Although not much can be done to mitigate the first situation, the second situation could be mitigated by sending tree cores to a dedicated tree ring laboratory for analysis, and the third situation could be improved through better field procedures.

As more blind check information becomes available, FIA data quality specialists may decide that a variable's MQO should be adjusted 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 in which data collection protocols and training could be enhanced. This ongoing process improves repeatability or may even lead to elimination of variables whose measurement is found to be unrepeatable.

Overview of Utah's Forests

This chapter discusses the status and trends of Utah'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 2003 through 2012. The sections "Ecoregion Provinces of Utah," "Forest Land Classification," and "Forest Land Ownership" include summaries of forest land and nonforest lands; the other parts of this section focus only on the forest land base.

Ecoregion Provinces of Utah

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 assess and treat these issues in a way that does not involve such boundaries. Ecoregions are often used as a non-political land division to help researchers study forest conditions. An ecoregion is a large landscape area that has relatively consistent patterns of physical and biological components that interact to form environments of similar productive capabilities, response to disturbances, and potentials for resource management (Cleland and others 2007). Ecoregions are classified in a descending hierarchy of provinces, sections, and subsections.

Utah is covered by parts of six different ecoregion provinces: (1) the Colorado Plateau Semi-Desert Province (313), (2) the American Semi-Desert and Desert Province (322), (3) the Intermountain Semi-Desert and Desert Province (341), (4) the Intermountain Semi-Desert Province (342), (5) the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province (M331), and (6) the Nevada-Utah Mountains-Semi-Desert-Coniferous Forest-Alpine Meadow Province (M341). Forest Inventory and Analysis uses the modifications to Bailey (1995) by Cleland and others (2007) to assign plots to ecological provinces, sections, and subsections (fig. 2). These six ecoregion provinces, as they pertain to Utah, are described by Bailey (1995, in italics) as follows:

Colorado Plateau Semi-Desert Province (313)—

> *"Cottonwoods and, more rarely, other trees grow along some of the permanent streams….The woodland zone is the most extensive, dominated by open stands of two-needle pinyon pine and several species of juniper, often termed a pygmy forest…. The montane zone extends over considerable areas on the high plateaus and mountains, but it is much smaller in area than the pinyon-juniper zone. Vegetation in the montane zone varies considerably from area to area. Douglas-fir is associated with ponderosa pine or else grows in more sheltered locations or at higher elevations. In Utah, by contrast, lodgepole pine and aspen are dominant." (Bailey 1995).*

The Colorado Plateau Semi-Desert Province has the third highest proportion of forest land of all the provinces in Utah at 38 percent. The pinyon/juniper woodland forest type is the most dominant at 74 percent with 98 percent located at elevations between 5,000 and 8,000 feet. According to our data, lodgepole pine, Engelmann spruce, and subalpine fir forest types are not present in this province in Utah (see Appendix C for common and scientific names of tree species mentioned in this report).

American Semi-Desert and Desert Province (322)—

> *"Along the higher northern edge of the province is a belt where the Joshua tree is prominent. At a still higher level is a belt of junipers and pinyons" (Bailey 1995).*

The American Semi-Desert and Desert Province contains the smallest amount of land area in Utah and has the fifth largest proportion of forest land of all the provinces in Utah at 15 percent. The pinyon/juniper woodland forest type covers 56 percent of the forest land in this province and is located at elevations of 4,000 to 6,000 feet.

Intermountain Semi-Desert and Desert Province (341)—

> *"Sagebrush dominates at lower elevations. Other important plants in the sagebrush belt are antelope bitterbrush, shadscale, fourwing saltbush, rubber rabbitbrush, spiny hopsage, horsebrush, and short-statured Gambel oak…. Above the sagebrush belt lies a woodland zone dominated by pinyon pine and juniper, similar to the pinyon-juniper woodland of the Colorado Plateau…. In the montane belt above the woodland zone, Douglas-fir occupies the higher and more sheltered slopes. In the subalpine belt, the characteristic trees are subalpine fir and Engelmann spruce. Only a few mountains rise high enough to support an alpine belt." (Bailey 1995).*

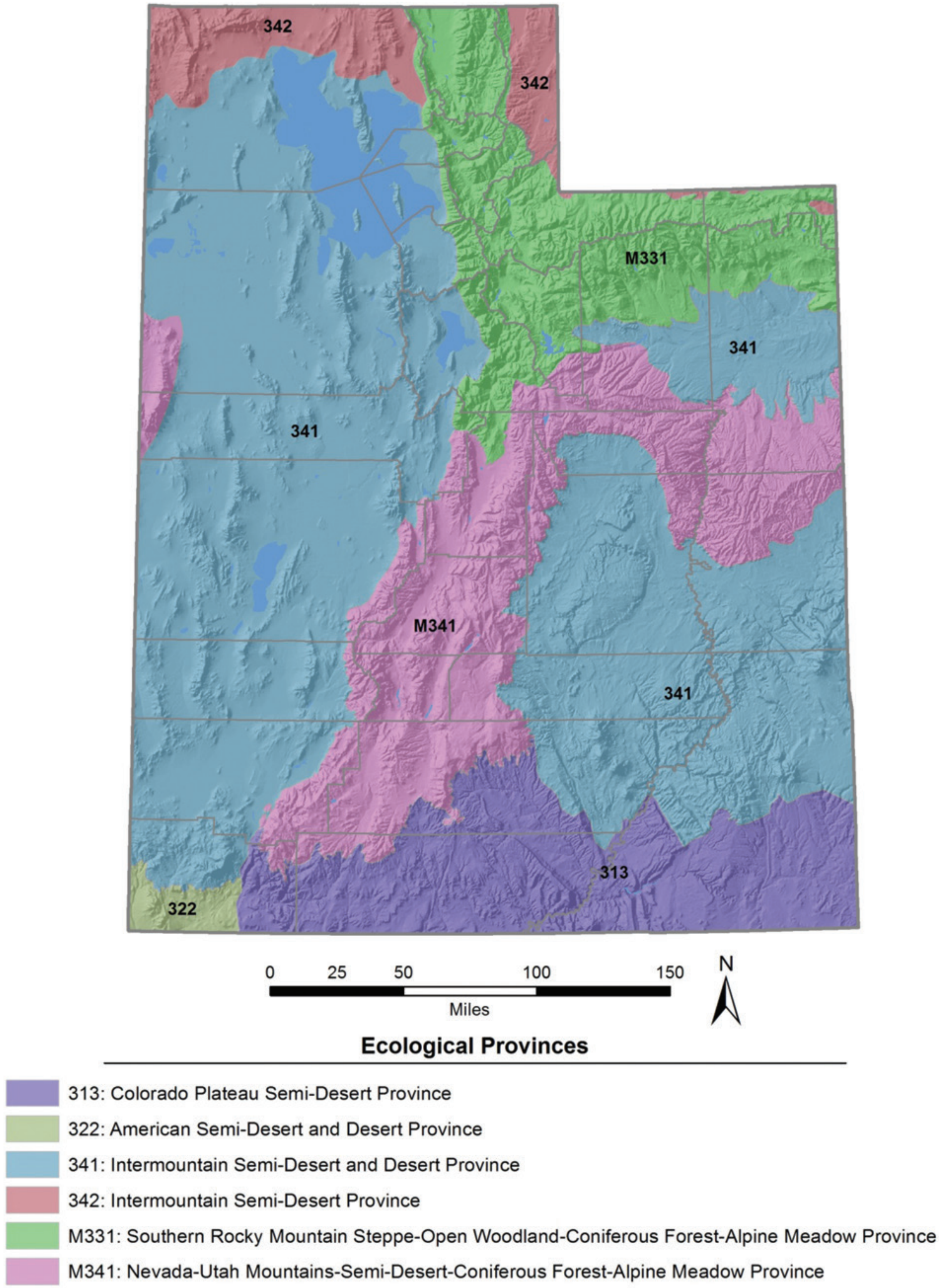


Figure 2—The six ecological provinces in Utah; background shows shaded relief and county boundaries.

The Intermountain Semi-Desert and Desert Province contains the largest amount of total land area of all the provinces in Utah. It has the fourth largest proportion of forest land at 20 percent and the largest proportion of nonforest land of all the provinces in the State. Sixty percent of the forest land in this province is dominated by the pinyon/juniper woodland forest type, with 96 percent of that located at elevations between 5,000 and 8,000 feet. Twenty-one percent of the forest land in this province is dominated by the juniper woodland forest type and is predominantly (93 percent) located between 5,000 and 8,000 feet.

Intermountain Semi-Desert Province (342)—

> *"The chief vegetation, sometimes called sagebrush steppe, is made up of sagebrush or shadscale mixed with short grasses. Moist alkaline flats support alkali-tolerant greasewood. Along streams in and near the mountains where the water is good, valley bottoms are lined with willows and sedges, which give way to greasewood and other alkali-tolerant plants as one moves away from the mountains. Lands in the Columbia River Basin with more than 10 in (260 mm) of rainfall per year have an open cover of bunchgrass, and are excellent for raising wheat" (Bailey 1995).*

The Intermountain Semi-Desert Province has the smallest proportion of forest land of any province in Utah at 13 percent. Fifty-seven percent of the forest land in this province is dominated by the juniper woodland forest type with the majority located at elevations of 5,000 to 7,000 feet. The pinyon/juniper woodland forest type covers 25 percent of all forest land located between 5,000 and 7,000 feet.

Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province (M331)—

> *"The uppermost (alpine) 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, which frequently alternate—ponderosa pine dominates on lower, drier, more exposed slopes, and Douglas-fir is predominant in higher, moister, more sheltered areas. After fire in the subalpine zone and in the upper part of the montane zone, the original forest trees are usually replaced by aspen or lodgepole pine. Grass, often mixed with sagebrush, regularly covers the ground in open ponderosa pine forests and some treeless areas. These treeless openings are usually small, and they often alternate (depending on slope exposure) with ponderosa pine forest. At the lower edge of the montane zone, they may open onto the adjacent grass and sagebrush belt. Below the montane belt is the foothill (woodland) zone. Dry rocky slopes in this zone often have a growth of shrubs in which mountain-mahogany and several kinds of scrub oak are conspicuous. Along the border of the Colorado Plateau Province, ponderosa pine and pinyon-juniper associations frequently alternate, depending on slope exposure" (Bailey 1995).*

The Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province has the largest amount of forest land of any province in Utah at almost 62 percent. According to our data, the aspen forest type is the most dominant at 20 percent.

Nevada-Utah Mountains-Semi-Desert-Coniferous Forest-Alpine Meadow Province (M341)—

> *"The woodland belt above the sagebrush zone is similar to the corresponding belt on the Colorado Plateau, with juniper and pinyon occupying lower mountain slopes. The belt is frequently interrupted as mountains give way to plains. In the montane zone above the woodland belt, ponderosa pine generally occupies the lower and more exposed slopes and Douglas-fir the higher and more sheltered ones. Typical species of the subalpine belt are subalpine fir and Engelmann spruce. Great Basin bristlecone pine, with some individuals more than 1,000 years old, occupies widely scattered peaks. Only a few mountains in this province rise high enough to support an alpine meadow belt" (Bailey 1995).*

The Nevada-Utah Mountains-Semi-Desert-Coniferous Forest-Alpine Meadow Province has the second highest amount of forest land of any province in Utah at 61 percent. According to our data, the pinyon/juniper woodland forest type is the most dominant at 40 percent.

Forest Land Classification

Historically, FIA has used a nationally consistent standard for defining different categories of forest land. These categories were originally developed to separate 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 at least 20 cubic feet of wood per acre per year from trees designated as a timber species and not withdrawn from timber production. Because of species characteristics and site conditions, unproductive forests are not capable of producing more than 20 cubic feet of wood per acre per year for trees designated as a timber species (see Appendix A for standard FIA terms and definitions).

Reserved forest land can also be divided by productivity. Some characteristics that influence productivity can be readily seen, such as the presence or absence of noncommercial species, rocky substrates, and high elevation. Although these distinctions may be important for management of reserved areas (for example, effects on visitor experience), wood production capability on reserved forest land is probably not the best way to characterize these forests.

The State of Utah covers more than 54.3 million acres (table 3). Thirty-four percent, or 18.3 million acres (table B2), of the area meets the definition of forest land (See Appendix A for standard FIA terms and definitions). Unreserved forest land accounts for 89 percent (16.3 million acres) of Utah's forest land. Twenty-one percent (3.8 million acres) of this unreserved forest land is classified as timberland, and 69 percent (12.5 million acres) is classified as unproductive. Eleven percent (2.0 million acres) of Utah's forest land is reserved, where just over three quarters of which is classified as unproductive (table B-2). The remaining 66 percent (36.0 million acres) of Utah's total land area is classified as either nonforest or water.

Forest Land Ownership

Table 3 shows that just over 75 percent (41.0 million acres) of Utah's total land area falls within the public domain, which includes almost 85 percent of the total forest land area. Lands held by the Department of the Interior's (DOI's) Bureau of Land Management (BLM) contain the largest portion (39 percent) of Utah's forest land at almost 7.2 million acres. Lands in the Forest Service's National Forest System (NFS) contain the second largest area of forest land at 35 percent, or 6.3 million acres; however, a larger proportion (77 percent) of NFS lands is forested compared to BLM lands (31 percent).

Ninety-two percent (5.8 million acres) of NFS forest land is unreserved, and 45 percent (2.9 million acres) of NFS forest land is classified as timberland. Eight percent (about 504 thousand acres) of NFS forest land is reserved. Other public agencies managing portions of forest land in Utah include the State of Utah with 1.5 million acres and the National Park Service with about 386 thousand acres. The Department of the Interior's U.S. Fish and Wildlife Service (USFWS), the Departments of Defense and Energy, and local (county, municipal, and other local) governments combined manage only 0.4 percent (almost 82 thousand acres) of Utah's forest land.

Table 3—Area of accessible forest land, (in thousand acres), by owner class and forest land status, Utah, 2003-2012.

Owner class	Forest land				Total forest land	Nonforest	Water	Total area
	Not Reserved		Total not reserved	Reserved				
	Timberland	Unproductive						
US Forest Service								
National Forest System	2,854,057	2,984,177	5,838,233	500,138	6,338,371	1,785,174	92,193	8,215,738
Other Forest Service	--	--	--	4,481	4,481	61,242	--	65,724
Total Forest Service	2,854,057	2,984,177	5,838,233	504,619	6,342,852	1,846,416	92,193	8,281,461
Other Federal								
National Park Service	--	--	--	386,028	386,028	1,424,929	139,685	1,950,641
Bureau of Land Management	108,332	6,054,221	6,162,553	1,008,951	7,171,504	15,639,100	25,583	22,836,186
U.S. Fish and Wildlife Service	--	--	--	6,590	6,590	54,822	30,564	91,975
Departments of Defense and Energy	--	31,030	31,030	--	31,030	1,803,141	6,113	1,840,284
Total other Federal	108,332	6,085,251	6,193,583	1,401,569	7,595,151	18,921,992	201,944	26,719,087
State and local government								
State	186,862	1,239,717	1,426,580	73,965	1,500,545	3,339,471	1,231,475	6,071,491
County and Municipal	20,515	16,210	36,725	--	36,725	13,297	--	50,022
Other local government	--	7,309	7,309	--	7,309	--	--	7,309
Total State and local	207,377	1,263,235	1,470,613	73,965	1,544,578	3,352,768	1,231,475	6,128,821
Private								
Undifferentiated private	608,984	2,205,916	2,814,900	1,980	2,816,880	10,284,928	103,853	13,205,660
Total private	608,984	2,205,916	2,814,900	1,980	2,816,880	10,284,928	103,853	13,205,660
All owners	3,778,749	12,538,579	16,317,329	1,982,132	18,299,461	34,406,103	1,629,465	54,335,030

All table cells without observations in the inventory sample are indicated by --. Columns and rows may not add to their totals due to rounding.

Privately owned forest land totals 2.8 million acres, or 15 percent of the State's forest land. Utah's private forest landowners consist of private individuals and families, corporations, tribes, unincorporated groups or associations, and non-governmental conservation organizations. Figure 3 shows the spatial distribution of FIA plots by ownership.

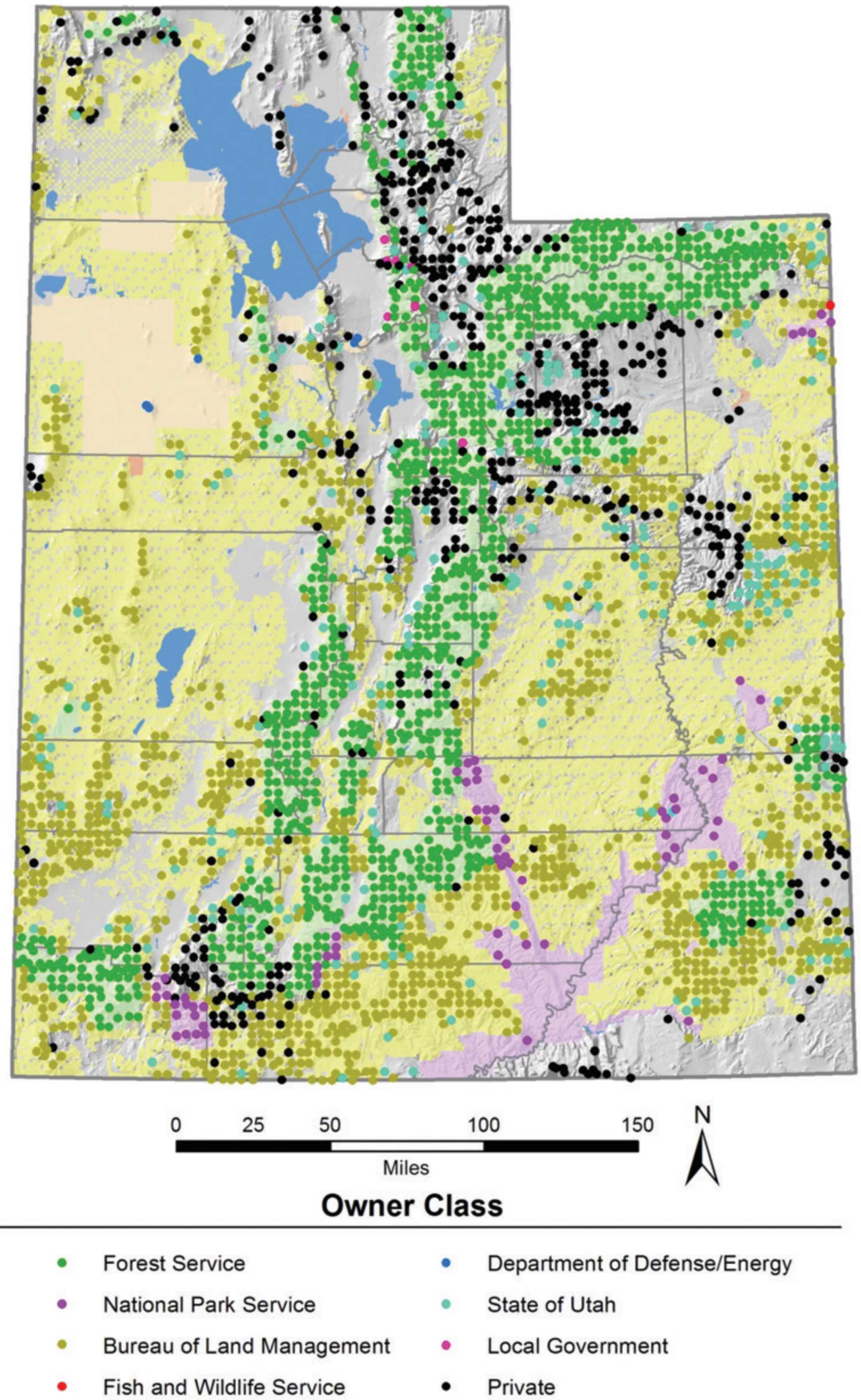


Figure 3—Distribution of inventory plots on forest land by owner class, Utah, 2003–2012. (Note: plot locations are approximate; some plots on private land were randomly swapped.)

Forest Types and Forest-Type Groups

Forest type is a classification of forest land based on the species forming a plurality of living trees growing in a particular forest (Arner and others 2001). Forest types are aggregated into forest-type groups, which may contain one or several forest types in a particular State (Appendix C). The distribution of forest types across the landscape is determined by factors such as climate, soil, elevation, aspect, and disturbance history. Many of these factors are reflected in Utah's ecoregion provinces. 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. Loss or gain of a particular forest type over time can be used to assess the impact of major disturbances such as fire, weather, insects, disease, and human-caused disturbances (for example, timber harvesting activity).

The pinyon/juniper forest-type group is the most predominant of the 10 forest-type groups in Utah, covering 10.7 million acres (table B3). It accounts for 59 percent of the forest land in the State, most of which is in the Intermountain Semi-Desert and Desert Province. Second in abundance is the woodland hardwoods forest-type group with 14 percent (2.5 million acres) of the State's forest land. Most of the woodland hardwoods forest-type group occurs in the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province and the Nevada-Utah Mountains Semi-Desert-Coniferous Forest-Alpine Meadow Province. The third most predominant is the aspen/birch forest-type group with 9 percent of the State's forest land (1.6 million acres) with almost equal proportions falling in the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province and the Nevada-Utah Mountains Semi-Desert-Coniferous Forest-Alpine Meadow Province. The fourth most predominant is the fir/spruce/mountain hemlock forest-type group with 8 percent of the State's forest land (1.5 million acres), which mostly falls in the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province and the Nevada-Utah Mountains Semi-Desert-Coniferous Forest-Alpine Meadow Province. Figure 4a through 4d shows the spatial distribution of these four most predominant forest-type groups by forest type, ecoregion province, and elevation in Utah. The Douglas-fir forest-type group covers about 553 thousand acres, followed by the lodgepole pine group at 427 thousand acres, and the ponderosa pine group at 347 thousand acres. The remaining forest-type groups in Utah are the elm/ash/cottonwood and other western softwoods groups, each covering about 62 thousand acres, and nonstocked group at 574 thousand acres.

Stand Age—The present age structure of Utah's forest area, in terms of stand age and forest-type group composition, provides insight into potential shifts in stand structure over time. On every FIA plot that is classified as forest land and that 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 assignment. For example, suppose an FIA plot consists of a softwood forest type where about 30 percent of the live trees were in the large diameter stand-size class (trees at least 9.0 inches in diameter and larger) and 70 percent were in the medium diameter stand-size class (trees between 5.0 and 9.0 inches in diameter). Because the stand would be classified as a medium diameter stand-size class, only the medium-size trees would be used in determining stand age. There are limitations to collecting data for stand age computation. Certain tree species, especially those that are very old, make repeatable measures of increment cores difficult. Certain stand types, such as Gambel oak, that are dominated by small-diameter trees, are very difficult to accurately assign a stand age. All nonstocked forest conditions—those forested areas that have less than 10 percent stocking of live trees because of disturbance—are assigned a stand age of zero.

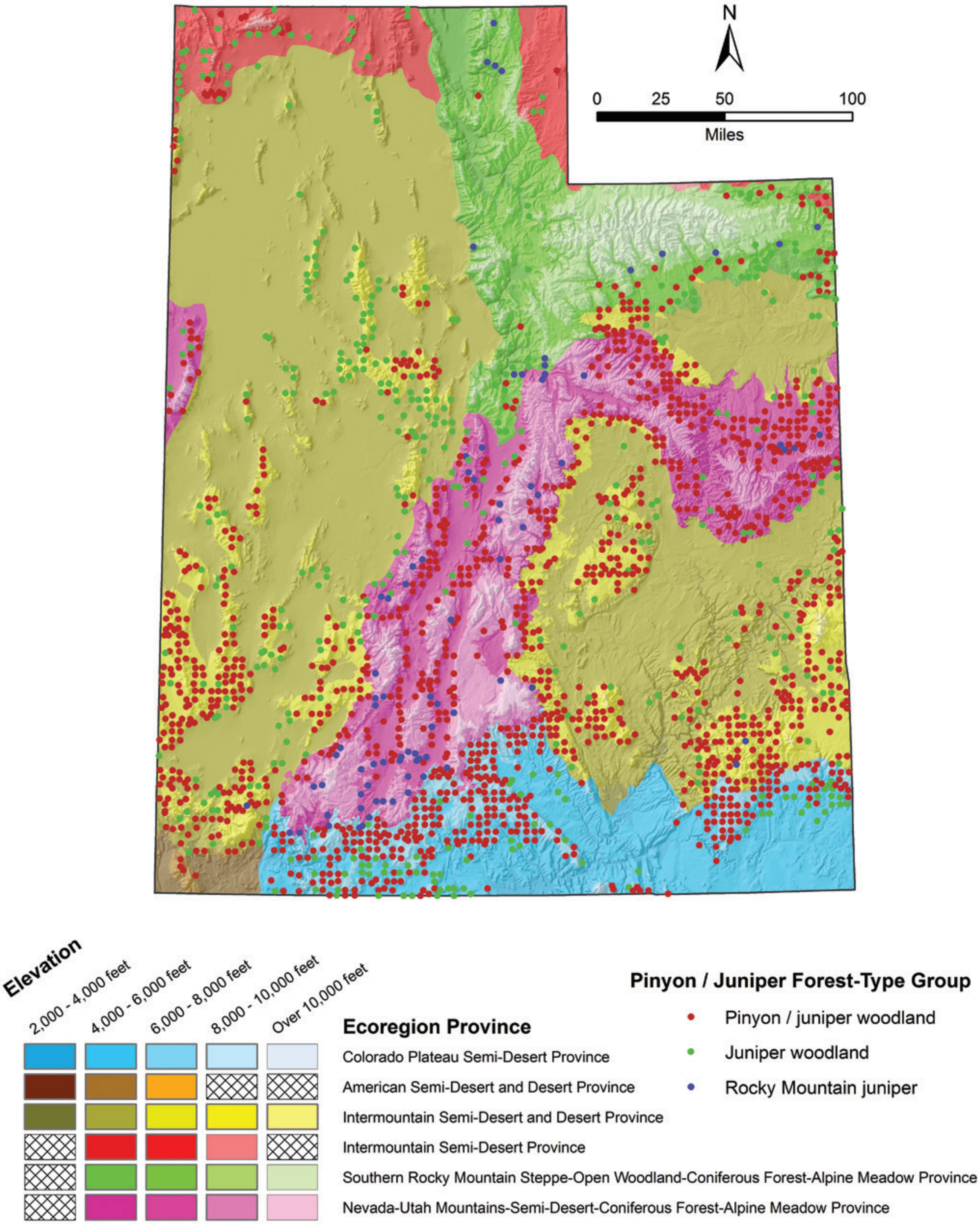


Figure 4(a)—Distribution of inventory plots for (a) Pinyon/juniper, (b) Woodland hardwoods, (c) Aspen/birch, and (d) Fir/spruce/mountain hemlock forest-type groups, by forest type, ecoregion province, and elevation, Utah, 2003-2012. (Note: plot locations are approximate; some plots on private land were randomly swapped.)

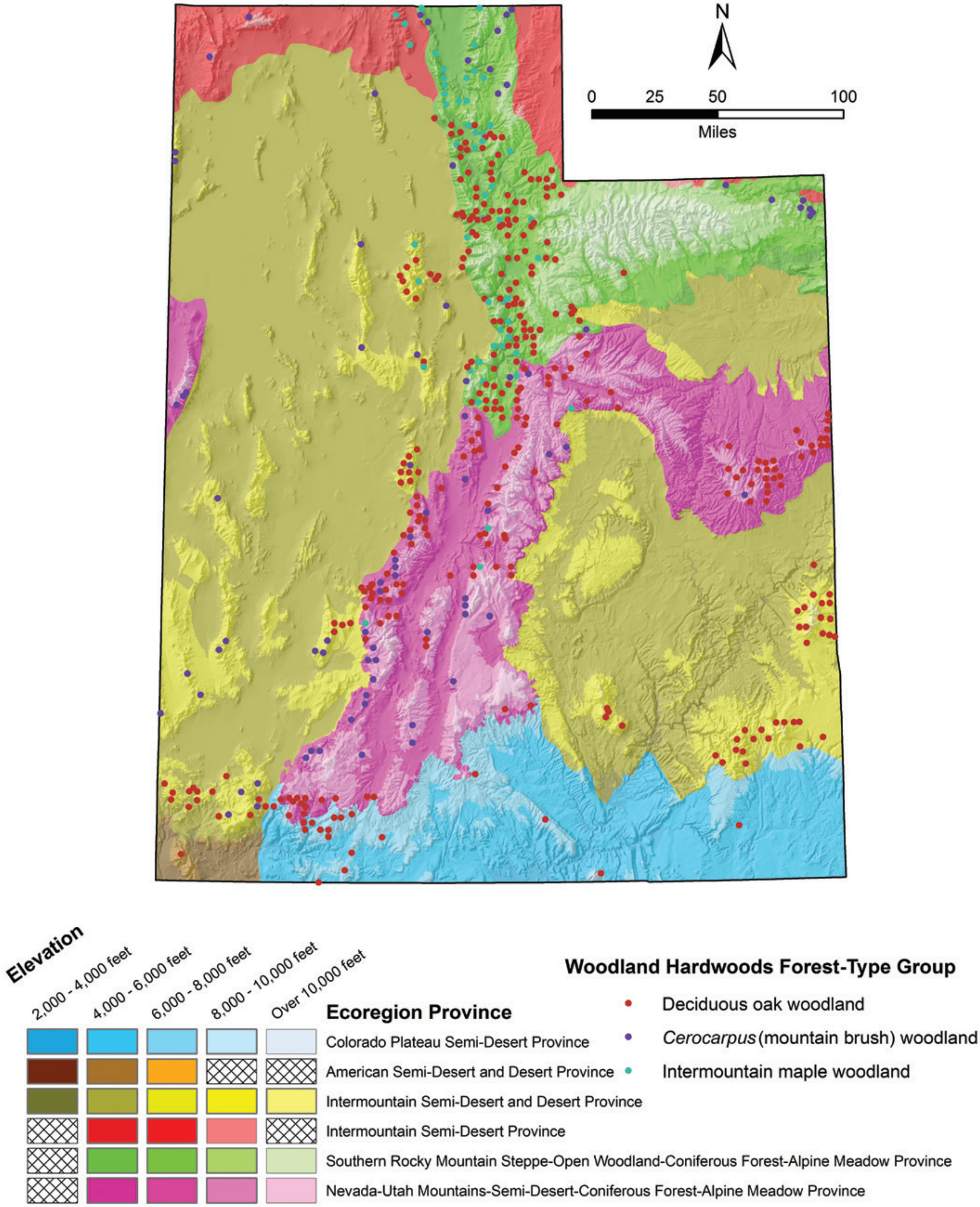


Figure 4(b) Woodland hardwoods group.

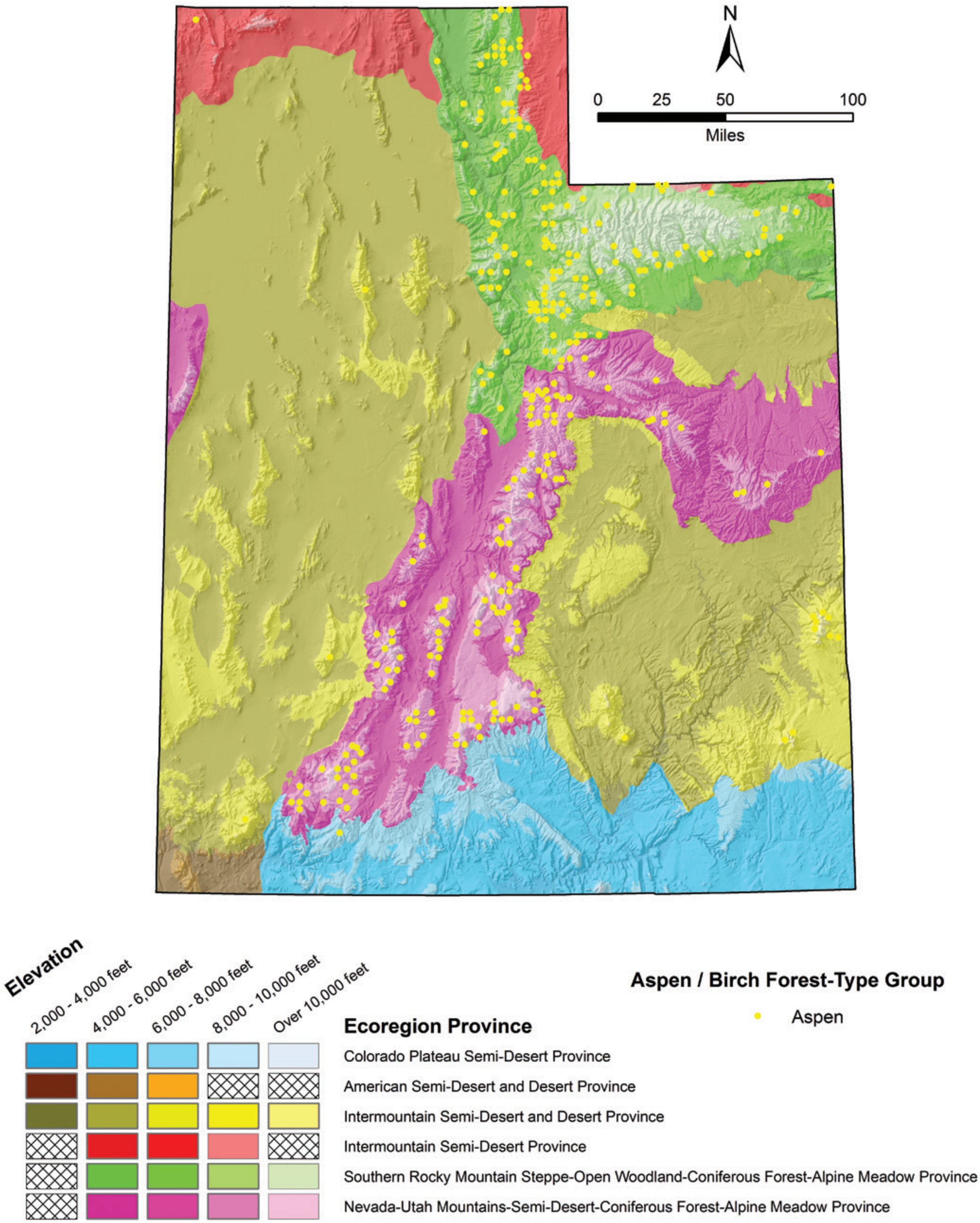


Figure 4(c) Aspen/birch group.

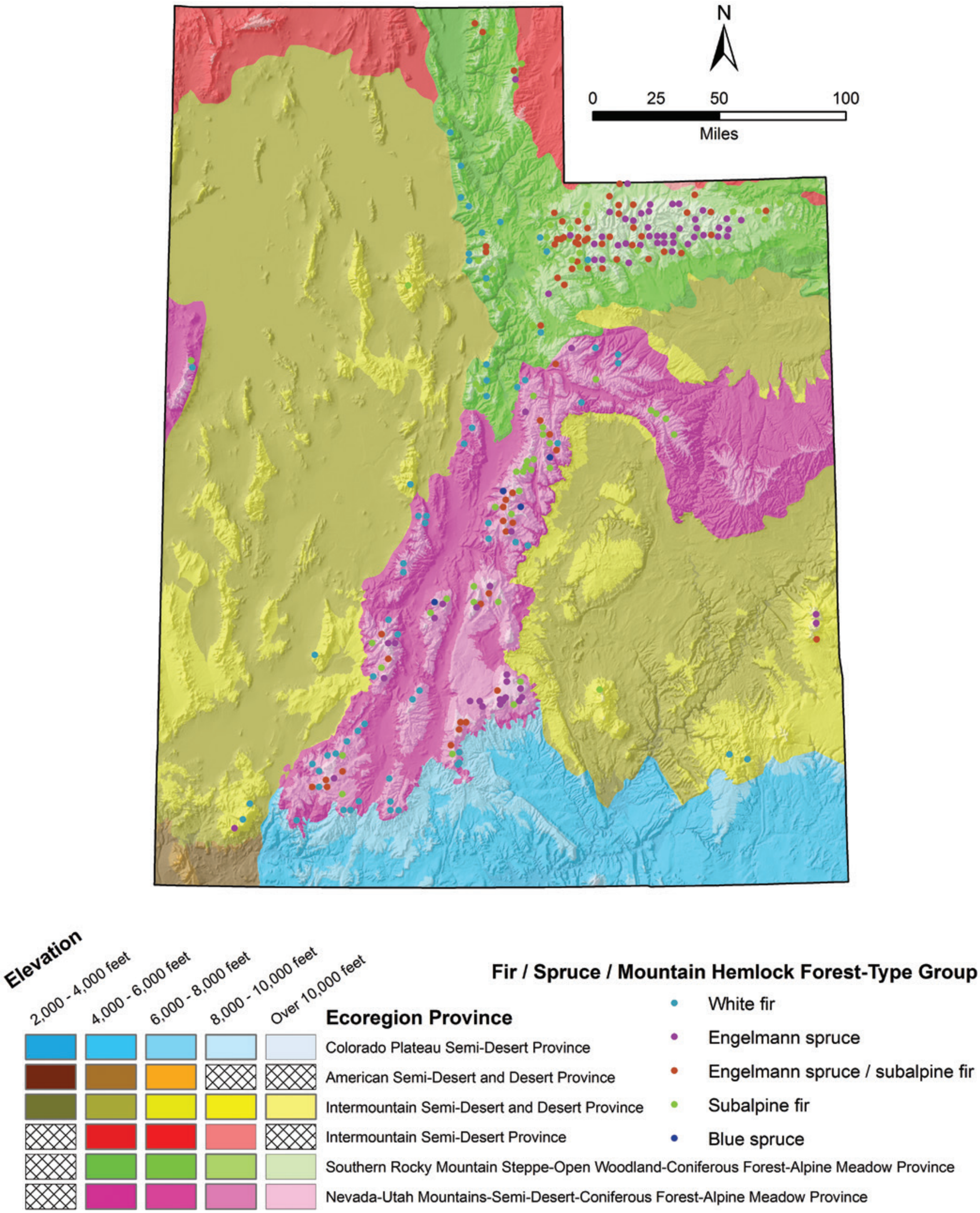


Figure 4(d) Fir/spruce/mountain hemlock group.

The largest proportion of Utah's forest land occurs in fairly old stands, with 58 percent of the State's forest land in stands older than 100 years (table B6). Just over 16 percent of the forest land is in stands more than 200 years of age and 11 percent are less than 20 years of age.

There is a considerable difference in stand age distribution between the major forest-type groups in the State (figs. 5a and 5b). The other western softwoods forest-type group, which includes long-lived species such as limber pine and Great Basin bristlecone pine, is the oldest with more than 73 percent of the forest area in stands over 140 years old (fig. 5a). Almost 54 percent of pinyon/juniper stands in the pinyon/juniper forest-type group are over 140 years old, making it the next oldest group (fig. 5b). The aspen/birch forest-type group, which is composed of the aspen forest type in Utah, is dominated by quaking aspen. This species is generally shorter lived than most Utah conifer species and is characterized by more stands in the younger age classes. More than 93 percent of aspen forests are in stands 120 years old and younger, making the aspen/birch forest-type group the youngest of those occupying more than 100 thousand acres in Utah. The woodland hardwoods forest-type group follows closely, with 89 percent of its forests in younger stands.

Number of Trees—A measure of the numbers of live trees is needed in a variety of silvicultural, forest health, and habitat management applications. To be meaningful, numbers of trees are usually combined with information about the size of the trees. Younger forest stands are usually composed of large numbers of small-diameter trees whereas older forest stands contain small numbers of large-diameter trees. Individual tree species are classified to species groups, and each species and species group are further classified as either softwood or hardwood (Appendix D).

There are an estimated 7.6 billion live trees at least 1.0 inch in diameter and larger on forest land in Utah (table B10). The woodland hardwoods species group is the most predominant species group, accounting for 46 percent, or 3.4 billion, of the live trees. Gambel oak is the most abundant tree species in this group, which also includes bigtooth maple and curlleaf mountain-mahogany. Next in abundance is the woodland softwoods species group at almost 2.0 billion trees. The sum of all softwood species groups is nearly 3.4 billion trees, which is almost 45 percent of the total number of trees in the State (fig. 6). Fifty-three percent of all softwood trees are less than 5.0 inches in diameter and 9 percent are 15.0 inches and larger in diameter. Utah juniper is the most abundant species in this group, which also includes common or two-needle pinyon, singleleaf pinyon, and Rocky Mountain juniper. Third in abundance is the cottonwood and aspen species group with 716 million trees, dominated by quaking aspen. At 596 million trees, the true fir species group is the fourth most predominant with subalpine fir more dominant than white fir.

Next in abundance is the lodgepole pine species group with 332 million trees, all of which are lodgepole pines. The sixth most predominant species group consists of Engelmann and other spruces at 213 million trees with Engelmann spruce having a much greater abundance than blue spruce. This species group is followed closely by the Douglas-fir species group at 212 million trees, all of which are Douglas-firs. The last three species groups in order of abundance are the ponderosa and Jeffrey pines (consisting of ponderosa pine), other western softwoods (consisting of limber pine and Great Basin bristlecone pine), and other western hardwoods (consisting of water birch, boxelder, and velvet ash) at 47 million, 18 million, and 8 million trees, respectively.

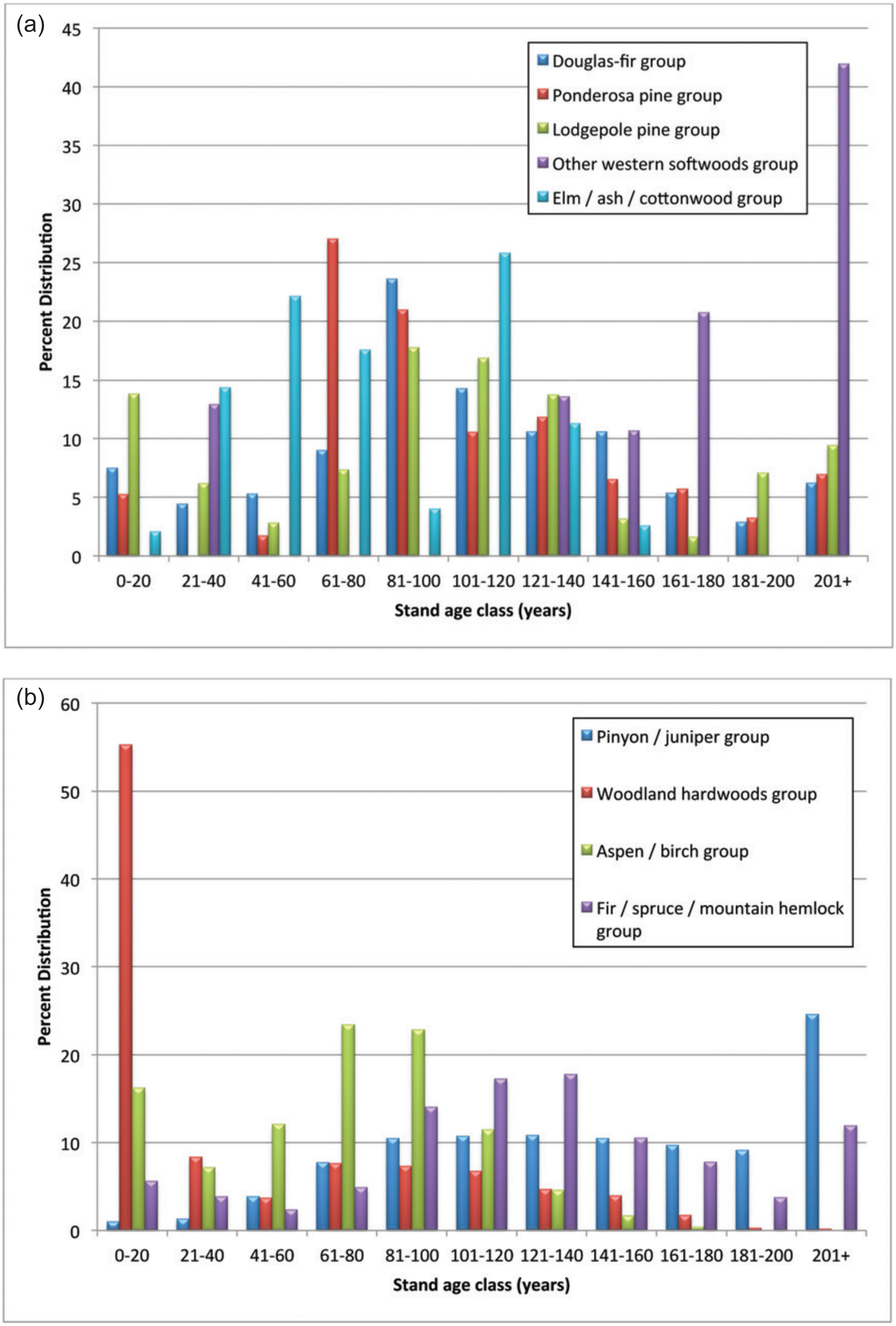


Figure 5—Distribution of forest land by stand age class (a) for minor forest-type groups and (b) for major forest-type groups, Utah, 2003–2012.

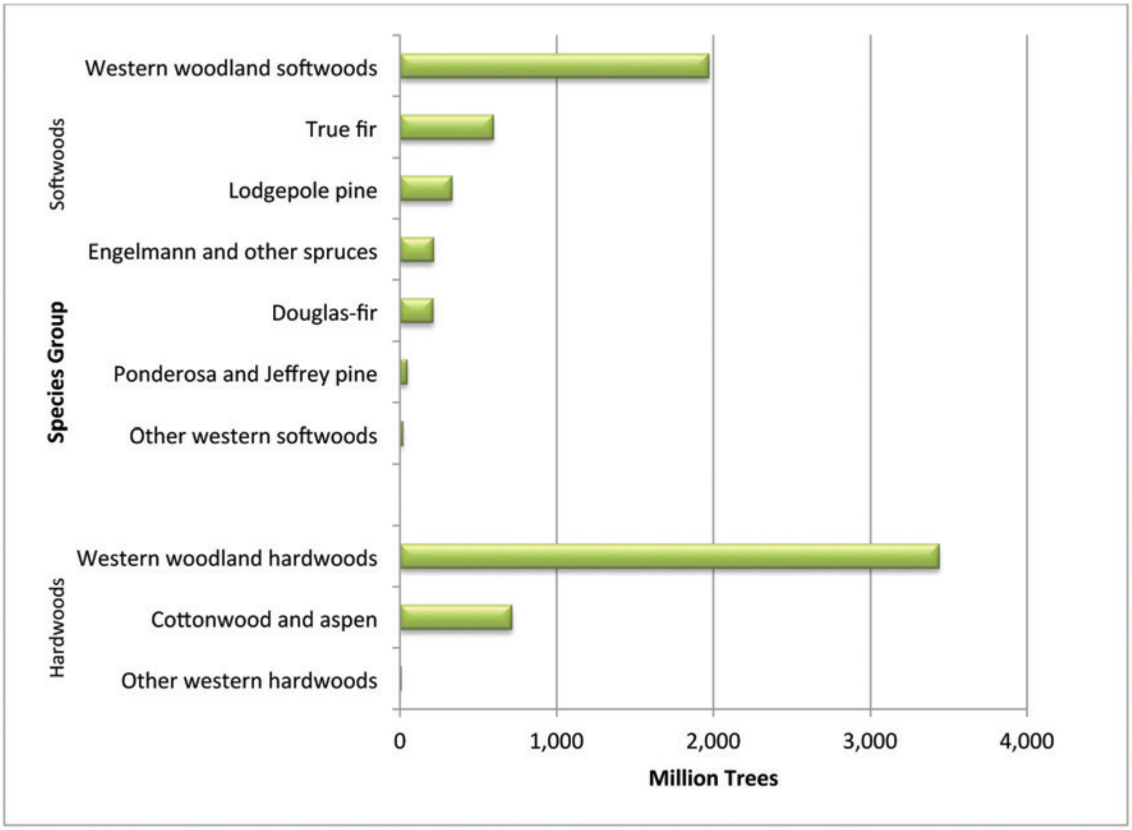


Figure 6—Number of live trees 1.0 inch in diameter and larger on forest land, by species group, Utah, 2003–2012. (Note: the number of live trees in the "Other western hardwoods" species group is too small to appear on this graph.)

Figure 7 shows numbers of live trees by diameter class for the three most predominant species groups in Utah. This figure not only shows the distribution of smaller and larger trees within each species group, but also illustrates the differences among species groups, which are likely due to differing ecologies and life histories. For trees less than 5.0 inches in diameter, the woodland hardwoods species group is the most dominant with 59 percent of all trees in those size classes compared to 16 percent in the woodland softwoods species group and 8 percent in the cottonwood and aspen species group. The woodland hardwood species group is dominated by small-diameter trees, with 80 percent of its trees in the 1.0- to 2.9-inch diameter class. In contrast, 80 percent of the smallest-diameter trees in the cottonwood and aspen species group include diameter classes up to 6.9 inches, and all diameter classes up to 12.9 inches account for 83 percent of the woodland softwood species group, making it the most evenly distributed among size classes.

Figure 8 shows numbers of live trees by diameter class (whether measured at breast height or root collar) as well as the distribution of many smaller trees compared to larger trees. Overall, trees less than 5.0 inches in diameter make up 72 percent of all live trees. Almost half (48 percent) of the trees less than 5.0 inches in diameter are Gambel oaks. Conversely, the second most common live tree, Utah juniper—a larger and longer-lived species—makes up 61 percent of live trees 15.0 inches in diameter and larger.

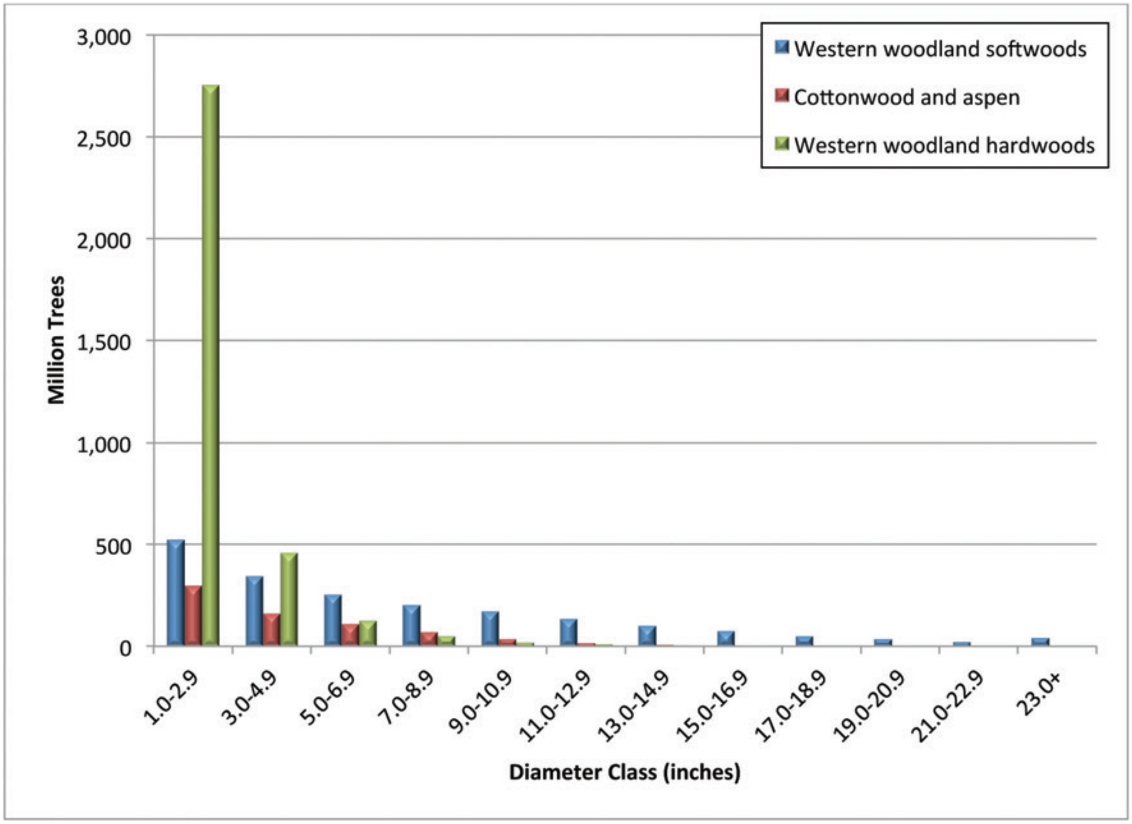


Figure 7—Number of live trees on forest land by three most predominant species groups and diameter class, Utah, 2003–2012.

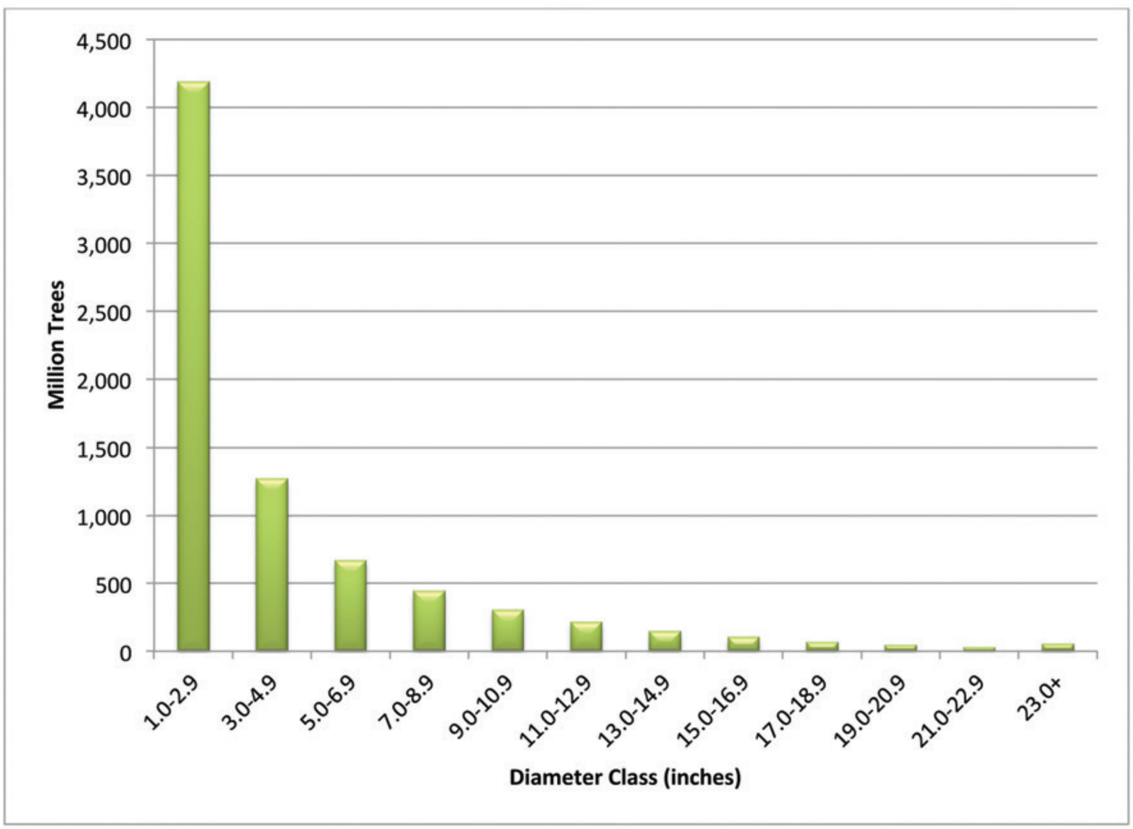


Figure 8—Number of live trees 1.0 inch in diameter and larger on forest land by diameter class, Utah, 2003–2012.

In terms of individual species, Gambel oak is by far the most abundant species on Utah's forest land, with 2.7 billion live trees (at least 1.0 inch in diameter and larger), or 36 percent of the total (fig. 9). The second most abundant species is Utah juniper, with 12 percent of the live trees, followed by common or two-needle pinyon and quaking aspen, each with about 9 percent of live trees. The most abundant timber conifer species on forest land is subalpine fir with more than 6 percent of the live trees.

On timberland (nonreserved and productive) in Utah, there are 592 million live growing-stock trees 5.0 inches diameter and larger, of which quaking aspen is the most abundant species with nearly 35 percent (table B11). The next most abundant growing-stock species on timberland are subalpine fir with 16 percent, lodgepole pine with 15 percent, Douglas-fir with 12 percent, Engelmann spruce with 11 percent, white fir with 7 percent, and ponderosa pine with 3 percent.

There are an estimated 423 million standing dead trees at least 5.0 inches in diameter and larger on forest land in Utah, or an average of 23.1 snags per forested acre (as compared to 114.2 live trees of the same diameters per acre). As with live trees, larger snags are less common than smaller snags, and often contribute more significantly to important forest landscape components such as wildlife habitat, nutrient cycles (including carbon), fire fuel loading, and soil formation. The average density for snags 11.0 inches in diameter and larger is 6.6 per acre. Very large snags, 19.0 inches in diameter and larger, occur on Utah forests at a density of nearly 1 per acre. In all size classes, the most common species for snags is Utah juniper. In both larger snag classes (11.0 inches in

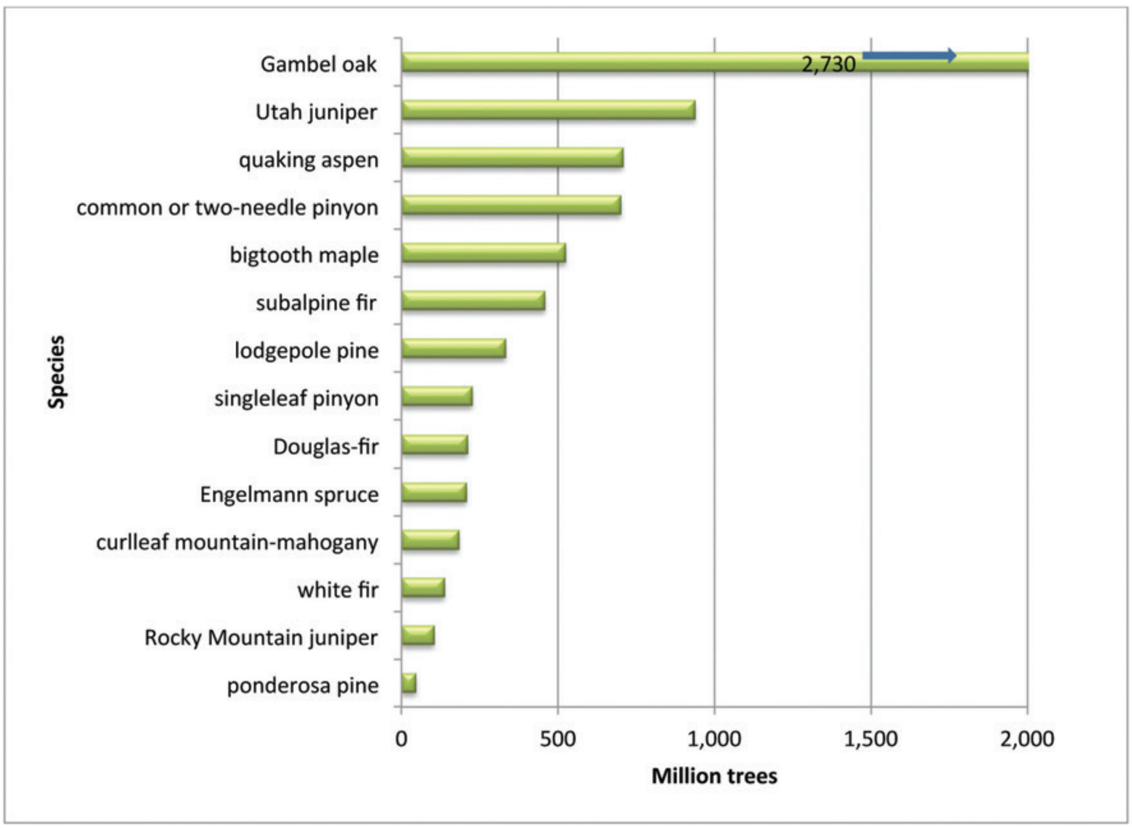


Figure 9—Number of live trees 1.0 inch in diameter and larger on forest land by species, Utah, 2003–2012.

diameter and larger and 19.0 inches in diameter and larger), the most abundant timber species for snags is Engelmann spruce. Snag densities are calculated over all forest land in the State, and do not take into account irregular distributions of dead trees caused by localized mortality events like fires, insect outbreaks, and diseases. Densities may vary considerably by sub-levels of forest land such as ownerships, counties, or forest types.

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 is interested in knowing where available timber volume is located, who owns it, the species composition, and the size distribution. Estimates of gross and net volume include only the merchantable portion or saw-log portion (for example, cubic-foot or board-foot) of trees. Biomass describes aboveground tree weight (oven-dry) by various components (merchantable bole and bark, tops and limbs, saplings). Net volumes are computed by deducting rotten, missing, or form defect portions from gross volume. Sources of these volume equations are documented in Appendix E. Biomass estimates are based on the component ratio method as described in Appendix J in Woudenberg and others (2010), which are based on gross volumes and exclude foliage.

Tables B12 through B16 show net volume of live trees 5.0 inches in diameter and larger on Utah forest land by various categories. The total net volume of wood in live and standing dead trees 5.0 inches in diameter and larger on Utahs forest land is 15.3 billion cubic feet (table B12) and 3.1 billion cubic feet (fig. 10), respectively.

The predominant species by volume are Utah juniper, which accounts for more than 26 percent of the total live net cubic-foot volume, followed by common or two-needle pinyon at 12 percent, quaking aspen at 11 percent, Engelmann spruce at 10 percent, and Douglas-fir at 9 percent (fig.10). Engelmann spruce makes up 22 percent of the total standing dead volume, followed by 16 percent for lodgepole pine, 11 percent for both Douglas-fir and subalpine fir, 10 percent for quaking aspen, and 9 percent for Utah juniper (fig. 10). The total aboveground weight of biomass (oven-dry) in live (at least 1.0 inch in diameter and larger) and standing dead trees (at least 5.0 inches diameter and larger) on Utahs forest land is 298 million tons and 51 million tons, respectively (fig. 11).

Another way to look at volume and biomass is by forest type, for which net volume and biomass per acre can be computed (table 4). These estimates include the different species that occur within each forest type. On a per-acre basis, the Engelmann spruce forest type has the highest net volume of live trees 5.0 inches in diameter and larger (2,441 cubic feet per acre), and the highest biomass of live trees 1.0 inch in diameter and larger (37.6 tons per acre). In contrast, pinyon/juniper woodland, the most common forest type in Utah, has about 683 cubic feet per acre of volume and 12.9 tons per acre of biomass. Estimates for forest types sampled on fewer than 20 plots such as the foxtail/bristlecone pine, limber pine, and blue spruce forest types tend to have higher errors associated with small sample sizes, but they are included in table 4 for reference.

The net volume of growing-stock trees on timberland in Utah is 6.4 billion cubic feet (table B17), or 42 percent of the total live volume on forest land. Softwood species make up 75 percent of the growing-stock volume. Quaking aspen accounts for the highest proportion of growing-stock volume of all tree species at 24 percent, followed by Engelmann spruce at 17 percent, Douglas-fir at 16 percent, subalpine fir at 14 percent, and lodgepole pine at 11 percent.

Table B19 shows that the net volume of sawtimber trees (International ¼-inch rule) on timberland is about 24.5 billion board feet. Engelmann spruce accounts for the most sawtimber of any tree species at 22 percent, followed by Douglas-fir at 19 percent, quaking aspen at 16 percent, subalpine fir at 15 percent, and ponderosa pine at 10 percent.

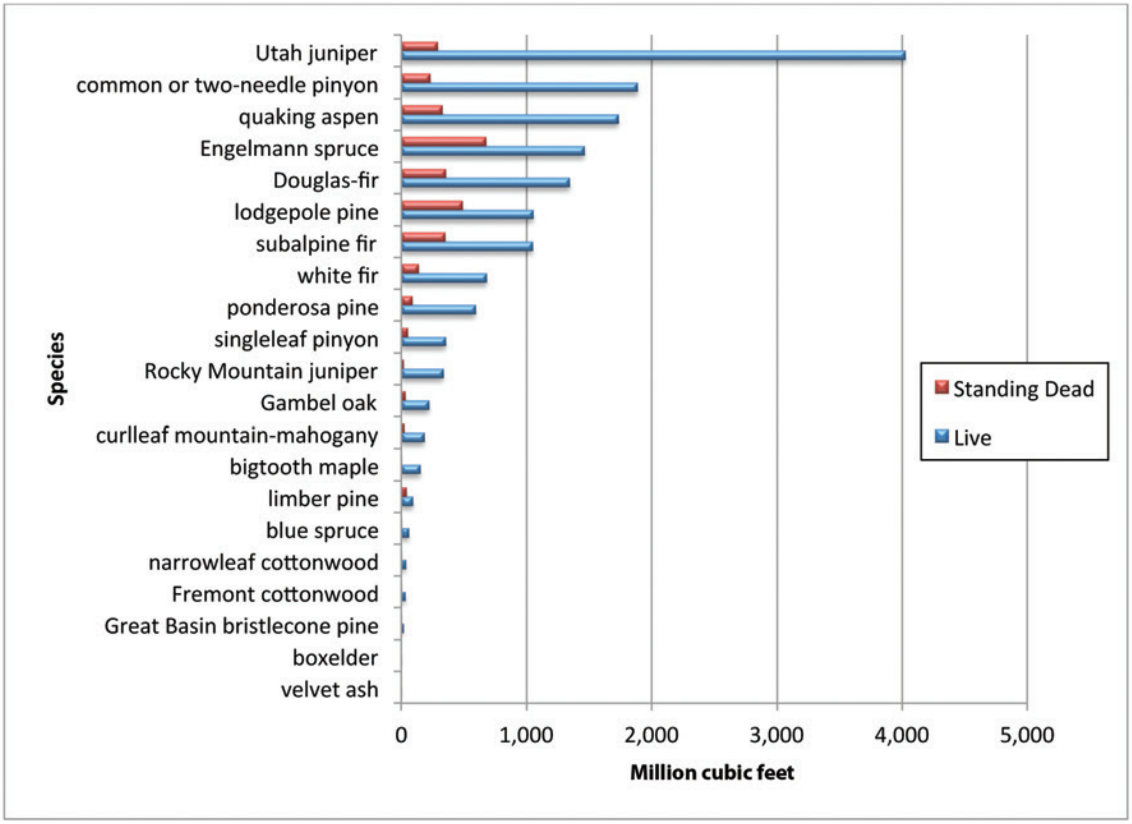


Figure 10—Net cubic-foot volume of all live and standing dead trees 5.0 inches in diameter and larger on forest land by species, Utah, 2003–2012.

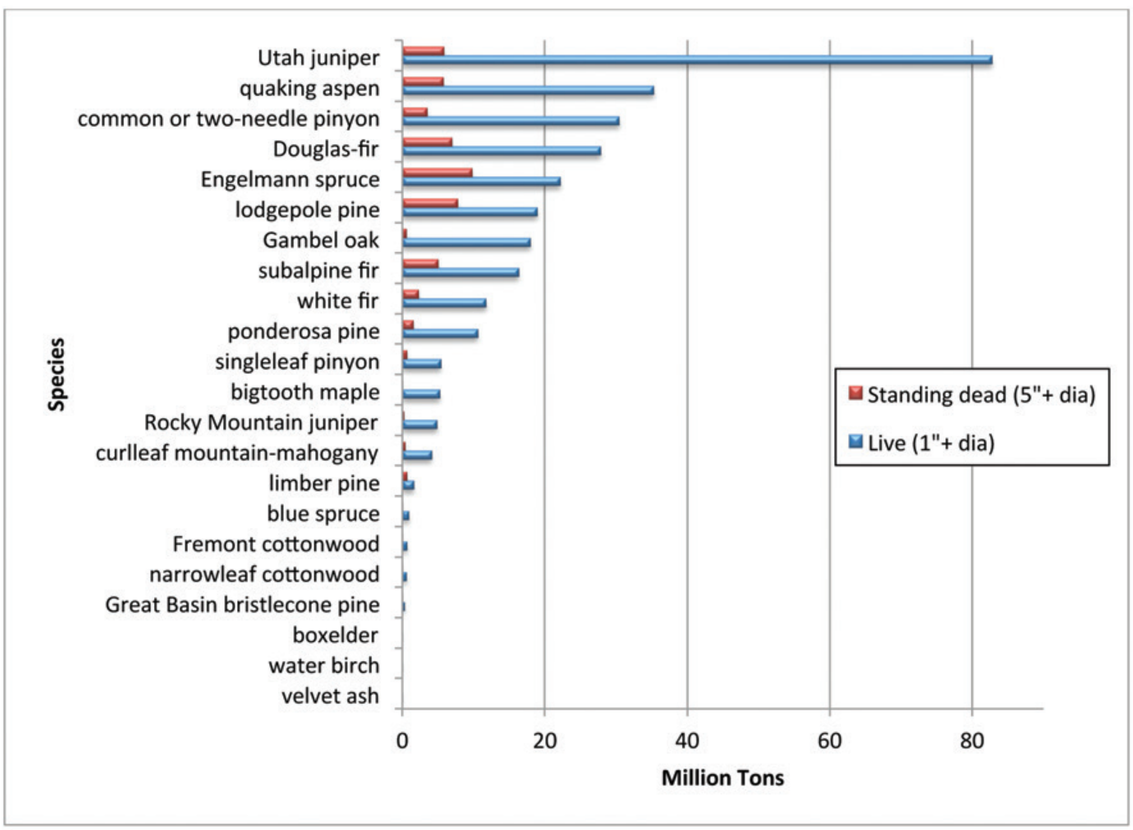


Figure 11—Oven-dry weight biomass of live trees 1.0 inch in diameter and larger and standing dead trees 5.0 inches in diameter and larger on forest land by species, Utah, 2003–2012.

Table 4—Net volume (cubic feet per acre) of live trees 5.0 inches diameter and larger, and biomass (oven-dry tons per acre) of live trees 1.0 inch diameter and larger by forest type on forest land, Utah, 2003-2012.

Forest type	Net volume	Biomass	Number of plots
	Types with adequate samples		
Engelmann spruce	2,441	37.6	68
Engelmann spruce / subalpine fir	2,186	35.3	68
Lodgepole pine	2,036	37.5	67
Subalpine fir	1,975	31.9	61
White fir	1,923	34.5	65
Douglas-fir	1,797	36.2	102
Ponderosa pine	1,375	25.4	62
Aspen	1,340	26.1	308
Rocky Mountain juniper	818	14.4	83
Intermountain maple woodland	782	20.6	58
Pinyon / juniper woodland	683	12.9	1,368
Cercocarpus (mountain brush) woodland	477	10.5	82
Juniper woodland	417	8.7	423
Deciduous oak woodland	195	10.2	334
Nonstocked	24	0.5	129
	Types with small samples		
Blue spruce	2,485	40.0	4
Limber pine	1,398	24.2	8
Cottonwood	991	19.6	17
Cottonwood / willow	880	15.6	2
Foxtail pine / bristlecone pine	838	15.3	4
All forest types	**836**	**16.3**	**3,176**

The total aboveground weight of biomass (oven-dry) of live trees 1.0 inch in diameter and larger is 298 million dry short tons, and 118.6 million dry short tons on timberland (table B29). Although biomass is usually sold by green weight, the water content of wood is highly variable geographically, seasonally, and even across portions of a single tree. This variability makes live-tree inventory estimates of green biomass unreliable and potentially misleading.

Forest Change Components: Growth, Mortality, and Removals

Forest vigor, sustainability, and timber supply are often assessed by what are referred to as forest change components: growth, mortality, and removals. More specifically, these change components help to quantify the change in tree volume over time. Growth, as reported here for FIA purposes, is typically expressed as net annual growth and is defined as the average annual growth in tree volume less the volume lost through mortality. Mortality, as reported here for FIA purposes, is the average annual net volume of trees dying over a given time period due to natural causes. Most often, tree mortality 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. Because estimates of growth and mortality were developed differently from estimates of removals, they are presented separately below.

Growth and Mortality—In Utah, growth and mortality are estimated differently for new inventory plots versus remeasurement plots; the latter make up most of the plots measured in 2000–2002 and again in 2010–2012. On new inventory plots (2003–2009), annual growth of live trees is estimated from a sample of increment core measurements based on the previous 10 years of radial growth. Mortality is estimated from trees that have died in the 5 years before the year of measurement. On remeasured inventory plots, annual growth of timber trees is estimated by comparing the previous (2000–2002) diameters to the current (2010–2012) diameters; for woodland tree species, growth continues to be estimated from increment cores. Mortality on remeasured plots is estimated by identifying trees that were alive at the time of the first measurement and dead at the time of the second measurement. Complete remeasurement data for the State—where the status of all plots and all trees on each plot are known at two points in time—will not be available until remeasurement data accrue over the next several years.

The annual estimate of gross growth of all live trees 5.0 inches in diameter and larger on forest land in Utah totaled nearly 207.2 million cubic feet. This is the sum of growth on all survivor and ingrowth trees. Survivor trees are defined as trees that were 5.0 inches in diameter and larger 10 years before the current measurement. Ingrowth trees are defined as trees that were less than 5.0 inches in diameter before the current measurement and then grew over the 5.0-inch diameter threshold during the previous 10 years. On average, annual mortality of trees 5.0 inches in diameter and larger was 256.7 million cubic feet (tables B25 through B27). Net growth is gross, or total, growth minus mortality, which approximates the average annual change in inventory volume, but does not include the average annual volume removed by timber harvesting. The difference between the gross growth and mortality results in a net annual growth estimate of –49.5 million cubic feet on forest land in Utah (tables B22 and B23).

The negative estimate of net annual growth indicates the inventory of live trees in Utah has decreased in the absence of trees removed from timber-harvesting activities. Large levels of tree mortality are offsetting gains from live tree growth. Net growth and mortality vary significantly by ownership group in Utah (fig. 12). Mortality of trees 5.0 inches in diameter and larger on NFS forest land averaged 182.4 million cubic feet compared to -53.7 million cubic feet of net annual growth. In contrast, mortality averaged 24.6 million cubic feet on privately owned forests compared to 7.6 million cubic feet of net annual growth.

Among the major inventory species, positive net growth was recorded only for quaking aspen and Utah juniper (fig. 13). Engelmann spruce exhibited the highest level of mortality of the eight species, which contributed to the highest negative net growth estimate of –30.8 million cubic feet. Net annual growth of lodgepole pine was –28.3 million cubic feet. Quaking aspen mortality averaged 25.3 million cubic feet and net growth averaged 11.6 million cubic feet per year. Several other species in Utah exhibited gross growth that was higher than mortality; however, the net growth for these species was relatively insignificant and the small number of sample plots limits the inferences that can be made.

Further examination of this change component across other resource attributes is warranted. Large differences were observed in per-acre estimates of mortality between major ownership groups and reserved status. Converting the State-level estimates of mortality into per-acre estimates removes the effect of differences in the amount of forest land administered by different ownership groups on mortality estimates. Across all ownerships, the per-acre estimate of annual mortality volume averages 14.0 cubic feet per year on forest land. Average annual mortality on reserved forest land was slightly

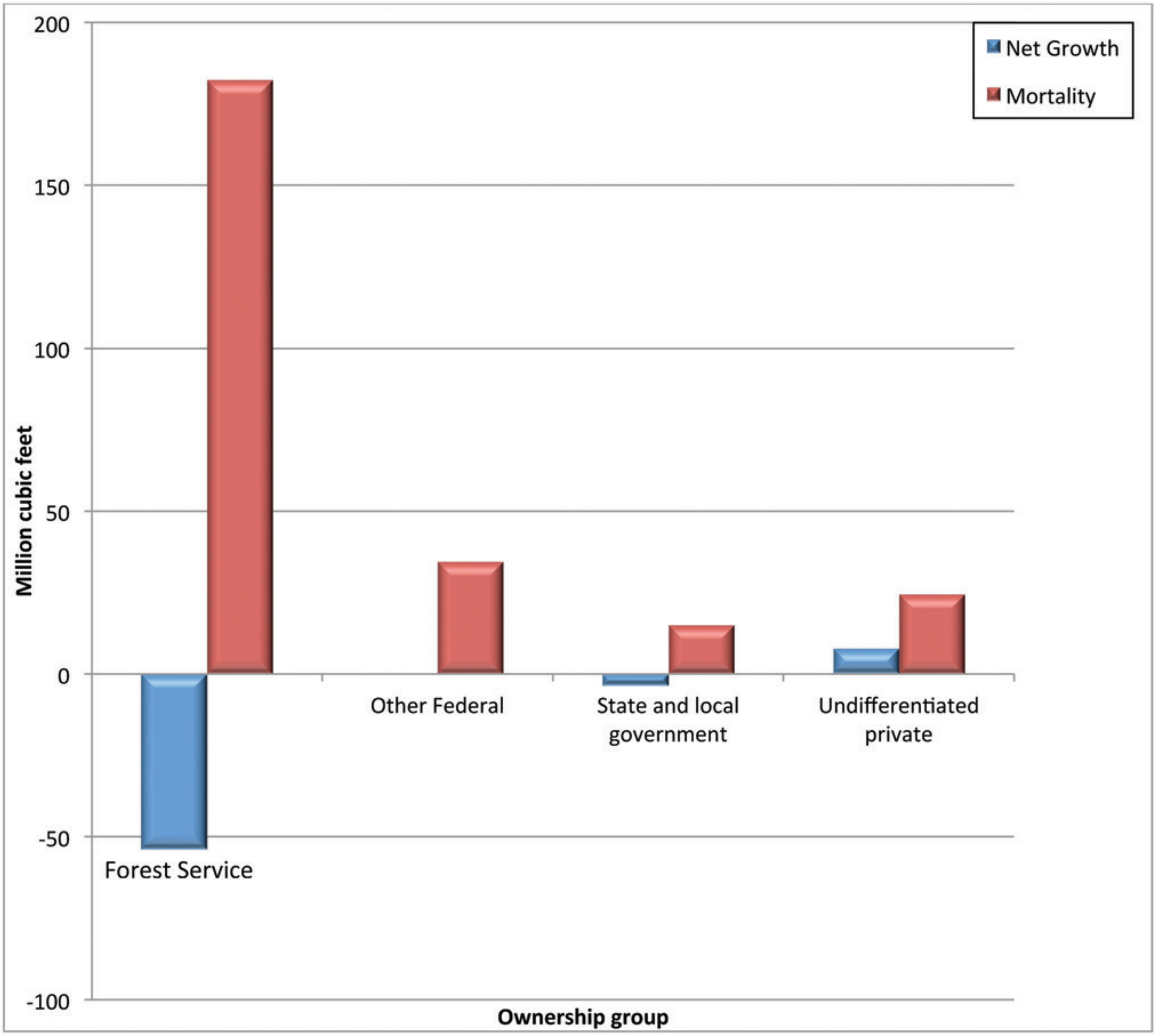


Figure 12—Net annual growth and mortality on forest land, by ownership group, Utah, 2003–2012. Net annual growth in the Other Federal category is too small to be displayed on this chart but was slightly negative.

higher than on unreserved forest land (15.8 cubic feet per acre compared to 13.8 cubic feet per acre). Reserved forest land administered by the USDA Forest Service recorded the highest average level of per-acre mortality at 48.2 cubic feet per acre (fig. 14). Mortality on reserved forest land administered by private landowners, other federal agencies, and State agencies averaged 4.8 cubic feet per acre. Large differences in mortality by ownership and by reserved versus unreserved status have been observed in other State inventories (Goeking and others 2014; Menlove and others 2012; Witt and others 2012). The assumption is that reserved NFS lands are composed forests typically more susceptible to insects, disease, and fire.

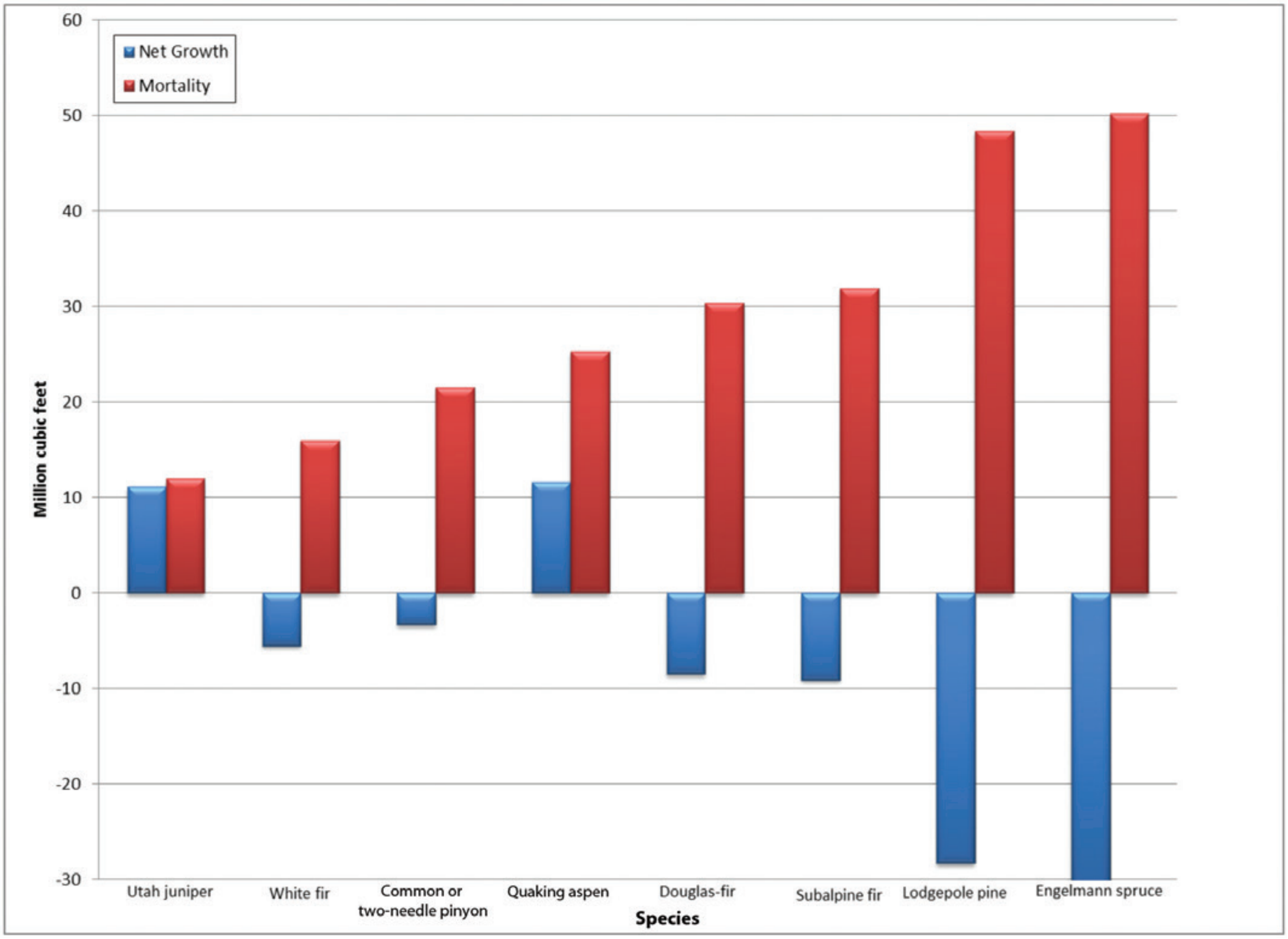


Figure 13—Net annual growth and mortality on forest land by eight major species, Utah, 2003–2012.

All trees classified as mortality are assigned a cause of death in the field. Drawing conclusions from mortality estimates by cause of death should be done with caution. Although the actual causal agent of mortality can be difficult to determine in the field, classification allows mortality estimates to be partitioned into informative categories. In Utah, the most prevalent causes of mortality were insects, disease, and fire (fig. 15). The potential interactions between insects, disease, and fire are complex, but mortality agents identified in the field should reflect the most proximate cause of death. Mortality from insects accounted for the largest share (49 percent) of total mortality. Disease was the second leading contributor to mortality, accounting for 22 percent of the total. Fire was the third highest contributor of mortality and accounted for 17 percent of the total. Utah juniper accounted for the largest share (24 percent) of mortality caused by fire. The high level of fire-caused death in this species during 2003–2012 is likely a result of the tree's prevalence in areas with large fires, including Utah's largest fire in recorded history, the Milford Flat fire in 2007. The "other" cause of death category includes trees that died owing to reasons the field crews were unable to determine.

Because insects were the leading cause of mortality, they are discussed further here. Nearly 82 percent of total Engelmann spruce mortality and nearly 68 percent of lodgepole pine mortality were attributed to insects. The most conspicuous mortality-causing insects for Engelmann spruce, lodgepole pine Douglas-fir, white fir, subalpine

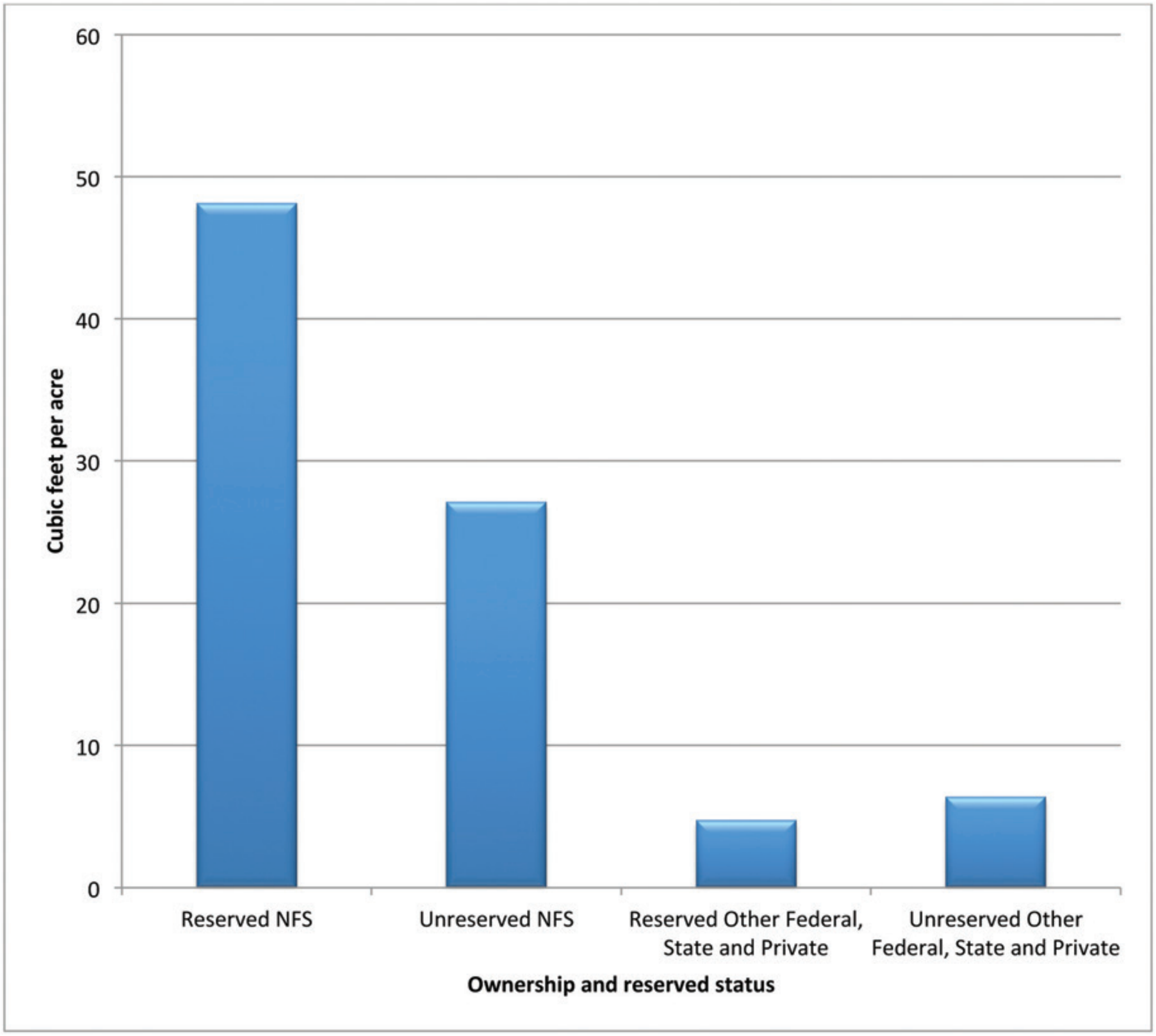


Figure 14—Average annual per-acre mortality on forest land by two major owner categories and reserved status, Utah, 2003–2012.

fir, and common or two-needle pinyon are bark beetles, so it is reasonable to attribute high levels of mortality to ongoing endemic or epidemic populations of these beetles. The spruce beetle (*Dendroctonus rufipennis*) is a native bark beetle that can grow to epidemic population levels in stands of mature, dense Engelmann spruce (Jenkins and others 2014). Extensive and severe spruce beetle-caused Engelmann spruce mortality has been reported in Utah since the 1980s (DeBlander and others 2010; DeRose and Long 2007; Dymerski and others 2001). Continued Engelmann spruce mortality is expected into the future (DeRose and others 2013) where the host resource has not already been exhausted.

The mountain pine beetle (*Dendroctonus ponderosae*) is a native bark beetle that preferentially attacks mature, dense stands of primarily lodgepole pine (Raffa and others 2008). The mountain pine beetle is also responsible for mortality in ponderosa pine and limber pine in Utah (Forest Health Protection 2014) and is likely responsible for a sizable portion of the mortality for those species during the 2003–2012 reporting period. Lodgepole pine mortality in Utah appears particularly acute because the range of the species is limited to the Uinta Mountains and the northern half of the Wasatch

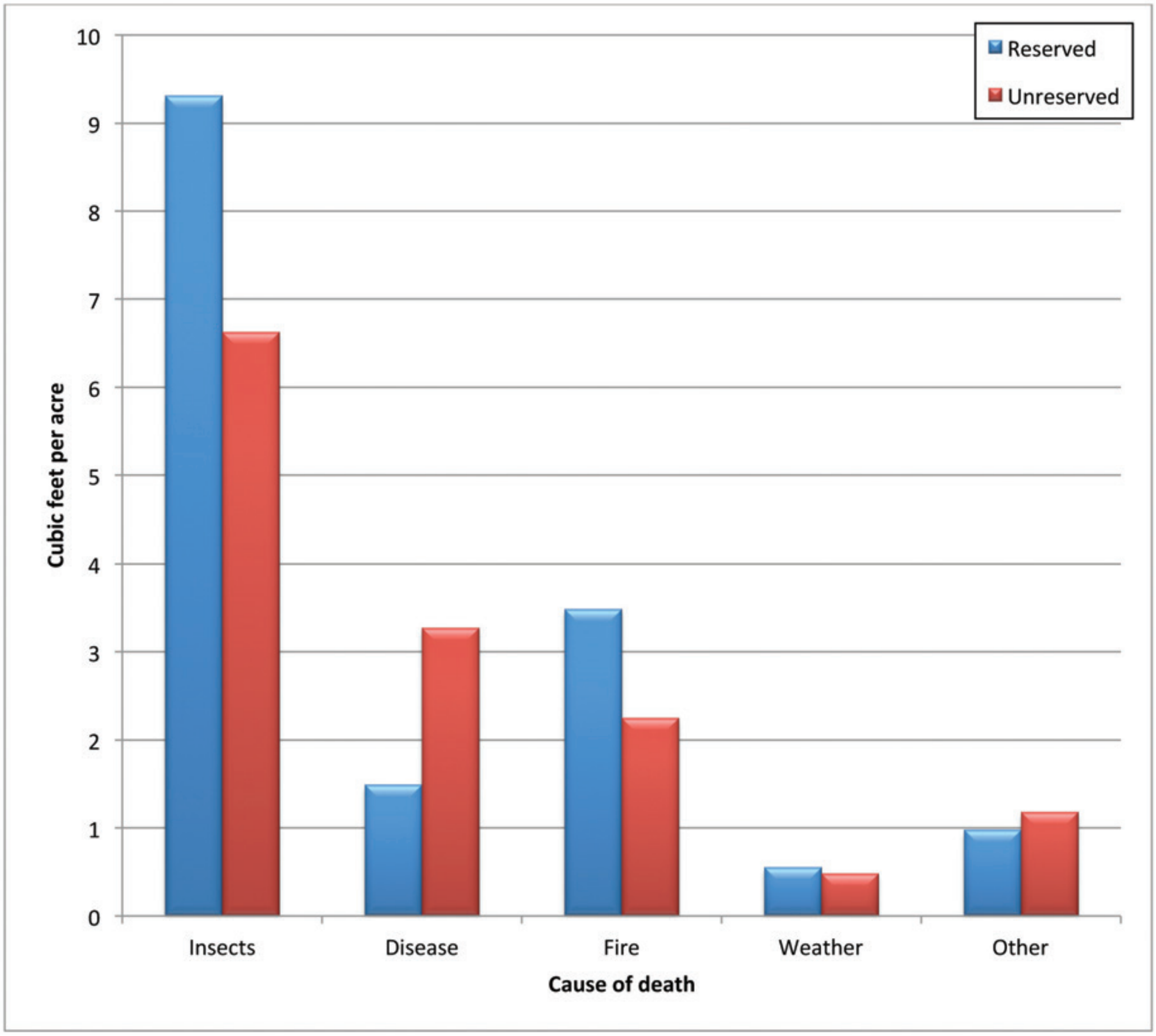


Figure 15—Average annual per-acre mortality on forest land, by reserved status and cause of death, Utah, 2003–2012.

Mountains in the northeast part of the State. The most severe mortality has occurred on the north slope of the Uinta Mountains (Forest Health Protection 2014).

The western balsam bark beetle (*Dryocoetes confusus*) is likely the primary mortality agent for subalpine fir although this beetle typically occurs as part of a "mortality complex" that involves several pests including root disease (Kegley 2006). The Douglas-fir beetle (*Dendroctonus pseudotsugae*) is the primary mortality agent for Douglas-fir in Utah and has been especially active in the southern half of the State (Forest Health Protection 2014). Insect-caused mortality to common or two-needle pinyon in Utah can be attributed to epidemic pinyon ips (*Ips confusus*) populations (Kleinman and others 2012). Another native beetle, this insect has been particularly active in response to drought conditions early in the 2000s (Shaw and others 2005). In stark contrast to the major conifer species in Utah, mortality in quaking aspen is attributed almost entirely to disease, and is covered in detail in the "Aspen Status and Trends" section.

Removals—Volume removed from forest inventory during timber harvesting is known as removals. Removals are another forest change component and an important indicator of the sustainability of timber harvest levels. Live-tree removals that exceed growth for extended periods could indicate overharvesting and decreasing forest inventory. Conversely, growth that greatly exceeds removals could signal the need for vegetation management to regulate density, inhibit insect and disease outbreaks, or reduce wildfire risk.

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; see Appendix A for standard FIA terms and definitions), or dead trees and other non-growing stock sources. The two general types of removals are timber products harvested for processing by mills and logging residue (in other words, volume cut or killed but not utilized). Removals, as reported here, are based on a 2007 census of Utah's primary forest products industry (Hayes and others 2012) and various logging utilization studies (McLain 1997; Morgan and others 2005; Morgan and Spoelma 2008). Removals data for 2012 are being developed, but were not available in time for this report.

Total removals from Utah's forests during 2007 were just over 16.0 million cubic feet (table 5). This total consisted of 14.9 million cubic feet of timber used for roundwood products (including fuelwood) and almost 1.2 million cubic feet of logging residue left in the forest as slash. Fuelwood, nearly all for residential use, accounted for almost 46 percent (7.3 million cubic feet) of total removals. Almost all fuelwood came from non-growing stock sources (dead trees).

Softwoods were the largest component of Utah's removals, accounting for 72 percent of total removals and 74 percent of removals for timber products (table 5). Hardwoods, predominantly aspen and cottonwood were used for pulpwood, fuelwood, and sawlogs.

Growing-stock removals totaled 4.6 million cubic feet, with softwoods accounting for 1.9 million cubic feet (42 percent). Nearly 95 percent (4.4 million cubic feet) of growing-stock removals went to wood products, including fuelwood. Sawlogs were the largest component (53 percent) of growing-stock removals, followed by pulpwood (35 percent), and logs for posts and small poles (5 percent). Less than 0.1 percent of growing-stock removals were used as fuelwood, and just 5 percent (0.2 million cubic feet) of growing-stock removals were logging residue (in other words, not utilized).

Private and tribal timberlands accounted for 36 percent (1.7 million cubic feet) of growing-stock removals; national forests accounted for 34 percent (1.6 million cubic feet). State and BLM lands were the source of the remaining 30 percent (1.4 million cubic feet) of growing-stock removals.

Total roundwood product output from all sources in Utah during 2007 was just shy of 14.9 million cubic feet, most (71 percent) of which came from non-growing stock sources. In addition to the 7.3 million cubic feet of fuelwood mentioned earlier, 1.5 million cubic feet of houselogs, 0.5 million cubic feet of posts and poles, and almost 1 million cubic feet of sawlogs came from dead trees (non-growing stock) (table 6). Of the 4.4 million cubic feet of roundwood output sourced from growing stock, sawlogs were the leading product type, accounting for 2.4 million cubic feet of output. Pulpwood accounted for 1.6 million cubic feet of the output from growing stock, and posts and poles, 0.2 million cubic feet. Sawtimber-size trees (which are softwood trees with diameters of 9.0 inches and larger and hardwood trees with diameters of 11.0 inches and larger) accounted for nearly 84 percent of the roundwood output from growing stock. The remainder came from poletimber-size trees (trees with diameters of 5.0 inches and larger but smaller than sawtimber thresholds).

Table 5—Volume of wood removals (in thousand cubic feet) by source of material, species group, and removal type, Utah, 2007.

Removal Type	Source of material						All sources		
	Growing stock			Growing stock					
	Softwoods	Hardwoods	Total	Softwoods	Hardwoods	Total	Softwoods	Hardwoods	Total
Roundwood Products									
Saw logs	1,535	913	2,447	902	83	985	2,436	996	3,432
Veneer logs	0	0	0	0	0	0	0	0	0
Pulpwood	0	1,641	1,641	0	110	110	0	1,751	1,751
Composite products	0	0	0	0	0	0	0	0	0
Fuelwood (including residential)*	2	0	2	6,235	1,107	7,342	6,237	1,107	7,344
Posts, poles, and pilings	243	0	243	535	4	539	778	4	782
Miscellaneous products	52	0	52	1,509	2	1,511	1,562	2	1,564
Total Roundwood Products	**1,832**	**2,554**	**4,386**	**9,181**	**1,306**	**10,487**	**11,013**	**3,860**	**14,873**
Logging Residues	101	141	242	466	451	917	568	592	1,159
Total Removals	**1,933**	**2,695**	**4,628**	**9,647**	**1,757**	**11,404**	**11,580**	**4,452**	**16,032**

* 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 6—Total roundwood output (in thousand cubic feet) by product and species group, and source of material, Utah, 2007.

Product and species group	Source of Material			
	Growing-stock trees			
	Sawtimber	Poletimber	Other sources	All sources
Sawlogs				
Softwood	1,357	178	902	2,436
Hardwood	807	106	83	996
Total	**2,164**	**284**	**985**	**3,432**
Veneer logs				
Softwood	0	0	0	0
Hardwood	0	0	0	0
Total	**0**	**0**	**0**	**0**
Pulpwood				
Softwood	0	0	0	0
Hardwood	1,451	190	110	1,751
Total	**1,451**	**190**	**110**	**1,751**
Composite Panels				
Softwood	0	0	0	0
Hardwood	0	0	0	0
Total	**0**	**0**	**0**	**0**
Poles and posts				
Softwood	0	243	535	778
Hardwood	0	0	4	4
Total	**0**	**243**	**539**	**782**
Other Miscellaneous				
Softwood	46	6	1,509	1,562
Hardwood	0	0	2	2
Total	**46**	**6**	**1,511**	**1,564**
Total Industrial Products				
Softwood	1,403	427	2,946	4,776
Hardwood	2,258	296	199	2,753
Total	**3,661**	**722**	**3,145**	**7,529**
Fuelwood (including residential)*				
Softwood	2	0	6,235	6,237
Hardwood	0	0	1,107	1,107
Total	**2**	**0**	**7,342**	**7,344**
All products				
Softwood	1,405	427	9,181	11,013
Hardwood	2,258	296	1,306	3,860
Total	**3,663**	**723**	**10,487**	**14,873**

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

Utah's timber harvest in 2012 was 19.4 million board feet Scribner rule, just one-third of what it was in 1992 (Sorenson and others 2014). In 2007, Utah's timber harvest was about one-half of the 1992 level; in 2002 it was about two-thirds of the 1992 level. These decreases in harvest volume were largely the result of harvest reductions from national forests. Volume harvested from national forests has declined by more than 75 percent, falling from almost 47 million board feet in 1992 to less than 16 million board feet in 2007 (Hayes and others 2012; Keegan and others 1995; McLain and others 1997), and just over 10 million board feet in 2012 (Sorenson and others 2014). Harvest volume declines from private and tribal lands were less pronounced during that period; volume harvested declined from 11.3 million board feet in 1992, to 9.2 million board feet in 2002, rose to 11.6 million board feet in 2007, and fell to about 6.3 million board feet in 2012. These declines in Utah's timber harvest volumes pose significant challenges to both the industry and forest sustainability, because the ability to conduct vegetation management and mitigate mortality impacts have decreased as timber processors and forest operators have gone out of business.

Sustainability of Utah's forests depends, in part, on management activities that generate sustainable harvest levels and support a forest products industry. Statewide, average annual gross growth of growing-stock trees on timberland was 116 million cubic feet, 25 times the 2007 growing-stock removals of 4.6 million cubic feet (table B39). When average annual growing-stock mortality on timberland (167.6 million cubic feet; table B28) is taken into account, average annual net growth was *negative* 51.6 million cubic feet (table B24). With about 10.5 million cubic feet of non-growing stock (mostly dead) removed for products, just 6 percent of annual mortality is being utilized. The very high levels of tree mortality on Utah's timberlands not only have an impact on the forest inventory, but also greatly influence the harvest-to-growth relationship, sustainability, and the availability of timber for the forest products industry.

Stand Density Index (SDI)

Stand density index (SDI; 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 (for example, Lilieholm and others 1994; Long and Shaw 2005; Smith and Long 1987).

Stand density index is usually presented as a percentage of a maximum SDI 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, and natural gaps and nonstockable patches tend to limit the potential crowding of trees. Average maximum density, which is used in normal yield tables and is equivalent to the A-line in Gingrich-type stocking diagrams (Gingrich 1967), is equal to about 80 percent of maximum SDI. There are several reasons that stands may have low SDI. Stands typically have low SDI after 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 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. A site is considered to be fully occupied at 35 percent of maximum SDI. At lower densities, individual tree growth is maximized, but stand growth is below potential; at higher densities, individual tree growth is below potential, but stand growth is maximized (Long 1985).

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. Because FIA data include stands covering the full range of structure, maximum SDIs have been developed specifically for FIA forest types. The revised maximum SDIs, which are compatible with FIA computation methods, are shown in table 7. Sources of the SDI equations are documented in Appendix E. For each condition that sampled forest land, SDI was computed by using the summation method (Shaw 2000), and the SDI percentage was calculated from the maximum SDI for the field-determined forest type found on the condition. The field-determined forest type is used instead of the computed forest type because recently disturbed conditions are frequently classified as "nonstocked" by the forest type algorithm (Arner and others 2001). There is no maximum SDI associated with the "nonstocked" forest type, so SDI percentage cannot be calculated. In fact, most nonstocked conditions are actually specific forest types with very low SDI. By using field-determined forest type for nonstocked conditions, we are better able to estimate the area of forest with low stocking in comparison to its potential.

When nonstocked forest types are taken into account, forests in Utah appear to remain well stocked despite recent fires, the ongoing mountain pine beetle outbreak, the early 2000s outbreak of pinyon ips (Shaw and others 2005), and other disturbances. More than 54 percent of forest acres are fully occupied (fig. 16). This percentage compares favorably with recent figures for neighboring States, such as Arizona (45 percent) and New Mexico (53 percent). Just over 21 percent of acres are considered overstocked, meaning that self-thinning mortality is imminent or currently occurring. Overstocked stands are unlikely to include much regeneration of shade-intolerant species, and any shade-tolerant species in the understory are likely to be growing slowly. Heavily stocked

Table 7—Maximum Stand Density Index by forest type, on forest land, Utah, 2003-2012.

Forest type	Maximum SDI
182 Rocky Mountain juniper	425
184 Juniper woodland	385
185 Pinyon / juniper woodland	370
201 Douglas-fir	485
221 Ponderosa pine	375
261 White fir	500
265 Engelmann spruce	500
266 Engelmann spruce / subalpine fir	485
268 Subalpine fir	470
269 Blue spruce	500
281 Lodgepole pine	530
365 Foxtail pine / bristlecone pine	470
366 Limber pine	410
703 Cottonwood	360
901 Aspen	490
971 Deciduous oak woodland	475
974 *Cercocarpus* (mountain brush) woodland	415
975 Intermountain maple woodland	540

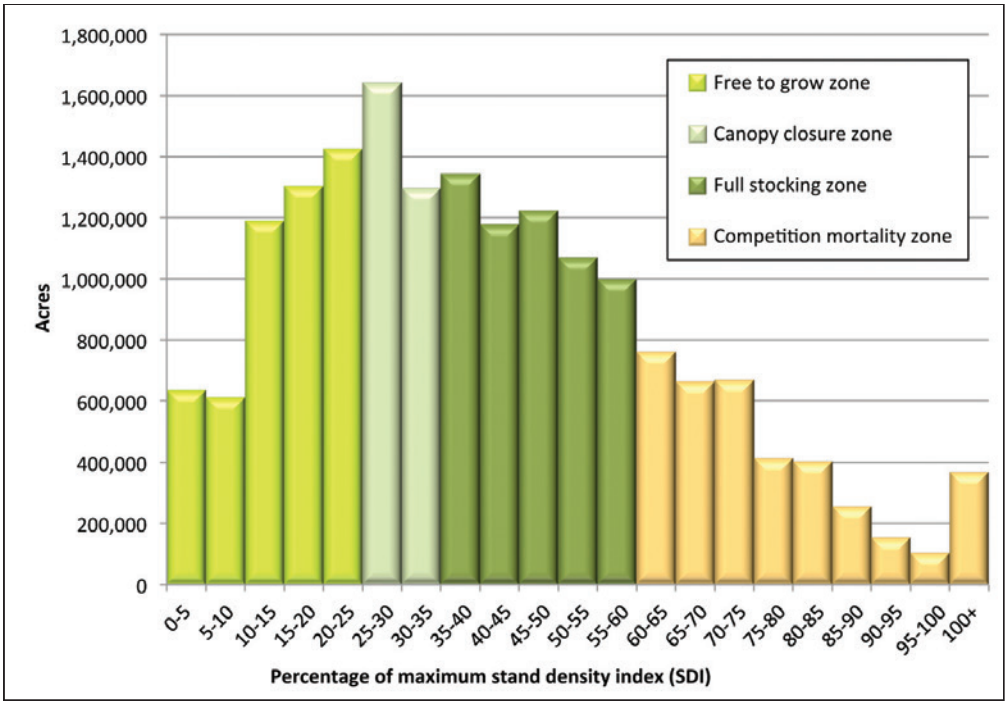


Figure 16—Distribution of stand density index (SDI) for forest conditions in Utah, 2003–2012.

stands typically contain relatively sparse herb and shrub communities as well. In many cases, heavily stocked stands can be considered at increased risk for accelerated mortality. The increased stress of competition can lead to more successful insect attacks or accelerated disease effects, or the high density level can make stands more prone to catastrophic fire.

Over time, SDI varies within the life cycle of each stand. However, at the scale of a forest or whole State, the area of forest that is becoming more dense will generally be offset by other areas that are becoming less dense, resulting in a roughly stable range of densities at the larger scales. Future inventories will be used to evaluate the trend in density as one of many indicators of forest change.

Utah's Forest Resources

Forests provide myriad values and resources to the people and wildlife of Utah. This chapter describes selected forest resources in Utah, including timber and the economic impacts of timber harvest, lichens, wildlife habitat, old forests, understory vegetation, down woody material, and soils.

Utah's Timber Harvest and Forest 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 Utah's primary forest products industry (Hayes and others 2012; Morgan and others 2006). Previous censuses in Utah measured 2002 and 2007 activities, and a report on the 2012 industry census was in preparation at time of press. This section reports key aspects of the 2012 industry census, including industrial timber harvest levels by product and ownership class as well as forest industry conditions like employment, sales value, and production levels. Summarized results from the census of 2012 activities were released in September 2014, and publication of the official report is expected in 2015.

Primary forest products facilities process timber (logs) into manufactured products such as lumber, and also include facilities that use bark or wood residue directly from timber processors. Eighteen facilities were active in 10 Utah counties in 2012 (fig. 17): 8 sawmills, 7 log home manufacturers, and 3 log furniture facilities.

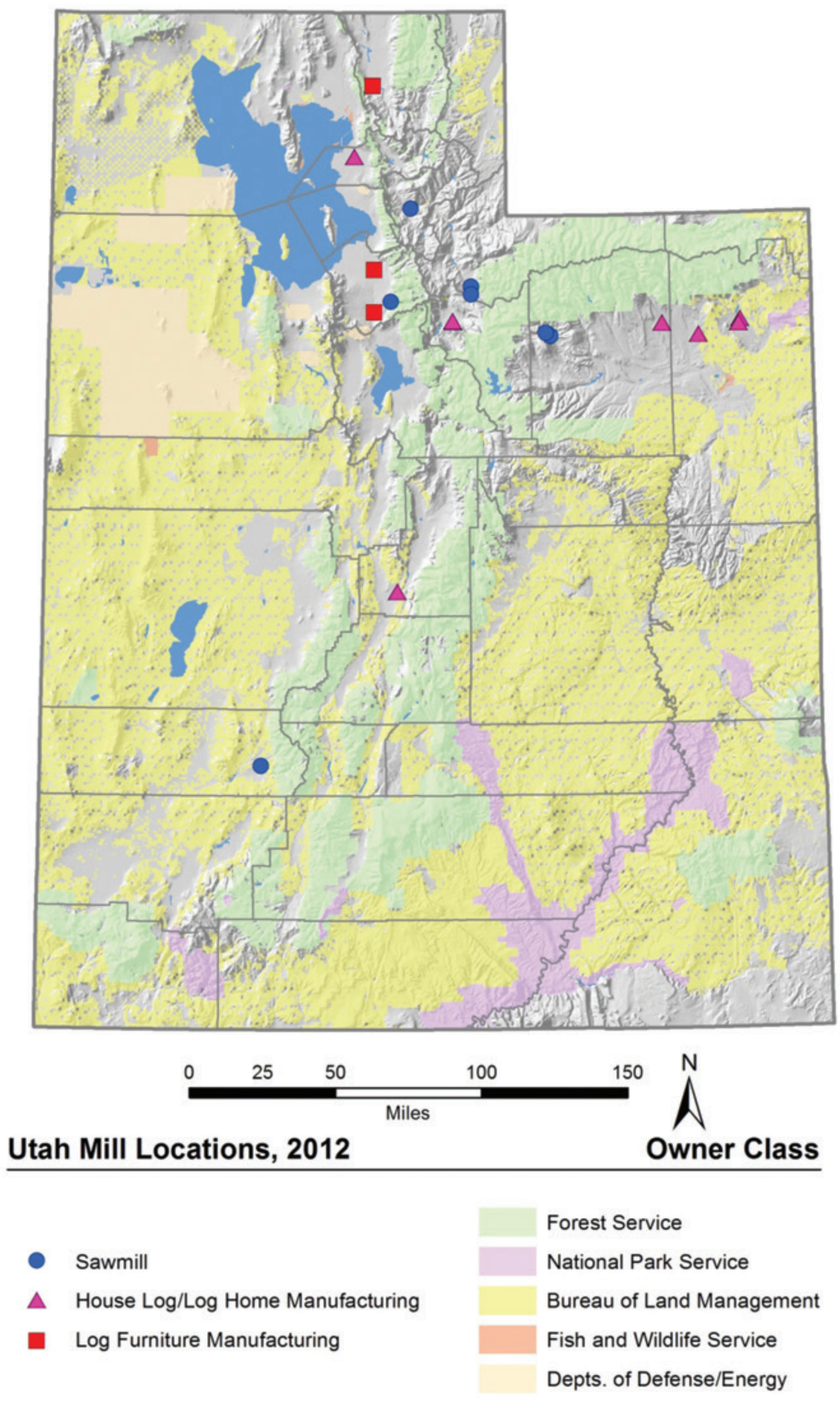


Figure 17—Primary wood processing facilities in Utah, 2012.

The industrial timber harvest in Utah during 2012 was 19.4 million board feet Scribner rule. About 12.2 million board feet (63 percent) of the harvest was dead timber. The 2012 harvest was about 64 percent of the 2007 harvest and 47 percent of the 2002 harvest (Hayes and others 2012). Private and tribal lands supplied about 33 percent of the 2012 harvest, and about 68 percent came from public lands, with national forests supplying 52 percent of the total. Sawlogs (that is, timber used for manufacturing lumber and other sawn products) accounted for 74 percent of the harvest volume. Lodgepole pine was the leading species harvested, accounting for 41 percent of the 2012 harvest volume, followed by Engelmann spruce (32 percent), Douglas-fir (11 percent), aspen and cottonwood (10 percent), and ponderosa pine (4 percent). In the north-central part of the State, Wasatch, Sanpete, and Summit Counties together produced about 46 percent of the commercial timber harvest volume, and San Juan and Garfield Counties in the south accounted for 12 percent. The majority (59 percent) of timber harvested in Utah during 2012 was processed in-State. Slightly more than 8 million board feet Scribner rule of timber was processed outside the State, and just 167 thousand board feet of timber from out-of-State was processed by mills in Utah.

Timber processors in Utah received 11.5 million board feet Scribner rule during 2012. The eight sawmills in the State used about 7 million board feet Scribner rule of logs and produced slightly less than 9.5 million board feet of lumber, with sales value of $3.4 million. The three largest sawmills in the State accounted for 75 percent of lumber production and each had an average annual production of 2.4 million board feet of lumber. The seven log home manufacturers operating in 2012 used about 4.4 million board feet Scribner rule of timber and had sales of about $10.3 million. Manufacturers of log furniture and posts and poles used 243 million board feet Scribner rule of timber and had combined sales of $1.4 million.

The forest products industry includes private sector foresters, loggers, and other forest workers, as well as employees at primary and secondary wood and paper products manufacturing facilities. Employment data from the U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System (USDC BEA 2012) showed employment in Utah's forest products industry totaled about 5,755 workers in 2012, with about 181 in forestry and logging, 2,784 in paper manufacturing, and 2,464 in wood product manufacturing. The BBER's 2012 census of Utah's forest products industry indicated about 112 full-time-equivalent employees at primary wood products manufacturing facilities. Secondary wood and paper manufacturing employment was estimated to be about 5,643 workers. Since 2007, total forest industry employment in Utah has declined by more than 2,000 workers, with small losses in forestry and logging and paper manufacturing and significant downsizing in wood product manufacturing.

As the results of the 2012 industry census indicate, Utah's timber harvest volume, employment in the various forest industry sectors, sales of wood products, and the number of active facilities in Utah have all declined from 2007 levels. The State's industry, like that in much of the western United States, continues to wrestle with the impacts of timber harvest reductions from federal lands since the 1990s (Keegan and others 2006; Morgan and others 2006) and the more recent Great Recession and U.S. homebuilding collapse (Keegan and others 2012; Woodall and others 2012), as well as high levels of tree mortality.

Forest Lichens

Surveys of epiphytic lichens (those growing on woody substrates) are one of several Ecosystem Indicators (formerly known as the Forest Health Monitoring or Phase 3 Indicators) collected by FIA crews. In the past, these indicators were measured nationally on FIA's Phase 3 grid (one-sixteenth of Phase 2 plots). Currently each FIA region now decides which of the Ecosystem Indicators to measure and scales the spatial and temporal intensity of sampling against available funding and client feedback. To date, 128 lichen surveys have been conducted across Utah and are used for the following analysis.

Lichens are commonly used as "canaries in the coal mine" for monitoring air quality and, more recently, climate change (Ellis 2012; Parmesan and Yohe 2003). Lichens are made up of a fungus living symbiotically with a photosynthetic partner, either an algae or cyanobacterium. They cannot store water, so environmental moisture (and any contaminants it carries) is absorbed opportunistically. Predictable shifts in species occur in the presence of pollutants such as sulfur dioxide, nitrogen-containing compounds (for example, ammonia, nitric acid, nitrogen oxides), and some aerosols. Data on lichen from FIA and from European forests are used for pollution mapping and evaluating the impact of emissions abatement strategies, especially for large-scale assessments where using air quality instruments is cost-prohibitive (Cape and others 2009; Fenn and others 2010; Geiser and others 2010; Hawksworth and Rose 1970; Jovan and McCune 2005; Jovan and others 2012).

For the lichen indicator, an FIA crew member searches a circular 0.378-hectare (0.93-acre) area centered on subplot 1 for lichens for up to 2 hours (Woodall and others 2010). Crews have collected lichen data at 128 plots in Utah between 2005 and 2010, finding 31 epiphytic lichen species in total (table 8) and an average of 5 species per plot (fig. 18). The low diversity they observed is not necessarily a sign of a problem; low rainfall and high summer heat naturally limit which species can survive. The most common species in Utah are widely used as positive indicators of nitrogen pollution in more temperate climates (Jovan 2008; Larsen Vilsholm and others 2009; van Herk 1999). For instance, the conspicuously orange nitrophytic species (those that thrive in nitrogen-rich environments) *Xanthomendoza* (fig. 19) and *Xanthoria* are found at all but 15 plots (fig. 20).

It is not clear whether nitrogen really is a widespread and serious air quality issue in Utah. Although FIA lichen data for the Southwest have not yet been thoroughly analyzed, lichens in California's dry oak woodlands suggest that for a given level of nitrogen pollution, nitrophytic species occur in higher abundance in drier forests. It was recently proposed that nitrogen and desiccation tolerance share the same physiological mechanism in lichens (Frahm 2013). Further, without a correction for climate, the Utah lichen data probably overstate air quality problems.

To aid in data interpretation, the Rocky Mountain Research Station will be conducting a calibration project to begin monitoring nitrogen, sulfur, and metals in throughfall at 10 sites under ponderosa pine in northern New Mexico. Beginning in spring 2015, lichen community surveys and pollutant levels in lichen tissue will be collected for each site. Results are expected to be available by spring 2017.

Table 8—Species list for lichen community surveys with human uses indicated, Utah, 2005-2010.

Scientific name	Common Name	Frequency	Human use
Bryoria simplicior	horsehair lichen	1	
*Candelaria pacifica**	lemon lichen	8	
Cladonia carneola	cup lichen	1	
Cladonia sulphurina	sulphur cup lichen	1	
Evernia divaricata	ring lichen	1	
*Flavopunctelia soredica***	flavopunctelia lichen	4	Dye source - Navajo - "flesh-color" dye. From Sharnoff list "Suminski, R. 1994. personal letter (determination by J. Marsh)."
*Letharia vulpina***	wolf lichen	1	"Interior native peoples used for yellowish-green dye for fur, moccasins, feathers, wood and other articles" Plants of Rocky Mountains, Lone Pine Press 1998.
Melanohalea elegantula	melanohalea lichen	60	
Melanohalea exasperata	melanohalea lichen	7	
Melanohalea exasperatula	melanohalea lichen	7	
Melanohalea subolivacea	melanohalea lichen	82	
Parmeliopsis ambigua	ambiguous bran lichen	2	Has compounds with antimicrobial properties (Rankovic, and others 2012)
Parmeliopsis hyperopta	bran lichen	1	
Phaeophyscia ciliata	ciliate wreath lichen	1	
Phaeophyscia hirsuta	hairy wreath lichen	26	
Phaeophyscia hispidula	hispid wreath lichen	1	
Phaeophyscia nigricans	wreath lichen	3	
Physcia adscendens, ***	rosette lichen	58	
*Physcia biziana**	rosette lichen	47	
*Physcia dimidiata**	rosette lichen	66	
Physcia dubia	rosette lichen	6	
Physciella chloantha	physciella	34	
Physciella nepalensis	Nepal physciella	4	
*Usnea hirta***	beard lichen	5	Usnic acid has weakly antimicrobial and anti-cancer properties (Brandao and others 2013, Mayer and others 2005); *Usnea* is used in deodorants and sold as a tincture in health food stores
*Usnea lapponica***	Lapland beard lichen	4	Usnic acid has weakly antimicrobial and anti-cancer properties (Brandao and others 2013, Mayer and others 2005); *Usnea* is used in deodorants and sold as a tincture in health food stores.
Usnea substerilis	beard lichen	1	Usnic acid has weakly antimicrobial and anti-cancer properties (Brandao and others 2013, Mayer and others 2005); *Usnea* is used in deodorants and sold as a tincture in health food stores.
Xanthomendoza fallax, ***	xanthomendoza lichen	36	
Xanthomendoza fulva, ***	xanthomendoza lichen	8	
*Xanthomendoza galericulata**	xanthomendoza lichen	59	
*Xanthomendoza montana**	xanthomendoza lichen	102	
Xanthoria polycarpa, ***	orange wall lichen	1	

* indicator species used by FIA for detecting nitrogen (Jovan 2008, McCune and Geiser 2009)
** species used by FIA and partners for mapping nitrogen, sulfur, heavy metals by analyzing tissue concentrations (Jovan and Carlberg 2007, McMurray et al. 2013, Root et al. 2013, Will Wolf unpublished)

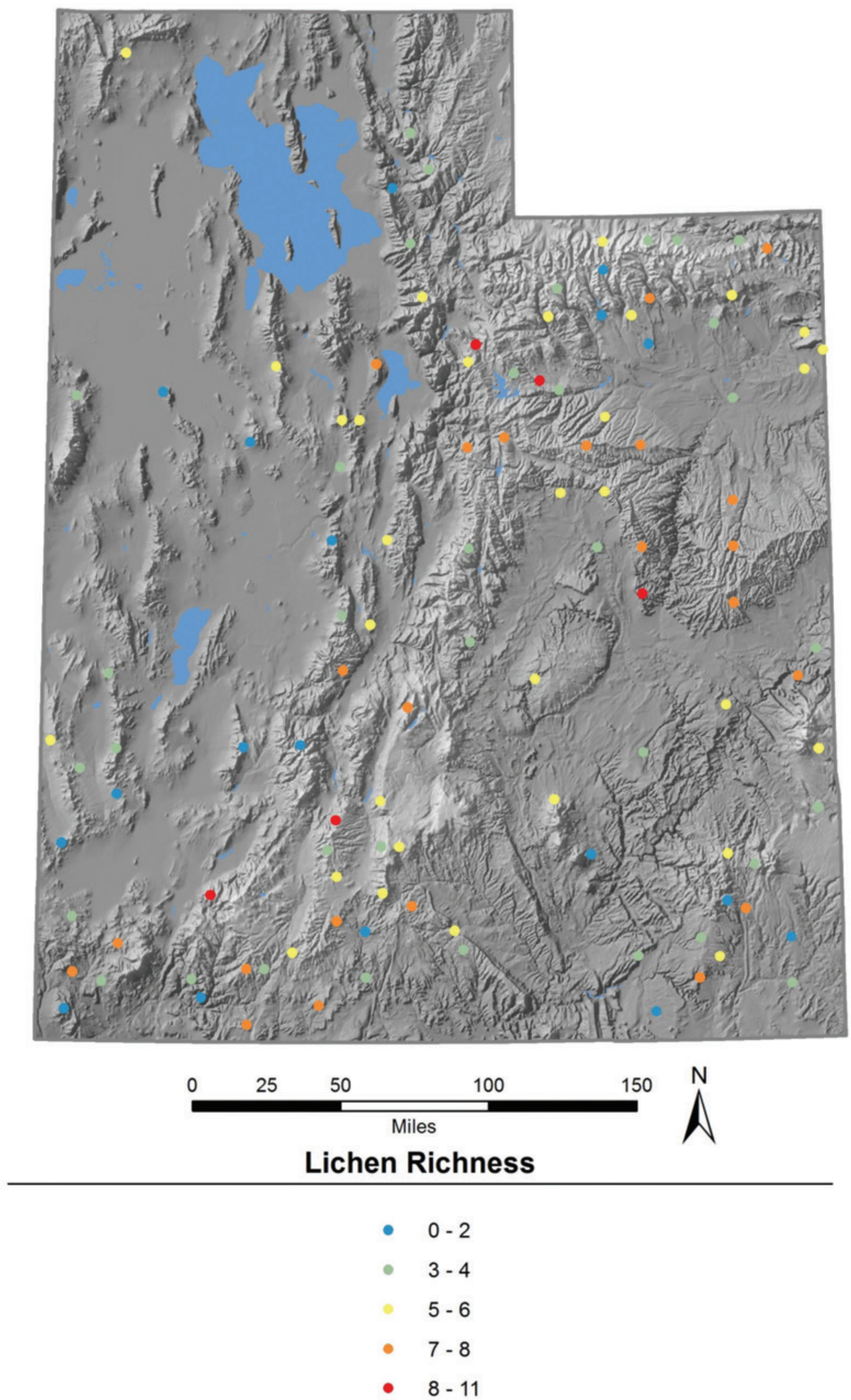


Figure 18—Distribution of total lichen species plots, Utah, 2005–2010. (Note: plot locations are approximate; some plots on private land were randomly swapped.)

Figure 19—*Xanthomendoza* species on Gambel oak in Utah.

Wildlife Habitat

Assessments of wildlife habitat often rely on forest attributes that describe stand structure and composition. Different forest attributes may serve as habitat indicators for different wildlife species, and they may include forest type, stand size or age, number of dead versus live trees, understory vegetation, and down woody material. This section presents two case studies where FIA data are being used as a tool for monitoring wildlife habitat. The first case study uses FIA data to monitor the available habitat of a threatened species, Lewis' woodpecker; and the second demonstrates the use of FIA data to quantify available habitat for three cavity-nesting bird species.

FIA Data as a Habitat Monitoring Tool: Lewis' Woodpecker—For decades, FIA plot data have been used to report trends in forest status, health, and resources. As additional forest attributes such as understory vegetation and down woody material have been added to the Phase 2 protocols, FIA data have also become increasingly useful for estimating and monitoring wildlife habitat and tracking changes in its quality and quantity over time. In some cases, we need to quantify and monitor habitat needs over time to assess the effectiveness of the management programs being implemented. Monitoring is often expensive and logistically cumbersome and might not provide useful information in a timely fashion. Data from FIA can be useful for estimating habitat over large areas and comparing trends over time with little or no additional costs to agencies managing the habitat in question. If FIA currently collects data on forest attributes found important to a focal species, these attributes can be compared at two different times, giving biologists the ability to detect trends in habitat availability for a species over large geographic areas in perpetuity.

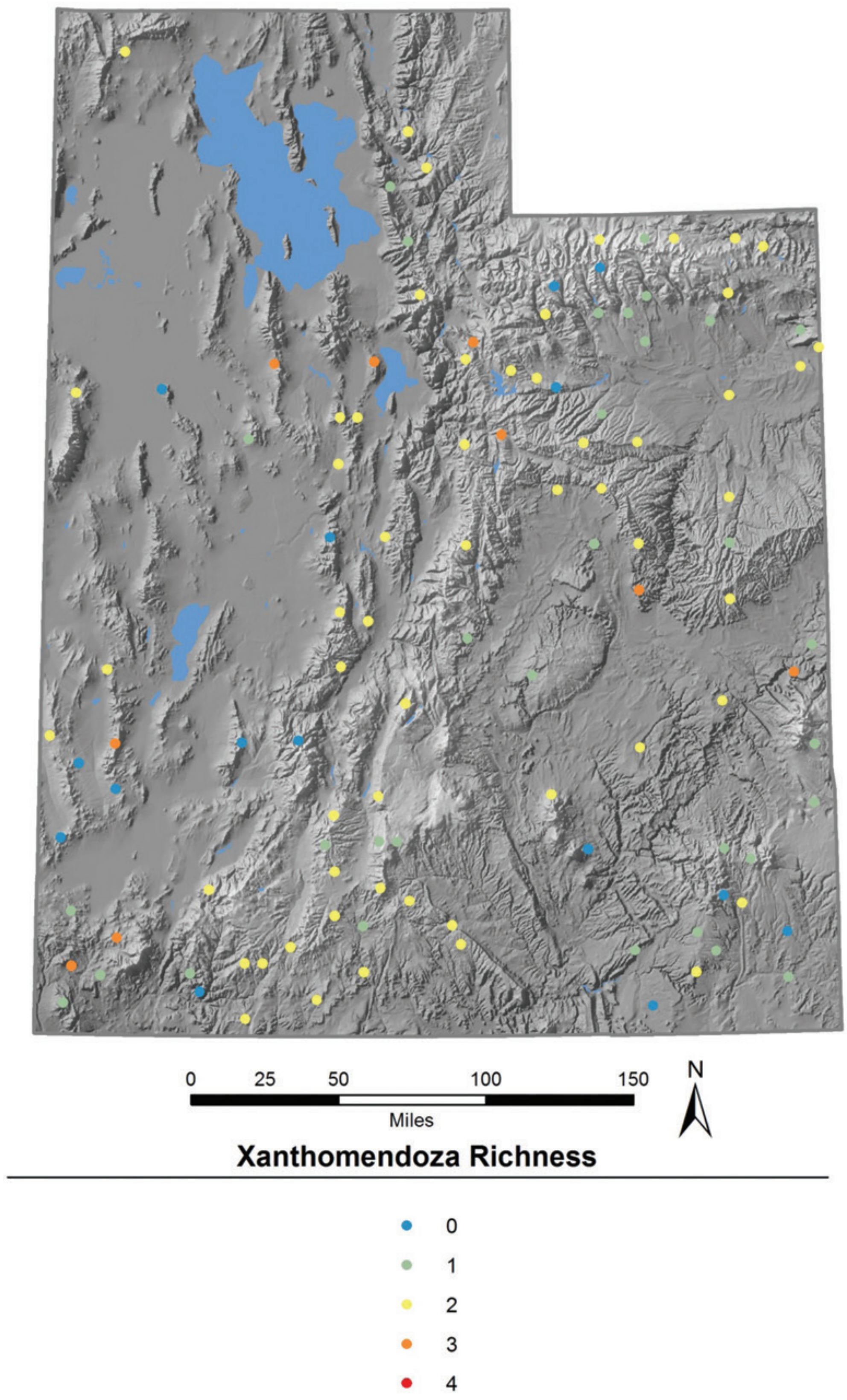


Figure 20—Distribution of *Xanthomendoza* plots, Utah, 2005–2010. (Note: plot locations are approximate; some plots on private land were randomly swapped.)

In this example, nesting habitat for Lewis' woodpecker (*Melanerpes lewis*) is used as a case study for the application of FIA data as a trend analysis tool for wildlife habitat. Lewis' woodpeckers can be found throughout western North America where open "park-like" forest stands or recent burns predominate and provide structure for mating and foraging activities (Bock 1970; Sousa 1983; Tobalske 1997). Because of this species' use of burned areas, Lewis' woodpecker has been categorized as a "burn specialist" (Block and Brennan 1987; Bock 1970; Raphael and White 1984; Saab and Vierling 2001). It is thought that the large numbers of dead and decaying trees (for nest and perch sites), presence of understory shrub cover (promoting high insect densities), and open canopy (for visibility and maneuverability when catching flies) found in burned pine forests are ideal for this species (Linder and Anderson 1998; Russell and others 2007; Saab and others 2007). However, some low-to-mid elevation unburned pine and aspen stands have been found to provide suitable structure and are used successfully by Lewis' woodpecker in the absence of large disturbed areas (Saab and Vierling 2001; Tobalske 1997; Vierling 1997).

For the following analysis, we used FIA plots initially visited in 2000–2002 and then revisited in 2010–2012. Plots that gained or lost status as accessible forest land between these two time periods were not included in the sample. Each plot was evaluated for structure preferred by Lewis' woodpecker based on criteria for nesting habitat. Canopy cover (less than 46 percent), understory shrub cover (more than 15 percent), and forest type (certain conifer and aspen types below 9,000 feet in elevation) were used to define suitability (Sousa 1983; Tobalske 1997). To detect changes in available habitat over the decade between plot measurement, conditions that met all or some of the habitat criteria in the 2000–2002 dataset (time 1) were compared to those that satisfied the habitat criteria in the 2010–2012 (time 2) dataset.

A total of 132 remeasured conditions met the forest type and elevation criteria for Lewis' woodpecker nesting habitat at time 1 compared to 122 conditions at time 2. Sixty conditions (45 percent) met maximum canopy cover criteria at time 1 and 68 (56 percent) met them at time 2. Twenty-five of the conditions (19 percent) providing theaforementioned attributes also provided suitable understory cover at time 1; 35 conditions (29 percent) did so at time 2. Figure 21 illustrates these differences between the two time series. The data suggest that nesting habitat for Lewis' woodpecker in undisturbed forests has increased in Utah since 2002. Aspen forests contain most of the nesting habitat for Lewis' woodpecker in the absence of highly disturbed forests, having 28 percent of the suitable conditions at time 1 (along with white fir) and 60 percent of them at time 2.

The reduction in the number of conditions found in suitable forest types below 9,000 feet in elevation is the result of a shift in forest type on some plots during the time between measurements. Most of this change occurred in aspen and Douglas-fir types. Two Douglas-fir and three aspen types changed to the subalpine fir forest type while four other aspen types changed to the deciduous oak woodland type. Subalpine fir and deciduous oak forest types do not provide the open subcanopy preferred by the bird. The other changes in suitable habitat between the two time periods are a reduction in habitat found in the white fir forest type and a large increase found in the aspen type. These results reflect how quickly suitable structure found in aspen forests can change. In the future, suitable habitat might show an overall decrease in these forests but an increase in another type. In these circumstances, Lewis' woodpeckers might have to switch nest site locations as often as every few years as understory and canopy conditions change. This switch might include using a different forest type or moving to suitable aspen forests at another location. As long as there is adequate acreage of aspen at the landscape scale,

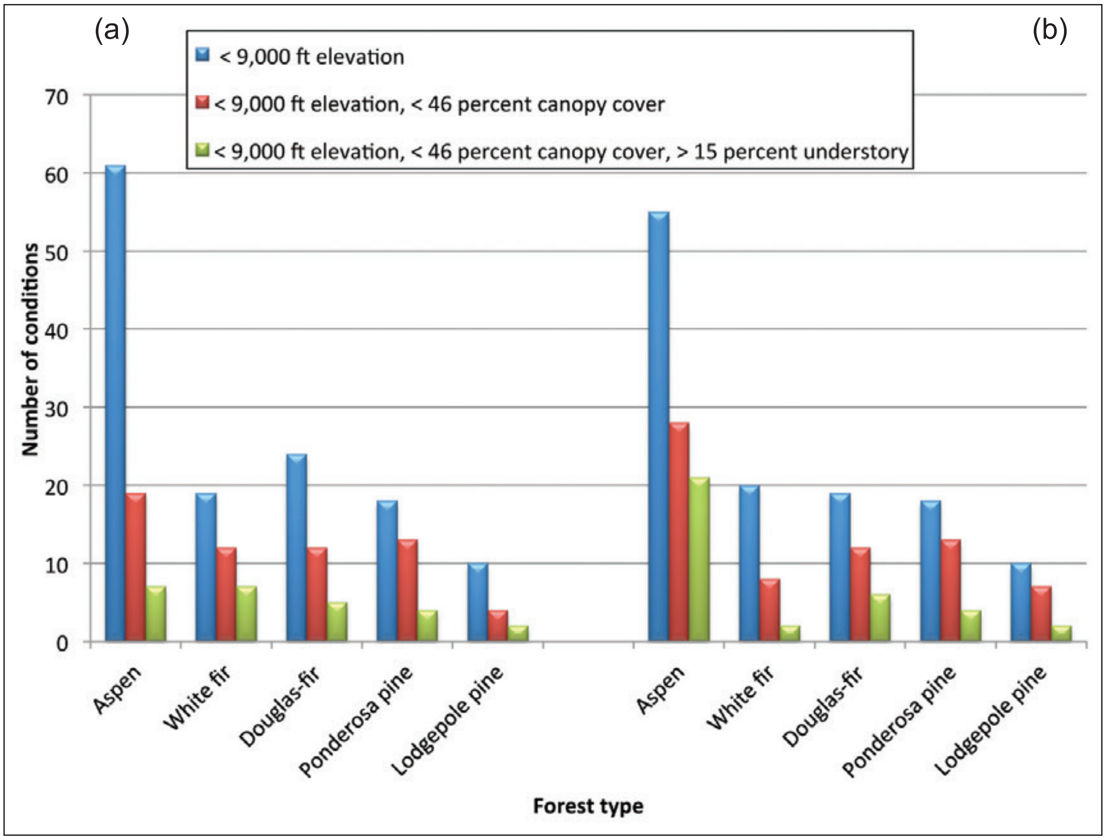


Figure 21—Number of conditions by forest type that meet or exceed nesting habitat preferences for Lewis' woodpecker in Utah in two times series: (a) 2000-2002 and (b) 2010-2012.

it continues to exist in a variety of structural states, and it is allowed to follow natural successional pathways, aspen is expected to continue to provide the bulk of the nesting habitat for Lewis' woodpecker when and where disturbed stands are not available.

Snags as Wildlife Habitat—Standing dead trees, or "snags," provide valuable habitat in forested ecosystems. There are countless organisms that use snags at some point in their life history, including bacteria, fungi, insects, rodents, cavity-nesting birds, bats, mustelids, and black bears. The height, diameter, species, condition, and spatial placement of standing dead trees are important variables to species as they consider a snag for nesting, roosting, or denning. Data on individual trees collected by FIA can be used to estimate the number and distribution of suitable snags for a variety of wildlife species.

Cavity-nesting birds are especially dependent on snags for both nesting and foraging activities. There are a handful of bird species that act as primary excavators of nest sites in this system. These birds create a cavity during one breeding season, but often abandon it and create a new cavity the next year. The old cavities are then occupied by secondary cavity-nesting birds, as well as a suite of mammalian species. Secondary cavity-nesters do not excavate their own nest sites and are dependent on primary excavators for their cavities. The suitability of an old cavity for a secondary nester often depends on the species of primary excavator that created it.

To illustrate how FIA data can be used to quantify snags important as wildlife habitat, we estimated the number of snags in Utah that met the diameter preferences for three important primary excavators by tree species, forest type, and stand age. The hairy woodpecker (*Picoides villosus*), red-naped sapsucker (*Sphyrapicus nuchalis*), and northern flicker (*Colaptes auratus*) each create different sized openings and cavities and are relatively abundant and widespread throughout the different forest types of Utah. Therefore they provide suitable nest sites for a wide variety of secondary nesting species. Suitability was based on mean diameters found to be used by these birds (Dobkin and others 1995; Flack 1976; Martin and others 2004; McClelland and others 1979).

There are an estimated 149 million snags in Utah that meet the diameter preferences of the hairy woodpecker (trees 10.0 inches in diameter and larger). The most abundant tree species contributing to these birds' nesting sites are Utah juniper (44.9 million snags), common or two-needle pinyon (19 million), and Engelmann spruce (16.9 million) (fig. 22). More than 96 million snags meet the diameter preferences of the red-naped sapsucker (trees 12.0 inches in diameter and larger). Utah juniper contributes most of these snags at 30.4 million, followed by Engelmann spruce (13.3 million), and twoneedle pinyon (11.6 million). Roughly 57 million suitable northern flicker snags (trees 14.0 inches in diameter and larger) are estimated to be located in Utah forests. The most common species of snags are Utah juniper (20.5 million), Engelmann spruce (10.1 million), and Douglas-fir (6.7 million). The pinyon/juniper woodland forest type contains by far the most snags meeting all three diameter preferences in Utah (110.1 million, fig. 23). The aspen forest type (29.2 million) is next in snag abundance, followed by the subalpine fir type (23.5 million).

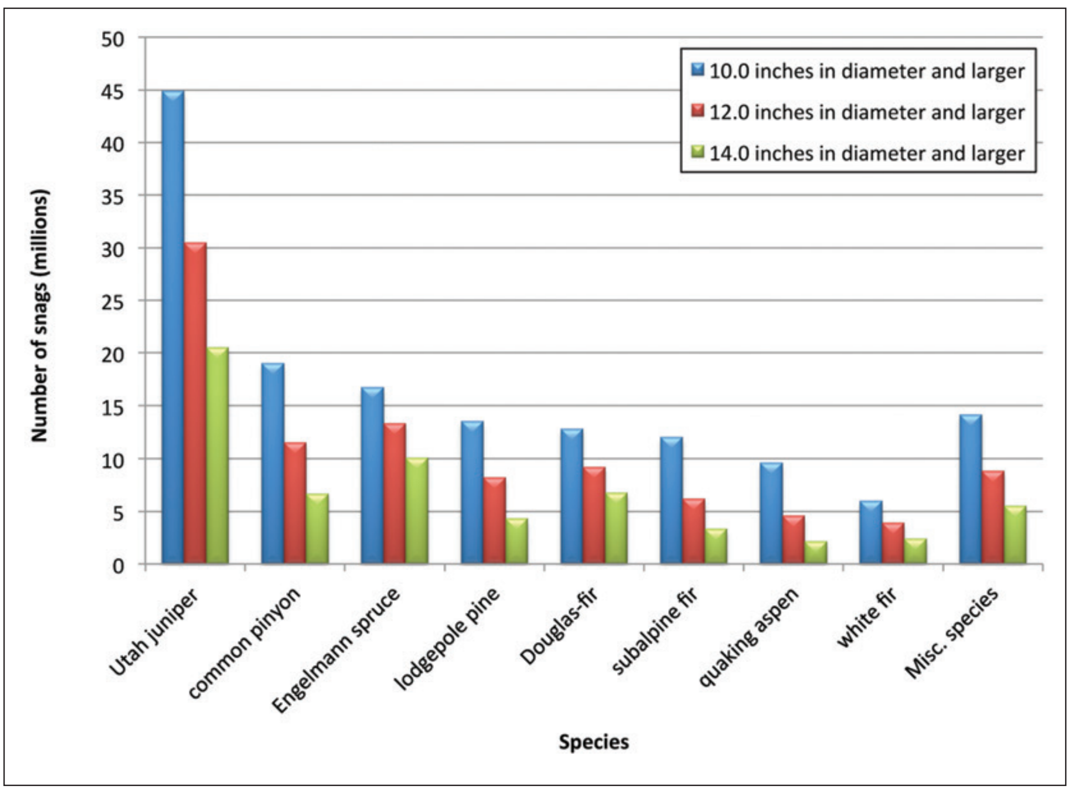


Figure 22—Estimated number of snags that meet diameter preferences of common cavity nesting birds by diameter class and tree species, Utah, 2003-2012.

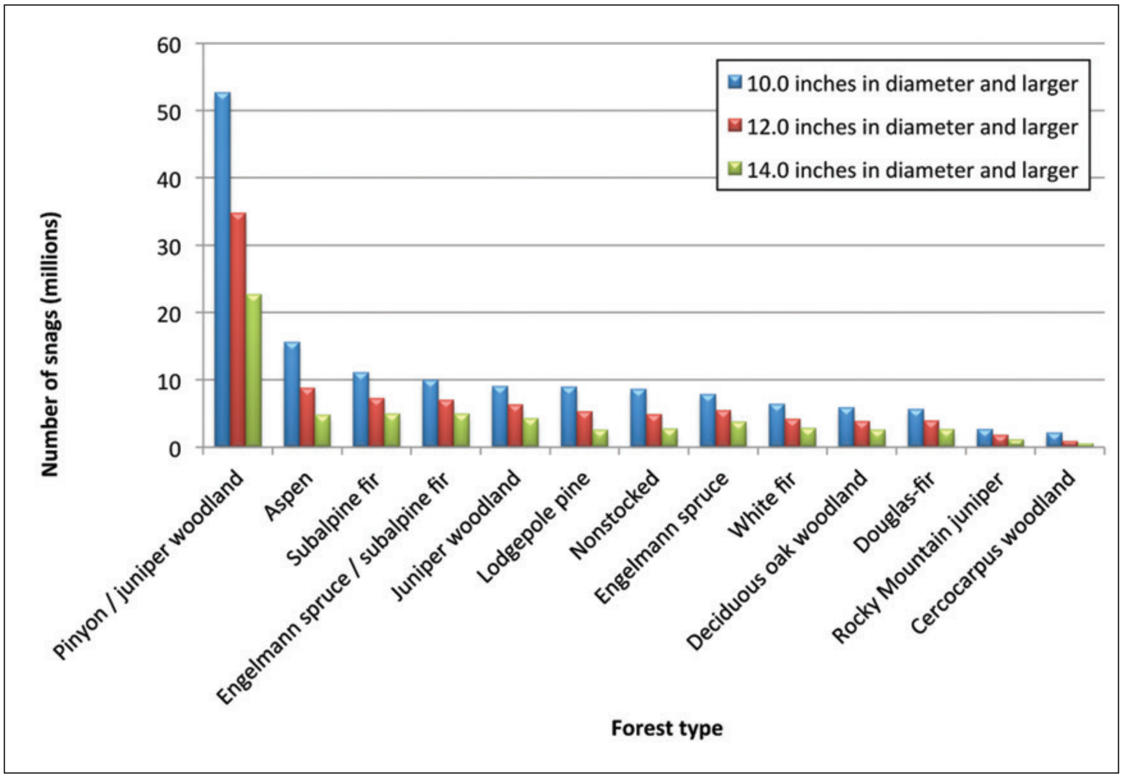


Figure 23—Estimated number of suitable snags for common cavity nesting birds by diameter class and forest type, Utah, 2003-2012.

A plurality (31 percent) of snags meeting the diameter preferences of all three cavity-nesting bird species (trees 14.0 inches in diameter and larger) in Utah are found in forests with stand ages of 121–180 years (fig. 24), followed by 61–120 years (25 percent) and 181–240 years (19 percent). With the exception of the non-stocked woodland type, all forest types in Utah have the majority of their snags in one of the aforementioned age classes. The non-stocked woodland forest type has most of its snags found in the 0- to 60-year-old age class. This forest type often includes areas disturbed by wildfire, disease, timber harvest, and insect infestations.

Variables other than snag size dimensions and numbers need to be considered when predicting suitable wildlife habitat for cavity-nesting birds. Proximity to forest edge and stand density of live trees are important to many of these species. The state of decay of a tree and its distance to foraging also play a role in nest site suitability. Data collected by FIA can address many of these factors and efforts are underway to build predictive models for these species with these data. These models can be valuable tools for federal and State land managers, as much of the forest area containing suitable snags occurs on public lands.

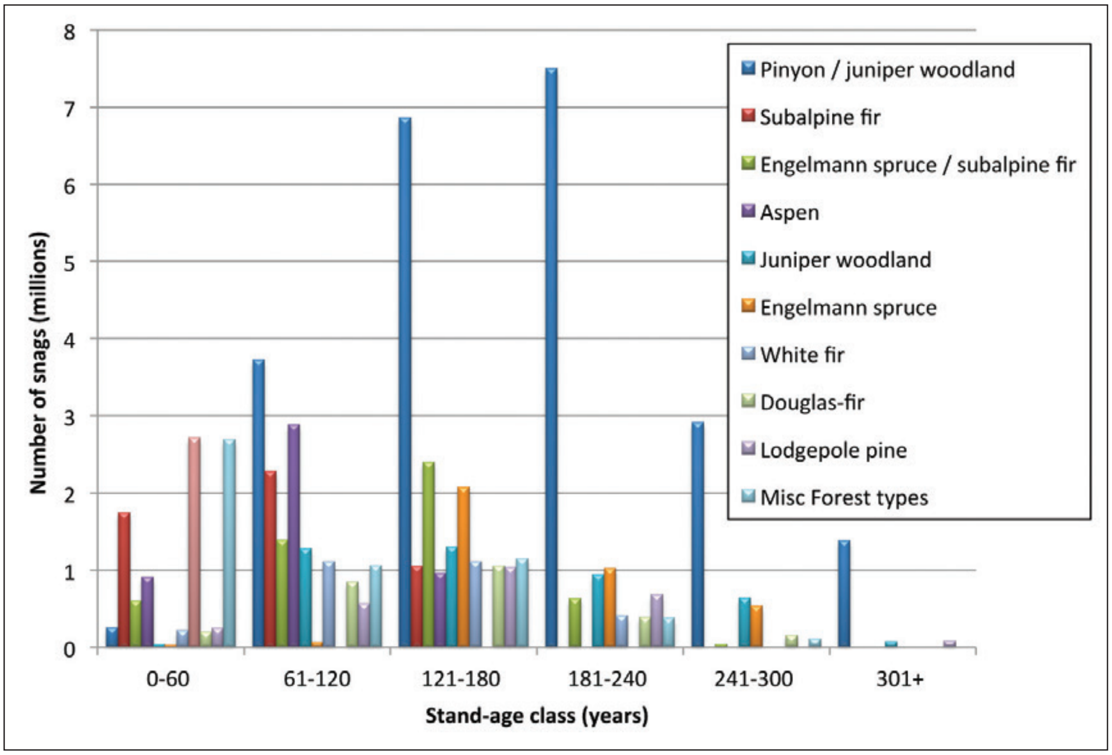


Figure 24—Number of snags in Utah meeting the diameter preferences of most cavity-nesting birds by stand-age class and forest type, Utah, 2003–2012.

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, over-mature, and old growth (Helms 2004). Standardized definitions are problematic because the final structure and age of a given forest stand depend on many biological and physical components, such as climate, geology, dominant tree species, and fire regimes (Kaufmann and others 2007; Vosick and others 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 and others 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 or old trees per acre, overall stand density, canopy characteristics, and downed logs (Fiedler and others 2007; Helms 2004).

One approach for assessing old forests by using FIA data simply defines old forests as those with a stand age of 150 years or older. Based on this threshold, about one-third of Utah's forest land is old forests (table 9), and the percentage varies by forest-type group. Six forest-type groups have more than 10 percent of their total area in stands at least 150 years old; in descending order of their total area, these are the pinyon/juniper,

Table 9—Total area (in acres) of each forest-type group, area (in acres) of each forest-type group with stand age of at least 150 years, and percentage of each forest-type group's total area that has a stand age of at least 150 years.

Forest-type group	All stands	Stand age 150+ years	Percentage of stands 150+ years
Pinyon / juniper group	10,747,520	5,308,854	49.4%
Douglas-fir group	552,635	111,042	20.1%
Ponderosa pine group	346,841	65,973	19.0%
Fir / spruce / mountain hemlock group	1,471,870	434,894	29.5%
Lodgepole pine group	427,320	84,196	19.7%
Other western softwoods group	61,721	45,258	73.3%
Elm / ash / cottonwood group	61,931	1,647	2.7%
Aspen / birch group	1,573,687	12,217	0.8%
Woodland hardwoods group	2,481,591	110,819	4.5%
Nonstocked	574,346	0	0.0%
All forest-type groups	**18,299,461**	**6,174,901**	**33.7%**

fir/spruce/mountain hemlock, Douglas-fir, lodgepole pine, ponderosa pine, and other western softwoods forest-type groups. Nearly half of the area covered by the pinyon/juniper forest-type group, or 5.3 million acres, occurs in stands at least 150 years old. Within the fir/spruce/mountain hemlock forest-type group, nearly 30 percent of stand area (0.4 million acres) is at least 150 years old. The forest-type group with the highest percentage of old forests (73 percent) was the other western softwoods forest-type group, which consists of the limber pine and foxtail pine/bristlecone pine forest types. The Douglas-fir, ponderosa pine, and lodgepole pine forest-type groups have similar percentages of stands that are 150 years old or older (20, 19, and 20 percent, respectively). Small percentages of aspen forests (less than 1 percent), cottonwood stands (less than 3 percent), and woodland hardwoods (less than 5 percent) occur in stands at least 150 years old.

The large differences between forest-type groups illustrate the need for type-specific definitions for identifying old forests. Some species or forest types may be more susceptible to stand-replacing disturbances and therefore have higher percentages of younger stand-age classes. 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 in limber pine or foxtail pine/bristlecone pine than in aspen forest types. As noted above, the forest-type group that includes the limber pine and foxtail pine/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 can 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 (Witt and others 2012), Montana (Menlove and others 2012), and Utah (DeBlander and others

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 showed that using different 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. In the future, researchers may use the FIA database to validate or even help to establish surrogate measurements for defining old forest structure by forest type, under different site conditions, and in different regions.

Understory Vegetation

The structure and composition of understory vegetation affects the overall diversity, productivity, and habitat quality of forested ecosystems. Understory vegetation data are collected on all Phase 2 plots by using two distinct protocols that characterize overall vegetation structure as well as species composition. Under the vegetation structure protocol, FIA 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 less than 5.0 inches in diameter). Under the species composition protocol, height class, growth habit, and percent cover are recorded for plant species that individually occupy at least 3 percent of the ground area. If more than four species occupy more than the cover threshold, then only the most abundant four species per life form are recorded. In Utah, the threshold for recording individual species was lowered to 3 percent from 5 percent beginning in 2011 (USDA FS 2006; 2011). Note that the vegetation structure protocol also includes all species that have less than the minimum thresholds for being recorded under the species composition protocol. In other words, it is possible that few species or no species are recorded under the species composition protocol, yet a much higher percent cover is recorded within the structure protocol. This situation could occur on plots where many species are present but where each species occupies less area than the cover threshold for individual species.

Figure 25 depicts the average percent cover of each plant growth habit within each of Utah's 20 forest types. This analysis was completed by first querying the table for Phase 2 understory vegetation structure, where the average cover of each life form was calculated for each plot; then these results were averaged across plots within each forest type. Understory trees cover more area than the other three growth habits in all forest types except for juniper woodland, limber pine, blue spruce, Douglas-fir forests, and nonstocked stands. Average understory tree cover ranges from 5 percent in juniper woodland to 33 percent in deciduous oak woodland. Shrubs occupy more area than forbs or graminoids on all forest types except for nonstocked stands, which are dominated by graminoid cover. Shrub cover ranges from 5 percent in bristlecone pine stands to 19 percent in blue spruce stands. Average graminoid cover was less than 7 percent in all forest types except for blue spruce (14 percent), aspen (11 percent), deciduous oak woodland (9 percent), Intermountain maple woodland (13 percent), and nonstocked stands (17 percent). Average forb cover was less than 7 percent in all forest types except for Engelmann spruce/subalpine fir (7 percent), aspen (14 percent), and Intermountain maple woodland (9 percent).

Data produced during the species composition protocol are summarized at the State level in table 10. Average cover for each species was calculated based only on plots where that species occurred, and within those plots, only on subplots where the species occurred. We use this method because an absence of a record for a particular species may mean either that it did not occur at all, or that its cover was less than the threshold required within the species composition protocol (either 3 or 5 percent; see USDA FS 2006 and 2011 for more information about these thresholds).

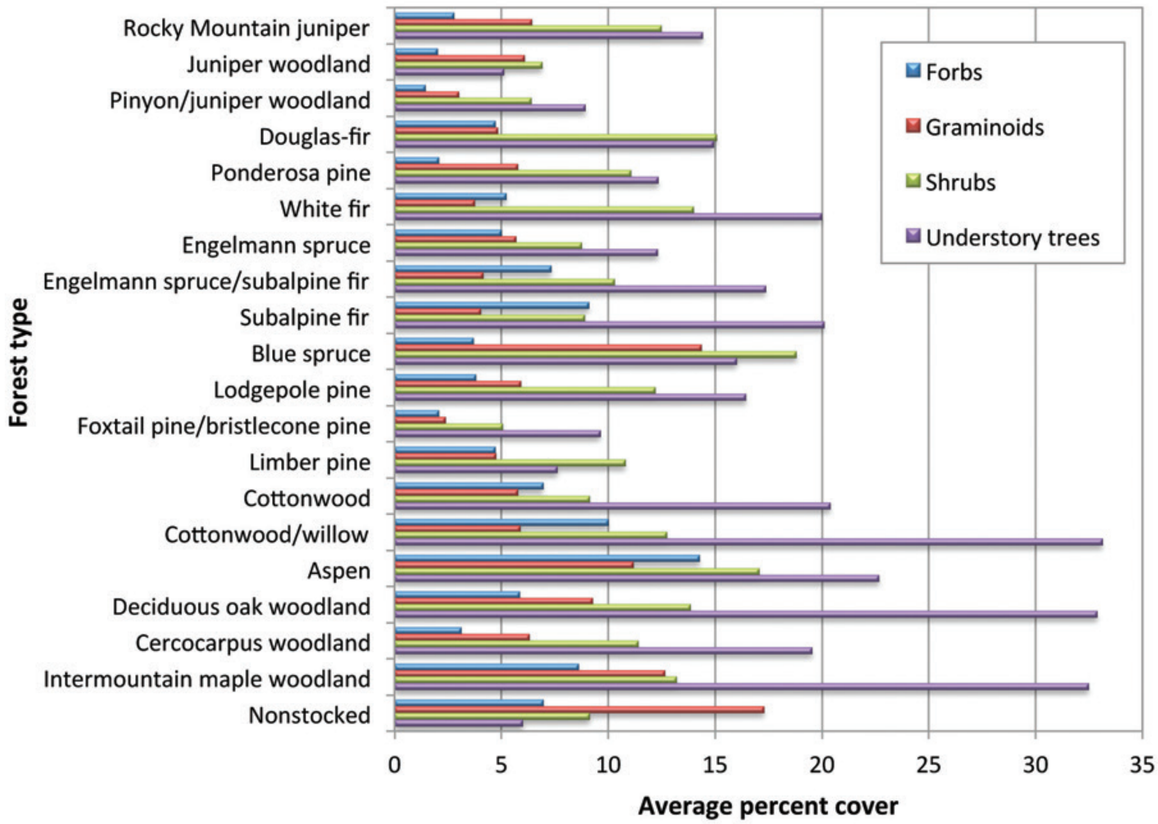


Figure 25—Average percent cover of the four understory vegetation growth habits (forb, graminoid, shrub, and understory tree), by forest type, Utah, 2003–2012. Cover of understory trees includes both tally and non-tally species with stem diameters of less than 5.0 inches in diameter.

Table 10—The most frequently recorded plant species in each growth habit, as well as the number of plots where they occurred, and their average percent cover, Utah, 2003-2012.

Growth habit	Species	Common name	Number of plots	Average cover
Forb	*Thalictrum fendleri*	Fendler's meadow-rue	54	7.8
	Lathyrus lanszwertii	Nevada pea	43	11.5
	Agastache urticifolia	nettleleaf giant hyssop or horse mint	38	10.5
	Vicia americana	American vetch	37	7.9
Graminoid	*Poa* spp.	meadow-grass or bluegrass	254	9.8
	Bromus tectorum	cheatgrass	238	13.7
	Bromus spp.	brome; many species	135	10.5
	Pseudoroegneria spicata	bluebunch wheatgrass	129	8.6
Shrub	*Artemisia tridentata*	big sagebrush	634	9.5
	Symphoricarpos oreophilus	mountain snowberry	567	13.6
	Cercocarpus montanus	alderleaf mountain mahogany	286	9.8
	Purshia tridentata	antelope bitterbrush	176	6.8
Understory tree	*Quercus gambelii*	Gambel oak	680	22.7
	Pinus edulis	common or two-needle pinyon	396	6.5
	Populus tremuloides	quaking aspen	330	16.3
	Juniperus osteosperma	Utah juniper	227	6.0

Although cover is recorded by height class for each species that meets this threshold, a total cover among all height classes is not recorded. Because the cover percentages among different height classes for a given species are likely not additive, the layer with the maximum cover was used for this analysis.

Almost 500 individual plant species were recorded on forest plots in Utah's forest inventory between 2003 and 2012. The four most frequently recorded species within each growth habit are listed in table 10. Gambel oak was recorded more frequently than any other species, and it had a higher mean cover percentage than the other common species listed in table 10. Other frequently recorded understory trees were common or two-needle pinyon; Utah's State tree, the quaking aspen; and Utah juniper. These four tree species are all tally trees that can also occur as understory components, where cover by species is estimated only for trees less than 5.0 inches in diameter. (Note that overstory tree canopy cover is recorded on all forest plots but is not included in this analysis of understory vegetation.) Big sagebrush (*Artemisia tridentata*) was recorded on more forest plots than any forb, graminoid, or other shrub species; it occurred on more than 600 plots and occupied an average cover of 9.5 percent cover. Mountain snowberry (*Symphoricarpos oreophilus*) was recorded on nearly 600 plots with an average cover of 13.6 percent. Note that cheatgrass (*Bromus tectorum*), an invasive species, was recorded on more than 200 forest plots and had a relatively high average cover (13.7 percent).

Down Woody Material

Down woody material (DWM) is an important component of forests that greatly affects fire behavior, wildlife habitat, soil stabilization, and carbon storage. Some examples of DWM are fallen trees, branches, and leaf litter commonly found within forests in various stages of decay. The main components of DWM are fine woody debris (FWD), coarse woody debris (CWD), litter, and duff. Fine woody debris composes the small diameter (1.0- to 3.0-inch) fire-related fuel classes (1-hr, 10-hr, 100-hr), and CWD composes the large diameter (3.0-inch +) 1,000-hr fuels.

Nationally, DWM is measured on Phase 3 plots. In 2006, IWFIA initiated a Phase 2 DWM inventory throughout the Interior West States in response to the increasing need for more intensive DWM information. This DWM analysis used regional Phase 2 protocols for data collected from 2006 to 2012. Owing to the presence of snow or other hazardous conditions, not all DWM components could be sampled on all plots.

Figure 26 shows the geographic distribution of Phase 2 DWM plots measured in Utah, as well as the total DWM biomass (tons per acre) at each plot. In general, DWM biomass abundance follows patterns of live biomass, which in turn follow regional climatic gradients (Garbarino and others 2015). Moist, high-elevation forest types common in the Southwest, like Engelmann spruce/subalpine fir, have relatively high DWM biomass. In contrast, drier forest types, such as pinyon/juniper woodland, have relatively low DWM biomass.

Table 11 shows the mean biomass (tons per acre) by DWM component, as well as the number of conditions where DWM was sampled, by forest type. The mean DWM biomass for Utah is about 10.4 tons per acre. The subalpine fir forest type has the highest mean DWM biomass (27.9 tons per acre). Among forest types with samples of 30 or more conditions, the Engelmann spruce/subalpine fir, lodgepole pine, aspen, and Intermountain maple woodland forest types also have mean DWM biomass of greater than 20 tons per acre. The lowest totals are found in juniper woodland (3.1 tons per acre) and pinyon/juniper woodland (5.2 tons per acre) forest types. Some of the values in table 11 may not be representative of their forest types due to small sample sizes.

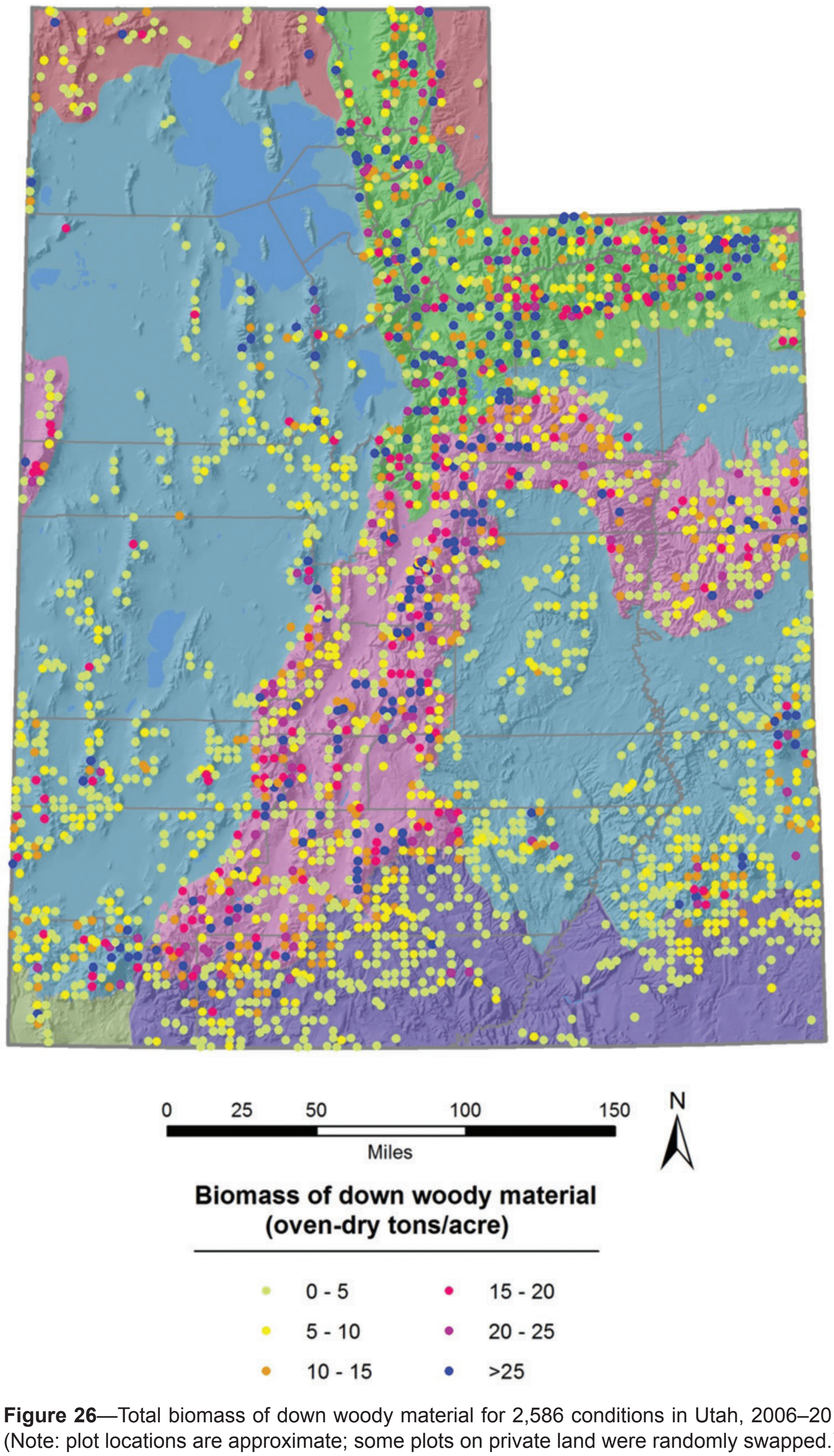


Figure 26—Total biomass of down woody material for 2,586 conditions in Utah, 2006–2012. (Note: plot locations are approximate; some plots on private land were randomly swapped.)

Table 11—Number of conditions sampled and mean biomass (tons per acre) by Down Woody Material (DWM) component, and forest type, Utah, 2006-2012.

Forest type	Number of conditions	FWD, small	FWD, medium	FWD, large	CWD	Duff	Litter	Total DWM
Rocky Mountain juniper	27	0.2	0.5	0.8	1.5	4.4	3.6	11.0
Juniper woodland	318	0.1	0.2	0.3	0.3	1.0	1.2	3.1
Pinyon-juniper woodland	1149	0.1	0.2	0.7	1.2	1.2	1.6	5.2
Douglas-fir	115	0.2	0.7	2.4	3.1	5.3	3.7	15.4
Ponderosa pine	55	0.1	0.4	1.4	2.3	4.7	4.7	13.6
White fir	66	0.2	0.6	2.5	5.0	6.4	3.6	18.4
Engelmann spruce	30	0.1	0.3	1.6	7.9	3.7	1.9	15.6
Engelmann spruce-subalpine fir	96	0.2	0.6	1.9	8.8	6.8	2.2	20.5
Subalpine fir	45	0.2	0.7	3.1	10.4	9.8	3.6	27.9
Blue spruce	4	0.2	0.5	2.2	8.0	7.5	3.0	21.4
Lodgepole pine	67	0.1	0.5	1.7	7.6	7.6	3.8	21.3
Great Basin bristlecone pine	3	0.1	0.1	1.2	5.0	0.6	0.8	7.9
Limber pine	5	0.1	0.6	1.6	6.3	2.8	2.2	13.5
Cottonwood	13	0.1	0.4	0.7	1.4	0.6	3.6	6.8
Aspen	211	0.1	0.4	1.8	4.1	9.0	5.7	21.0
Deciduous oak woodland	279	0.1	0.4	0.9	0.4	6.9	7.1	15.8
Cercocarpus woodland	62	0.1	0.4	0.8	0.7	6.6	5.2	13.9
Intermountain maple woodland	41	0.1	0.5	1.7	1.3	10.9	8.1	22.8
Total	**2,586**	**0.1**	**0.3**	**1.1**	**2.2**	**3.7**	**3.1**	**10.4**

Fuel loadings by DWM component are essential for predicting fire behavior. For most forest types, fine- and coarse-woody components account for 40 to 60 percent of total DWM biomass, with the remainder being litter and duff. However, in deciduous woodland types, such as deciduous oak woodland, *Cercocarpus* woodland, and Intermountain maple woodland, more than 80 percent of the total is made up of litter and duff. In some coniferous woodland types, such as Rocky Mountain juniper and juniper woodland, more than 70 percent of DWM biomass is in litter and duff. A few higher elevation types, including Engelmann spruce, Great Basin bristlecone pine, and limber pine, have the largest proportions of their biomass in the fine- and coarse-woody fractions. Fuel loading in the CWD, duff, and litter classes varies considerably among forest types; FWD classes show less variation among forest types.

Surface fuel classifications of duff, litter, fine woody debris, and coarse woody debris for estimating fire effects were compiled from a wide variety of recent fuel sampling projects conducted across the contiguous United States (Lutes and others 2009). For each FIA condition, fuel loading values from these four fuel classes were used to identify 1 of 21 potential fuel loading models (FLMs) described by Lutes and others (2009). For this DWM dataset, 20 of the 21 possible FLMs were identified. Figure 27 displays the number of conditions identified by FLM class. The largest proportion (1,454 conditions, or 56 percent) occurred in the class 11 FLM, followed by classes 21 (371 conditions, or 14 percent) and 31 (248 conditions, or 10 percent). These three classes have also been found to be the most abundant in other States (for example, Goeking and others 2014), but not necessarily in the same rank order. Although these plot classifications are currently under review, once they are objectively classified they can be used as inputs to fire effects models to compute smoke emissions, fuel consumption, and carbon released to the atmosphere.

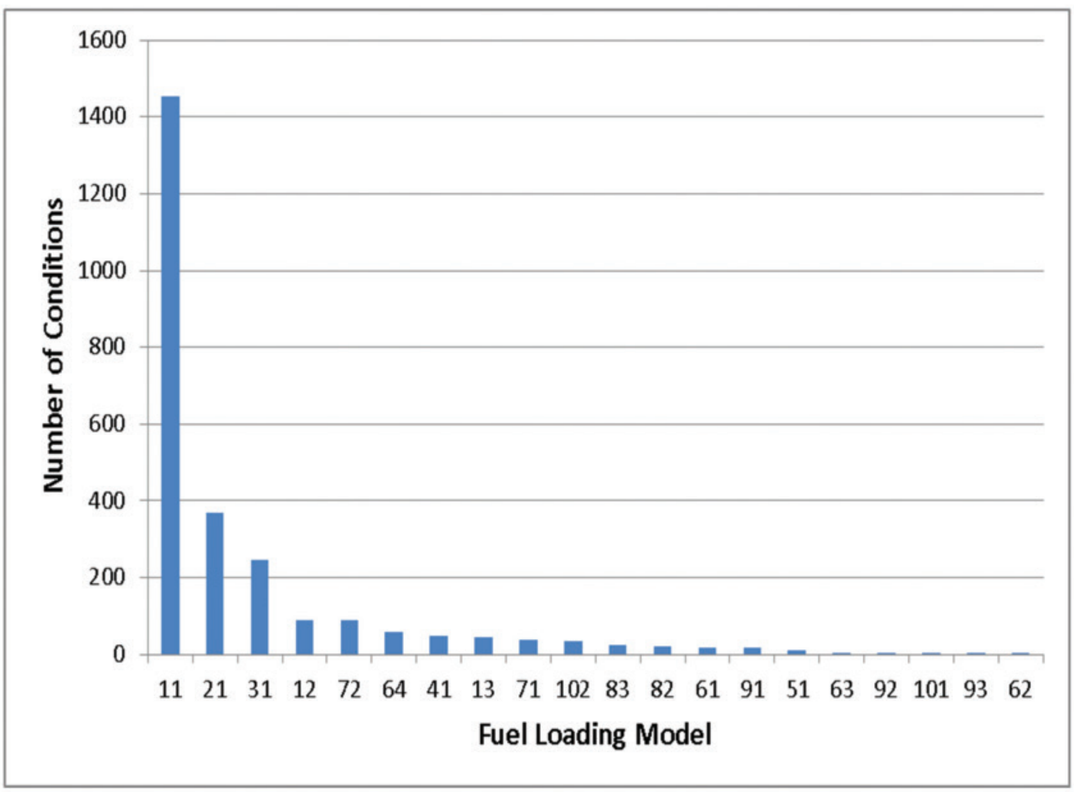


Figure 27—Distribution of the fuel loading models (FLMs) found on at least 10 conditions in Utah, 2006–2012.

Expressions of structural diversity in terms of CWD diameters and decay classes are important criteria for wildlife habitat. Field crews identify one of five large-end diameter classes for each Phase 2 CWD piece tallied. This information may be critical for wildlife species that use large-diameter logs for habitat, to give just one example. Decay classes range from class 1, which are newly fallen trees with no decay, to class 5, which still resemble a log but often blend into the duff and litter layers. Although decay class 5 pieces contribute to biomass and carbon pools, their large-end diameter class is not recorded due to their degree of decomposition.

Figure 28 shows that the Engelmann spruce/subalpine fir forest type has the highest percentage of CWD pieces in the 21-inch diameter and larger class (3 percent). Four other forest types capable of producing large down wood—Engelmann spruce, white fir, Douglas-fir, and ponderosa pine—have 2.3 to 2.9 percent of their CWD pieces in the 21.0-inch diameter and larger class. Only white fir, Engelmann spruce, and Engelmann spruce/subalpine fir types have more than 8 percent of pieces in the next smaller size class (15.0 to 21.9 inches in diameter). For all forest types, with the exception of Engelmann spruce/subalpine fir, the plurality (42 to 52 percent) of CWD pieces fall into the 5.0- to 8.9-inchs diameter class. For Engelmann spruce-subalpine fir, the plurality occurs in the next larger size class, but only by a small margin.

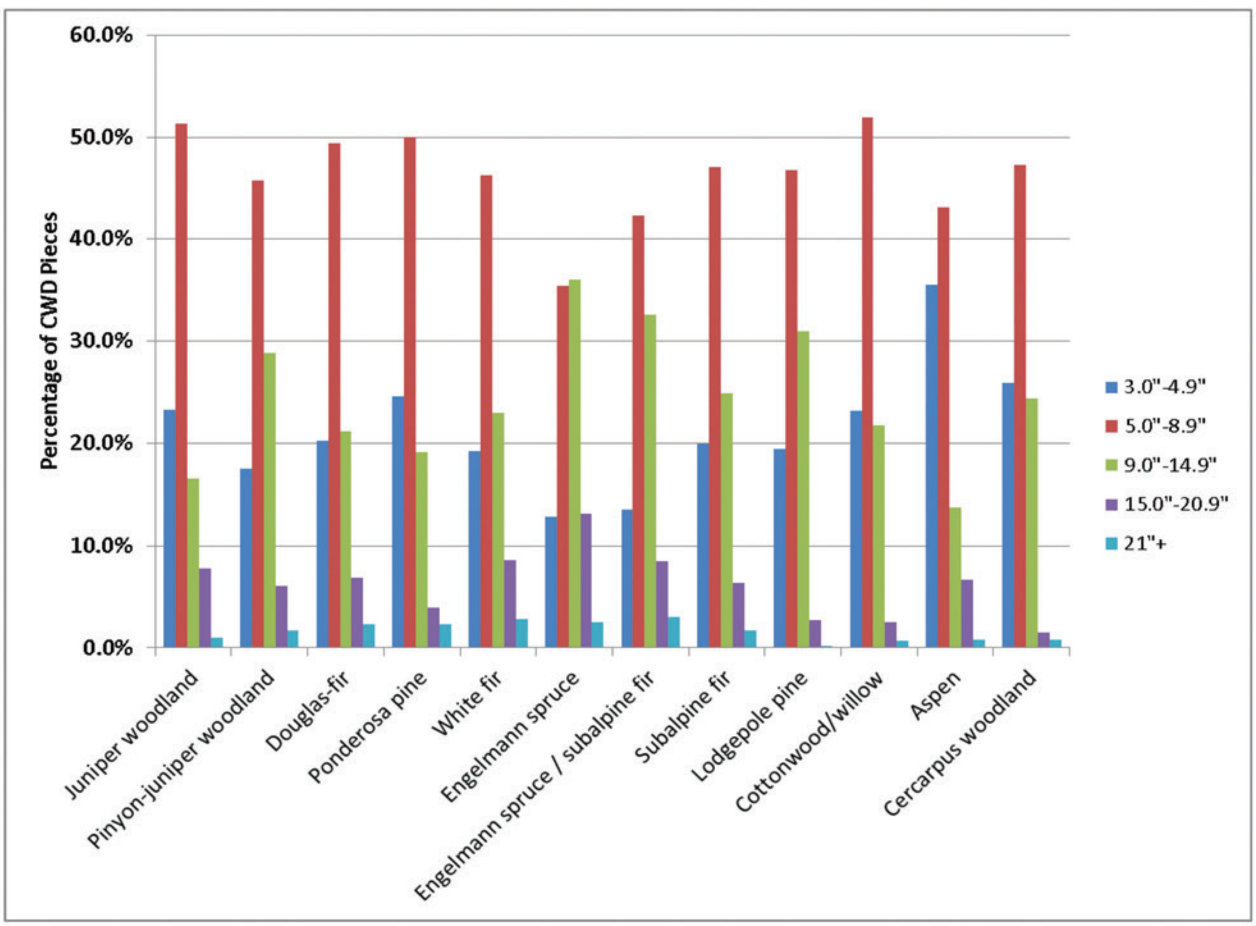


Figure 28—Distribution of coarse woody debris (CWD) piece sizes for forest types with tallies of at least 100 pieces, Utah, 2006–2012.

Figure 29 shows the percentage of CWD pieces in each decay class by forest type. For most types, the decay class distribution of CWD pieces follows a somewhat normal distribution—that is, most pieces are in decay class 3, whereas decay classes 1 and 5 have the fewest pieces. For most forest types this distribution is somewhat skewed toward the higher decay classes, meaning that class 4 pieces tend to be more abundant than class 2 pieces (fig. 29).

One possible interpretation of this pattern is that most pieces remain in classes 3 and 4 the longest, although there is likely to be some interaction between piece size and longevity in any given decay class. Small pieces are more likely to decay rapidly, and the two smallest size classes (3.0 to 4.9 inches diameter and 5.0 to 8.9 inches diameter) typically account for 65 to 75 percent of all pieces (fig. 28). Therefore, it is not surprising to find a large fraction of pieces in the more advanced decay classes. Repeat measurements, which will be done on future plot visits, should reveal new information on DWM dynamics in Utah forests.

Although this analysis included only condition-level, per-acre estimates of DWM attributes, future analyses will allow the expansion of plot-level information to Statewide population estimates based on Interior West's FIA regional Phase 2 DWM database. The impacts and implications of expanding plot-level information to the State will be analyzed. Furthermore, a national Phase 2 DWM protocol has been adopted to support a more robust dataset for future assessments of fire fuel, wildlife structure, and carbon.

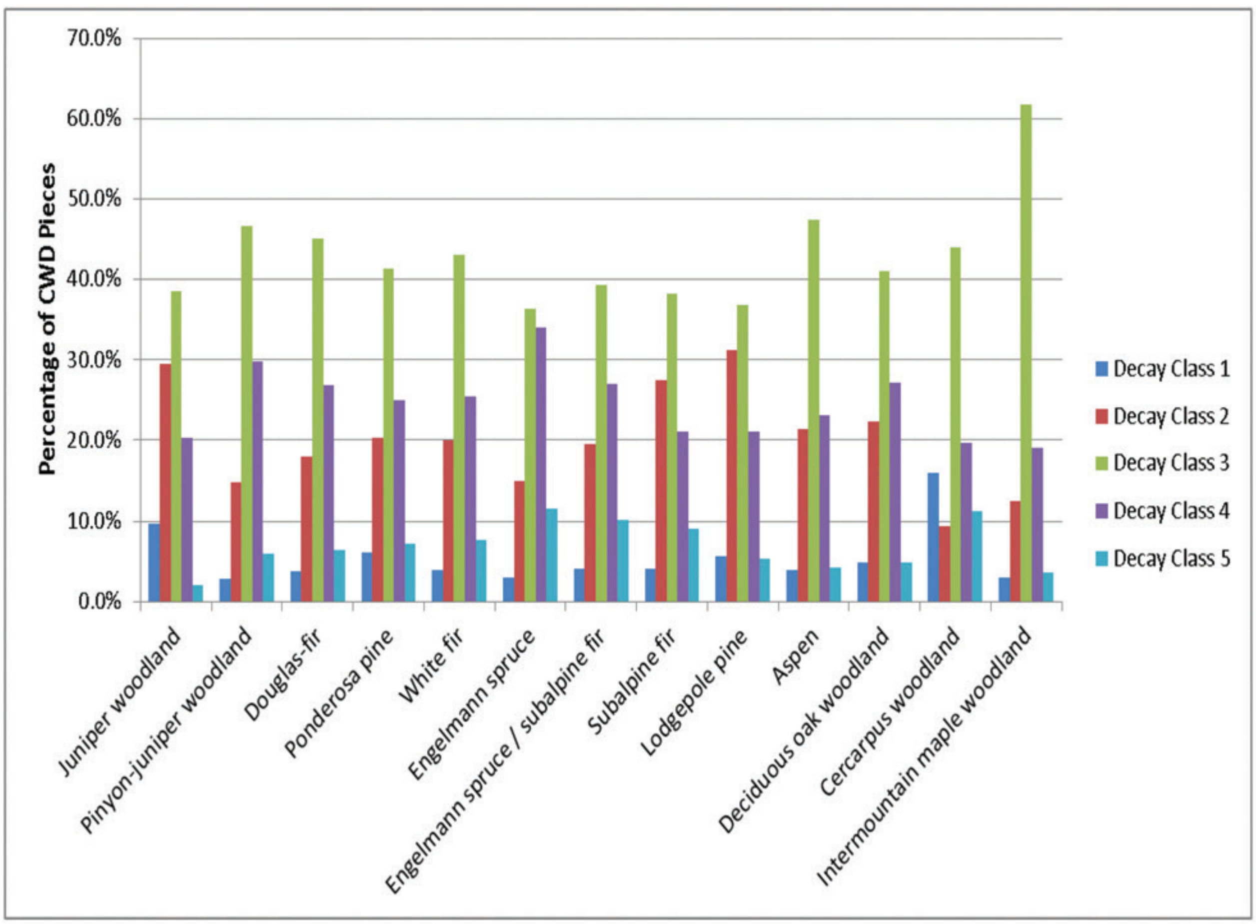


Figure 29—Distribution of coarse woody debris (CWD) pieces by decay class for forest types with tallies of at least 100 pieces, Utah, 2006–2012.

The new protocols will be compatible with Interior West's FIA current regional DWM protocols, permitting continuous monitoring of DWM status and trends. As estimates of DWM are improved and refined, and then combined with FIA's understory vegetation and standing tree inventory, FIA will be better positioned to estimate total forest biomass.

Forest Soils

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.

The FIA Soil Indicator of forest health was developed to assess the status and trend of forest soil resources in the U.S. across all ecoregions, forest types, and land ownership categories (O'Neill and others 2005). For this report, data were analyzed and are reported by forest type groups. Tables B38 through B39g are a complete listing of the mean soil properties organized by forest type group in Utah. These are least-squares means generated by the SAS GLMMIX data analysis software program with the Tukey means comparison test option (SAS Institute, Inc. 2011). 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. In the first sampling cycle in Utah, most samples were collected in 2000 through 2004, but some plots were sampled for the first time in later years (2006 through 2010). The second sampling cycle was done in 2006 through 2010 but there were not as many soil samples collected in the second cycle so some forest type groups remain under-represented 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 Utah and are highlighted in the discussion below.

Forest soil resource data are available for seven forest type groups in Utah. These are the western hardwoods (includes deciduous oak and *Cercocarpus* woodlands), pinyon/juniper group (includes Rocky Mountain juniper, juniper woodland, and Pinyon/Juniper woodland), ponderosa pine, lodgepole pine, Douglas-fir, aspen, and Spruce/fir group (includes white fir, Engelmann spruce, subalpine fir, and mixed Engelmann spruce/subalpine fir). Most of the soil samples represent the Pinyon/Juniper groups, with less sampling in the other forest type groups in Utah.

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. The western hardwood and 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 to Douglas-fir and Spruce/fir forests. When expressed in terms of mega grams of carbon (C) per hectare of forest area, soil C stocks also generally increase with elevation and/ or soil moisture storage (figures 30a and 31a). The soil C stock data shown in figure 30a, are for all plots sampled during the first cycle of plot visits from 2000 through 2010 (n = 197), whereas the C stock data summarized in figure 31a, are for only those plots sampled twice (n = 82). There was no significant change in soil C storage between the first and second soil sampling visits, although variability is high since a much 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 much less forest floor accumulation than in wetter higher-elevation forests. Among all forest types except

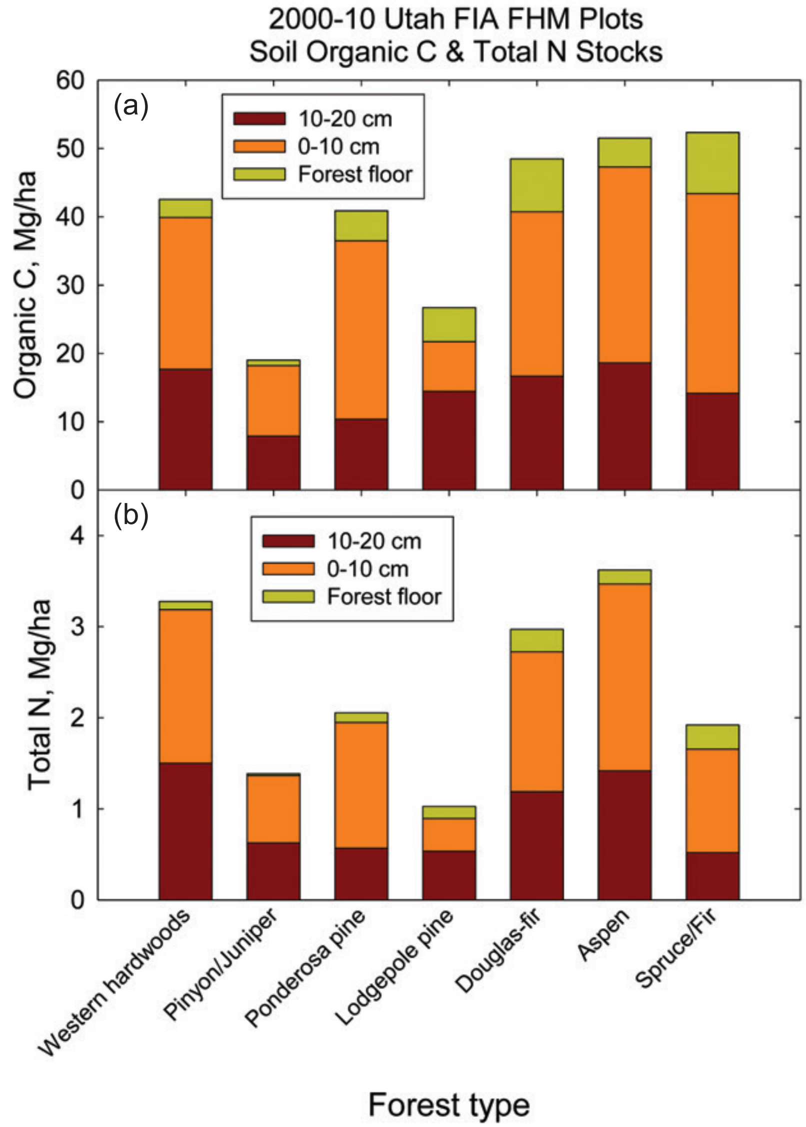


Figure 30—Distribution of (a) organic carbon, and (b) total nitrogen stocks in megagrams per hectare (Mg/ha) in the forest floor, 0 to 10 cm, and 10 to 20 cm mineral soil depths in seven forest type groups in Utah. Soil samples were collected in 2000 through 2010 (first plot visit only) from western hardwoods, (includes deciduous oak and *Cercocarpus* woodlands), Pinyon/Juniper group (includes Rocky Mountain juniper, juniper woodland, and Pinyon/Juniper woodland), ponderosa pine, lodgepole pine, Douglas-fir, aspen, and Spruce/Fir/ (includes white fir, subalpine fir, Engelmann spruce, and mixed Engelmann spruce/subalpine fir) forest type groups.

lodgepole pine, most soil C is stored in the top 10-cm of mineral soil, followed by the 10-20 cm increment, followed by forest floor. Overall, the Pinyon/Juniper group and lodgepole pine store the least amount of C in Utah forest soils.

Soil nitrogen (N) stocks show a more mixed response to climatic gradients in Utah than do C stocks (figures 30b and 31b). Aspen and western hardwood forests store more N in the mineral soil than any other forest group in Utah (figure 30b). Aspen forests store significantly 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 (table B38).

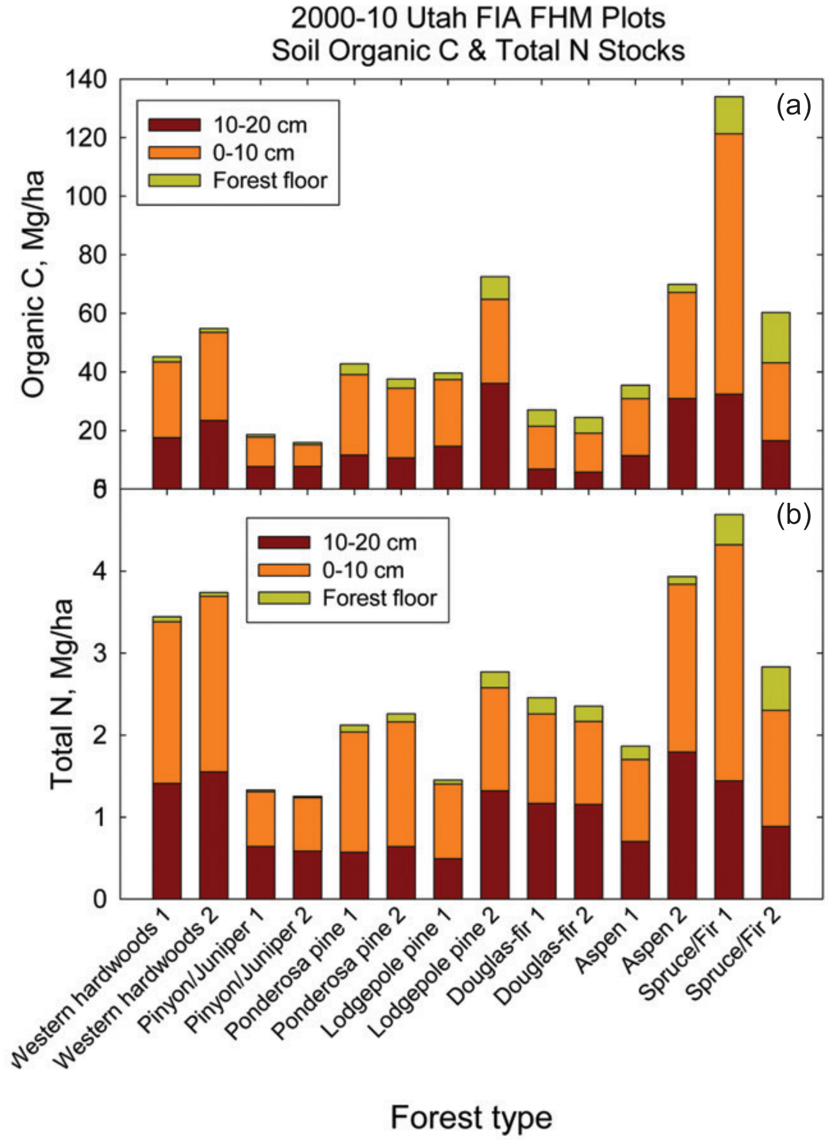


Figure 31—Distribution of (a) organic carbon, and (b) total nitrogen stocks in megagrams per hectare (Mg/ha) in the forest floor, 0 to 10 cm, and 10 to 20 cm mineral soil depths in seven forest type groups in Utah. Soil samples were collected in 2000 through 2010 (first and second plot visits) from western hardwoods, (includes deciduous oak and *Cercocarpus* woodlands), Pinyon/Juniper group (includes Rocky Mountain juniper, juniper woodland, and Pinyon/Juniper woodland), ponderosa pine, lodgepole pine, Douglas-fir, aspen, and Spruce/Fir/ (includes white fir, subalpine fir, Engelmann spruce, and mixed Engelmann spruce/subalpine fir) forest type groups. Data from only those plots visited twice are shown.

Low C/N is a good indicator of relative organic matter decomposition rate. Therefore nutrient rich aspen leaves decompose more quickly and easily compared to Spruce/fir needles. There was no significant change in soil N storage between the first and second soil sampling visits, but again variability is high because a much smaller number of plots were revisited than were sampled the first time.

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 (SOM) content where bulk density decreases exponentially with increasing SOM (O'Neill and others 2005). In Utah forests, the lowest soil bulk densities tend to be found under western hardwood, Douglas-fir, aspen, and Spruce/fir forests (figure 32b), and these forests have the highest organic C concentrations (figure 33a). Douglas-fir and Spruce/fir forests are often found on rockier sites with higher coarse fragment content (figure 32c).

It is important to distinguish between organic and inorganic forms of C in soils. Organic forms participate in a wide array of biogeochemical reactions including serving as substrate for microbial decomposition, thus contributing to atmospheric CO2. Inorganic forms stored as carbonate minerals such as calcite (CaCO3) tend to be more biologically inert, but can be dissolved during physical, chemical, and biologically mediated mineral weathering reactions. In Utah, significant amounts of inorganic soil C are stored in carbonate minerals under western hardwood and Pinyon/Juniper group forests (figure 33a). In contrast, the wetter, higher-elevation Douglas-fir, aspen, and Spruce/fir forest soils store higher concentrations of organic C (figure 33a). Soil N concentrations tend to track organic C concentrations with more soil N found in higher-elevation forest type groups (figure 33b), and also in western hardwoods.

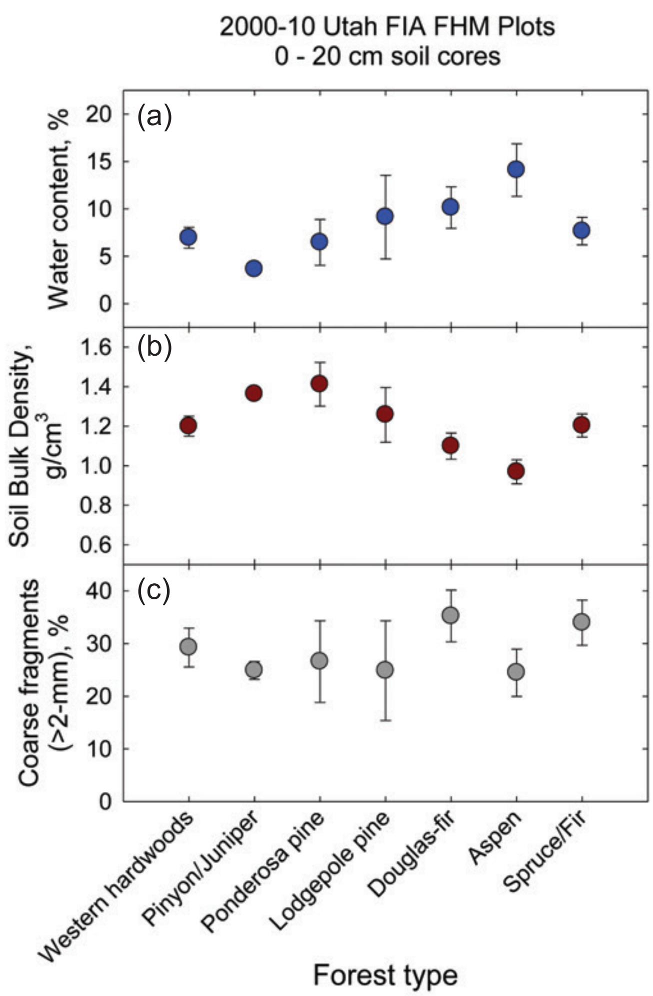


Figure 32— Soil water content (a), bulk density (b), and coarse fragment (>2 mm) content (c) of the top 20 cm of mineral soil in seven forest type groups in Utah.

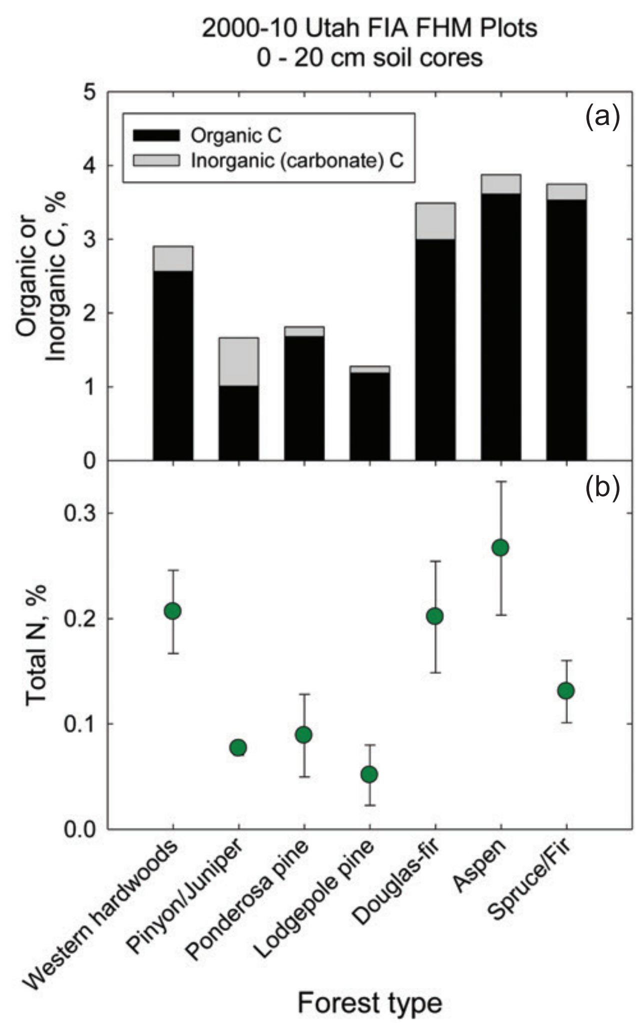


Figure 33— Carbon forms (organic, carbonate) (a) and total nitrogen (b) in the top 20 cm of mineral soil in seven forest type groups in Utah.

Soil pH is often closely related to the presence of carbonate minerals in soils. Thus, the higher pH forest soils are found under western hardwoods, Pinyon/Juniper, and Douglas-fir (figure 34a), the same forest type groups with relatively high amounts of soil carbonates (figure 33a). These soils are near-neutral to alkaline. Lodgepole pine forests tend to occupy moderately acidic soils in Utah. Higher elevation Spruce/fir forests in Utah are found on slightly acidic soils. All the forest soils in Utah 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 (figure 34b). The lower-elevation, higher pH soils under western hardwoods, Pinyon/Juniper group, and ponderosa pine tend to have low levels of bicarbonate-extractable P (figure 34c). Lodgepole pine soils are also low in bicarbonate-extractable P. Bicarbonate-extractable P is used as a measure of bioavailable P for plant uptake. Aspen soils contain the highest amounts of bicarbonate-extractable P.

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 and others 2007). Lower values indicate increased risk of soils-related forest health decline. Spatial changes in SQI on the landscape can be used

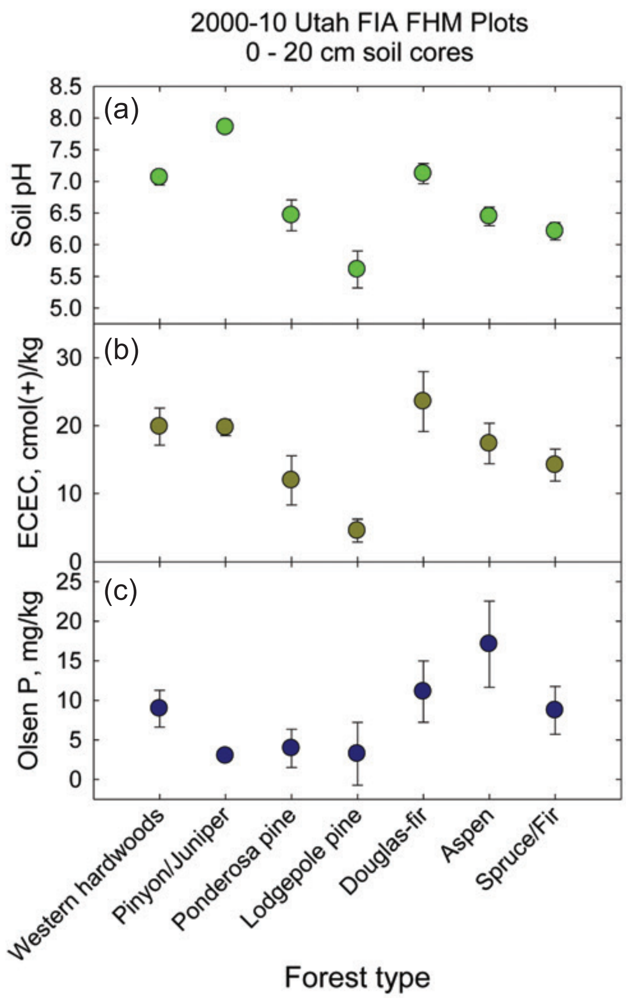


Figure 34— Soil pH (a), effective cation exchange capacity (ECEC) (b), and (c) Olsen (pH 8.5, 0.5 M $NaHCO_3$) extractable phosphorus (P) in the top 20 cm of mineral soil in seven forest type groups in Utah.

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 (figure 35). The highest SQI forest soils in Utah are found under western hardwood, ponderosa pine, and the higher elevation Douglas-fir, aspen, and Spruce/fir forests. This reflects the overall higher organic matter content 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 Utah, lodgepole pine tends to occupy the lower pH, lower organic matter content, and lower nutrient content (less productive) soils.

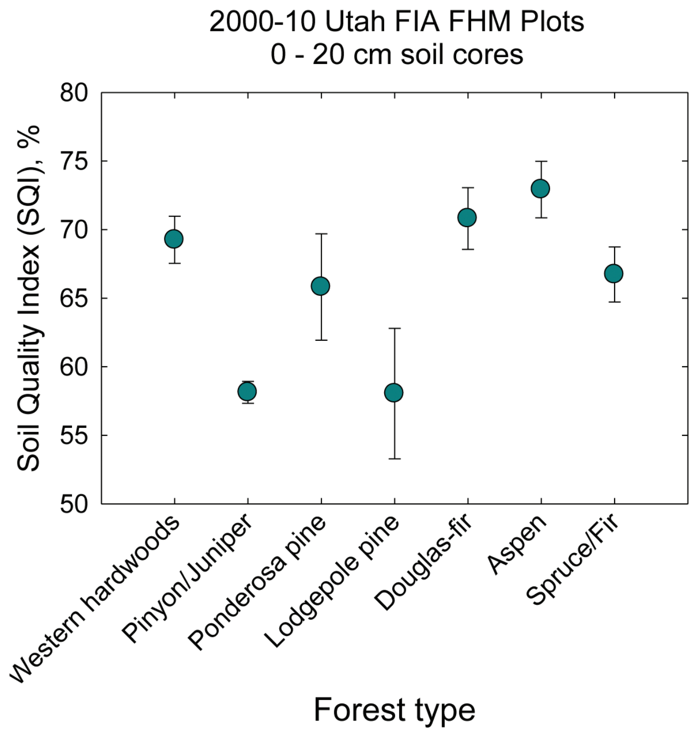


Figure 35—Soil quality index (SQI) in the top 20 cm of mineral soil in seven forest type groups in Utah.

Current Issues in Utah's Forests

Drought-Related Effects on Pinyon/Juniper Woodlands

Collectively, pinyon/juniper and juniper woodlands make up the most common forest type in the American Southwest, covering more than 36 million acres in 10 U.S. States and extending into Mexico. In Utah, these types account for 10.7 million acres of forest land, or nearly 59 percent of the area having 10 percent or more cover in trees. The pinyon/juniper forest type is defined by the presence of one or more pinyon species—either common or two-needle pinyon or, singleleaf pinyon—and one or more juniper species; pure stands of pinyon are not considered a separate type by the FIA program. Juniper woodland types are dominated by various juniper species, but other species, excluding pinyons, may be present as a minor component. To most laypersons and many managers, the term pinyon/juniper woodland (or P-J, for short) includes all lands dominated by pinyons or junipers, or both. For convenience, in this section the term "pinyon/juniper woodland" refers to all lands covered by this common use of the term.

With the start of the Interior West FIA annual inventory in 2000, forest managers and researchers began to notice an increase in the incidence of insects and disease in pinyon/juniper woodland and several other forest types. At that time, drought was also evident across much of the Southwest, including Utah (fig. 36). As the drought progressed, tree mortality appeared to be increasing and there was growing interest in using FIA data to quantify the effects of drought, insects, and disease on pinyon/juniper woodland (Shaw and others 2005). The drought-related mortality episode has provided an opportunity to test the utility of the FIA annual inventory system for quantifying rapid change in pinyon/juniper woodland over a large geographic area (Shaw 2006).

Since implementation of the annual inventory system in Utah, the earliest of all Interior West States, we have been able to capture the progression of mortality due to the drought of the early 2000s as it occurred. During the first 10 years of annual inventory, the mortality window for first-time measurement trees was 5 years, and field crews made their best estimate of actual year of mortality. Assignment of mortality year for visits up to 5 years post-mortality is known to be generally reliable because of rapid changes in tree condition (Kearns and others 2005), but correct assignment becomes increasingly difficult with time. Most mortality trees removed by firewood cutting, blown down, or no longer "on the stump" for other reasons would still be missed by the first visit of annual inventory although these situations cover only a small percentage of tally trees. During remeasurement years (2010–2012 of the current inventory), however, all mortality is captured by accounting for all trees found on the first visit. As a result, the estimate of drought-related mortality in Utah can be considered among the best of all Interior West States.

Pinyon mortality from all causes in the Interior West began to increase in 2001, and appears to have peaked between 2005 and 2007 (fig. 37a). Since then, mortality rates have decreased in most States and appear to be returning to background mortality rates. Drought persists in the Southwest. Although drought is not severe in Utah (fig. 36), fire

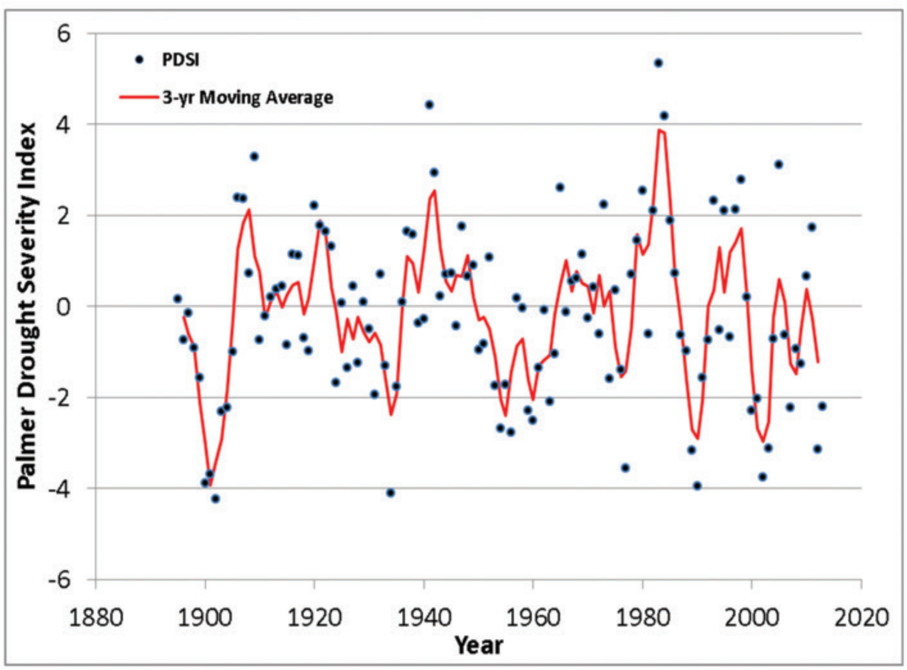
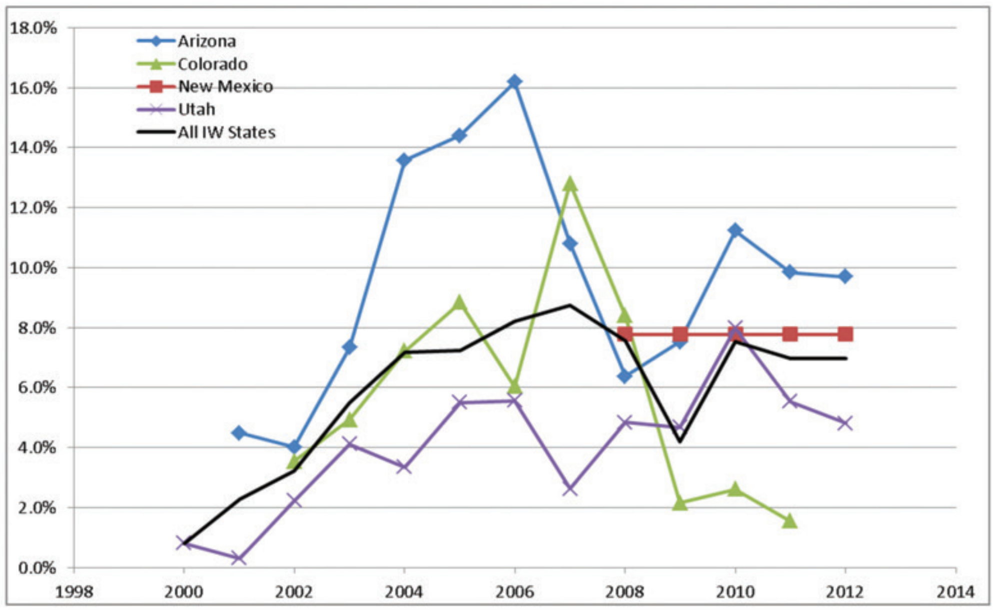


Figure 36—Palmer Drought Severity Index (PDSI) for Utah, 1895–2013. Positive values indicate relatively moist conditions and negative values indicate drought. Points are the average for all climate divisions in Utah (National Climatic Data Center 1994) and red line is the 3-year moving average.

continues to affect pinyon/juniper woodland in many areas across the State. Mortality of pinyon in Utah in the 2000s appears to be lower than the average mortality percentage for pinyons in all Interior West States combined, which was about 4 to 5 percent of the total basal area. Among the States that make up the Four Corners, Utah has had on average the lowest level of pinyon mortality since 2000, but a somewhat higher level than Colorado for the past several years. Mortality rates in Utah never approached the peaks found in Arizona nor averages in New Mexico.

Juniper species have shown to be much more resistant to drought-related mortality than pinyon species. From 2000 to 2003 the mortality rate, from all causes, of juniper species in the Interior West States rose from a very small fraction to around 2 percent,

(a)



(b)

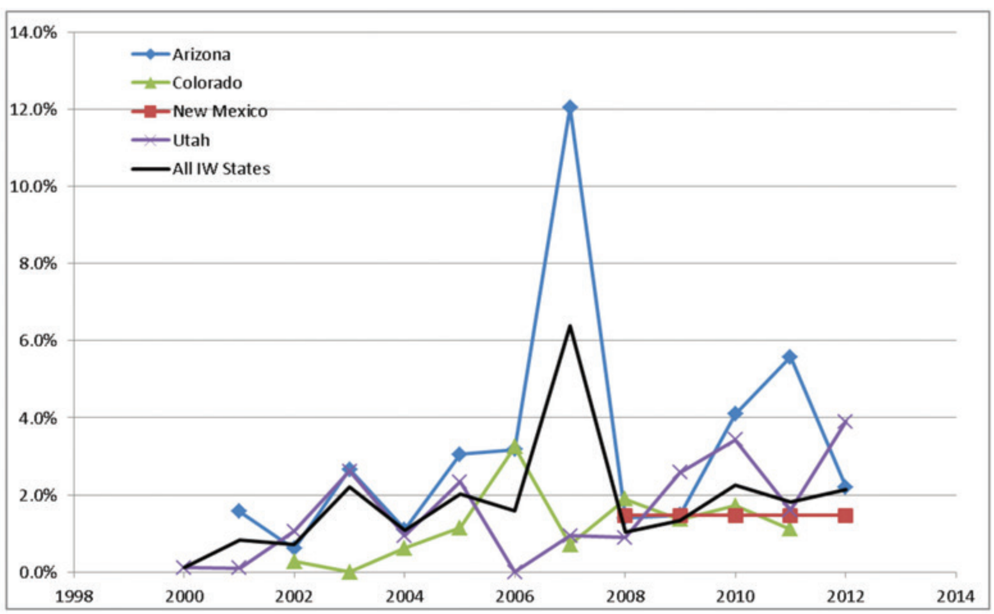


Figure 37—Annual mortality by measurement year for (a) pinyon, and (b) juniper species in the Interior West States.

and has remained generally steady since then (fig. 37b). The apparent "spike" in juniper mortality seen in 2007 is mostly a result of the large number of "catch-up" plots in Arizona that were located in recently burned areas. The juniper mortality rate in Utah is about on par with the mortality rate for the Interior West since 2000, but in recent years the rate in Utah has increased somewhat. This increase is partly due to direct drought effects, but the larger portion is most likely a secondary effect of wildland fire.

The dramatic visual effect of drought-related mortality of pinyon species—dying trees with reddened foliage over large landscapes—brought much public and media attention. Because there were typically local "hot spots" of mortality that were surrounded by large areas of comparatively low mortality, it was difficult to obtain unbiased quantitative estimates of the true extent of mortality. In some cases, mortality estimates were extrapolated from local sites to entire States. For example, one account reported that 90 percent of the pinyon trees in Arizona had been killed (Society of American Foresters 2004). A preliminary analysis of the available data in Arizona, Colorado, and Utah (Shaw and others 2005) showed a clear upward trend in mortality, but a population-level mortality that was not nearly as high as initially feared. Although mortality of pinyon/juniper woodland in Utah is elevated as compared to the pre-drought years, it has remained below the levels found in other States.

In Utah, pinyon/juniper woodland has maintained positive net growth during a decade when many other forest types have undergone negative net growth (table B22). However, elevated rates of mortality have resulted in lower net growth than was estimated during the 1993 periodic inventory (O'Brien 1999; table B22) and the 2005 annual inventory (DeBlander and others 2010; table B22). The current estimate of net growth in the pinyon/juniper forest-type group is 19.9 million cubic feet per year, as compared to 33.3 million cubic feet per year in 2005 (DeBlander and others 2010) and 36.8 million cubic feet per year for Rocky Mountain juniper, Utah juniper, singleleaf pinyon, and common or two-needle pinyon combined in 1993 (O'Brien 1999). Although the species-specific net growth from 1993 is not directly comparable to the annual forest-type group estimates, the comparison of the current estimate to previous estimates supports the finding that net growth is down substantially as compared with non-drought periods.

One persistent question about the current episode of drought-related mortality is: "How does the current episode compare with previous drought-related die-offs?" The climatic record shows that similar droughts occurred in the Southwest during the early 1900s and mid-1950s (National Climatic Data Center 1994). Breshears and others (2005) characterized the recent mortality event as response to "global-change-type drought," and suggested that recent conditions have been hotter than in the 1950s. Some of the conclusions about the relative magnitude of recent mortality and the mortality of the 1950s are based on the lack of evidence, in the form of remaining dead woody material, from the 1950s. Despite the perceived long-term persistence of woody material in the arid Southwest, pinyons may decay or physically break down rather quickly. Although Kearns and others (2005) found that pinyon snags could persist as long as 25 years, they found that "extremely fragmented" dead trees were present for an average of 16.2 years before decaying. Because the impacts of the 1950s drought were not well studied and there is a great deal of uncertainty surrounding the possible surviving evidence of pinyon mortality, the relative magnitude of the two mortality episodes remains uncertain.

The recent drought has undoubtedly harmed the pinyon/juniper resource in Utah, either directly from drought effects or indirectly from fire effects, but the magnitude of impact differs widely between the pinyon and juniper components. Differential mortality among species on the same site has been shown by Mueller and others (2005), who found mortality of common or two-needle pinyon to be 6.5 times higher than oneseed juniper mortality during two drought events in northern Arizona. Future mortality rates will likely depend on temperature and precipitation trends. The mortality event of the early 2000s corresponded with a shift of the Palmer Drought Severity Index (PDSI) from positive (wetter) to negative (drier) values; the decrease in mortality rate corresponded with a temporary shift back to positive values. In recent years PDSI has become neutral to somewhat negative when averaged over Utah as a whole. Drought trends will likely determine whether there is a resurgence in mortality, but other factors, such as what effects the earlier drought-induced "thinning" of dense stands will have on competition and water relations, will also play a role. The dynamics of this forest type have important implications for carbon storage, because dead trees have released growing space to the survivors and new regeneration. Although there has been a short-term loss in living biomass, there may be a long-term increase in carbon storage while dead wood persists and new growth accumulates. It will be possible to determine the actual trends as FIA continues to monitor these woodlands into the future.

Aspen Status and Trends

Aspen is the widest ranging tree species in North America. It is present in all States in the Interior West and occupies a wide elevation range, from 2,000 feet in northern Idaho to 11,700 feet in Colorado. It is also found on a broad range of sites, and occurs in 26 of the forest types that occur in the Interior West. Aspen is intolerant of shade and relatively short lived, which makes it prone to replacement by conifers through successional change. In the Interior West, it also reproduces infrequently by seeding, relying mostly on root sprouting for reproduction. However, aspen responds well to fire and cutting, and it is able to dominate heavily disturbed sites for many years following severe disturbance. In addition, there is some evidence that aspen is able to persist in conifer-dominated forests by exploiting gaps in the conifer canopy that are caused by insects, disease, windthrow, and other smaller scale disturbances.

In recent years, there has been concern about the future of aspen on the landscape, primarily with regard to the characteristics of aspen and how they relate to changes in disturbance regimes. The earliest concerns were related to successional change in the Interior West, where fire suppression has decreased disturbance rates and, as a result, aspen regeneration rates (Kay 1997). In addition, it has been shown that large populations of herbivores can inhibit aspen regeneration where it occurs spontaneously or after disturbance (for example, Hessl and Graumlich 2002). The lack of disturbance allows conifers to gain dominance where they are present, and in pure aspen stands, consumption of regeneration by ungulates could lead to loss of senescing overstory trees without replacement. More recent concerns are related to prolonged droughts that have an impact on aspen (for example, Anderegg and others 2013) and other forest types (for example, Shaw and others 2005; Thompson 2009). Drought appears to have contributed to mortality in many low-elevation stands (Worrall and others 2008), and in some of these regeneration is either lacking or suppressed by herbivores.

Bartos and Campbell (1998) suggested that similar changes—aspen-dominated acres dropping by 60 percent—had occurred in Utah as compared with "historical" extent, although the time scale over which this change is believed to have occurred was not specified. These assessments of "lost" aspen acres were based on the assumption that forested acres with a minority aspen component were, at one time in the recent past, dominated by aspen in pure or nearly pure stands. This assumption may not be reasonable because there are many situations where aspen may persist normally as a minor stand component. To determine the true trend of the aspen population it is necessary to consider several metrics.

Current inventory data show that there are nearly 1.6 million acres of the aspen forest type in Utah, as compared to 1.4 million acres found during the 1993 inventory (O'Brien 1999). When all acres where aspen is present are considered, the current inventory data show that at least one live aspen stem was present on about 2.9 million acres in 1993 and 2.8 million acres in the current inventory. These figures suggest that although the total number of acres with aspen present has remained somewhat steady, the proportion of aspen-dominated acres may have increased slightly (fig. 38). Of all inventoried forest in Utah, aspen-dominated acres accounted for just over 8.6 percent in 1993 and 8.8 percent in 2012.

On a live-tree volume basis, there were about 1.73 billion cubic feet of live aspen volume found in the current inventory, compared to an estimated 1.75 billion cubic feet in 1993. Currently, 85 percent of live aspen volume in Utah occurs in aspen-dominated stands, with the remaining 15 percent distributed as a minor component on 1.3 million acres of other forest types. Another way to compare volume from the previous and current inventories is to normalize data on a common basis—for example, volume per acre. During the 1993 periodic inventory in aspen-dominated stands (aspen forest type), the average volume per acre of all aspen (live and standing dead) was just over 1,015 cubic feet per acre, with nearly 960 cubic feet per acre in live aspen. In the current inventory, aspen-dominated stands averaged 1,187 cubic feet per acre of live and dead aspen volume, with 939 cubic feet per acre in live aspen. For all stands with an aspen component of trees at least 1.0 inch in diameter and larger, aspen averaged just over 717 cubic feet per acre of volume in the periodic inventory, with about 669 cubic feet per acre in live aspen. These numbers were comparable in the current inventory: 742 cubic feet per acre of live and dead aspen, and 624 cubic feet per acre in live aspen. The per-acre decline in aspen volume is approximately 7 percent, or 0.3 percent per year, on average, since the last periodic inventory. However, it is unlikely that the decline has been steady over this period.

Population trend can also be expressed in terms of net accumulation or loss of volume or biomass. In the 1993 inventory, net aspen volume growth was estimated at nearly 31.8 million cubic feet per year. This is comparable to the estimates of 31.6 million cubic feet per year in 2008 and 33.0 million cubic feet per year in 2009 (fig. 39). However, since 2009 there has been an apparent steady decline in net growth of aspen in Utah. Part of this apparent decline is due to the transition of annual inventory in Utah to remeasurement in 2010. During periodic inventories and first-visit annual inventories, some unknown quantity of mortality is lost due to removals or quick transition from standing live to down dead. During remeasurement, each tree from the previous visit is accounted for, so nearly all losses to mortality are known. Therefore, the apparent year-on-year decline in net growth is partly an artifact of combining remeasurement plot data with the earlier annual first-visit plot data. As a result, it will not be possible to precisely estimate decadal net growth until a full cycle of remeasurement has been completed in 2019.

Comparisons between the 1993 periodic inventory results and current inventory data suggest that there has been no significant net change in aspen extent in Utah, but stocking appears to have declined slightly. The small differences between inventories, in terms of aspen-dominated acreage and live aspen volume in aspen-dominated stands, are within the error ranges of the estimates. This is not to say that the aspen population has remained unchanged over time. The normal expectation for undisturbed forest land is a general increase in volume over time. Given that live aspen volume per acre is lower than was found in the last periodic inventory and in previous annual inventories (DeBlander and others 2010), it appears that drought, fire, and other disturbances are affecting the amount of aspen growing stock. Net growth of aspen currently remains positive but, as noted above, remeasurement of the early annual plots may revise growth estimates for the past 10 years into negative territory.

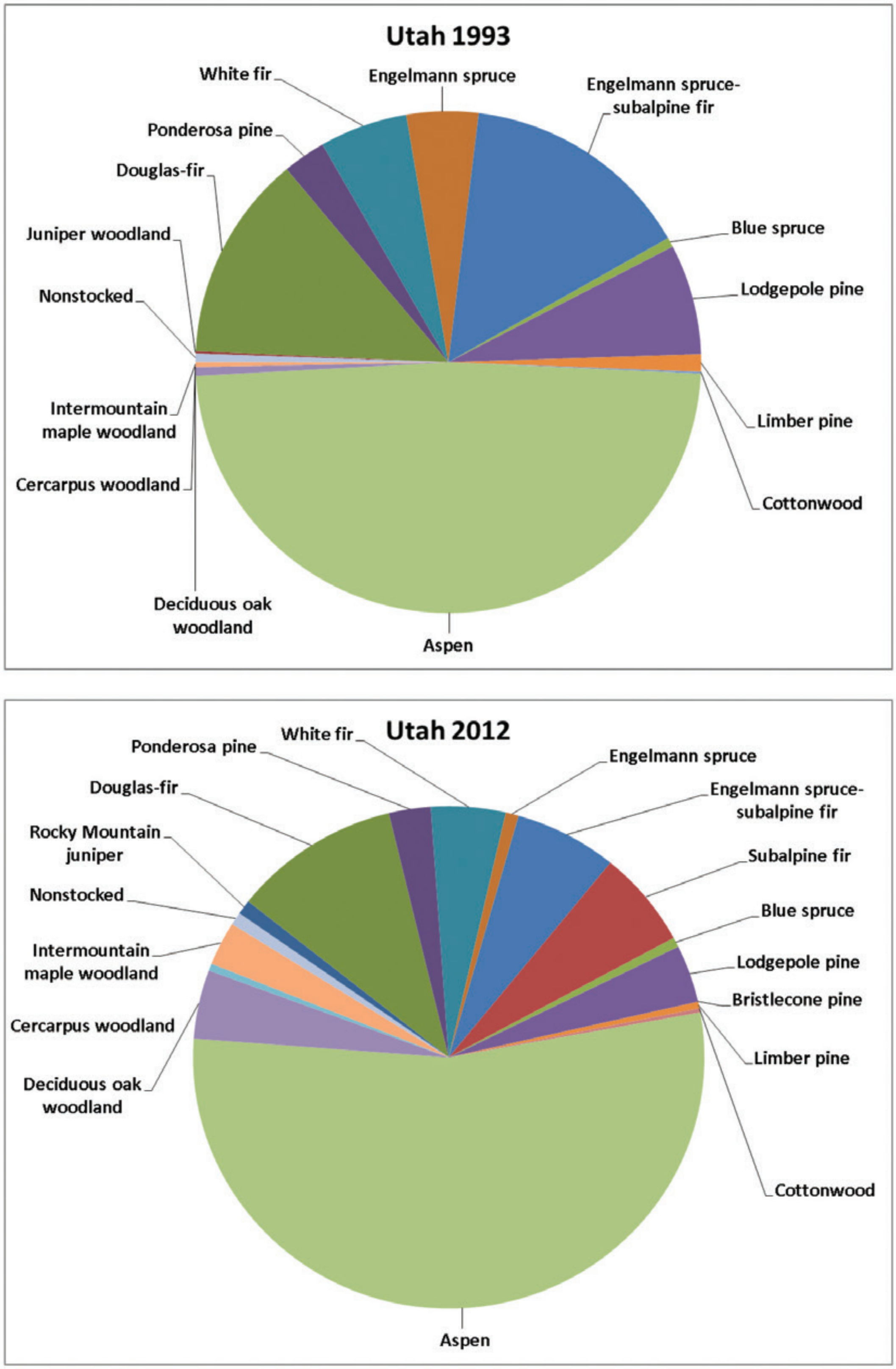


Figure 38—Proportion of acreage in each forest type with an aspen component in Utah, 1993 and 2012. The aspen forest type is defined as having at least 50-percent stocking of aspen. (Note: some changes in the FIA forest typing rules occurred between 1993 and the current inventory. For example, theEngelmann spruce/subalpine fir type of 1993 is now divided into Engelmann spruce/subalpine fir and the subalpine fir types. Other changes have modified the thresholds of certain types, so changes in forest type can be due solely to rule changes.)

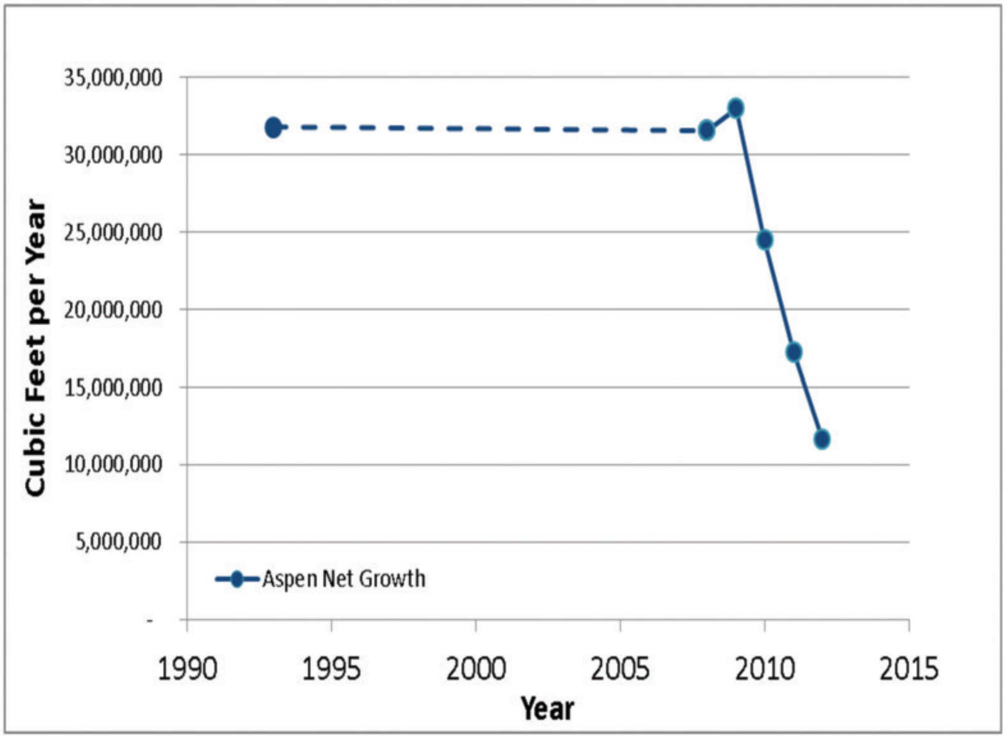


Figure 39—Average annual net growth for aspen in Utah, 1993–2012.

Whether aspen maintains positive net growth in the short term or long term largely depends on the causes of mortality. Natural senescence of stands is occurring constantly as aspen stems reach the end of their natural lifespan (Schier 1975). During periods of drought, large areas of older, less resilient stands may die off (Worrall and others 2008). Although naturally declining stands also regenerate naturally, high browsing pressure from ungulates, wild and domestic, can effectively suppress regeneration (Hart and Hart 2001; Kay 2001) and lead to elimination of some clones (Schier 1975). Although this suppression is known to occur, so far it does not appear to have reduced the area occupied by aspen in Utah.

Aspen stand replacement by fire, on the other hand, is expected to have a generally beneficial effect on aspen in the long term. Pearson (1914) observed that remnant aspen were scattered throughout many spruce forests in New Mexico. Given that these stands were likely in a late stage of succession, they were likely dominated by aspen in the late 1700s or early 1800s. Even when aspen remains as a minor component in mixed stands, it can quickly reassert dominance after stand-replacing fire. For example, Patton and Avant (1970) documented aspen densities of more than 10,000 stems per acre after a fire in a spruce-fir forest in New Mexico. Unburned areas of the stand were estimated to have only 100 stems per acre. Fire-related regeneration events can be episodic. Touchan and others (1996) reconstructed the fire history for several sites in the Jemez Mountains of New Mexico. Although major fires were distributed throughout the 1800s, aspen regeneration was associated with only a few events in different places. Today, aspen stems or stands of this age class (more than 120 years old) are the ones in greatest need of regeneration.

Many studies have shown aspen to be in decline at local scales (for example, Bartos and Campbell 1998; Di Orio and others 2005; Johnson 1994; Worrall and others 2008), whereas other analyses have shown increased dominance of aspen in some landscapes (Kulakowski and others 2004). It is not surprising that studies documenting loss are more numerous, because unexplained or unexpectedly high mortality events tend to attract the attention of managers, researchers, and the public. Because these changes are evident to a wide range of observers, there is a tendency to extrapolate local conditions to larger areas. Although in the current inventory we have detected substantial mortality, which is evident in the decline in aspen net growth, our results do not support the assertion of wide-scale decline in Utah.

Aspen is found in many forest types with a wide variety of associate tree species, and the characteristics of aspen-dominated stands and stands with aspen as a minor component vary considerably over the range of the species. Therefore generalization is difficult, especially when based on the limited data available in most studies. In addition, local or regional trends may differ from those of the population as a whole, because agents like drought and fire are not evenly distributed over the landscape. With continued monitoring under the annual inventory system, however, FIA will be able to assess regional- and population-scale trends in aspen with a higher degree of confidence than has been possible in the past.

Damage to Live Trees

Damage agents are recorded for live trees at least 5.0 inches in diameter. Between 2003 and 2012, FIA used 50 damage codes that represent a wide range of biotic, abiotic, and anthropogenic agents. These codes fall within eight general groups: insects, disease, fire, animals, weather, suppression, form defect, and human-caused. Individual trees can be assigned up to three damage agents, in decreasing order of their perceived impact on the tree. The protocol is based on a threshold system, where only trees with serious damage are assigned damage agent codes. Although somewhat subjective, the general rule is that damage should be recorded when it will cause at least one of the following:

- Prevent the tree from living to maturity, or surviving 10 more years if already mature.
- Prevent the tree from producing marketable products.
- Reduce (or already has seriously reduced) the quality of potential marketable products from the tree.

Two main categories of damage agents can be extracted from these rules. First, agents that are likely to prevent a tree from living to maturity or surviving for 10 years after the inventory date tend to be those related to insects, disease, fire, and atmospheric effects (such as drought, flooding, and wind). Second, agents that preclude or affect merchantability are more likely to be problems with form defect, such as forks, broken tops, or bole scars. The second group may or may not affect tree survival so that not all trees with damage recorded are expected to die, and some of those with poor merchantability may live to typical upper ages for their species.

The list of damage agents is often confused with the list of mortality agents (see "Forest Change Components: Growth, Mortality, and Removals" in the "Overview of Utah's Forests" chapter). Not all damage agents are potential mortality agents and there is only partial overlap between the two agent lists.

Since 1981, Interior West FIA has used a regionally defined damage protocol. During this time, the protocol has remained consistent, with only minor modifications to the damage categories. In 2013, FIA implemented a nationally consistent protocol for non-lethal damage to trees. Almost all of the damage categories used in the national protocol directly correspond to the Interior West regional categories, ensuring that trends in damage agents can be tracked over space and time.

From 2003 through 2012, the Utah annual inventory tallied 59,043 live trees at least 5.0 inches in diameter. Of those, 32 percent had at least one damage agent (primary damage), 9 percent had a secondary damage agent, and 2 percent had a tertiary damage agent (table 12).

Large overall differences in recorded damage agents existed between the woodland and timber species (see Appendix C for the tree species listed in each group). Twenty-two percent of the woodland species had primary damage, about 5 percent had secondary damage, and less than 1 percent had tertiary damage. In contrast, primary damage was recorded on nearly half (48 percent) of the timber trees, secondary damage on 17 percent, and tertiary damage on 4 percent. Although there was a large difference in the proportion of trees with a primary damage agent between the woodland and timber species, the most common damage agent for both was form defects, followed by disease (table 12).

Woodland species accounted for 35,471 of the live trees 5.0 inches in diameter and larger tallied between 2003 and 2012, and 78 percent of these trees had no damage. Form defect occurred in about 12 percent of trees. Within the form defect group 41 percent had dead tops, 36 percent had heartwood scar on boles, and 13 percent had defects unidentified by the field crew. Disease was recorded in 7 percent of woodland trees. Nearly 63 percent of diseased trees had stem or butt rots, and about 20 percent had dwarf mistletoe (*Arceuthobium* spp.). Insect damage agents on woodland trees consisted primarily of bark beetles and defoliators. Animal damage was split evenly between porcupines (*Erethizon dorsatum*) and sapsuckers (*Sphyrapicus* spp.). Almost all of the weather damage was from drought effect. Finally, human-caused damage consisted mostly of woodland cutting, presumably for firewood.

Of the 23,572 timber trees tallied, more than half (52 percent) had no damage. Form defects were recorded in 35 percent of trees. The four most common damage agents in the form group were sweep/taper (45 percent), forks in the merchantable portion of the bole (24 percent), and heartwood scars and dead tops (7 percent and 6 percent, respectively). Disease, which affected 11 percent of timber trees, was dominated by cankers (52 percent) and stem/butt rots (32 percent). Insect damage to timber trees consisted primarily of bark beetles, which was not surprising considering the amount of recent mortality in Utah attributable specifically to bark beetles (see "Forest Change Components: Growth, Mortality, and Removals" in the "Overview of Utah's Forests" chapter). Animal damage in timber species was primarily from big game. Although drought was

Table 12—Percentage of timber trees, woodland trees, and all tally tree species assigned each damage agent group for primary damaging agents, Utah, 2003-2012.

Damage agent group	Annual inventory (2003-2012)		
	Timber	Woodland	All species
No damage	51.9%	78.2%	67.7%
Insects	1.1%	0.7%	0.8%
Diseases	10.9%	6.8%	8.5%
Fire	0.1%	0.1%	0.1%
Animals	0.2%	0.6%	0.4%
Weather	0.5%	0.7%	0.7%
Suppression	0.3%	0.2%	0.2%
Form Defect	34.9%	12.2%	21.2%
Human	<0.01%	0.5%	0.4%
All damage agent groups	**100.0%**	**100.0%**	**100.0%**

recorded as the most common weather-related damage in woodland species, virtually none was reported for timber species. However, drought is known to interact with other damaging agents, such as insects and diseases, by inducing stress in affected trees.

Recent Fires

Fire is a major disturbance that influences the structure and dynamics of Utah'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 and others 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; Egan 2009; Pyne 2008) now carries about the same amount of live tree volume per acre as areas outside the fires, although the mean stand age is somewhat lower and the volume is generally distributed among smaller trees (Wilson and others 2010).

During the period covered by this report there were many fire complexes in Utah. Some FIA plots within fire boundaries were measured before, and some were measured after, the fires occurred. As a result, some fire perimeters contain both pre-fire and post-fire plots, while others may contain only pre-fire or only post-fire plots. Pre-fire plots represent the original conditions in areas that later burned; only post-fire plots provide insight into the short-term effects of fire. Therefore, 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.

The Monitoring Trends in Burn Severity (MTBS) program, is an interagency effort being conducted and maintained by the 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 program is to map the perimeters and severities of large wildland fires (including wildfire, wildland fire use, and prescribed fire) across all lands of the United States. In western States, the project includes all fires larger than 1,000 acres (Eidenshenk and others 2007). The analysis presented here is based on fire perimeters identified by the MTBS program between 2003 and 2012 and on FIA plot data collected in Utah during that period. These fire perimeters included just over 3 percent of plots in Utah. Forty-two percent of the area of plots within fire perimeters was forested, and 58 percent was nonforest.

Data from the MTBS program showed that 292 fire perimeters from 224 different fires burned just over 2 million acres in Utah between 2003 and 2012. Of the total land area burned by these fires, the largest proportion was on federal land managed by the BLM at 50 percent, which accounts for 43 percent of the burned forest land. The second highest proportion (20 percent) of total land area burned was held by private landowners and accounts for 13 percent of the burned forest land. The third highest proportion of total land area burned was on NFS lands at 18 percent, representing 34 percent of the burned forest land (table 13).

Forested plots measured between 2003 and 2012 fell within the boundaries of 66 fire perimeters. The remaining 226 fire perimeters contained only nonforest plots or had no sampled FIA plots. The largest fire—the Milford Flat fire, at nearly 349 thousand acres—encompassed 59 FIA plots, which was more than any other fire. Eighteen percent of the plot area was forested. The second largest fire—the Clay Springs fire, at just over 107 thousand acres—encompassed 18 FIA plots. Twenty-one percent of the plot area was forested. The next eight largest fires were all greater than 40 thousand acres and encompassed between four and nine FIA plots.

Table 13—Percentage of total land area burned and forest land area burned, 2003-2012, Utah.

Landowner Description	Percent of Total Land Burned	Percent of Forest Land Burned
National Forest System	18	34
National Park Service	2	4
Bureau of Land Management	50	43
Department of Defense/Energy	4	1
State	7	5
Private	20	13

When plot-based area estimates were compared to MTBS fire area estimates, agreement was best for large fires that contained a large number of FIA plots. For smaller fires, the plot-based area estimates versus MTBS-based area estimates show less agreement. For example, the plot-based area estimate for the Milford Flat fire is just over 351 thousand acres of land, an overestimated difference of 1 percent. The plot-based area estimate for the Clay Springs fire is just over 108 thousand acres, an overestimated difference of less than 1 percent. In contrast with the two largest fires, the plot-based area estimate for the Seeley fire is 47 percent less than the MTBS fire area estimate: nearly 24 thousand acres versus the MTBS estimate of just over 44 thousand acres. The plot-based area estimate for the Dallas Canyon fire was nearly 48 thousand acres compared to the MTBS fire area estimate of just over 43 thousand acres—an overestimate of 9 percent. The plot-based area estimate for the Twitchell Canyon fire was nearly 27 thousand acres compared to the MTBS fire area estimate of nearly 43 thousand acres—an underestimate of 38 percent. These three fires are much smaller in size and therefore contain fewer FIA plots. They help to demonstrate that although the plot-based estimates and MTBS fire area estimates for smaller fires can be similar, it is not appropriate to draw inferences about the proportions of forest and nonforest areas within small, individual fires. Although the average size of the fires in the MTBS database for the time period analyzed is larger than the full-cycle, single-plot scaling factor for FIA plots (about 6,000 acres), at least 10 plots are normally required for reasonable area estimates. Therefore, the proportion of burned acreage in forest versus nonforest should be estimated by aggregating a large number of plots and burned areas.

Given that population-scale estimates are difficult to produce even with a full inventory, another approach is to compare per-acre estimates of forest attributes. Using FIA data to construct such estimates requires examining individual forest conditions, rather than entire plots, because forested plots may comprise a single forested condition, multiple forested conditions, or a combination of forested and non-forested conditions (see the "Plot Configuration"section in the "Inventory Methods" chapter for more information about conditions). There were 3,354 forested conditions measured on 3,176 plots in Utah between 2003 and 2012. Of these forest conditions, 3,207 were located outside the MTBS fire perimeters and 147 were located inside (fig. 40). Of the conditions located inside the fire perimeters, 85 were measured before the fires occurred and 71 were measured after the fires occurred. These values do not sum to 147 because some plots were located in multiple overlapping fire perimeters, where some were measured before the fires and others were measured after the fires. Conditions located outside the burned areas had an average of 103 square feet of total basal area per acre in live and dead trees, and 88 square feet in only live trees.

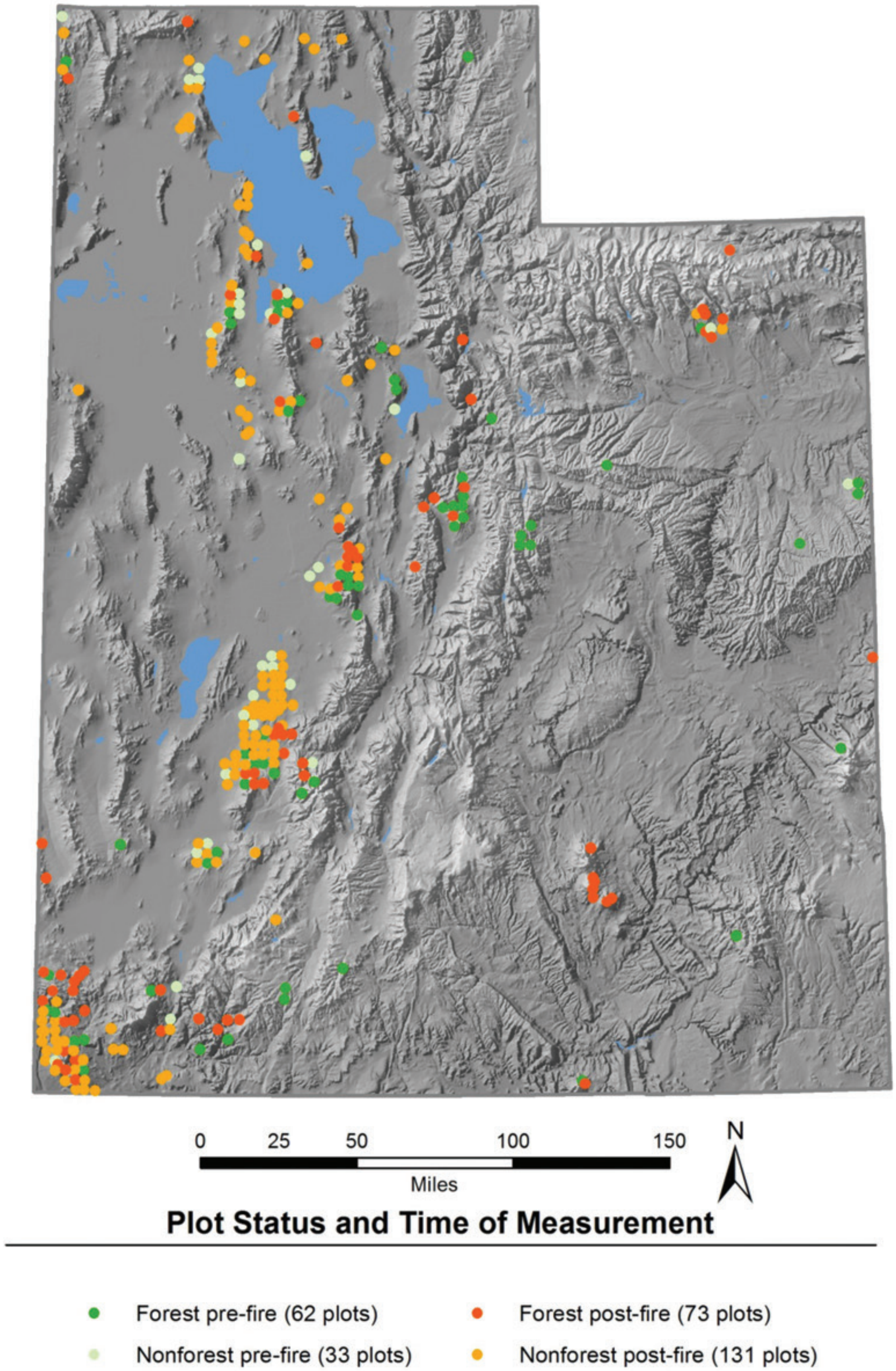


Figure 40—Distribution of plots that occur within Monitoring Trends in Burn Severity (MTBS) fire perimeters from 2003–2012, by plot status (forest versus nonforest) and time of measurement (pre-fire versus post-fire), Utah, 2003–2012. (Note: plot locations are approximate; some plots on private land were randomly swapped.)

Conditions within the burned areas that were measured before the fires averaged 74 square feet of total basal area per acre in live and dead trees and 62 square feet per acre of only live trees. The pre-fire conditions within the fire perimeters appear to have less basal area than conditions outside the burned areas. However, the proportion of live basal area relative to total basal area (live plus dead) was 85 percent for pre-fire plots and 84 percent for plots outside fire perimeters, suggesting that the burned areas did not have extraordinarily high basal area of standing dead trees before the fires. Instead, the lower total basal area indicates that these stands may have had lower stand density, smaller trees, or more down wood than stands outside fire perimeters.

When comparing within-fire pre-burn conditions to within-fire post-burn conditions, it is possible to estimate the proportion of trees killed within burned areas. Conditions located within fire boundaries and measured after the fires averaged 67 total square feet of basal area per acre, with 25 square feet of basal area remaining in live trees. A comparison of the average live basal area from the post-fire conditions to the pre-fire conditions (25 square feet per acre versus 62 square feet per acre) is consistent with the expectation that fire would result in a reduction of the basal area for live trees. If we assume that the pre-burn measurements are representative of the initial, pre-fire conditions at post-burn plots, then it would appear that the average fire-caused mortality was about 37 square feet per acre, or about 60 percent of the pre-fire live basal area. The ratio of live to total basal area was 37 percent in post-burn stands, compared to 85 percent and 84 percent observed on pre-fire and unburned plots, respectively. The lower average total basal area found in post-burn conditions as compared to pre-burn conditions (67 versus 74 square feet per acre) is consistent with the expectation that fire would consume some basal area or cause some trees to fall down after burning.

One beneficial effect of fire is the potential stimulation of aspen regeneration. Utah contains nearly 1.6 million acres of the aspen forest type and about 2.8 million acres with some aspen component. Of the 533 conditions measured with some aspen component, 12 were located within MTBS fire boundaries, and 7 of these were measured post-fire. Two of these post-fire conditions included very young stands that were composed primarily of seedlings and saplings growing around large, dead conifers that were killed by the fire. Although this sample is very small, it suggests that the potentially fire-disturbed area with aspen present is nearly 34 thousand acres, or about 2 percent of all acres with an aspen component. If we convert this figure to an annual rate and assume that fire will be evenly distributed over time and space, it would take about 471 years for all acres with aspen present to be disturbed by fire. This rate may be lower than would be necessary to maintain aspen across the Utah landscape. However, other inventory data show that aspen forest types are fairly stable throughout Utah (see "Aspen Status and Trends" earlier in this chapter). Ongoing monitoring will provide more precise estimates of disturbance intervals and long-term trends than can be made with these shorter term data.

The analyses in this section should be considered only a first approximation of fire effects on Utah'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 mortality tends to be all-or-none at the plot scale. Remeasurement data will be necessary to confirm the portions of standing live and dead trees that are consumed by fire and converted to the down woody material pool.

Noxious and Invasive Plant Species

Noxious Plant Species—Noxious plant species can negatively affect forest communities by displacing native flora, altering fire regimes, reducing diversity in the plant and pollinator communities, and generally reducing the diversity and resiliency of forest ecosystems (Daehler and Carino 1999; Hejda and others 2009; Williamson 1998). Field crews record any instance where a noxious weed is found on a plot that contains a forested condition. These records allow documentation of the spatial and temporal extent of these species as plots are revisited. Although cheatgrass (*Bromus tectorum*) is not listed as noxious in Utah, it is a non-native annual grass that is quickly invading many areas of the State. There is considerable interest in the occurrence of cheatgrass on Utah's forests, but because it is not officially considered "noxious" by the State of Utah, cheatgrass data are collected in a different manner and will be discussed in a separate section. A summary of the prevalence of noxious weeds on Utah's forest land is presented below.

A total of 3,777 plots were used to assess the occurrence of noxious plant species ("weeds") in Utah. Nine weed species were documented on forested plots in Utah, with one or more found on 115 sampled plots (3 percent of the plots). Canada thistle (*Cirsium arvense*) and nodding plumeless thistle (*Carduus nutans*) were the most common weed species by a large margin. These two species accounted for almost 77 percent of the weed occurrences on Utah's forest land (fig. 41).

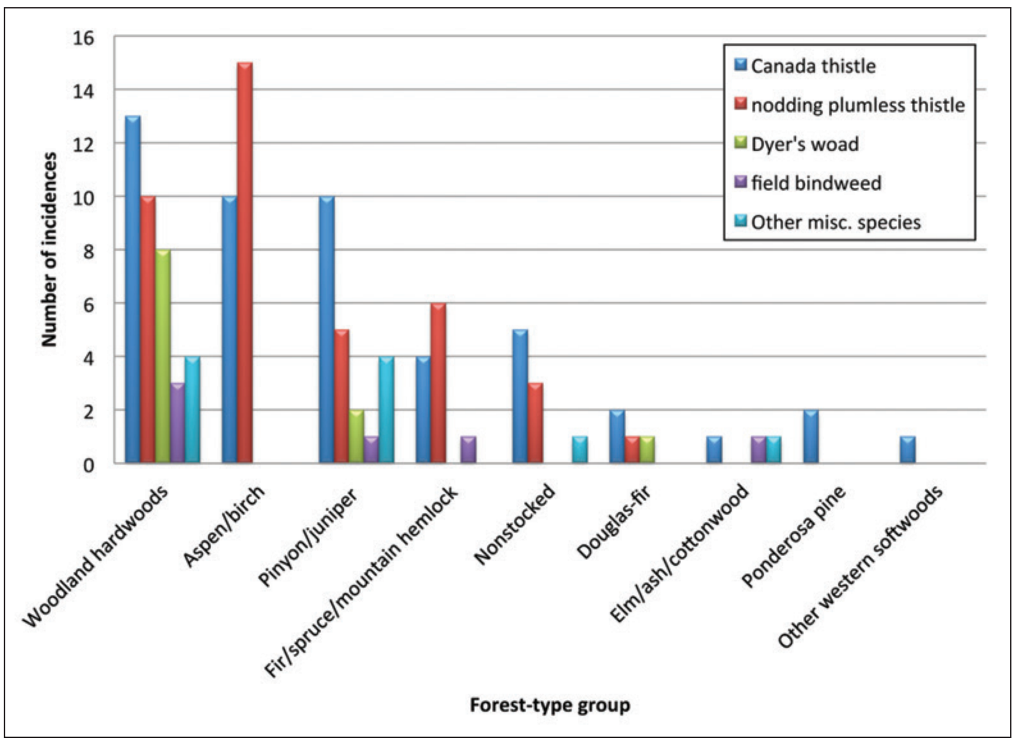


Figure 41—Incidence of weeds on forest land by noxious weed species and forest-type group, Utah, 2003–2012. The Other misc. species group consists of at least one record each of whitetop (*Cardaria draba*), Scotch cotton thistle (*Onopordum acanthium*), hardheads (*Acroptilon repens*), yellow star-thistle (*Centaurea solstitialis*), and spotted knapweed (*Centaurea stoebe*).

The woodland hardwoods forest-type group had the most locations with at least one weed species, followed by the aspen/birch group (fig. 41). The Gambel oak, aspen, and other hardwood forest types appear to be the most susceptible to weed invasion. This heightened susceptibility may be due to one or more factors, such as soil and moisture conditions, accessibility to livestock grazing, road and foot traffic, and high frequency of both natural and human-induced disturbance (Di Tomaso 2000; Harlan and Wet 1965).

Stand age appeared to be related to on the frequency of weed occurrence, with 75 percent of the observations located in stands less than 100 years old and 88 percent found on stands less than 151 years old (fig. 42). Plant communities in young forest stands may not be fully established when weed species are introduced to the area. Therefore, site conditions may favor introduction and establishment of invasive species in unfilled niches in the system. Communities in older and undisturbed stands are generally stable and thus more resilient to invasion by weed species. It should be noted that stand age and condition proportion are correlated (older stands tend to be a single condition more often than younger stands), so we would expect this trend, given the stand-age relationship discussed above.

Multiple conditions on a plot indicate ecotones between forest types or between forest and nonforest conditions. The dynamic nature of these ecotones in terms of site occupation, utilization, and species composition makes them more susceptible to occupation by weeds than the more stable interior of the stands. In Utah, 30 percent of forested conditions sampled consisted of these fragmented conditions, with nearly 6 percent having a weed species present. Single-condition plots make up the remaining 70 percent of the sample, with weeds present on only 2 percent of them.

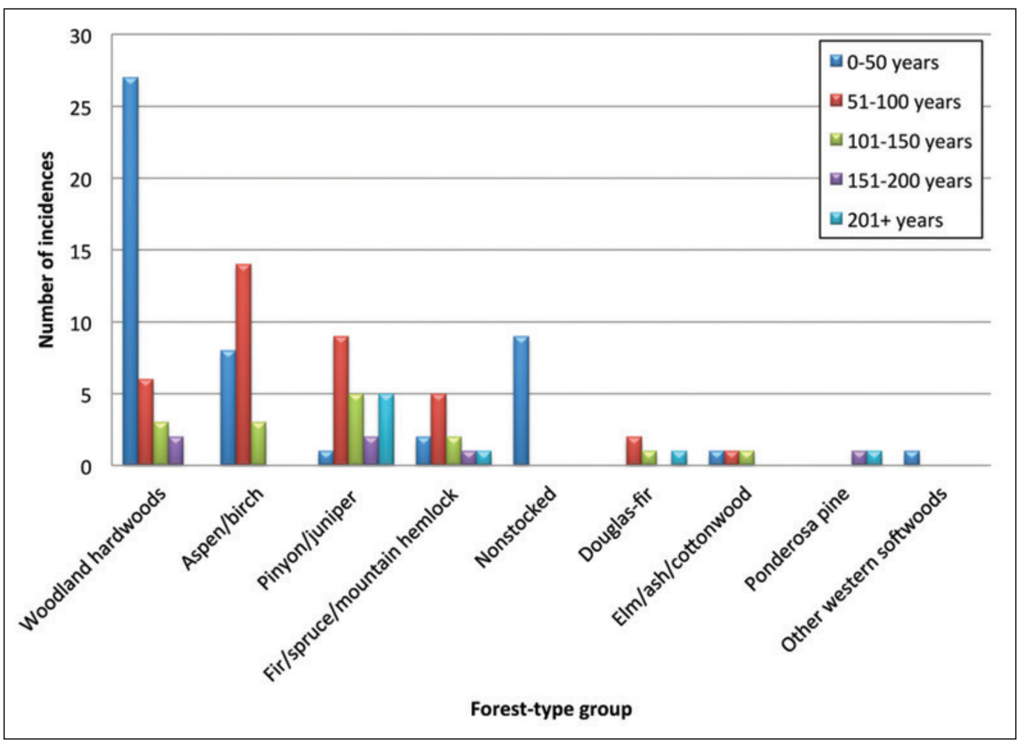


Figure 42—Incidence of weeds on forest land by forest-type group and stand-age group, Utah, 2003–2012.

Cheatgrass—Cheatgrass is a non-native annual grass that has invaded and displaced native vegetation throughout the Interior West. Cheatgrass begins growth and produces seeds earlier than most native species, thus gaining a competitive advantage for the limited resources in the arid environments of Utah and other States. Cheatgrass presents a threat to western ecosystems and a challenge to those that manage the lands where it has established. For example, the fine fuels created by cheatgrass alter fire frequency in the areas where it is found in abundance. These fuels can perpetuate the spread of the species by creating new areas to invade after a fire disturbance. Both public and private land managers are interested in a better understanding of the influences on spatial and temporal patterns of cheatgrass along with any other information that can be used to mitigate infestation. Data collected by FIA can be used to identify areas infested or most susceptible to infestation. This information can also be used to test cheatgrass models currently being developed or refine those already being implemented.

In the Interior West, FIA crews record cheatgrass on Phase 2 plots when it occurs at or above the cover threshold required for observations within understory vegetation procedures. Note that in Utah, this threshold was 5 percent through 2010, and was lowered to 3 percent in 2011 (see "Understory Vegetation" in the "Utah's Forest Resources" chapter). Understory vegetation was recorded only for plots with forested conditions present (USDA FS 2011). Therefore, the data do not reflect trace amounts of cheatgrass or cheatgrass on nonforest portions of plots. A summary of the area and characteristics of plots infested with cheatgrass in Utah is presented below.

Cheatgrass met the minimum cover threshold (5 percent for 2003–2010, and 3 percent for 2011–2012) on 266 conditions in Utah (fig. 43). The pinyon/juniper forest-type group had 166 conditions, which represent 62 percent of the total number of cheatgrass occurrences detected in Utah. The woodland hardwoods forest-type group had the next highest number of conditions with 53 (20 percent), followed by nonstocked with 43 conditions (16 percent). All other forest-type groups combined had a total of four conditions with cheatgrass occurrence, accounting for less than 2 percent of the total number of incidences of cheatgrass on forest land. Most of the cheatgrass sampled occurred on plots at 6,000 to 7,000 feet in elevation, with the 5,000- to 6,000-foot elevation group having the next highest number of incidences (fig. 44). The woodland hardwoods forest-type group had more acres of infested forest in the 7,000- to 8,000-foot elevation group than in lower elevation groups. This is likely due to the inclusion of *Cercocarpus* (mountain mahogany) woodlands, which usually occur at higher elevations than most other western hardwood forest types.

In stark contrast to species officially listed as noxious in Utah, cheatgrass is not found in abundance in any timber forest types. With the exception of two occurrences in aspen, one in cottonwood and one in white fir, all plots with cheatgrass that reached the cover threshold were found in either nonstocked or woodland forest types—the vast majority in the pinyon/juniper forest-type group. The forest types in this group often occur in areas that have lower soil moisture and less understory species diversity than higher elevation sites. These may be factors that affect an area's susceptibility to invasion. Other possible factors influencing the predominance of cheatgrass include the type, level, and frequency of disturbance (natural and human-induced) in low-elevation areas and their juxtaposition to range lands where cheatgrass thrives. Finally, the pattern of cheatgrass incidence across the elevation gradient may be driven by a corresponding moisture gradient. Plots located at higher elevations typically have more soil moisture, lower temperatures, and a shorter growing season, which are all factors that may impede the introduction and establishment of cheatgrass in these areas.

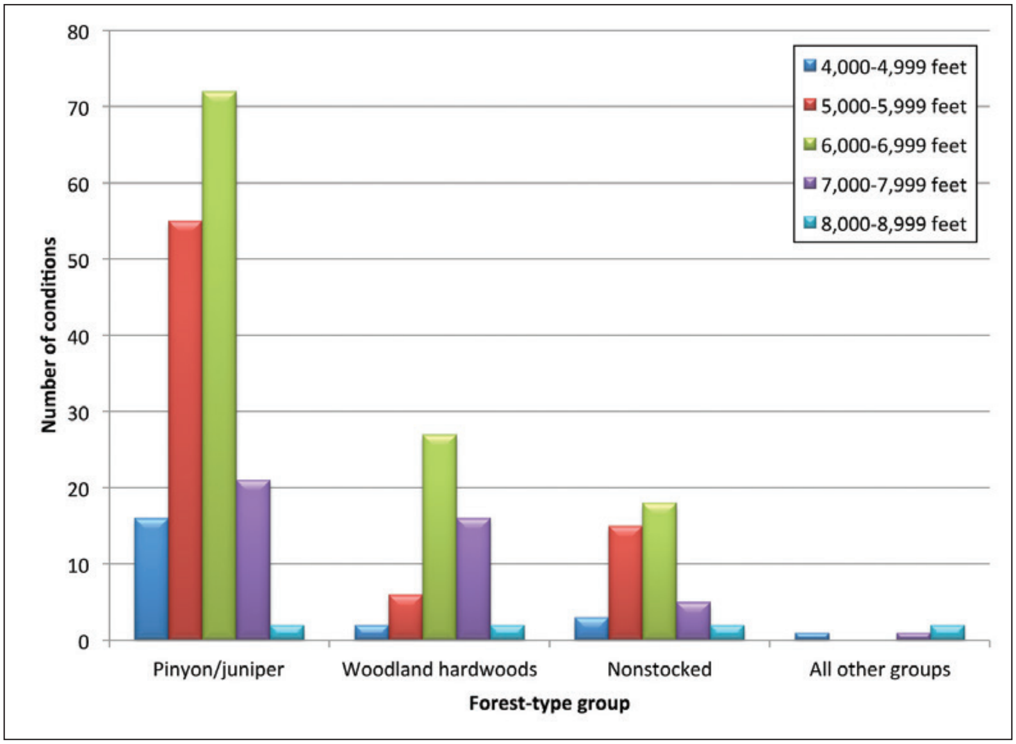


Figure 43—Number of forested conditions infested with cheatgrass by forest-type group and elevation group, Utah, 2003–2012.

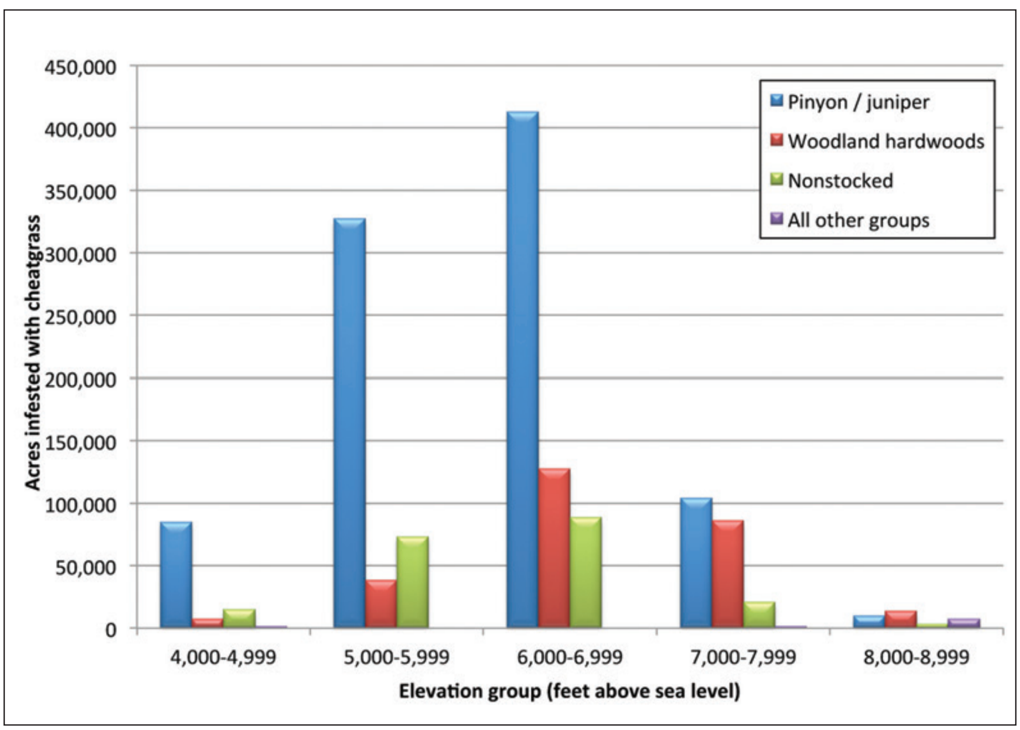


Figure 44—Estimated acres of forest land infested with cheatgrass (>3 percent cover) by elevation class, Utah, 2003–2012.

Conclusions and Future Analysis

Utah's 18.3 million acres of forest land are occupied by 22 FIA forest tree species of varying ages and size classes. These species in different combinations make up 10 different forest-type groups and 20 different forest types distributed across 6 ecoregion provinces. Major forest-type groups are pinyon/juniper, woodland hardwoods, aspen/birch, and fir/spruce/mountain hemlock. These forests provide a wide range of valuable services and products, including watershed protection, air and water quality, wildlife habitat, recreation and scenic value, and wood products.

Eighty-five percent of Utah's forest land is in the public domain, with 39 percent managed by the BLM and 35 percent in the National Forest System. Only 15 percent of Utah's forests is owned by private landowners.

Utah's forests show trends of increasing mortality and declining growth. Mortality exceeded gross growth for six of the eight major inventory species in Utah. Quaking aspen and Utah juniper were the only major species with positive net growth. Engelmann spruce exhibited the highest level of mortality of the eight species, which contributed to the highest negative net growth estimate of –30.8 million cubic feet per year. Net annual growth of lodgepole pine was –28.3 million cubic feet. Quaking aspen mortality averaged 25.3 million cubic feet and net growth averaged 11.6 million cubic feet per year. National Forest System lands accounted for 71 percent of total average annual mortality, which was higher than any other ownership category. Mortality currently exceeds growth on national forest lands in Utah. Major factors affecting recent mortality include insects, wildfires, and disease, all of which are likely related to multi-year weather patterns such as drought.

Utah's timber harvest in 2012 was 33 percent lower than in 2007. The State's timber harvest in 2007 was 73 percent of what it was in 2002 and only about one-half of the 1992 level. These declines in Utah's timber harvest volumes pose significant challenges to both the industry and forest sustainability, because the ability to conduct vegetation management and mitigate mortality impacts has decreased as timber processors and forest operators have gone out of business.

Many of the analyses included in this report demonstrate the utility of FIA data as a monitoring and planning tool for a wide range of objectives. Not all relevant analyses could be included here, however, and more in-depth analyses will be conducted by FIA analysts and FIA data users on a wide range of topics. Data from FIA's annualized inventory will continue to provide valuable information to resource managers and researchers who are interested in the heath, status, and quantity of resources provided by Utah's forests.

References

Amacher, M.C.; O'Neill, K.P.; Perry, C.H. 2007. Soil vital signs: a new index for assessing forest soil health. RMRS-RP-65WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 12 p.

Anderegg, W.R.; Plavcová, L.; Anderegg, L.D.; Hacke, U.G.; Berry, J.A.; Field, C.B. 2013. Drought's legacy: Multiyear hydraulic deterioration underlies widespread aspen forest die-off and portends increased future risk. Global Change Biology. 19(4): 1188–1196.

Arner, S.L.; Woudenberg, S.; Waters, S.; Vissage, J.; MacLean, C.; Thompson, M.; Hansen, M. 2001. National algorithms for determining stocking class, stand size class, and forest type of Forest Inventory and Analysis plots. Internal Report. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA. 65 p. Online: http://www.fia.fs.fed.us/library/sampling/docs/supplement4_121704.pdf. [June 18, 2015].

Bailey, R.G. 1995. Descriptions of the ecoregions of the United States. 2nd ed. rev. and expanded. Misc. Publ. No. 1391. Washington, DC: U.S. Department of Agriculture, Forest Service. Online: http://www.fs.fed.us/land/ecosysmgmt/. [July 30, 2013].

Bartos, D.L.; Campbell, R.B., Jr. 1998. Decline of quaking aspen in the Interior West—examples from Utah. Rangelands. 20(1): 17–24.

Bechtold, W.A.; Patterson, P.L., eds. 2005. The enhanced Forest Inventory and Analysis program—national sampling design and estimation procedures. Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 85 p.

Blackard, J.A.; Finco, M.V.; Helmer, E.H.; Holden, G.R.; Hoppus, M.L.; Jacobs, D.M.; Lister, A.J.; Moisen, G.G.; Nelson, M.D.; Reimann, R.; Ruefenacht, B.; Salajanu, D.; Weyermann, D.L.; Winterberger, K.C.; Brandeis, T.J.; Czaplewski, R.L.; McRoberts, R.E.; Patterson, P.L.; Tymcio, R.P. 2008. Mapping U.S. forest biomass using nationwide forest inventory data and moderate resolution information. Remote Sensing of Environment. 112: 1658–1677.

Block, W.M.; Brennan, L.A. 1987. Characteristics of Lewis' Woodpecker habitat on the Modoc Plateau, California. Western Birds. 18: 209–212.

Bock, C.E. 1970. The ecology and behavior of the Lewis woodpecker (*Asyndesmus lewis*). University of California Publication of Zoology. 92: 1–100.

Brandao, L.F.G; Alcantara, G.B.; Matos, M.F.C.; Bogo, D.; Freitas, D.S.; Oyama, N.M.; Honda, N.K. 2013. Cytotoxic evaluation of phenolic compounds from lichens against melanoma cells. Chemical and Pharmaceutical Bulletin. 61: 176-183.

Breshears, D.D.; Cobb, N.S.; Rich, P.M.; Price, K.P.; Allen, C.D.; Balice, R.G.; Romme, W.H.; Kastens, J.H.; Floyd, M.L.; Belnap, J.; Anderson, J.J.; Myers, O.B.; Meyer, C.W. 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings of the National Academy of Sciences of the United States of America. 102(42): 15144–15148.

Brickell, J.E. 1968. A method for constructing site index curves from measurements of tree age and height—its application to inland Douglas-fir. Res. Pap. INT-47. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 23 p.

Brickell, J.E. 1970. Equations and computer subroutines for estimating site quality of eight Rocky Mountain species. Res. Paper INT-75. Ogden, UT: U.S. Department of Agriculture, Forest Service, IntermountainResearch Station. 22 p.

Cape, J.N.; van der Eerden, L.J.; Sutton, L.J.; Leith, I.D.; Sutton, M.A. 2009. Evidence for changing the critical level for ammonia. Environmental Pollution. 157(3): 1033–1037.

Chojnacky, D.C. 1985. Pinyon-juniper volume equations for the central Rocky Mountain States. Res. Note INT-339. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 27 p.

Chojnacky, D.C. 1994. Volume equations for New Mexico's pinyon-juniper dryland forests. Res. Note INT-471. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 9 p.

Cleland, D.T.; Freeouf, J.A.; Keys, J.E., Jr.; Nowacki, G.J.; Carpenter, C.; McNab, W.H. 2007. Ecological subregions: sections and subsections for the conterminous United States. Gen. Tech. Rep. GTR-WO-76. Washington, DC: U.S. Department of Agriculture, Forest Service.

Cohen, S.; Miller, D. 1978. The big burn: the Northwest's fire of 1910. Missoula, MT: Pictorial Histories Publishing Co. 96 p.

Daehler, C.C., Carino, D.A. 1999. Threats of invasive plants to the conservation of biodiversity. In: Chou, C.H.; Waller, G.R.; Reinhard, C., eds. Biodiversity and allelopathy: from organisms to ecosystems in the Pacific. Taipei, Taiwan: Academia Sinica: 21–27.

DeBlander, L.T.; Shaw, J.D.; Witt, C.; Menlove, J.; Thompson, M.T.; Morgan, T.A.; DeRose, R.J.; Amacher, M.C. 2010. Utah's forest resources, 2000-2005. Resour. Bull. RMRS RB-10. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 144 p.

DeRose, R.J.; Bentz, B.J.; Long, J.N.; Shaw, J.D. 2013. Effect of increasing temperatures on the distribution of spruce beetle in Engelmann spruce forests of the Interior West, USA. Forest Ecology and Management. 308: 198–206.

DeRose, R.J.; Long, J.N. 2007. Disturbance, structure, and composition: spruce beetle and Engelmann spruce forests on the Markagunt Plateau, Utah. Forest Ecology and Management. 244(1): 16–23.

Di Orio, A.P.; Callasa, R.; Schaefer, R.J. 2005. Forty-eight year decline and fragmentation of aspen (*Populus tremuloides*) in the South Warner Mountains of California. Forest Ecology and Management. 206(1–3): 307–313.

Di Tomaso, J.M. 2000. Invasive weeds in rangelands: species, impacts, and management. Weed Science. 48(2): 255–265.

Dobkin, D.S.; Rich, A.C.; Pretare, J.A.; Pyle, W.H. 1995. Nest-site relationships among cavity-nesting birds of riparian and snowpocket aspen woodlands in the northwestern Great Basin. The Condor. 97: 694–707.

Dymerski, A.D.; Anhold, J.A.; Munson, A.S. 2001. Spruce beetle (*Dendroctonus rufipennis*) outbreak in Engelmann spruce (*Picea engelmannii*) in central Utah (1986-1998). Western North American Naturalist. 61(1): 11–18.

Edminster, C.B.; Beeson, R.T.; Metcalf, G.B. 1980. Volume tables and point-sampling factors for ponderosa pine in the front range of Colorado. Res. Pap. RM-218. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.

Edminster, C.B.; Mowrer, H.T.; Hinds, T.E. 1982. Volume tables and point-sampling factors for aspen in Colorado. Res. Pap. RM-232. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 16 p.

Edminster, C.B.; Mowrer, H.T.; Sheppard, W.D. 1985. Site index curves for aspen in the Central Rocky Mountains. Res. Note RM-453. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

Egan, T. 2009. The big burn: Teddy Roosevelt and the fire that saved America. Boston, MA: Houghton Mifflin Harcourt. 324 p.

Eidenshenk J.; Schwind, B.; Brewer, K.; Zhu, Z.; Quayle, B.; Howard, S. 2007. A project for monitoring trends in burn severity. Fire Ecology 3(3): 3-21.

Ellis, C.J. 2012. A risk-based model of climate change threat: hazard, exposure, and vulnerability in the ecology of lichen epiphytes. Botany. 91(1): 1–11.

Fenn, M.E.; Allen, E.B.; Weiss, S.B.; Jovan, S.; Geiser, L.H.; Tonnesen, G.S.; Johnson, R.F.; Rao, L.E.; Gimeno, B.S.; Yuan, F.; Meixner T.; Bytnerowicz, A. 2010. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. Journal of Environmental Management. 91(12): 2404–2423.

Fiedler, C.E.; Friederici, P.; Petruncio, M. 2007. Monitoring old growth in frequent-fire landscapes. Ecology and Society. 12(2): 22. Online: http://www.ecologyandsociety.org/vol12/iss2/art22/. [May 5, 2014].

Flack, J.A.D. 1976. Bird populations of aspen forests in western North America. Ornithological Monographs 19. Washington, DC: American Ornithologist's Union. 97 p.

Frahm, J.P. 2013. Contents of amino acids and osmotic values of epiphytic lichens as indicators for regional atmospheric nitrogen loads. Archive for Lichenology. 9: 1–11.

Forest Health Protection. 2014. 2013 Insect and disease survey by subwatersheds (6^{th} level HUCs). [Leaflet]. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. 2 p. Online: http://www.fs.fed.us/foresthealth/technology/pdfs/IDSurvey_2013_placemat.pdf. [March 25, 2015].

Garbarino, M.; Marzano, R.; Shaw, J.D.; Long, J.N. 2015. Environmental drivers of detrital dynamics in woodlands and forests. Ecological Applications. 6(3): 1-23 article 30.

Geiser, L.H.; Jovan, S.E.; Glavitch, D.A.; Porter, M.K. 2010. Lichen-based critical loads for atmospheric nitrogen deposition in Western Oregon and Washington Forests, USA. Environmental Pollution. 158(7): 2412–2421.

Gillespie, A.J.R. 1999. Rationale for a national annual forest inventory program. Journal of Forestry. 97(12): 16–20.

Gingrich, S.F. 1967. Measuring and evaluating stocking and stand density in Upland Hardwood forests in the Central States. Forest Science. 13: 38–53.

Goeking, S.A.; Shaw, J.D.; Witt, C.; Thompson, M.T.; Werstak, C.E., Jr.; Amacher, M.C.; Stuever, M.; Morgan, T.A.; Sorenson, C.B.; Hayes, S.W.; McIver, C.P. 2014. New Mexico's forest resources, 2008–2012. Resour. Bull. RMRS-RB-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 144 p.

Hann, D.W.; Bare, B.B. 1978. Comprehensive tree volume equations for major species of New Mexico and Arizona: I. Results and methodology. Res. Note INT-209. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 43 p.

Harlan, J.R.; deWet, J.M.J. 1965. Some thoughts about weeds. Economic Botany. 19(1): 16–24.

Hart, J.H.; Hart, D.L. 2001. Heartrot fungi's role in creating Picid nesting sites in living aspen. In: Sheppard, W.D.; Binkley, D.; Bartos, D.L.; Stohlgren, T.J.; Eskew, L.G., eds., Sustaining aspen in western landscapes: symposium proceedings. Grand Junction, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 460 p.

Hayes, S.W.; Morgan, T.A.; Berg, E.C.; Daniels, J.M.; Thompson, M.T. 2012. The Four Corners timber harvest and forest products industry, 2007. Resour. Bull. RMRS-RB-13. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 61 p.

Hawksworth, D.L.; Rose, F. 1970. Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens. Nature. 227(5254): 145–148.

Hejda, M.; Pyšek, P.; Jarošík, V. 2009. Impact of invasive plants on the species richness, diversity and composition of invaded communities. Journal of Ecology. 97: 393–403.

Helms, J.A. 2004. Old growth: What is it? Journal of Forestry. 102(3): 8–12.

Hessl, A.E.; Graumlich, L.J. 2002. Interactive effects of human activities, herbivory and fire on quaking aspen (*Populus tremuloides*) age structures in western Wyoming. Journal of Biogeography. 29: 889–902.

Jenkins, M.J.; Hebertson, E.G.; Munson, A.S. 2014. Spruce beetle biology, ecology and management in the Rocky Mountains: an addendum to spruce beetle in the Rockies. Forests. 5: 21–71.

Jenny, H. 1994. Factors of soil formation—a system of quantitative pedology. Dover edition. New York: Dover Publications. 191 p.

Johnson, M. 1994. Changes in southwestern forests: stewardship implications. Journal of Forestry. 92(12): 16–19.

Jovan, S. 2008. Lichen bioindication of biodiversity, air quality, and climate: baseline results from monitoring in Washington, Oregon, and California. PNW-GTR-737. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 115 p.

Jovan, S.; Carlberg, T. 2007. Nitrogen Content of *Letharia vulpina* tissue from forests of the Sierra Nevada, California: Geographic patterns and relationships to ammonia estimates and climate. Environmental Monitoring and Assessment. 129(1-3): 243-251.

Jovan, S.; McCune, B. 2005. Air-quality bioindication in the Greater Central Valley of California, with epiphytic macrolichen communities. Ecological Applications. 15(5): 1712–1726.

Jovan, S.; Riddell, J.; Padgett, P.E.; Nash, T.H. 2012. Eutrophic lichens respond to multiple forms of N: implications for critical levels and critical loads research. Ecological Applications. 22(7): 1910–1922.

Kaufmann, M.R.; Binkley, D.; Fulé, P.Z.; Johnson, M.; Stephens, S.L.; Swetnam, T.W. 2007. Defining old growth for fire-adapted forests of the western United States. Ecology and Society. 12(2): 15. Online: http://www.ecologyandsociety.org/vol12/iss2/art15/. [May 5, 2014].

Kay, C.E. 1997. Is aspen doomed? Journal of Forestry. 95(5): 4–11.

Kay, C.E. 2001. Long-term aspen exclosures in the Yellowstone ecosystem. In: Shepperd, W.D.; Binkley, D.; Bartos, D.L.; Stohlgren, T.J.; Eskew, L.G., comps. Sustaining aspen in western landscapes. Proceedings RMRS-P-18. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 225–242.

Kearns, H.S.J.; Jacobi, W.R.; Johnson, D.W. 2005. Persistence of pinyon pine snags and logs in southwestern Colorado. Western Journal of Applied Forestry 20(4):247-252.

Keegan, C.E.; Morgan, T.A.; Gebert, K.M.; Brandt, J.P.; Blatner, K.A.; Spoelma, T.P. 2006. Timber-processing capacity and capabilities in the western United States. Journal of Forestry. 104(5): 262–268.

Keegan, C.E.; Sorenson, C.B.; Morgan, T.A.; Hayes, S.W.; Daniels, J.M. 2012. Impact of the Great Recession and housing collapse on the forest products industry in the western United States. Forest Products Journal. 61(8): 625–634.

Keegan, C.E.; Wichman, D.P.; Van Hooser, D.D. 1995. Utah's forest products industry: a descriptive analysis, 1992. Resour. Bull. INT-RB-83. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 21 p.

Kegley, S. 2006. Management guide for western balsam bark beetle. Web guide 4.9.Forest Health Protection and State Forestry Organizations. Online: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5188058.pdf. [July 2010].

Kemp, P.D. 1956. Region 1 volume tables for ADP cruise computations. Timber Cruising Handbook R1-2430-31. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region.

Kershaw, L.; MacKinnon, A.; Pojar, J. 1998. Plants of the Rocky Mountains. Edmonton, CA: Lone Pine Publishing. 384 p.

Kleinman, S.J.; DeGomez, T.E.; Snider, G.B.; Williams, K.E. 2012. Large-scale pinyon ips (*Ips confusus*) outbreak in southwestern United States tied with elevation and land cover. Journal of Forestry. 110(4): 194–200.

Kulakowski, D.; Veblen, T.T.; Drinkwater, S. 2004. The persistence of quaking aspen (*Populus tremuloides*) in the Grand Mesa area, Colorado. Ecological Applications. 14 (5): 1603–1614.

Larsen Vilsholm, R.; Wolseley, P.A.; Søchting, U.; Chimonides, P.J. 2009. Biomonitoring with lichens on twigs. The Lichenologist. 41(2): 189–202.

Lilieholm, R.J.; Long, J.N.; Patla, S. 1994. Assessing goshawk nest stand habitat using stand density index. Cooper Ornithological Society. Studies in Avian Biology. 16: 18–24.

Linder, K.A.; Anderson, S.H. 1998. Nesting habitat of Lewis' Woodpecker in southeastern Wyoming. Journal of Field Ornithology. 69 (1): 109–116.

Long, J.N. 1985. A practical approach to density management. Forest Chronicle. 61: 23–37.

Long, J.N.; Daniel, T.W. 1990. Assessment of growing stock in uneven-aged stands. Western Journal of Applied Forestry. 5: 93–96.

Long, J.N.; Shaw, J.D. 2005. A density management diagram for even-aged ponderosa pine stands. Western Journal of Applied Forestry. 20: 205–215.

Lutes, D.C.; Keane, R.E.; Caratti, J.F. 2009. A surface fuel classification for estimating fire effects. International Journal of Wildland Fire. 18: 802–814.

Martin, K.; Aitken, K.E.H.; Wiebe, K.L. 2004. Nest sites and nest webs for cavity-nesting communities in British Columbia, Canada: nest characteristics and niche partitioning. Condor. 106 (1): 5–19.

Mayer, M.; O'Neill, M.A.; Murray, K.E.; Santos-Magalhães, N.S.; Carneiro-Leão, A.M.A.; Thompson, A.M.; Appleyard, V.C.L. 2005. Usnic acid: A non-genotoxic compound with anticancer properties. Anti-Cancer Drugs. 16 (8): 805-809.

McClelland, R.B.; Frissell, S.S.; Fischer, W.C.; Halvorson, C.H. 1979. Habitat management for hole-nesting birds in forests of western larch and Douglas-fir. Journal of Forestry. 77: 480–483.

McLain, W.H. 1997. Logging utilization—Utah 1993. Resour. Bull. INT-RB-90. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 9 p.

McCune, B.; Geiser, L. 2009. Macrolichens of the Pacific Northwest. Second Edition. Oregon State University Press, Corvallis, Oregon. 448 pp.

McLain, W.H.; Keegan, C.H.; Wichman, D.P. 1997. Utah timber production and mill residue, 1992. Resour. Bull. INT-RB-92. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 16 p.

McMurray, J.; Roberts, D.; Fenn, M.; Geiser, L.; Jovan, S. 2013. Using epiphytic lichens to monitor nitrogen deposition near natural gas drilling operations in the Wind River Range, WY, USA. Water, Air, and Soil Pollution. 224 (3): 1-14.

Menlove, J.; Shaw, J.D.; Thompson, M.T.; Witt, C.; Amacher, M.C.; Goeking, S.A.; Morgan, T.A.; Sorenson, C.; Mclver, C.; Werstak, C. 2012. Montana's forest resources, 2003–2009. Resour. Bull. RMRS-RB-15. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 140 p.

Morgan, T.A.; Dillon, T.;. Keegan, C.E.; Chase, A.L.; Thompson, M.T. 2006. The Four Corners timber harvest and forest products industry, 2002. Resour. Bull. RMRS-RB-7. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 63 p.

Morgan, T.A.; Spoelma, T.P. 2008. California logging utilization, 2004. Western Journal of Applied Forestry. 23 (1): 12–18.

Morgan, T.A.; Spoelma, T.P.; Keegan, C.E.; Chase, A.L.; Thompson, M.T. 2005. Montana logging utilization, 2002. Res. Pap. RMRS-RP-52. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 12 p.

Mueller, R.C.; Scudder, C.M.; Porter, M.E.; Trotter, R.T., III; Gehring, C.A.; Whitham, T.G. 2005. Differential tree mortality in response to severe drought: evidence for long-term vegetation shifts. Journal of Ecology. 93: 1085–1093.

Myers, C.A.; Edminster, C.B. 1972. Volume tables and point-sampling factors for Engelmann spruce in Colorado and Wyoming, 1972. Res. Pap. RM-95. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 23 p.

National Climatic Data Center. 1994. Time bias corrected divisional temperature precipitation-drought index. Documentation for dataset TD-9640. Available from DBMB, NCDC, NOAA, Federal Building, 37 Battery Park Avenue, Asheville, NC 28801-2733. 12 p.

O'Brien, R.A. 1999. Utah's forest resources, 1993. Resour. Bull. RMRS-RB-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 105 p.

O'Neill, K.P.; Amacher, M.C.; Perry, C.H. 2005. Soils as an indicator of forest health: a guide to the collection, analysis, and interpretation of soil indicator data in the Forest Inventory and Analysis program. Gen. Tech. Rep. GTR-NC-258. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 5 p.

Parmesan, C.; Yohe, G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature. 421(6918): 37–42.

Patterson, P.L.; Coulston, J.W.; Roesch, F.A.; Westfall, J.A.; Hill, A.D. 2012. A primer for non-response in the US Forest Inventory and Analysis program. Environmental Monitoring and Assessment. 184(3): 1423–1433.

Patton, D.R.; Avant, H.D. 1970. Fire stimulated aspen sprouting in a spruce-fir forest in New Mexico. Res. Note RM-RN-159. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 3 p.

Pearson, G. 1914. The role of aspen in the reforestation of mountain burns in Arizona and New Mexico. Plant World. 17: 249–260.

Pollard, J.E.; Westfall, J.A.; Patterson, P.L.; Gartner, D.L.; Hansen, M.; Kuegler, O. 2006. Forest Inventory and Analysis national data quality assessment report 2000 to 2003. Gen. Tech. Rep. RMRS-GTR-181. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 43 p.

Pyne, S.J. 2008. Year of the fires: the story of the great fires of 1910. Rev. ed. Missoula, MT: Mountain Press Publishing Company. 320 p.

Raffa, K.F.; Aukema, B.H.; Bentz, B.J.; Carroll, A.L.;. Hicke, J.A.; Turner, M.G.; Romme, W.H. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. BioScience. 58(6): 501–517.

Rankovic, B.; Kosanic, M. 2012. Antimicrobial activities of different extracts of *Lecanora atra*, *Lecanora muralis*, *Parmelia saxatilis*, and *Parmeliopsis ambigua*. Pakistan Journal of Botany. 44 (1): 429-433.

Raphael, M.G.; White, M. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildlife Monograph. 86: 1–66.

Reineke, L.H. 1933. Perfecting a stand density index for even-aged forests. Journal of Agricultural Research. 46(7): 627–638.

Reinhardt, E.D.; Keane, R.E.; Calkin, D.E.; Cohen, J.D. 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. Forest Ecology and Management. 256: 1997–2006.

Root, H.T.; Geiser, L.H.; Fenn, M.E.; Jovan, S.; Hutten, M.A.; Ahuja, S.; McMurray, J.A. 2013. A simple tool for estimating throughfall nitrogen deposition in forests of western North America using lichens. Forest Ecology and Management. 306 (0): 1-8.

Russell, R.E.; Saab, V.A.; Dudley, J.G. 2007. Habitat-suitability models for cavity-nesting birds in a postfire landscape. Journal of Wildlife Management. 71(8): 2600–2611.

Saab, V.A.; Vierling, K.T. 2001. Reproductive success of Lewis's Woodpecker in burned pine and cottonwood riparian forests. Condor. 103(3): 491–501.

Saab, V.A.; Russell, R.E.; Dudley, J.G. 2007. Nest densities of cavity-nesting birds in relation to postfire salvage logging and time since wildfire. Condor. 109: 97–108.

SAS Institute Inc. 2011. SAS/STAT 9.3 user's guide. Cary, NC.

Schier, G.A. 1975. Deterioration of aspen clones in the middle Rocky Mountains. Res. Pap. INT-170. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.

Shaw, J.D. 2000. Application of stand density index to irregularly structured stands. Western Journal of Applied Forestry. 15: 40–42.

Shaw, J.D. 2006. Drought-related mortality in pinyon/juniper woodlands: a test case for the FIA annual inventory system. In: R.E. McRoberts, G.A. Reams, P.C. Van Deusen, and W.H. McWilliams (eds.) Proceedings of the sixth annual forest inventory and analysis symposium, September 20-24, 2004, Denver, Colorado. General Technical Report WO-70. Washington DC: USDA Forest Service. 126 p.

Shaw, J.D.; Steed, B.E.; DeBlander, L.T. 2005. Forest Inventory and Analysis (FIA) annual inventory answers the question: What is happening to pinyon/juniper woodlands. Journal of Forestry. 103(6): 280–285.

Smith, F.W.; Long, J.N. 1987. Elk hiding and thermal cover guidelines in the context of lodgepole pine stand density. Western Journal of Applied Forestry. 2: 6–10.

Society of American Foresters. 2004. Western US drought outlook improves. The Forestry Source. 9(12): 1, 5.

Sorenson, C.; Morgan, T.; Simmons E.; Berg E.; Scudder, M.; Hayes, S.; McIver C. 2014. The Four Corners timber harvest and forest products industry, 2012. 40 p. Online: http://www.bber.umt.edu/pubs/forest/fidacs/UT2012.pdf. [June 18, 2015].

Stage, A.R. 1966. Simultaneous derivation of site-curve and productivity rating procedures. Society of American Foresters Proceedings 1966: 134-136. Original equations were reformulated by John D. Shaw. Documentation on file at U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Stage, A.R. 1969. Computing procedure for grand fir site evaluation and productivity estimation. Res. Note INT-98.Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Sousa, P.J. 1983. Habitat Suitability Index models: Lewis' Woodpecker. FWS/OBS 82/10.32. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 14 p.

Thompson, M.T. 2009. Analysis of conifer mortality in Colorado using Forest Inventory and Analysis's annual forest inventory. Western Journal of Applied Forestry. 24(4): 193–197.

Tobalske, B.W. 1997. Lewis' Woodpecker (*Melanerpes lewis*). In: Poole, A.; Gill, F., eds. The birds of North America, No. 284. Philadelphia: The Academy of Natural Sciences, and Washington, DC: The American Ornithologists' Union.

Touchan, R.; Allen, C.D.; Swetnam, T.W. 1996. Fire history and climatic patterns in ponderosa pine and mixed-conifer forests of the Jemez Mountains, northern New Mexico. In: Allen, C.D., ed. Fire effects in southwestern forests: proceedings of the second La Mesa Fire Symposium. Gen. Tech. Rep. RM-GTR-286. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experimental Station: 33–46.

U.S. Department of Commerce, Bureau of Economic Analysis [USDC BEA]. 2012. Regional accounts data. Table SA25N. Online: http://www.bea.gov/regional/[June 7, 2013].

U.S. Department of Agriculture, Forest Service [USDA FS]. 2006. Interior West Forest Inventory and Analysis Forest Survey field procedures, Version 4.0. Online: http://www.fs.fed.us/rm/ogden/data-collection/pdf/p2_midas_40_final_reduced.pdf. [June 2013].

U.S. Department of Agriculture, Forest Service [USDA FS]. 2011. Interior West Forest Inventory and Analysis Forest Survey field procedures, Version 5.0. Online: http://www.fs.fed.us/rm/ogden/data-collection/pdf/iwfia_p2_50.pdf. [June 2013].

van Herk, C.M. 1999. Mapping of ammonia pollution with epiphytic lichens in theNetherlands. The Lichenologist. 31(1): 9–20.

Vierling, K.T. 1997. Habitat selection of Lewis' Woodpeckers in Southeastern Colorado. Wilson Bulletin. 109 (1): 121–130.

Vosick, D.; Ostergren, D.M.; Murfitt, L. 2007. Old-growth policy. 2007. Ecology and Society. 12(2): 19. Online: http://www.ecologyandsociety.org/vol12/iss2/art19/. [May 5, 2014].

Williamson, M. 1998.Measuring the impact of plant invaders in Britain. In: Starfinger, U.; Edwards, K.; Williamson, M., eds. Plant invasions: ecological mechanisms and human responses. Leyden, the Netherlands: Backhuys Publishers: 57–68.

Wilson, M.J.; DeBlander, L.T.; Halverson, K.A. 2010. Resource impacts of the 1910 fires: a Forest Inventory and Analysis (FIA) perspective. Powerpoint presentation given at: 1910 Fires: A Century Later. Wallace, ID, May 20–22, 2010. Unpublished document on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Ogden, UT.

Witt, C.; Shaw, J.D.; Thompson, M.T.; Goeking, S.A.; Menlove, J. Amacher, M.C.; Morgan, T.A.; Werstak, C. 2012. Idaho's forest resources, 2004–2009. Resour. Bull. RMRS-RB-14. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 134 p.

Wolf, W.; S.; Jovan, S.; Neitlich, P.; Peck, J. E.; Rosentreter, R. 2015. Lichen-based indices to quantify responses to climate and air pollution across northeastern U.S.A. The Bryologist. 118 (1): 59-82.

Woodall, C.W.; Conkling, B.L.; Amacher, M.C.; Coulston, J.W.; Jovan, S.; Perry, C.H.; Schulz, Beth; Smith, G.C.; Will Wolf, S. 2010. The Forest Inventory and Analysis database version 4.0: database description and users manual for Phase 3. Gen. Tech. Rep. NRS-61. Newtown Square, PA**:** U.S. Department of Agriculture, Forest Service, Northern Research Station. 180 p.

Woodall, C.W., Ince, P.J., Skog, K.E., Aguilar, F.X., Keegan, C.E., Sorenson, C.B., Hodges, D.G., Smith, W.B. 2012. An Overview of the Forest Products Sector Downturn in the United States. Forest Products Society, Forest Products Journal, 61(8), pp. 595-603.

Worrall, J.J.; Egeland, L.; Eager, T.; Mask, R.A.; Johnson, E.W.; Kemp, P.A.; Shepperd, W.D. 2008. Rapid mortality of *Populus tremuloides* in southwestern Colorado, USA. Forest Ecology and Management. 255(3–4): 686–696.

Woudenberg, S.W.; Conkling, B.L.; O'Connell, B.M.; LaPoint, E.B.; Turner, J.A.; Waddell, K.L. 2010. The Forest Inventory and Analysis database: database description and user's manual version 4.0 for Phase 2. Gen. Tech. Rep. RMRS-GTR-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 339 p.

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 annual net growth—Average annual net change in volume of trees 5.0 inches d.b.h./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 diameter at breast height (d.b.h.); for woodland species, it is based on diameter at root collar (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 aboveground 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 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 rules, 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 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 and 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 aboveground), 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 and 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", or 8" class) 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/field location— A reference to the sample site or plot; an area containing the field location center 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 12 feet from the center of each subplot at an azimuth of 90 degrees, 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 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. and 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.

Hardwood trees—Dicotyledonous trees, usually broadleaf and deciduous.

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 (delineates or 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 reserved status, owner group, 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 and 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—For the first annual measurement (plots measured prior to 2010 in Utah), mortality trees included all standing or down dead trees 5.0 inches d.b.h./d.r.c. and larger that were alive within the previous 5 years; beginning with annual remeasurement, mortality trees included all trees that were alive at the previous measurement and dead (standing or down) during the most recent measurement.

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.

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 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 at least 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 mean annual increment). 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."

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 Wilderness designation).

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 condition; **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 dead 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; do not consider cut and removed volume. 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 and 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 and 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.

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. Diameters for timber species are measured at breast height (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 or more 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 Preservation 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 root collar (d.r.c.).

Note: For the FIA national glossary, please download the following WinZip archive: http://fiadocumentation.fia.unlv.edu/fia/ab/fia_glossary_July_2011.zip. Certain terms and definitions presented in this report may be regional add-ons and/or a variations of the terms and definitions found in FIA national glossary.

Appendix B: Standard Forest Resource Tables

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Table B3—Area of accessible forest land by forest-type group, and productivity class.

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Table B18—Net volume of growing-stock trees on timberland by species group, and ownership group.

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Table B39d—Mean water, carbon, and nitrogen contents of forest floor and soil cores by forest type, Utah, visit 2, 2006-2010.

Table B39e—Mean physical and chemical properties of soil cores by forest type, Utah, visit 2, 2006-2010.

Table B39f—Mean exchangeable cation concentrations in soil cores by forest type, Utah, visit 2, 2006-2010.

Table B39g—Mean extractable trace element concentrations in soil cores by forest type, Utah, visit 2, 2006-2010.

Table B1—Percentage of plot area by plot status, Utah, 2003-2012.

Land status			Percentage of plot area
Accessible forest land			
	Unreserved forest land		
		Timberland	6.4
		Unproductive	21.6
		Total unreserved forest land	28.0
	Reserved forest land		
		Productive	0.8
		Unproductive	2.7
		Total reserved forest land	3.4
Total accessible forest land			**31.4**
Nonforest and other land			
	Nonforest land		61.5
	Water		
		Census	2.9
		Non-Census	0.1
Total nonforest and other land			**64.5**
Total nonsampled land			
	Access denied		1.3
	Hazardous conditions		2.0
	Other		0.7
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, Utah, 2003-2012.

Owner class	Unreserved forests			Reserved forests			All forest land
	Timberland	Unproductive	Total	Productive	Unproductive	Total	
Forest Service							
National forest	2,854.1	2,984.2	5,838.2	388.5	111.6	500.1	6,338.4
Other national forest	- -	- -	- -	- -	4.5	4.5	4.5
Other Federal							
National Park Service	- -	- -	- -	44.4	341.7	386.0	386.0
Bureau of Land Management	108.3	6,054.2	6,162.6	21.9	987.1	1,009.0	7,171.5
Fish and Wildlife Service	- -	- -	- -	- -	6.6	6.6	6.6
Department of Defense or Energy	- -	31.0	31.0	- -	- -	- -	31.0
State and local government							
State	186.9	1,239.7	1,426.6	- -	74.0	74.0	1,500.5
Local (county, municipal, etc.)	20.5	16.2	36.7	- -	- -	- -	36.7
Other non-Federal lands	- -	7.3	7.3	- -	- -	- -	7.3
Private							
Undifferentiated private	609.0	2,205.9	2,814.9	- -	2.0	2.0	2,816.9
All owners	**3,778.7**	**12,538.6**	**16,317.3**	**454.8**	**1,527.3**	**1,982.1**	**18,299.5**

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, Utah, 2003-2012.

	Site-productivity class (cubic feet/acre/year)							
Forest-type group	0-19	20-49	50-84	85-119	120-164	165-224	225+	All classes
Pinyon / juniper group	10,747.5	- -	- -	- -	- -	- -	- -	10,747.5
Douglas-fir group	5.9	410.6	129.5	6.5	- -	- -	- -	552.6
Ponderosa pine group	18.0	310.5	18.4	- -	- -	- -	- -	346.8
Fir / spruce / mountain hemlock group	30.1	969.3	414.0	58.4	- -	- -	- -	1,471.9
Lodgepole pine group	33.1	382.9	11.3	- -	- -	- -	- -	427.3
Other western softwoods group	18.3	43.4	- -	- -	- -	- -	- -	61.7
Elm / ash / cottonwood group	7.8	38.0	11.3	4.8	- -	- -	- -	61.9
Aspen / birch group	226.4	1,114.2	233.1	- -	- -	- -	- -	1,573.7
Woodland hardwoods group	2,481.6	- -	- -	- -	- -	- -	- -	2,481.6
Nonstocked	497.2	63.9	13.2	- -	- -	- -	- -	574.3
All forest-type groups	14,065.9	3,332.8	830.9	69.8	- -	- -	- -	18,299.5

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 forest land status, Utah, 2003-2012.

	Forest Service		Other Federal		State and local government		Undifferentiated private		
Forest-type group	Timberland	Other forest land	Timberland	Other forest land	Timberland	Other forest land	Timberland	Other forest land	All forest land
Pinyon / juniper group	- -	1,706.0	- -	6,692.6	- -	1,023.0	- -	1,325.9	10,747.5
Douglas-fir group	301.4	24.3	40.8	12.2	63.5	- -	110.5	- -	552.6
Ponderosa pine group	229.5	18.3	6.2	30.5	23.8	- -	32.8	5.9	346.8
Fir / spruce / mountain hemlock group	1,061.0	251.4	21.0	12.0	31.4	- -	95.0	- -	1,471.9
Lodgepole pine group	288.2	123.9	- -	- -	- -	- -	15.2	- -	427.3
Other western softwoods group	20.4	10.3	- -	3.0	6.6	8.0	13.4	- -	61.7
Elm / ash / cottonwood group	3.1	- -	4.9	19.1	9.0	- -	24.3	1.6	61.9
Aspen / birch group	897.9	169.6	22.5	1.5	66.4	12.4	314.5	88.9	1,573.7
Woodland hardwoods group	- -	1,096.4	- -	431.4	- -	254.9	- -	698.9	2,481.6
Nonstocked	52.6	88.6	13.0	284.6	6.7	38.9	3.2	86.7	574.3
All forest-type groups	2,854.1	3,488.8	108.3	7,486.8	207.4	1,337.2	609.0	2,207.9	18,299.5

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, Utah, 2003-2012.

Forest-type group	Stand-size class					All size classes
	Large diameter	Medium diameter	Small diameter	Chaparral	Nonstocked	
Pinyon / juniper group	10,071.1	484.3	192.1	- -	- -	10,747.5
Douglas-fir group	435.3	51.2	66.1	- -	- -	552.6
Ponderosa pine group	322.6	5.9	18.3	- -	- -	346.8
Fir / spruce / mountain hemlock group	1,129.6	192.5	149.8	- -	- -	1,471.9
Lodgepole pine group	191.1	130.9	105.3	- -	- -	427.3
Other western softwoods group	53.7	- -	8.0	- -	- -	61.7
Elm / ash / cottonwood group	42.8	15.8	3.3	- -	- -	61.9
Aspen / birch group	281.4	922.2	370.1	- -	- -	1,573.7
Woodland hardwoods group	455.6	449.6	1,576.4	- -	- -	2,481.6
Nonstocked	- -	- -	- -	- -	574.3	574.3
All forest-type groups	12,983.3	2,252.5	2,489.3	- -	574.3	18,299.5

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 accessible forest land, in thousand acres, by forest-type group and stand-age class, Utah, 2003-2012.

	Stand-age class (years)												
Forest-type group	**Non stocked**	**1-20**	**21-40**	**41-60**	**61-80**	**81-100**	**101-120**	**121-140**	**141-160**	**161-180**	**181-200**	**201+**	**All classes**
Pinyon / juniper group	- -	107.9	144.7	414.4	833.0	1,125.2	1,153.3	1,167.0	1,126.6	1,047.0	981.5	2,646.7	10,747.
Douglas-fir group	- -	41.5	24.6	29.3	50.0	130.6	79.1	58.7	58.8	29.7	16.0	34.4	552.
Ponderosa pine group	- -	18.3	- -	6.1	93.7	72.7	36.7	41.1	22.7	19.9	11.3	24.2	346.
Fir / spruce / mountain hemlock group	- -	83.1	56.7	35.2	72.1	206.6	254.5	261.8	155.3	115.1	55.4	176.1	1,471.
Lodgepole pine group	- -	59.1	26.5	12.1	31.4	76.1	72.2	58.8	13.5	6.9	30.3	40.4	427.
Other western softwoods group	- -	- -	8.0	- -	- -	- -	- -	8.4	6.6	12.8	- -	25.9	61.
Elm / ash / cottonwood group	- -	1.3	8.9	13.7	10.9	2.5	16.0	7.0	1.6	- -	- -	- -	61.
Aspen / birch group	- -	255.7	113.3	190.0	368.9	360.0	180.5	72.3	26.9	6.0	- -	- -	1,573.
Woodland hardwoods group	- -	1,372.4	207.5	91.8	189.4	182.1	168.4	116.0	98.0	43.8	7.3	4.9	2,481.
Nonstocked	574.3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	574.
All forest-type groups	574.3	1,939.3	590.4	792.5	1,649.4	2,155.8	1,960.8	1,791.2	1,510.0	1,281.3	1,101.8	2,952.6	18,299.

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 accessible forest land, in thousand acres, by forest-type group and stand origin, Utah, 2003-2012.

Forest-type group	Stand origin: Natural stands	Stand origin: Artificial regeneration	All forest land
Pinyon / juniper group	10,741.6	5.9	10,747.5
Douglas-fir group	552.6	- -	552.6
Ponderosa pine group	346.8	- -	346.8
Fir / spruce / mountain hemlock group	1,471.9	- -	1,471.9
Lodgepole pine group	427.3	- -	427.3
Other western softwoods group	61.7	- -	61.7
Elm / ash / cottonwood group	61.9	- -	61.9
Aspen / birch group	1,567.0	6.7	1,573.7
Woodland hardwoods group	2,481.6	- -	2,481.6
Nonstocked	574.3	- -	574.3
All forest-type groups	18,286.8	12.6	18,299.5

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 accessible forest land, in thousand acres, by forest-type group and primary disturbance class, Utah, 2003-2012.

Forest-type group	Disturbance class											All forest land
	None	Insects	Disease	Fire	Wild animals	Domestic animals	Weather	Vegetation	Other	Human	Geologic	
Pinyon / juniper group	9,875,801	301,040	185,082	67,876	31,014	138,327	109,864	6,258	13,339	6,129	12,789	10,747,520
Douglas-fir group	431,657	67,678	39,943	7,425	--	--	5,932	--	--	--	--	552,635
Ponderosa pine group	306,951	6,087	12,051	21,752	--	--	--	--	--	--	--	346,841
Fir / spruce / mountain hemlock group	1,162,518	192,696	58,024	8,141	--	1,483	13,164	--	6,568		29,275	1,471,870
Lodgepole pine group	231,532	169,560	19,651	6,577	--	--	--	--	--	--	--	427,320
Other western softwoods group	55,144	6,577	--	--	--	--	--	--	--	--	--	61,721
Elm / ash / cottonwood group	53,752	--	4,020	3,330	--	--	829	--	--	--	--	61,931
Aspen / birch group	1,254,333	70,057	167,150	48,335	--	18,452	13,532	--	--	--	1,827	1,573,687
Woodland hardwoods group	2,227,770	34,148	8,754	153,173	3,239	20,109	27,088	--	7,309	--	--	2,481,591
Nonstocked	366,135	1,402	6,696	189,359	--	10,754	--	--	--	--	--	574,346
All forest-type groups	15,965,595	849,245	501,372	505,967	34,253	189,125	170,409	6,258	27,215	6,129	43,891	18,299,461

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, Utah, 2003-2012.

Forest-type group	Stand-size class					All size classes
	Large diameter	Medium diameter	Small diameter	Chaparral	Nonstocked	
Douglas-fir group	404.8	51.2	60.2	- -	- -	516.2
Ponderosa pine group	280.0	5.9	6.3	- -	- -	292.2
Fir / spruce / mountain hemlock group	911.0	183.3	114.1	- -	- -	1,208.5
Lodgepole pine group	106.9	118.2	78.3	- -	- -	303.5
Other western softwoods group	40.4	- -	- -	- -	- -	40.4
Elm / ash / cottonwood group	23.7	14.2	3.3	- -	- -	41.2
Aspen / birch group	260.4	799.6	241.3	- -	- -	1,301.3
Nonstocked	- -	- -	- -	- -	75.5	75.5
All forest-type groups	2,027.3	1,172.5	503.4	- -	75.5	3,778.7

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 1.0 inch d.b.h./d.r.c.), in thousand trees, on forest land by species group and diameter class, Utah, 2003-2012.

	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	65,469	50,515	25,822	21,497	14,506	10,354	8,302	6,335	3,629	1,924	2,213	723	238	71	37	211,634
Ponderosa and Jeffrey pines	8,799	8,463	5,688	4,949	4,009	3,920	2,793	2,648	1,783	1,332	1,433	445	419	182	--	46,863
True fir	327,996	107,984	59,900	38,646	21,017	15,791	8,831	6,173	3,612	2,539	2,225	916	170	84	158	596,043
Engelmann and other spruces	74,171	44,514	26,591	19,889	15,376	10,619	7,674	5,955	3,479	1,785	2,389	588	260	112	42	213,443
Lodgepole pine	129,022	85,892	56,396	29,047	15,221	8,757	4,596	2,213	639	393	119	42	--	--	--	332,335
Other western softwoods	4,477	4,276	2,405	2,005	1,460	1,419	614	428	321	245	346	112	--	--	77	18,185
Other																
Woodland softwoods	524,280	345,500	254,677	204,420	172,484	135,804	101,704	76,939	50,685	36,823	40,399	17,178	7,331	2,307	1,339	1,971,871
All softwoods	1,134,215	647,144	431,478	320,453	244,072	186,664	134,514	100,691	64,147	45,041	49,123	20,005	8,418	2,756	1,654	3,390,375
Hardwood species groups																
Western hardwood species groups																
Cottonwood and aspen	297,416	162,467	110,352	71,976	38,594	18,393	8,817	4,088	2,425	711	497	40	--	--	--	715,777
Other western hardwoods	6,415	933	243	159	37	42	--	--	--	--	--	--	--	--	--	7,829
Other																
Woodland hardwoods	2,753,592	461,360	128,675	51,377	21,555	11,981	5,457	2,170	1,414	443	546	38	32	37	--	3,438,674
All hardwoods	3,057,423	624,760	239,270	123,512	60,186	30,415	14,274	6,259	3,838	1,155	1,043	77	32	37	--	4,162,280
All species groups	4,191,638	1,271,903	670,748	443,965	304,258	217,080	148,788	106,950	67,985	46,196	50,166	20,082	8,449	2,793	1,654	7,552,654

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 5.0 inches d.b.h. /d.r.c.), in thousand trees, on timberland by species group and diameter class, Utah, 2003-2012.

Species group	Diameter class (inches)													All classes
	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+	
Softwood species groups														
Western softwood species groups														
Douglas-fir	19,509	15,792	10,785	8,027	6,143	4,598	2,539	1,483	1,604	538	150	71	- -	71,240
Ponderosa and Jeffrey pines	3,052	3,252	2,531	2,599	2,053	1,832	1,034	738	840	261	272	146	- -	18,611
True fir	50,333	33,035	17,372	13,477	7,503	4,765	3,046	1,995	1,590	672	88	44	158	134,079
Engelmann and other spruces	19,070	14,407	11,531	7,422	5,503	4,228	2,667	1,288	1,925	434	226	34	42	68,775
Lodgepole pine	45,252	21,770	10,024	5,032	2,661	1,496	317	232	40	- -	- -	- -	- -	86,825
Other western softwoods	1,282	1,069	897	800	398	273	209	178	236	81	- -	- -	77	5,499
All softwoods	138,499	89,325	53,140	37,356	24,261	17,192	9,812	5,914	6,234	1,986	736	295	277	385,028
Hardwood species groups														
Western hardwood species groups														
Cottonwood and aspen	85,304	58,495	32,937	15,997	8,041	3,531	1,933	583	329	- -	- -	- -	- -	207,150
Other western hardwoods	168	84	- -	42	- -	- -	- -	- -	- -	- -	- -	- -	- -	294
All hardwoods	85,472	58,579	32,937	16,039	8,041	3,531	1,933	583	329	- -	- -	- -	- -	207,444
All species groups	223,971	147,904	86,077	53,396	32,302	20,723	11,745	6,497	6,563	1,986	736	295	277	592,472

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 live trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, by owner class and forest-land status, Utah, 2003-2012.

Owner class	Unreserved forests			Reserved forests			All forest land
	Timberland	Unproductive	Total	Productive	Unproductive	Total	
Forest Service							
National forest	5,254.4	1,740.3	6,994.7	947.8	67.6	1,015.5	8,010.2
Other national forest	- -	- -	- -	- -	1.7	1.7	1.7
Other Federal							
National Park Service	- -	- -	- -	53.1	156.5	209.6	209.6
Bureau of Land Management	111.9	3,313.6	3,425.4	21.8	576.2	598.0	4,023.4
Fish and Wildlife Service	- -	- -	- -	- -	8.1	8.1	8.1
Department of Defense or Energy	- -	8.3	8.3	- -	- -	- -	8.3
State and local government							
State	312.7	633.0	945.7	- -	44.6	44.6	990.3
Local (county, municipal, etc.)	46.3	6.0	52.3	- -	- -	- -	52.3
Other non-Federal lands	- -	2.8	2.8	- -	- -	- -	2.8
Private							
Undifferentiated private	802.8	1,196.3	1,999.2	- -	- -	- -	1,999.2
All owners	6,528.2	6,900.3	13,428.4	1,022.7	854.8	1,877.4	15,305.9

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 B13—Net volume of live trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand-size class, Utah, 2003-2012.

Forest-type group	Stand-size class					All size classes
	Large diameter	Medium diameter	Small diameter	Chaparral	Nonstocked	
Pinyon / juniper group	6,645.9	133.6	14.4	- -	- -	6,793.9
Douglas-fir group	918.4	51.3	23.2	- -	- -	993.0
Ponderosa pine group	469.6	1.1	6.1	- -	- -	476.9
Fir / spruce / mountain hemlock group	2,892.7	214.4	45.8	- -	- -	3,153.0
Lodgepole pine group	555.8	257.1	57.1	- -	- -	870.0
Other western softwoods group	76.2	- -	0.7	- -	- -	76.9
Elm / ash / cottonwood group	52.3	7.4	- -	- -	- -	59.7
Aspen / birch group	788.0	1,252.3	68.0	- -	- -	2,108.3
Woodland hardwoods group	297.0	297.3	166.1	- -	- -	760.4
Nonstocked	- -	- -	- -	- -	13.8	13.8
All forest-type groups	12,695.9	2,214.6	381.5	- -	13.8	15,305.9

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 B14—Net volume of live trees (at least 5.0 inches d.b.h./d.r.c), in million cubic feet, on forest land by species group and ownership group, Utah, 2003-2012.

Species group	Ownership group				All owners
	Forest Service	Other Federal	State and local government	Undifferentiated private	
Softwood species groups					
Western softwood species groups					
Douglas-fir	826.2	134.3	150.1	234.4	1,345.1
Ponderosa and Jeffrey pines	436.8	76.6	24.2	54.0	591.6
True fir	1,444.2	46.7	64.6	173.0	1,728.4
Engelmann and other spruces	1,459.0	0.4	18.4	43.1	1,520.9
Lodgepole pine	1,004.0	2.8	- -	47.3	1,054.1
Other western softwoods	70.7	6.1	2.0	30.6	109.5
Other					
Woodland softwoods	1,252.9	3,858.3	630.0	858.4	6,599.6
All softwoods	6,493.7	4,125.3	889.3	1,440.7	12,949.0
Hardwood species groups					
Western hardwood species groups					
Cottonwood and aspen	1,301.0	37.6	115.1	345.6	1,799.4
Other western hardwoods	0.3	0.2	1.0	- -	1.5
Other					
Woodland hardwoods	216.9	86.3	39.9	212.9	555.9
All hardwoods	1,518.2	124.1	156.1	558.5	2,356.9
All species groups	8,011.9	4,249.4	1,045.4	1,999.2	15,305.9

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 B15—Net volume of live trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, on forest land by species group and diameter class, Utah, 2003-2012.

	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	40	94	121	150	185	201	152	107	157	79	39	10	11	1,345
Ponderosa and Jeffrey pines	6	18	27	46	52	71	61	65	100	47	66	33	--	592
True fir	100	177	189	239	201	199	156	142	155	97	26	16	32	1,728
Engelmann and other spruces	45	100	152	175	198	216	172	105	209	70	45	20	14	1,521
Lodgepole pine	164	213	207	184	135	84	30	27	8	3	--	--	--	1,054
Other western softwoods	3	7	9	14	10	9	8	8	17	8	--	--	16	109
Other														
Woodland softwoods	247	423	624	757	774	776	635	579	798	493	278	117	97	6,600
All softwoods	605	1,032	1,328	1,565	1,555	1,556	1,214	1,032	1,444	796	455	196	170	12,949
Hardwood species groups														
Western hardwood species groups														
Cottonwood and aspen	210	365	380	305	223	134	107	39	34	3	--	--	--	1,799
Other western hardwoods	0	0	0	1	--	--	--	--	--	--	--	--	--	2
Other														
Woodland hardwoods	170	139	91	62	37	23	15	7	8	1	1	2	--	556
All hardwoods	380	504	471	367	260	157	123	45	42	3	1	2	--	2,357
All species groups	985	1,537	1,799	1,932	1,815	1,713	1,337	1,077	1,486	800	456	198	170	15,306

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 live trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand origin, Utah, 2003-2012.

Forest-type group	Stand origin		All forest land
	Natural stands	Artificial regeneration	
Pinyon / juniper group	6,791.8	2.1	6,793.9
Douglas-fir group	993.0	- -	993.0
Ponderosa pine group	476.9	- -	476.9
Fir / spruce / mountain hemlock group	3,153.0	- -	3,153.0
Lodgepole pine group	870.0	- -	870.0
Other western softwoods group	76.9	- -	76.9
Elm / ash / cottonwood group	59.7	- -	59.7
Aspen / birch group	2,106.1	2.2	2,108.3
Woodland hardwoods group	760.4	- -	760.4
Nonstocked	13.8	- -	13.8
All forest-type groups	15,301.6	4.3	15,305.9

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 B17—Net volume of growing-stock trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, on timberland by species group and diameter class, Utah, 2003-2012.

	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	32	72	95	122	145	155	113	86	118	65	23	10	- -	1,036
Ponderosa and Jeffrey pines	4	13	18	32	40	53	37	40	60	28	44	26	- -	394
True fir	86	155	160	208	174	155	136	120	112	72	16	8	32	1,434
Engelmann and other spruces	34	74	116	125	147	155	135	77	171	51	42	9	14	1,149
Lodgepole pine	134	162	138	108	81	59	15	17	3	- -	- -	- -	- -	718
Other western softwoods	2	4	7	8	7	6	5	7	13	6	- -	- -	16	80
All softwoods	291	480	533	603	595	583	442	347	477	221	125	53	62	4,812
Hardwood species groups														
Western hardwood species groups														
Cottonwood and aspen	174	315	335	272	206	121	88	33	23	- -	- -	- -	- -	1,567
Other western hardwoods	0	0	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
All hardwoods	174	315	335	273	206	121	88	33	23	- -	- -	- -	- -	1,569
All species groups	465	795	868	876	801	704	530	380	500	221	125	53	62	6,381

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 5.0 inches d.b.h./d.r.c.), in million cubic feet, on timberland by species group and ownership group, Utah, 2003-2012.

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	648.0	49.2	128.9	210.2	1,036.3
Ponderosa and Jeffrey pines	327.2	12.0	21.8	33.3	394.3
True fir	1,207.4	25.8	63.6	137.3	1,434.1
Engelmann and other spruces	1,091.2	0.3	18.4	39.3	1,149.2
Lodgepole pine	667.8	2.8	- -	47.0	717.6
Other western softwoods	47.6	2.9	1.5	28.5	80.5
All softwoods	3,989.2	93.1	234.2	495.6	4,812.0
Hardwood species groups					
Western hardwood species groups					
Cottonwood and aspen	1,170.4	12.7	108.7	275.6	1,567.5
Other western hardwoods	- -	- -	1.0	- -	1.0
All hardwoods	1,170.4	12.7	109.7	275.6	1,568.5
All species groups	5,159.7	105.7	343.9	771.2	6,380.5

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, Utah, 2003-2012.

Species group	Diameter class (inches)											All classes
	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+	
Softwood species groups												
Western softwood species groups												
Douglas-fir	326	535	704	790	608	464	664	379	142	61	- -	4,674
Ponderosa and Jeffrey pines	59	141	208	290	221	232	349	170	270	169	- -	2,109
True fir	644	976	883	805	721	639	601	389	80	43	169	5,951
Engelmann and other spruces	479	609	776	850	758	433	1,000	303	252	50	92	5,602
Lodgepole pine	526	482	402	300	81	96	13	- -	- -	- -	- -	1,900
Other western softwoods	20	27	27	27	26	32	62	28	- -	- -	90	339
All softwoods	2,054	2,770	3,001	3,062	2,415	1,896	2,689	1,270	744	324	352	20,574
Hardwood species groups												
Western hardwood species groups												
Cottonwood and aspen	- -	1,359	1,097	679	511	187	126	- -	- -	- -	- -	3,958
Other western hardwoods	- -	1	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
All hardwoods	- -	1,360	1,097	679	511	187	126	- -	- -	- -	- -	3,959
All species groups	2,054	4,130	4,097	3,741	2,926	2,083	2,814	1,270	744	324	352	24,533

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, Utah, 2003-2012.

Species group	Ownership group				All owners
	Forest Service	Other Federal	State and local government	Undifferentiated private	
Softwood species groups					
Western softwood species groups					
Douglas-fir	530.9	40.4	109.8	173.0	854.0
Ponderosa and Jeffrey pines	298.4	11.1	21.2	31.0	361.8
True fir	927.7	21.6	42.0	105.9	1,097.2
Engelmann and other spruces	915.1	- -	15.2	31.0	961.3
Lodgepole pine	342.5	2.4	- -	41.3	386.2
Other western softwoods	41.6	2.3	1.3	26.8	72.1
All softwoods	3,056.2	77.8	189.6	409.1	3,732.6
Hardwood species groups					
Western hardwood species groups					
Cottonwood and aspen	470.7	3.6	38.3	104.6	617.3
Other western hardwoods	- -	- -	0.4	- -	0.4
All hardwoods	470.7	3.6	38.7	104.6	617.7
All species groups	3,526.9	81.4	228.3	513.7	4,350.3

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 feet. Columns and rows may not add to their totals due to rounding.

Table B21—Average annual net growth of live trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, by owner class and forest land status, Utah, 2003-2012.

Owner class	Unreserved forests			Reserved forests			All forest land
	Timberland	Unproductive	Total	Productive	Unproductive	Total	
Forest Service							
National forest	-48.1	6.8	-41.4	-6.4	-6.0	-12.3	-53.7
Other national forest	- -	- -	- -	- -	0.0	0.0	0.0
Other Federal							
National Park Service	- -	- -	- -	-2.2	0.0	-2.2	-2.2
Bureau of Land Management	-2.4	3.0	0.5	0.7	1.3	2.1	2.6
Fish and Wildlife Service	- -	- -	- -	- -	-0.1	-0.1	-0.1
Department of Defense or Energy	- -	0.1	0.1	- -	- -	- -	0.1
State and local government							
State	-5.2	0.7	-4.6	- -	0.1	0.1	-4.5
Local (county, municipal, etc.)	0.4	0.3	0.7	- -	- -	- -	0.7
Other non-Federal lands	- -	0.0	0.0	- -	- -	- -	0.0
Private							
Undifferentiated private	1.1	6.5	7.6	- -	- -	- -	7.6
All owners	-54.3	17.2	-37.0	-7.8	-4.7	-12.5	-49.5

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 live trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand-size class, Utah, 2003-2012.

	Stand-size class					
Forest-type group	**Large diameter**	**Medium diameter**	**Small diameter**	**Chaparral**	**Nonstocked**	**All size classes**
Pinyon / juniper group	18.2	1.8	-0.1	- -	- -	19.9
Douglas-fir group	-2.4	0.7	0.4	- -	- -	-1.2
Ponderosa pine group	3.5	0.1	0.1	- -	- -	3.7
Fir / spruce / mountain hemlock group	-30.2	-12.6	-3.2	- -	- -	-46.0
Lodgepole pine group	-17.3	-2.3	1.1	- -	- -	-18.4
Other western softwoods group	-0.9	0.0	0.0	- -	- -	-0.9
Elm / ash / cottonwood group	0.7	0.3	0.0	- -	- -	1.0
Aspen / birch group	1.4	6.9	-4.0	- -	- -	4.3
Woodland hardwoods group	1.7	7.0	-8.4	- -	- -	0.4
Nonstocked	- -	- -	- -	- -	-12.3	-12.3
All forest-type groups	-25.2	2.0	-14.1	- -	-12.3	-49.5

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 live trees (at least 5.0 inches d.b.h./d.r.c.), in million cubic feet, on forest land by species group and ownership group, Utah, 2003-2012.

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	-3.5	-3.6	-3.6	2.2	-8.5
Ponderosa and Jeffrey pines	0.9	-1.0	-0.5	0.8	0.3
True fir	-9.9	-2.1	0.1	-2.7	-14.6
Engelmann and other spruces	-30.0	0.0	0.4	-0.2	-29.8
Lodgepole pine	-26.0	- -	- -	-2.4	-28.3
Other western softwoods	-1.8	-0.1	0.0	0.2	-1.6
Other					
Woodland softwoods	1.8	4.9	0.2	2.6	9.5
All softwoods	-68.4	-1.9	-3.4	0.7	-73.1
Hardwood species groups					
Western hardwood species groups					
Cottonwood and aspen	9.9	1.2	-1.3	3.2	13.0
Other western hardwoods	0.0	0.0	0.0	- -	0.0
Other					
Woodland hardwoods	4.8	1.1	0.9	3.7	10.5
All hardwoods	14.7	2.3	-0.4	6.9	23.6
All species groups	-53.7	0.4	-3.8	7.6	-49.5

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 5.0 inches d.b.h./d.r.c.), in million cubic feet, on timberland by species group and ownership group, Utah, 2003-2012.

	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	-4.4	-2.5	-3.8	2.3	-8.3
Ponderosa and Jeffrey pines	4.0	0.1	-0.3	0.4	4.2
True fir	-7.3	-0.3	0.0	-2.6	-10.2
Engelmann and other spruces	-31.5	0.0	0.4	-0.3	-31.5
Lodgepole pine	-14.7	- -	- -	-2.3	-17.1
Other western softwoods	-1.2	0.0	0.0	0.2	-1.0
All softwoods	-55.1	-2.8	-3.7	-2.3	-63.9
Hardwood species groups					
Western hardwood species groups					
Cottonwood and aspen	9.8	0.3	-1.2	3.4	12.3
Other western hardwoods	- -	- -	0.0	- -	0.0
All hardwoods	9.8	0.3	-1.2	3.4	12.3
All species groups	-45.3	-2.4	-4.9	1.1	-51.6

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 5.0 inches d.b.h./d.r.c.), in million cubic feet, by owner class and forest land status, Utah, 2003-2012.

	Unreserved forests			Reserved forests			
Owner class	**Timberland**	**Unproductive**	**Total**	**Productive**	**Unproductive**	**Total**	**All forest land**
Forest Service							
National forest	142.6	15.4	158.1	17.1	7.1	24.3	182.4
Other Federal							
National Park Service	- -	- -	- -	3.0	1.5	4.5	4.5
Bureau of Land Management	4.1	23.2	27.4	- -	2.2	2.2	29.6
Fish and Wildlife Service	- -	- -	- -	- -	0.1	0.1	0.1
State and local government							
State	10.0	4.7	14.7	- -	0.3	0.3	15.0
Local (county, municipal, etc.)	0.1	0.0	0.1	- -	- -	- -	0.1
Private							
Undifferentiated private	17.1	8.0	25.0	- -	- -	- -	25.0
All owners	173.9	51.4	225.3	20.1	11.2	31.3	256.7

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 5.0 inches d.b.h./d.r.c.), in million cubic feet, on forest land by forest-type group and stand-size class, Utah, 2003-2012.

Forest-type group	Stand-size class					All size classes
	Large diameter	Medium diameter	Small diameter	Chaparral	Non stocked	
Pinyon / juniper group	31.9	0.8	0.4	- -	- -	33.1
Douglas-fir group	16.3	0.7	0.1	- -	- -	17.2
Ponderosa pine group	2.5	- -	- -	- -	- -	2.5
Fir / spruce / mountain hemlock group	69.4	17.3	4.3	- -	- -	91.0
Lodgepole pine group	24.0	10.0	1.2	- -	- -	35.2
Other western softwoods group	1.7	0.1	- -	- -	- -	1.8
Elm / ash / cottonwood group	0.4	0.0	0.0	- -	- -	0.4
Aspen / birch group	11.5	27.1	6.5	- -	- -	45.1
Woodland hardwoods group	2.3	1.7	13.9	- -	- -	17.9
Nonstocked	- -	- -	- -	- -	12.6	12.6
All forest-type groups	160.0	57.7	26.4	- -	12.6	256.7

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 5.0 inches d.b.h./d.r.c.), in million cubic feet, on forest land by species group and ownership group, Utah, 2003-2012.

	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	15.7	6.0	5.9	2.9	30.4
Ponderosa and Jeffrey pines	4.9	1.9	0.7	0.0	7.5
True fir	37.4	2.8	1.3	6.4	47.9
Engelmann and other spruces	49.4	- -	0.0	0.8	50.2
Lodgepole pine	45.5	- -	- -	2.9	48.4
Other western softwoods	2.5	0.2	- -	- -	2.7
Other					
Woodland softwoods	9.1	22.4	4.4	4.3	40.1
All softwoods	164.4	33.3	12.2	17.2	227.2
Hardwood species groups					
Western hardwood species groups					
Cottonwood and aspen	16.5	0.0	2.8	6.2	25.5
Other					
Woodland hardwoods	1.4	0.8	0.1	1.6	4.0
All hardwoods	17.9	0.8	2.9	7.8	29.5
All species groups	182.4	34.2	15.1	25.0	256.7

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 5.0 inches d.b.h./d.r.c.), in million cubic feet, on timberland by species group and ownership group, Utah, 2003-2012.

	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	13.7	3.4	5.6	2.3	25.0
Ponderosa and Jeffrey pines	0.4	0.0	0.5	0.0	1.0
True fir	30.9	0.5	1.3	5.8	38.6
Engelmann and other spruces	47.3	- -	0.0	0.8	48.1
Lodgepole pine	29.7	- -	- -	2.8	32.5
Other western softwoods	1.7	0.0	- -	- -	1.7
All softwoods	123.7	4.0	7.4	11.8	146.9
Hardwood species groups					
Western hardwood species groups					
Cottonwood and aspen	13.9	0.0	2.6	4.1	20.7
All hardwoods	13.9	0.0	2.6	4.1	20.7
All species groups	137.7	4.0	10.0	15.9	167.6

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 live trees (at least 1.0 inch d.b.h./d.r.c.), in thousand dry short tons, by owner class and forest land status, Utah, 2003-2012.

	Unreserved forests			Reserved forests			All forest land
Owner class	Timberland	Unproductive	Total	Productive	Unproductive	Total	
Forest Service							
National forest	93,507	39,481	132,988	15,591	1,508	17,099	150,088
Other national forest	- -	- -	- -	- -	22	22	22
Other Federal							
National Park Service	- -	- -	- -	1,016	3,100	4,116	4,116
Bureau of Land Management	2,144	64,385	66,529	436	11,075	11,511	78,040
Fish and Wildlife Service	- -	- -	- -	- -	159	159	159
Department of Defense or Energy	- -	282	282	- -	- -	- -	282
State and local government							
State	6,234	13,081	19,315	- -	845	845	20,160
Local (county, municipal, etc.)	759	246	1,005	- -	- -	- -	1,005
Other non-Federal lands	- -	61	61	- -	- -	- -	61
Private							
Undifferentiated private	15,975	28,118	44,092	- -	22	22	44,115
All owners	118,619	145,653	264,272	17,043	16,732	33,775	298,047

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 live trees (at least 1.0 inch d.b.h./d.r.c.), in thousand dry short tons, on forest land by species group and diameter class, Utah, 2003-2012.

Species group	Diameter class (inches)														All classes
	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+	
Softwood species groups																
Western softwood species groups																
Douglas-fir	189	802	852	1,933	2,458	3,015	3,694	3,989	3,021	2,110	1,621	1,472	879	660	1,163	27,859
Ponderosa and Jeffrey pines	17	80	120	325	484	828	933	1,260	1,078	1,140	859	896	404	413	1,731	10,568
True fir	728	1,492	1,523	2,655	2,808	3,525	3,008	2,969	2,298	2,146	1,447	906	453	979	1,155	28,092
Engelmann and other spruces	162	549	694	1,522	2,270	2,600	2,917	3,171	2,515	1,523	1,576	1,464	570	444	1,147	23,125
Lodgepole pine	426	1,647	2,711	3,446	3,302	2,911	2,129	1,322	463	421	121	- -	42	- -	- -	18,943
Other western softwoods	6	49	60	124	166	250	165	151	144	132	85	191	91	35	261	1,909
Other																
Woodland softwoods	1,369	3,040	4,104	7,130	10,632	13,111	13,723	14,015	11,655	10,666	8,290	6,871	5,498	3,908	9,527	123,539
All softwoods	2,896	7,661	10,064	17,136	22,120	26,240	26,569	26,877	21,175	18,137	13,999	11,799	7,938	6,439	14,984	234,034
Hardwood species groups																
Western hardwood species groups																
Cottonwood and aspen	932	3,257	4,241	6,869	6,830	5,312	3,808	2,281	1,795	634	309	246	- -	51	- -	36,565
Other western hardwoods	19	32	6	10	4	11	- -	- -	- -	- -	- -	- -	- -	- -	- -	83
Other																
Woodland hardwoods	10,574	7,314	3,007	2,402	1,523	1,019	607	361	247	107	109	29	13	- -	54	27,365
All hardwoods	11,526	10,603	7,254	9,282	8,358	6,341	4,415	2,642	2,042	741	418	275	13	51	54	64,013
All species groups	14,422	18,264	17,318	26,418	30,477	32,582	30,984	29,519	23,216	18,878	14,417	12,074	7,951	6,490	15,038	298,047

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 survey unit, county, and forest land status, Utah, 2003-2012.

	Unreserved forests			Reserved forests			
Survey unit and county	Timberland	Unproductive	Total	Productive	Unproductive	Total	All forest land
Northern							
Box Elder	16.5	350.4	366.8	3.8	2.3	6.1	372.9
Cache	147.3	135.6	282.9	20.0	10.1	30.1	313.0
Davis	11.4	13.1	24.5	- -	- -	- -	24.5
Morgan	79.7	104.7	184.4	- -	- -	- -	184.4
Rich	72.6	25.4	98.0	- -	- -	- -	98.0
Salt Lake	43.7	96.1	139.8	12.2	19.2	31.4	171.2
Summit	456.0	153.2	609.3	92.0	13.8	105.8	715.1
Tooele	16.3	433.1	449.4	11.9	11.9	23.8	473.2
Utah	145.0	518.0	663.1	21.9	- -	21.9	685.0
Wasatch	318.0	177.3	495.3	- -	- -	- -	495.3
Weber	32.2	94.2	126.4	- -	- -	- -	126.4
Total	**1,338.8**	**2,101.2**	**3,440.0**	**161.9**	**57.3**	**219.2**	**3,659.2**
Uinta							
Daggett	175.8	138.4	314.2	- -	- -	- -	314.2
Duchesne	380.0	536.1	916.0	201.0	8.1	209.1	1,125.2
Uintah	197.2	758.2	955.4	- -	39.5	39.5	994.9
Total	**752.9**	**1,432.7**	**2,185.6**	**201.0**	**47.6**	**248.6**	**2,434.2**
Central							
Juab	35.8	436.5	472.3	5.5	5.5	11.0	483.4
Millard	38.0	650.8	688.7	- -	4.5	4.5	693.2
Piute	81.0	144.7	225.8	- -	- -	- -	225.8
Sanpete	159.5	381.9	541.3	- -	- -	- -	541.3
Sevier	191.7	480.6	672.3	- -	- -	- -	672.3
Wayne	52.7	151.2	203.9	- -	88.5	88.5	292.5
Total	**558.8**	**2,245.7**	**2,804.4**	**5.5**	**98.5**	**104.0**	**2,908.5**

(continued)

Table B31—(Continued)

Eastern							
Carbon	134.8	386.0	520.7	- -	- -	- -	520.7
Emery	95.1	571.5	666.7	- -	- -	- -	666.7
Grand	102.6	833.6	936.3	- -	14.5	14.5	950.8
San Juan	103.0	1,527.4	1,630.3	4.7	55.7	60.4	1,690.7
Total	**435.5**	**3,318.5**	**3,754.0**	**4.7**	**70.2**	**74.9**	**3,828.9**
Southwestern							
Beaver	48.4	736.4	784.9	- -	- -	- -	784.9
Garfield	369.8	785.3	1,155.1	33.7	462.8	496.4	1,651.5
Iron	138.8	762.2	900.9	7.9	4.7	12.6	913.5
Kane	113.4	539.7	653.1	20.4	693.8	714.2	1,367.3
Washington	22.4	616.9	639.3	19.8	92.4	112.2	751.5
Total	**692.8**	**3,440.5**	**4,133.3**	**81.7**	**1,253.6**	**1,335.4**	**5,468.7**
All counties	**3,778.7**	**12,538.6**	**16,317.3**	**454.8**	**1,527.3**	**1,982.1**	**18,299.5**

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, Utah, 2003-2012.

	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									
Box Elder	6.6	27.4	- -	141.2	- -	20.9	9.9	166.9	372.9
Cache	128.8	103.2	- -	- -	- -	14.7	18.5	47.8	313.0
Davis	- -	6.5	- -	- -	11.4	- -	- -	6.5	24.5
Morgan	13.1	- -	- -	- -	- -	12.6	66.6	92.1	184.4
Rich	36.4	- -	9.0	20.8	1.5	4.6	25.7	- -	98.0
Salt Lake	29.7	63.1	- -	5.9	14.0	17.7	- -	40.8	171.2
Summit	343.7	122.8	- -	6.9	6.9	6.9	105.4	122.4	715.1
Tooele	1.5	67.0	5.9	314.9	3.0	40.1	6.0	34.9	473.2
Utah	129.0	342.2	7.3	49.7	7.3	58.3	1.5	89.8	685.0
Wasatch	259.4	62.2	- -	- -	25.1	39.2	33.5	75.9	495.3
Weber	17.2	27.1	- -	- -	- -	5.7	15.0	61.3	126.4
Total	965.5	821.6	22.2	539.4	69.2	220.8	281.9	738.6	3,659.2
Uinta									
Daggett	168.1	68.5	- -	32.8	6.1	35.8	1.5	1.4	314.2
Duchesne	275.9	284.7	- -	70.6	26.2	50.5	77.9	339.4	1,125.2
Uintah	160.9	42.8	7.2	469.9	6.6	105.7	22.4	179.2	994.9
Total	605.0	396.0	7.2	573.2	38.9	192.0	101.8	520.0	2,434.2
Central									
Juab	20.7	74.8	4.1	261.7	- -	23.6	11.0	87.4	483.4
Millard	38.0	273.3	- -	299.3	- -	46.7	- -	36.0	693.2
Piute	79.8	61.2	- -	69.6	1.3	14.0	- -	- -	225.8
Sanpete	146.3	102.0	- -	105.8	- -	51.1	13.1	122.9	541.3
Sevier	181.2	317.2	- -	93.7	- -	27.6	10.5	42.2	672.3
Wayne	41.9	56.2	10.0	158.0	- -	19.2	0.8	6.2	292.5
Total	507.8	884.7	14.1	988.2	1.3	182.1	35.5	294.7	2,908.5

(continued)

Table B32—(Continued)

Eastern									
Carbon	20.1	10.0	14.1	227.1	26.1	63.4	74.5	85.5	520.7
Emery	78.3	57.1	- -	379.6	- -	120.4	16.8	14.5	666.7
Grand	30.4	49.5	11.3	530.2	59.4	211.8	1.5	56.7	950.8
San Juan	80.9	301.2	1.6	1,018.8	6.2	83.9	14.3	183.8	1,690.7
Total	209.6	417.8	27.0	2,155.7	91.7	479.4	107.2	340.5	3,828.9
Southwestern									
Beaver	34.9	67.3	13.5	609.3	- -	43.2	- -	16.5	784.9
Garfield	355.0	423.6	14.8	753.8	- -	80.0	- -	24.3	1,651.5
Iron	83.1	116.1	3.4	514.8	6.3	79.5	46.0	64.2	913.5
Kane	86.6	23.5	- -	1,012.9	- -	54.0	26.7	163.6	1,367.3
Washington	6.5	338.0	6.0	339.5	- -	6.1	9.8	45.5	751.5
Total	566.2	968.6	37.8	3,230.4	6.3	262.8	82.6	314.1	5,468.7
All counties	2,854.1	3,488.8	108.3	7,486.8	207.4	1,337.2	609.0	2,207.9	18,299.5

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 survey unit, county, and stand-size class, Utah, 2003-2012.

Inventory unit and county	Stand-size class					All size classes
	Large diameter	Medium diameter	Small diameter	Chaparral	Nonstocked	
Northern						
Box Elder	11.4	0.5	4.6	- -	- -	16.5
Cache	84.6	41.5	13.8	- -	7.4	147.3
Davis	11.4	- -	- -	- -	- -	11.4
Morgan	37.6	38.8	3.3	- -	- -	79.7
Rich	36.4	21.4	14.8	- -	- -	72.6
Salt Lake	34.9	7.0	1.7	- -	- -	43.7
Summit	185.5	164.2	104.7	- -	1.7	456.0
Tooele	10.4	- -	5.9	- -	- -	16.3
Utah	90.5	47.8	6.7	- -	- -	145.0
Wasatch	127.6	131.8	51.9	- -	6.7	318.0
Weber	11.4	11.5	9.3	- -	- -	32.2
Total	641.9	464.3	216.8	- -	15.8	1,338.8
Uinta						
Daggett	85.7	64.3	22.9	- -	2.9	175.8
Duchesne	218.2	104.7	57.0	- -	- -	380.0
Uintah	108.0	56.6	21.4	- -	11.1	197.2
Total	411.9	225.6	101.4	- -	14.1	752.9
Central						
Juab	26.2	5.5	4.1	- -	- -	35.8
Millard	30.1	7.9	- -	- -	- -	38.0
Piute	22.8	36.6	16.5	- -	5.1	81.0
Sanpete	70.0	65.2	24.2	- -	- -	159.5
Sevier	95.6	80.4	9.2	- -	6.6	191.7
Wayne	28.6	17.5	6.7	- -	- -	52.7
Total	273.3	213.1	60.6	- -	11.7	558.8

(continued)

Table B33—(Continued)

Eastern						
Carbon	66.3	41.1	27.3	- -	- -	134.8
Emery	62.9	12.6	15.4	- -	4.2	95.1
Grand	59.5	19.4	19.8	- -	4.0	102.6
San Juan	96.8	6.2	- -	- -	- -	103.0
Total	285.5	79.3	62.6	- -	8.2	435.5
Southwestern						
Beaver	19.5	22.9	6.0	- -	- -	48.4
Garfield	214.7	104.8	34.1	- -	16.3	369.8
Iron	87.9	44.8	6.1	- -	- -	138.8
Kane	86.6	9.4	15.8	- -	1.6	113.4
Washington	6.1	8.3	- -	- -	8.0	22.4
Total	414.8	190.1	62.0	- -	25.9	692.8
All counties	2,027.3	1,172.5	503.4	- -	75.5	3,778.7

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 survey unit, county, and stocking class, Utah, 2003-2012.

Inventory unit and county	Stocking class of growing-stock trees					All classes
	Nonstocked	Poorly stocked	Moderately stocked	Fully stocked	Over- stocked	
Northern						
Box Elder	1.2	6.1	9.2	- -	- -	16.5
Cache	7.4	50.7	70.8	16.9	1.5	147.3
Davis	- -	11.4	- -	- -	- -	11.4
Morgan	- -	45.4	21.3	13.1	- -	79.7
Rich	- -	13.4	13.7	41.2	4.4	72.6
Salt Lake	- -	15.7	14.0	7.0	7.0	43.7
Summit	3.2	121.4	233.1	74.2	24.2	456.0
Tooele	- -	- -	13.4	3.0	- -	16.3
Utah	- -	44.0	65.8	33.8	1.5	145.0
Wasatch	6.7	65.6	143.5	87.2	15.1	318.0
Weber	- -	3.5	22.9	5.7	- -	32.2
Total	18.4	377.2	607.5	282.1	53.7	1,338.8
Uinta						
Daggett	2.9	65.8	76.5	30.6	- -	175.8
Duchesne	1.5	141.1	144.2	77.3	15.9	380.0
Uintah	11.1	34.1	50.3	98.3	3.3	197.2
Total	15.6	240.9	271.0	206.2	19.2	752.9
Central						
Juab	- -	5.5	9.7	20.7	- -	35.8
Millard	4.7	1.6	19.0	12.7	- -	38.0
Piute	5.1	5.1	5.1	29.2	36.6	81.0
Sanpete	- -	78.3	23.0	51.5	6.6	159.5
Sevier	6.6	25.1	75.7	56.6	27.7	191.7
Wayne	- -	22.8	23.3	6.7	- -	52.7
Total	16.4	138.4	155.7	177.3	70.9	558.8

(continued)

Table B34—(Continued)

Eastern						
Carbon	6.0	20.1	49.1	57.5	2.0	134.8
Emery	4.2	21.0	29.4	37.6	2.8	95.1
Grand	4.0	43.7	19.8	19.4	15.8	102.6
San Juan	- -	19.0	43.5	38.9	1.6	103.0
Total	14.2	103.8	141.9	153.3	22.2	435.5
Southwestern						
Garfield	17.8	101.9	110.0	125.3	14.8	369.8
Iron	- -	28.1	31.7	69.7	9.4	138.8
Kane	1.6	61.6	33.0	17.2	- -	113.4
Washington	8.0	- -	10.7	3.8	- -	22.4
Total	27.4	194.6	207.9	232.8	30.2	692.8
All counties	91.9	1,054.9	1,384.0	1,051.8	196.2	3,778.7

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 5.0 inches d.b.h./d.r.c.), in million cubic feet, and sawtimber trees, in million board feet (International 1/4-inch rule), on timberland by survey unit, county, and major species group, Utah, 2003-2012.

	Growing stock					Sawtimber				
	Major species group					Major species group				
Inventory unit and county	Pine	Other softwoods	Soft hardwoods	Hard hardwoods	All species	Pine	Other softwoods	Soft hardwoods	Hard hardwoods	All species
Northern	(In million cubic feet)					(In million cubic feet)				
Box Elder	- -	10.9	0.0	- -	10.9	- -	39.7	- -	- -	39.7
Cache	63.7	170.1	48.5	1.3	283.6	286.8	835.8	109.9	4.0	1,236.5
Davis	- -	24.8	0.3	- -	25.1	- -	136.6	- -	- -	136.6
Morgan	0.4	144.5	15.6	- -	160.6	1.4	745.6	15.5	- -	762.5
Rich	42.6	77.7	60.0	- -	180.3	217.5	375.4	145.2	- -	738.1
Salt Lake	- -	74.3	34.2	- -	108.5	- -	370.3	126.8	- -	497.1
Summit	257.7	290.8	95.1	- -	643.5	654.7	1,311.0	144.8	- -	2,110.6
Tooele	- -	26.8	- -	- -	26.8	- -	126.4	- -	- -	126.4
Utah	0.6	275.8	51.9	- -	328.3	2.2	1,321.8	144.4	- -	1,468.4
Wasatch	21.5	241.5	215.1	- -	478.1	91.5	1,061.9	479.9	- -	1,633.3
Weber	- -	50.0	6.5	- -	56.4	- -	262.9	1.8	- -	264.7
Total	386.4	1,387.2	527.1	1.3	2,302.1	1,254.1	6,587.5	1,168.4	4.0	9,013.9
Uinta										
Daggett	119.5	82.8	2.6	- -	205.0	212.5	339.3	0.8	- -	552.6
Duchesne	147.1	326.2	59.1	- -	532.4	442.2	1,384.0	73.3	- -	1,899.5
Uintah	172.4	199.7	54.2	1.4	427.7	474.5	863.2	94.7	1.4	1,433.7
Total	439.1	608.8	115.9	1.4	1,165.2	1,129.2	2,586.4	168.8	1.4	3,885.8
Central										
Juab	17.2	63.0	0.4	- -	80.6	76.4	291.5	- -	- -	367.9
Millard	- -	55.4	19.6	- -	75.0	- -	209.4	74.7	- -	284.2
Piute	4.8	83.9	93.4	- -	182.1	17.2	357.1	167.6	- -	541.9
Sanpete	- -	144.6	86.2	- -	230.8	- -	650.1	221.6	- -	871.7
Sevier	4.0	171.3	164.6	- -	339.9	14.8	718.1	501.9	- -	1,234.8
Wayne	11.0	29.5	7.0	3.1	50.6	58.5	126.8	13.7	5.8	204.8
Total	37.0	547.8	371.3	3.1	959.1	166.9	2,353.0	979.6	5.8	3,505.2

(continued)

Table B35—(Continued)

Eastern										
Carbon	1.0	123.2	69.4	- -	193.7	1.3	566.8	168.1	- -	736.2
Emery	6.1	143.3	42.3	- -	191.7	23.6	708.0	145.1	- -	876.8
Grand	20.7	74.1	75.4	- -	170.3	121.5	281.3	227.2	- -	630.0
San Juan	98.4	111.2	65.2	1.6	276.3	534.7	535.3	258.4	8.2	1,336.6
Total	126.2	451.9	252.3	1.6	832.0	681.1	2,091.4	798.8	8.2	3,579.5
Southwestern										
Beaver	12.4	49.7	25.4	- -	87.5	69.9	209.5	35.4	- -	314.9
Garfield	128.8	348.6	98.3	- -	575.7	700.0	1,509.5	124.7	- -	2,334.2
Iron	4.8	145.9	143.4	- -	294.0	24.2	567.2	592.4	- -	1,183.8
Kane	50.5	72.2	21.8	- -	144.6	278.2	297.9	58.1	- -	634.2
Washington	7.1	7.6	5.7	- -	20.4	44.4	23.4	13.7	- -	81.5
Total	203.6	623.9	294.6	- -	1,122.2	1,116.7	2,607.5	824.4	- -	4,548.5
All counties	1,192.4	3,619.6	1,561.2	7.3	6,380.5	4,347.9	16,225.8	3,939.9	19.4	24,533.0

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 t their totals due to rounding.

Table B36—Average annual net growth of growing-stock trees (at least 5.0 inches d.b.h. /d.r.c.), in million cubic feet, and sawtimber trees, in million board feet (International 1/4-inch rule), on timberland by survey unit, county, and major species group, Utah, 2003-2012.

	Growing stock					Sawtimber				
	Major species group					Major species group				
Inventory unit 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 cubic feet)				
Northern										
Box Elder	- -	0.1	0.0	- -	0.1	- -	0.6	- -	- -	0.6
Cache	0.4	1.6	0.2	0.1	2.4	2.7	12.8	1.8	0.2	17.5
Davis	- -	0.3	0.0	- -	0.3	- -	1.6	- -	- -	1.6
Morgan	0.0	2.5	-0.4	- -	2.1	0.1	15.8	-0.4	- -	15.4
Rich	-0.7	1.4	0.7	- -	1.5	-3.6	6.9	2.9	- -	6.1
Salt Lake	- -	1.6	0.2	- -	1.7	- -	7.6	0.3	- -	7.9
Summit	-13.4	-0.9	0.8	- -	-13.5	-46.9	6.2	3.1	- -	-37.6
Tooele	- -	-0.1	- -	- -	-0.1	- -	-0.5	- -	- -	-0.5
Utah	0.0	-0.5	0.2	- -	-0.2	0.1	-3.3	0.0	- -	-3.2
Wasatch	0.2	-1.4	2.4	- -	1.2	1.4	-1.8	21.1	- -	20.6
Weber	- -	0.8	0.3	- -	1.1	- -	6.7	-0.2	- -	6.5
Total	-13.4	5.4	4.5	0.1	-3.4	-46.3	52.4	28.5	0.2	34.9
Uinta										
Daggett	3.1	-2.2	0.2	- -	1.1	8.1	-9.8	0.0	- -	-1.7
Duchesne	-4.6	-3.2	1.0	- -	-6.7	-11.5	-14.1	3.5	- -	-22.1
Uintah	-0.7	-0.7	0.4	0.0	-1.0	-7.3	2.1	3.6	0.0	-1.6
Total	-2.1	-6.1	1.6	0.0	-6.6	-10.7	-21.9	7.1	0.0	-25.4
Central										
Juab	0.1	0.0	0.0	- -	0.1	0.4	1.4	- -	- -	1.8
Millard	- -	0.6	0.3	- -	0.9	- -	4.1	1.4	- -	5.4
Piute	0.0	0.9	1.5	- -	2.4	-0.3	2.9	11.3	- -	13.9
Sanpete	- -	-22.6	1.6	- -	-21.1	- -	-115.1	17.7	- -	-97.4
Sevier	0.0	-6.0	1.4	- -	-4.6	0.2	-25.0	16.1	- -	-8.7
Wayne	0.1	-0.2	0.1	0.1	0.1	0.4	-1.8	0.1	0.0	-1.4
Total	0.2	-27.3	4.9	0.1	-22.1	0.7	-133.6	46.6	0.0	-86.3

(continued)

Table B36—(Continued)

Eastern										
Carbon	0.0	-1.3	0.5	- -	-0.8	0.7	-1.2	8.8	- -	8.3
Emery	-0.9	-9.3	0.3	- -	-9.9	-5.2	-46.0	10.8	- -	-40.3
Grand	-0.3	-1.4	-0.5	- -	-2.2	-1.4	-3.1	-1.4	- -	-5.9
San Juan	1.5	0.3	-0.5	0.1	1.3	9.3	3.0	-3.0	1.8	11.1
Total	0.3	-11.7	-0.2	0.1	-11.6	3.4	-47.2	15.2	1.8	-26.8
Southwestern										
Beaver	0.1	-0.2	0.2	- -	0.1	0.4	-1.5	3.1	- -	1.9
Garfield	0.6	-5.1	0.1	- -	-4.3	4.8	-10.8	5.0	- -	-1.0
Iron	0.1	-4.1	0.7	- -	-3.4	0.2	-18.4	11.4	- -	-6.8
Kane	0.4	-0.9	0.1	- -	-0.4	2.3	-2.2	0.5	- -	0.6
Washington	0.0	-0.1	0.1	- -	0.0	0.1	0.1	0.2	- -	0.4
Total	1.1	-10.3	1.3	- -	-7.9	7.8	-32.9	20.2	- -	-4.9
All counties	-13.9	-50.0	12.0	0.3	-51.6	-45.1	-183.2	117.7	2.0	-108.6

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 or board feet. Columns and rows may not add to their totals due to rounding.

Table B37—Sampling errors (in percent) by survey unit and county for area of timberland, volume, average annual net growth, average annual removals, and average annual mortality on timberland, Utah, 2003-2012.

Survey unit and county	Forest area	Timberland area	Growing stock (on timberland)				Sawtimber (on timberland)			
			Volume	Growth	Removals	Mortality	Volume	Growth	Removals	Mortality
Northern										
Box Elder	9.52	54.04	74.32	66.32	- -	70.91	74.08	58.08	- -	- -
Cache	6.93	15.15	25.85	40.43	- -	36.67	27.65	40.97	- -	37.60
Davis	49.10	70.86	71.77	74.23	- -	- -	71.52	74.39	- -	- -
Morgan	9.16	21.85	34.07	60.30	- -	58.02	37.90	47.16	- -	72.48
Rich	13.30	18.96	26.32	79.60	- -	57.22	30.71	87.62	- -	69.01
Salt Lake	10.42	31.73	46.32	62.17	- -	88.53	48.27	66.81	- -	73.81
Summit	4.27	7.89	11.82	34.52	- -	18.88	14.82	49.76	- -	21.93
Tooele	7.35	55.27	66.74	100.00	- -	99.99	68.50	100.00	- -	99.99
Utah	4.17	17.71	24.81	100.00	- -	44.41	27.90	100.00	- -	52.78
Wasatch	5.52	9.80	15.29	100.00	- -	26.93	19.08	85.45	- -	32.82
Weber	12.34	38.46	55.66	59.62	- -	70.20	60.80	74.13	- -	100.00
Total	2.22	5.00	7.84	100.00	- -	13.34	9.39	96.54	- -	15.88
Uinta										
Daggett	6.07	11.14	14.97	100.00	- -	43.95	22.54	100.00	- -	54.78
Duchesne	3.59	10.71	14.31	47.99	- -	22.01	16.48	58.67	- -	23.66
Uintah	4.22	15.79	20.31	100.00	- -	42.37	23.91	100.00	- -	51.64
Total	2.52	7.28	10.26	77.79	- -	18.51	12.37	86.87	- -	21.71
Central										
Juab	6.64	38.26	49.97	100.00	- -	62.76	54.16	46.72	- -	65.92
Millard	9.61	100.00	100.00	100.00	- -	100.00	100.00	100.00	- -	100.00
Piute	7.45	20.66	29.22	49.09	- -	36.19	37.76	57.80	- -	47.75
Sanpete	5.14	17.32	21.83	49.13	- -	39.87	24.06	54.96	- -	41.11
Sevier	4.26	14.46	19.54	79.44	- -	34.45	23.20	100.00	- -	39.75
Wayne	9.34	28.99	31.34	100.00	- -	77.19	35.30	100.00	- -	86.48
Total	3.09	11.04	14.68	50.70	- -	27.76	16.31	68.13	- -	30.18

(continued)

Table B37—(Continued)

Eastern										
Carbon	4.36	19.13	28.15	19.13	- -	45.48	31.65	94.05	- -	46.50
Emery	6.13	22.66	30.39	22.66	- -	47.24	33.20	80.63	- -	49.01
Grand	4.46	23.33	36.69	23.33	- -	52.94	39.19	100.00	- -	58.38
San Juan	3.34	22.71	28.08	22.71	- -	48.12	28.23	71.35	- -	51.80
Total	2.21	10.89	15.34	10.89	- -	28.09	16.35	100.00	- -	31.66
Southwestern										
Beaver	3.71	32.72	42.62	100.00	- -	53.32	45.24	100.00	- -	66.14
Garfield	3.18	11.09	14.74	75.38	- -	24.73	15.60	100.00	- -	27.82
Iron	3.61	19.09	24.33	94.02	- -	39.07	27.02	100.00	- -	44.02
Kane	3.65	22.04	27.53	100.00	- -	44.22	28.10	100.00	- -	55.07
Washington	4.72	47.13	62.14	100.00	- -	70.77	74.13	65.07	- -	77.77
Total	1.68	8.38	11.08	59.31	- -	18.71	11.85	100.00	- -	22.11
All counties	1.01	3.44	4.92	31.48	- -	9.76	5.63	76.04	- -	11.63

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

Table B38—Mean water, carbon, and nitrogen contents of forest floor and soil cores by forest type, Utah, visit 1, 2000-2010.

Forest Type	Soil Layer	Number of Plots	Water Content	Organic Carbon	Inorganic Carbon	Total Nitrogen	C/N Ratio	Forest Floor Mass	Organic Carbon	Total Nitrogen
	cm		%	%	%	%		Mg/ha	Mg/ha	Mg/ha
Western hardwoods group	Forest floor	21	13.59	29.28	--	0.927	32.4	9.20	2.626	0.089
	0–10	21	6.52	3.05	0.38	0.232	13.1	--	22.249	1.686
	10–20	19	7.39	2.15	0.31	0.183	11.8	--	17.658	1.501
Pinyon / Juniper group	Forest floor	118	5.68	28.99	--	0.640	47.4	2.57	0.808	0.019
	0–10	100	3.04	1.13	0.63	0.082	13.8	--	10.313	0.740
	10–20	85	4.29	0.92	0.69	0.072	13.0	--	7.907	0.627
Ponderosa pine	Forest floor	5	21.38	31.95	--	0.776	42.7	12.81	4.391	0.105
	0–10	4	6.83	2.71	0.14	0.141	18.6	--	26.110	1.381
	10–20	4	6.19	1.01	0.12	0.057	17.3	--	10.367	0.567
Lodgepole pine	Forest floor	3	51.43	47.38	--	1.277	42.1	6.83	4.999	0.133
	0–10	3	9.04	1.09	0.09	0.054	19.4	--	7.274	0.358
	10–20	2	11.25	1.55	0.09	0.054	29.8	--	14.440	0.536
Douglas-fir	Forest floor	12	14.20	30.65	--	0.988	32.2	23.87	7.740	0.247
	0–10	12	10.49	3.72	0.47	0.237	15.9	--	24.044	1.534
	10–20	11	9.82	2.41	0.52	0.172	14.0	--	16.688	1.189
Aspen	Forest floor	19	26.72	32.79	--	1.166	28.5	12.86	4.219	0.154
	0–10	14	14.16	4.58	0.27	0.327	13.9	--	28.654	2.051
	10–20	14	13.57	2.78	0.25	0.210	13.0	--	18.629	1.417
Spruce / Fir group	Forest floor	19	20.72	31.65	--	0.922	36.5	21.16	8.945	0.265
	0–10	14	7.75	5.10	0.23	0.197	26.0	--	29.221	1.135
	10–20	15	6.62	2.47	0.20	0.090	27.0	--	14.177	0.521

Western hardwoods group includes deciduous oak woodland and *Cercocarpus* woodland; Pinyon/Juniper group includes Rocky Mountain juniper, juniper woodland, and Pinyon/Juniper woodland; Spruce/Fir group includes white fir, Engelmann spruce, subalpine fir, and mixed Engelmann spruce/subalpine fir. Water content and forest floor mass are reported on an oven-dry weight basis (105°C).

Table B39a—Mean physical and chemical properties of soil cores by forest type, Utah, visit 1, 2000-2010.

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 hardwoods group	0–10	21	71	1.13	28.27	6.99	6.47	30.5	11.9
	10–20	19	68	1.26	30.22	6.97	6.61	24.4	6.7
Pinyon / Juniper group	0–10	100	60	1.33	21.26	7.68	7.28	18.0	5.1
	10–20	85	57	1.39	28.51	7.76	7.34	8.6	1.8
Ponderosa pine	0–10	4	68	1.37	24.93	6.31	6.09	7.7	6.0
	10–20	4	64	1.45	28.21	6.59	5.84	2.6	2.6
Lodgepole pine	0–10	3	61	1.12	27.98	5.58	5.22	12.8	5.4
	10–20	2	55	1.40	21.73	5.76	4.88	16.0	2.0
Douglas-fir	0–10	12	74	1.02	32.98	7.41	6.65	35.7	15.5
	10–20	11	68	1.17	37.45	7.89	6.82	35.9	8.0
Aspen	0–10	14	74	0.94	24.82	6.71	5.89	59.7	19.2
	10–20	14	72	0.99	24.11	6.86	5.92	58.5	15.2
Spruce / Fir group	0–10	14	71	1.16	29.38	6.28	5.77	47.2	9.8
	10–20	15	62	1.25	38.52	6.48	5.69	41.3	7.8

SQI = Soil Quality Index

(continued)

Table B39b—Mean exchangeable cation concentrations in soil cores by forest type, Utah, visit 1, 2000-2010.

Forest Type	Soil Layer	Number of Plots	1 M NH_4Cl Exchangeable cations					
			Na	K	Mg	Ca	Al	ECEC
	cm		mg/kg					cmolc/kg
Western hardwoods group	0–10	21	10	243	253	3561	1	20.93
	10–20	19	11	248	239	3179	1	18.80
Pinyon / Juniper group	0–10	100	13	177	231	3284	1	19.26
	10–20	85	28	161	258	3377	1	20.14
Ponderosa pine	0–10	4	10	224	199	2072	1	12.90
	10–20	4	17	180	194	1723	1	11.02
Lodgepole pine	0–10	3	11	63	86	742	2	4.59
	10–20	2	7	100	80	677	19	4.58
Douglas-fir	0–10	12	7	358	360	3879	2	23.58
	10–20	11	11	250	328	3969	1	23.50
Aspen	0–10	14	77	338	331	3085	2	19.56
	10–20	14	85	302	275	2367	3	15.37
Spruce / Fir group	0–10	14	14	184	216	2884	39	17.65
	10–20	15	8	122	151	1781	15	11.38

(continued)

Table B39c—Mean extractable trace element concentrations in soil cores by forest type, Utah, visit 1, 2000-2010.

Forest Type	Soil Layer	Number of Plots	1 M NH_4Cl Extractable							
			Mn	Fe	Ni	Cu	Zn	Cd	Pb	S
	cm		mg/kg							
Western hardwoods group	0–10	21	9.1	0.00	0.01	0.00	0.00	0.06	0.06	17.4
	10–20	19	9.8	1.17	0.02	0.03	0.15	0.05	0.40	34.3
Pinyon /Juniper group	0–10	100	2.0	0.09	0.02	0.00	0.01	0.03	0.10	10.8
	10–20	85	1.9	0.23	0.02	0.03	0.04	0.01	0.20	45.1
Ponderosa pine	0–10	4	9.2	0.00	0.07	0.00	0.05	0.02	0.00	13.3
	10–20	4	10.6	0.02	0.06	0.00	0.11	0.01	0.02	15.7
Lodgepole pine	0–10	3	11.9	4.77	0.15	0.00	0.03	0.06	0.00	5.5
	10–20	2	36.5	0.10	0.09	0.00	0.40	0.04	0.20	3.4
Douglas-fir	0–10	12	6.9	2.01	0.26	0.00	0.00	0.04	0.09	25.3
	10–20	11	3.0	0.08	0.01	0.00	0.06	0.01	0.24	18.5
Aspen	0–10	14	30.0	0.07	0.02	0.00	0.15	0.16	0.06	67.6
	10–20	14	10.7	0.43	0.03	0.02	0.16	0.08	0.14	67.1
Spruce / Fir group	0–10	14	26.9	0.10	0.03	0.00	0.05	0.11	0.06	18.0
	10–20	15	20.5	0.38	0.02	0.00	0.34	0.04	0.10	11.0

(continued)

Table B39d—Mean water, carbon, and nitrogen contents of forest floor and soil cores by forest type, Utah, visit 2, 2006-2010.

Forest Type	Soil Layer	Number of Plots	Water Content	Organic Carbon	Inorganic Carbon	Total Nitrogen	C/N Ratio	Forest Floor Mass	Organic Carbon	Total Nitrogen
	cm		%	%	%	%		Mg/ha	Mg/ha	Mg/ha
Western hardwoods group	Forest floor	8	6.66	30.09	--	0.956	31.6	5.34	1.529	0.053
	0–10	5	5.78	3.75	0.35	0.275	13.8	--	29.344	2.073
	10–20	5	11.58	2.87	0.24	0.192	14.9	--	23.784	1.608
Pinyon / Juniper group	Forest floor	54	8.52	35.90	--	0.808	46.6	2.09	0.697	0.017
	0–10	45	3.29	0.85	0.47	0.076	10.9	--	7.559	0.676
	10–20	43	5.02	0.83	0.54	0.062	12.8	--	7.810	0.584
Ponderosa pine	Forest floor	4	26.27	24.43	--	0.767	32.6	14.53	3.441	0.110
	0–10	4	7.01	2.35	0.31	0.153	15.5	--	23.199	1.514
	10–20	3	7.68	0.96	0.36	0.060	16.5	--	10.246	0.644
Lodgepole pine	Forest floor	2	25.12	29.43	--	0.762	44.6	29.32	9.705	0.292
	0–10	2	37.33	2.14	0.25	0.106	21.7	--	23.960	1.103
	10–20	1	29.67	3.03	0.49	0.113	26.6	--	33.572	1.336
Douglas-fir	Forest floor	2	7.44	38.87	--	1.340	30.3	17.82	7.465	0.232
	0–10	1	6.45	3.44	0.60	0.195	13.9	--	22.601	1.233
	10–20	1	10.91	1.36	0.64	0.158	7.1	--	10.444	1.221
Aspen	Forest floor	5	33.96	39.44	--	1.392	29.8	6.56	2.830	0.104
	0–10	3	32.71	4.99	0.34	0.341	15.8	--	49.700	3.608
	10–20	3	26.55	2.64	0.15	0.179	15.4	--	42.462	2.950
Spruce / Fir group	Forest floor	7	22.59	29.65	--	0.997	29.9	31.65	11.554	0.370
	0–10	4	11.26	3.17	0.29	0.175	18.5	--	13.299	0.704
	10–20	3	7.26	1.98	0.49	0.095	20.4	--	8.837	0.424

Western hardwoods group includes deciduous oak woodland and *Cercocarpus* mountainbrush woodland; Pinyon/Juniper group includes Rocky Mountain juniper, juniper woodland, and Pinyon/Juniper woodland; Spruce/Fir group includes white fir, Engelmann spruce, subalpine fir, and mixed Engelmann spruce/subalpine fir.
Water content and forest floor mass are reported on an oven-dry weight basis (105°C).

(continued)

Table B39e—Mean physical and chemical properties of soil cores by forest type, Utah, visit 2, 2006-2010.

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 hardwoods group	0–10	5	76	1.13	29.45	7.02	6.60	38.1	21.3
	10–20	5	69	1.16	27.93	7.10	6.55	30.4	10.6
Pinyon / Juniper group	0–10	45	56	1.33	24.80	7.84	7.15	16.6	4.6
	10–20	43	54	1.49	27.78	7.87	7.19	9.5	2.3
Ponderosa pine	0–10	4	65	1.17	15.61	6.53	5.81	16.1	4.3
	10–20	3	57	1.53	26.83	6.40	5.87	10.2	2.3
Lodgepole pine	0–10	2	63	1.36	30.14	5.80	5.12	19.7	7.4
	10–20	1	64	1.52	16.65	5.42	4.91	16.2	0.1
Douglas-fir	0–10	1	70	1.35	50.54	6.99	7.05	38.9	21.3
	10–20	1	60	1.20	35.43	7.25	7.64	33.5	5.5
Aspen	0–10	3	77	1.24	19.06	6.34	6.45	87.8	21.7
	10–20	3	71	1.67	25.70	6.55	6.54	62.6	10.6
Spruce / Fir group	0–10	4	69	0.88	33.52	6.22	5.82	66.8	20.5
	10–20	3	66	1.15	49.13	6.20	5.86	42.7	9.9

SQI = Soil Quality Index

(continued)

Table B39f—Mean exchangeable cation concentrations in soil cores by forest type, Utah, visit 2, 2006-2010.

Forest Type	Soil Layer	Number of Plots	1 M NH_4Cl Exchangeable cations					
			Na	K	Mg	Ca	Al	ECEC
	cm		mg/kg					cmolc/kg
Western hardwoods group	0–10	5	18	334	267	3258	2	19.96
	10–20	5	16	273	226	2739	0	16.63
Pinyon / Juniper group	0–10	45	48	133	204	2707	1	16.32
	10–20	43	45	136	233	3068	0	18.41
Ponderosa pine	0–10	4	5	162	172	1943	1	11.75
	10–20	3	14	157	161	1414	1	9.10
Lodgepole pine	0–10	2	24	102	200	1659	4	10.70
	10–20	1	6	97	170	1525	24	9.83
Douglas-fir	0–10	1	0	273	216	2649	1	15.82
	10–20	1	36	246	381	4852	1	28.45
Aspen	0–10	3	159	558	421	3714	0	25.83
	10–20	3	103	328	219	2047	0	14.64
Spruce / Fir group	0–10	4	28	184	181	1739	40	11.31
	10–20	3	18	125	154	1457	12	9.55

(continued)

Table B39g—Mean extractable trace element concentrations in soil cores by forest type, Utah, visit 2, 2006-2010.

Forest Type	Soil Layer	Number of Plots	1 M NH_4Cl Extractable							
			Mn	Fe	Ni	Cu	Zn	Cd	Pb	S
	cm		mg/kg							
Western hardwoods group	0–10	5	0.0	25.04	0.00	0.00	0.00	0.09	0.00	15.3
	10–20	5	0.0	0.00	0.01	0.00	0.00	0.05	0.00	27.3
Pinyon / Juniper group	0–10	45	1.1	0.33	0.00	0.00	0.00	0.00	0.11	3.5
	10–20	43	1.1	0.11	0.00	0.00	0.00	0.00	0.10	37.0
Ponderosa pine	0–10	4	6.3	0.17	0.00	0.00	0.01	0.01	0.29	5.8
	10–20	3	1.9	0.00	0.00	0.00	0.02	0.00	0.10	4.9
Lodgepole pine	0–10	2	16.9	1.31	0.00	0.00	0.01	0.03	0.66	4.8
	10–20	1	26.6	0.61	0.12	0.00	0.14	0.02	0.00	6.3
Douglas-fir	0–10	1	6.7	0.69	0.20	0.00	0.00	0.00	0.67	14.4
	10–20	1	2.6	0.02	0.00	0.00	0.02	0.02	0.27	16.1
Aspen	0–10	3	18.2	1.29	0.02	0.00	0.04	0.15	0.43	74.0
	10–20	3	0.0	0.14	0.00	0.00	0.00	0.09	0.43	58.9
Spruce / Fir group	0–10	4	19.2	0.09	0.01	0.00	0.10	0.21	0.18	0.0
	10–20	3	4.0	0.31	0.00	0.00	0.00	0.08	0.12	2.3

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

Forest types are usually named for the predominant species (or group of species) on the condition. To determine the forest type, the stocking (site occupancy) of softwood and hardwood trees is estimated. 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 dominate 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. Descriptions of special rules refer only to species in the current inventory, and may differ slightly for other States and 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: subalpine fir, Douglas-fir, Engelmann spruce, lodgepole pine, white fir, bigtooth maple

Other species: Gambel oak, Rocky Mountain juniper, blue spruce, ponderosa pine, curlleaf mountain-mahogany, limber pine, Fremont cottonwood, narrowleaf cottonwood

DOUGLAS-FIR GROUP (T)

Douglas-fir

Predominant species: Douglas-fir

Associate species: quaking aspen, white fir, subalpine fir, Rocky Mountain juniper, Engelmann spruce, limber pine, ponderosa pine, common or two-needle pinyon, Gambel oak, curlleaf mountain-mahogany

Other species: lodgepole pine, Utah juniper, Great Basin bristlecone pine, bigtooth maple, blue spruce

ELM/ASH/COTTONWOOD GROUP (T)

Cottonwood

Predominant species: narrowleaf cottonwood, Fremont cottonwood

Associate species: none identified

Other species: water birch, subalpine fir, blue spruce, Rocky Mountain juniper, common or two-needle pinyon, ponderosa pine, Gambel oak

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

Cottonwood/willow

Predominant species: narrowleaf cottonwood

Associate species: none identified

Other species: boxelder, bigtooth maple, Douglas-fir, white fir, quaking aspen, Rocky Mountain juniper, ponderosa pine, Gambel oak

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

FIR/SPRUCE/MOUNTAIN HEMLOCK GROUP (T)

Blue spruce

Predominant species: blue spruce
Associate species: quaking aspen
Other species: Rocky Mountain juniper, subalpine fir

Engelmann spruce

Predominant species: Engelmann spruce
Associate species: lodgepole pine, subalpine fir, quaking aspen, Douglas-fir
Other species: limber pine
Special rules: To use Engelmann spruce stocking predominance, subalpine fir stocking must be less than 5 percent of the total. If subalpine fir stocking is 5 percent or more, Engelmann spruce stocking must be at least 75 percent of the total.

Engelmann spruce/subalpine fir

Predominant species: Engelmann spruce, subalpine fir
Associate species: quaking aspen, lodgepole pine, Douglas-fir, limber pine
Other species: white fir, blue spruce
Special rules: The combined stocking of Engelmann spruce with subalpine fir is predominant. Stocking of Engelmann spruce and subalpine fir must each be between 5 and 74 percent of the total.

Subalpine fir

Predominant species: subalpine fir
Associate species: quaking aspen, Douglas-fir, lodgepole pine, Engelmann spruce, limber pine
Other species: white fir, curlleaf mountain-mahogany, Rocky Mountain juniper
Special rules: 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 stocking must be at least 75 percent of the total.

White fir

Predominant species: white fir
Associate species: Douglas-fir, quaking aspen, Gambel oak, curlleaf mountain-mahogany, Rocky Mountain juniper, ponderosa pine
Other species: bigtooth maple, limber pine, Engelmann spruce, common or two-needle pinyon, Great Basin bristlecone pine, Utah juniper, subalpine fir, lodgepole pine, water birch

LODGEPOLE PINE GROUP (T)

Lodgepole pine

Predominant species: lodgepole pine
Associate species: Engelmann spruce, subalpine fir, quaking aspen, Douglas-fir
Other species: ponderosa pine, Rocky Mountain juniper

NONSTOCKED

Nonstocked

Predominant species: various, most often Utah juniper, but most nonstocked conditions have no live-tree stocking.
Associate species: various, limber pine and Rocky Mountain juniper are the only non-dominant species found on multiple conditions.

Other species: Seldom more than two species on a condition. Complete species list: Utah juniper, common or two-needle pinyon, Douglas-fir, Rocky Mountain juniper, quaking aspen, limber pine, Fremont cottonwood, ponderosa pine, subalpine fir, white fir, Gambel oak, curlleaf mountain-mahogany, singleleaf pinyon.

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 SOFTWOODS GROUP (T)

Foxtail pine/bristlecone pine

Predominant species: Great Basin bristlecone pine

Associate species: white fir

Other species: common or two-needle pinyon, Douglas-fir, curlleaf mountain-mahogany, Rocky Mountain juniper, ponderosa pine, Engelmann spruce, quaking aspen, limber pine

Special rules: This is mostly an "either/or" forest type. Foxtail pine does not occur in Utah, so this type will always be predominantly Great Basin bristlecone pine.

Note: In the previous periodic inventory, Great Basin bristlecone pine was not distinguished from Rocky Mountain bristlecone pine. The species code used for all bristlecone pines in that inventory was retained for Rocky Mountain bristlecone pine. Therefore, species-based reports using Utah 1993 data may return results for "Rocky Mountain bristlecone pine." These are almost certainly Great Basin bristlecone pines.

Limber pine

Predominant species: limber pine

Associate species: Douglas-fir, curlleaf mountain-mahogany, Rocky Mountain juniper

Other species: ponderosa pine, subalpine fir, Engelmann spruce, common or two-needle pinyon, quaking aspen

PINYON/JUNIPER GROUP (W)

Juniper woodland

Predominant species: Utah juniper

Associate species: Gambel oak

Other species: Rocky Mountain juniper, curlleaf mountain-mahogany, ponderosa pine, bigtooth maple, velvet ash, Douglas-fir, white fir

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, singleleaf pinyon, Arizona pinyon pine

Associate species: curlleaf mountain-mahogany, Rocky Mountain juniper, Gambel oak

Other species: Douglas-fir, ponderosa pine, Fremont cottonwood, white fir, limber pine, Great Basin bristlecone pine, narrowleaf cottonwood, velvet ash, bigtooth maple

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: Gambel oak, curlleaf mountain-mahogany, common or two-needle pinyon, ponderosa pine, white fir, Douglas-fir, quaking aspen, narrowleaf cottonwood

Other species: Utah juniper, Great Basin bristlecone pine, bigtooth maple, limber pine, Engelmann spruce, singleleaf pinyon, blue spruce

PONDEROSA PINE GROUP (T)

Ponderosa pine

Predominant species: ponderosa pine

Associate species: Douglas-fir, Rocky Mountain juniper, quaking aspen, Gambel oak, tcommon or two-needle pinyon, curlleaf mountain-mahogany, white fir

Other species: Utah juniper, lodgepole pine, subalpine fir, limber pine, blue spruce, singleleaf pinyon, Engelmann spruce, bigtooth maple

WOODLAND HARDWOODS GROUP (W)

***Cercocarpus* (mountain brush) woodland**

Predominant species: curlleaf mountain-mahogany

Associate species: Rocky Mountain juniper, Gambel oak, common or two-needle pinyon, Utah juniper, singleleaf pinyon, Douglas-fir, bigtooth maple, ponderosa pine, white fir

Other species: quaking aspen, limber pine, Great Basin bristlecone pine

Deciduous oak woodland

Predominant species: Gambel oak

Associate species: bigtooth maple, Rocky Mountain juniper, common or two-needle pinyon, Utah juniper, quaking aspen, curlleaf mountain-mahogany, ponderosa pine

Other species: Douglas-fir, white fir, singleleaf pinyon, boxelder, blue spruce, subalpine fir

Intermountain maple woodland

Predominant species: bigtooth maple

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

Other species: Rocky Mountain juniper, narrowleaf cottonwood, white fir, curlleaf mountain-mahogany, boxelder

Special rules: Currently, bigtooth maple is the only species evaluated for this type. In the previous periodic inventory, Rocky Mountain maple was included.

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

HARDWOODS

Cotttonwood and aspen group (T)

Fremont cottonwood (*Populus fremontii*)

Narrowleaf cottonwood (*Populus angustifolia*)

Quaking aspen (*Populus tremuloides*)

Other western hardwoods group (T)

Boxelder (*Acer negundo*)

Velvet ash (*Fraxinus velutina*)

Water birch (*Betula occidentalis*)

Woodland hardwoods group (W)

Bigtooth maple (*Acer grandidentatum*)

Curlleaf mountain-mahogany (*Cercocarpus ledifolius*)

Gambel oak (*Quercus gambelii*)

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 group (T)

Lodgepole pine (*Pinus contorta*)

Other western softwoods group (T)

Great Basin bristlecone pine (*Pinus longaeva*)

Limber pine (*Pinus flexilis*)

Ponderosa and Jeffrey pines group (T)

Ponderosa pine (*Pinus ponderosa*)

True fir group (T)

Subalpine fir (*Abies lasiocarpa*)

White fir (*Abies concolor*)

Woodland softwoods group (W)

Rocky Mountain juniper (*Juniperus scopulorum*)

Singleleaf pinyon (*Pinus monophylla*)

Common or two-needle pinyon (*Pinus edulis*)

Utah juniper (*Juniperus osteosperma*)

Appendix E: Volume and Site Index Equation Sources

Volume

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

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

Edminster and others (1980) was used for ponderosa pine volume estimation in northeastern Utah.

Edminster and others (1982) was used for quaking aspen, and water birch volume estimation in northeastern Utah.

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

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

Myers and Edminster (1972) was used for blue spruce, Douglas-fir, Engelmann spruce, Great Basin bristlecone pine, limber pine, lodgepole pine, subalpine fir, and white fir volume estimation in northeastern Utah.

Volume equations provided by the USDA Forest Service's Northern Research Station were used to estimate volume of boxelder and velvet ash. [Documentation on file at U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.]

Site Index

Brickell (1968) was used for Douglas-fir site index estimation.

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

Edminster and others (1985) was used for boxelder, Fremont cottonwood, narrowleaf cottonwood, quaking aspen, velvet ash, and water birch site index estimation.

Stage (1966; 1969) was used for grand fir site index estimation. [Original equations were reformulated by John D. Shaw. Documentation on file at U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.]

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