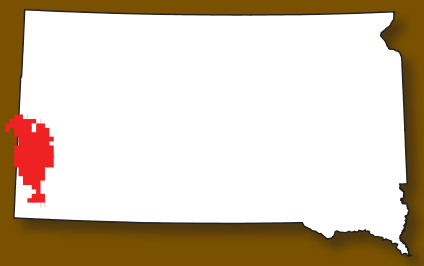
Forests of the Black Hills National Forest 2011



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USDA United States Department of Agriculture

Forest Service

Abstract

This inventory of the Black Hills National Forest (BHNF) covers the years 2007–2011 on the South Dakota portion of the forest and 2005 on the Wyoming portion. It reports more than 1.16 million acres of forest land dominated by ponderosa pine. Forest features reported on include volume, biomass, growth, removals, mortality, carbon, snags, and down woody material, along with information on forest economics. This report provides the public with a set of forest statistics that may be used in the Black Hills' land management decisionmaking.

Acknowledgments

The authors would like to thank the many people who contributed to the inventory and analysis of the Black Hills National Forest. Primary field crew and Quality Assurance staff that collected field data included Bob Adams, Nathan Cochran, Michael Downs, Adam Felts, Thomas Goff, Tim Halberg, Brent Hummel, Dick Kessle, Mark Majewsky, Sheldon Murphy, Greg Pugh, Douglas Rollins, and Earl Sheehan. Reviewers of report drafts included Blaine Cook, Deanna Reyher, and Ed Fischer of the Black Hills National Forest.

Cover: Aerial photo of the Black Hills National Forest, September 2011. Photo by Beth Doten, U.S. Forest Service, Black Hills National Forest.

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Foreword

Understanding forest inventory is essential in building a greater understanding of complex forest conditions, and the interdependent plants, animals, and human uses and opportunities. This report, summarizing information collected through 2011, characterizes the Black Hills National Forest of South Dakota and Wyoming, with both quantifiable information and a basic discussion of what the numbers mean. Resource professionals and interested readers will benefit from this reliable inventory, a key milestone since the 2002 survey, for using in trend analysis, adding context to project planning, and aiding in future forest planning. If you enjoy learning about the big picture of the BHNF's inventory, you will enjoy reading and retaining this well-done report!

Craig Bobzien, Forest Supervisor, Black Hills National Forest

Contents

Highlights

- The amount of forest land in the Black Hills National Forest (BHNF) is estimated at 1.16 million acres.
- Ponderosa pine is the dominant forest type.
- Live aboveground tree biomass is estimated to be 30.2 million oven-dry short tons.
- Eleven tree species were documented in the BHNF. The five most common in terms of number of trees were ponderosa pine (*Pinus ponderosa*), quaking aspen (*Populus tremuloides*), bur oak (*Quercus macrocarpa*), white spruce (*Picea glauca*), and paper birch (*Betula papyifera*).
- Average annual net growth of ponderosa pine growing stock on timberland is estimated to exceed 21 million cubic feet/year.
- The net growth to removals ratio of ponderosa pine growing stock on timberland is 0.88.
- The BHNF holds more than 55 million tons of carbon. The largest carbon stocks are in the soil organic matter pool.
- Compared to ponderosa pine forests in neighboring Montana, the BHNF's ponderosa pine forests have larger coarse woody debris and litter fuel loadings in tons per acre.
- Net sawtimber volume on the BHNF is estimated at more than 4.98 billion board feet (Scribner rule).
- In 2009, 29.3 million cubic feet of industrial roundwood was harvested from the BHNF and processed at nearby mills.

Aerial survey of the beetle kill in the Deefield Lake area, Mystic Ranger District of the Black Hills National Forest.
Photo by Gary Chancey, U.S. Forest Service, Black Hills National Forest.

Forest Features

Aerial photo of the Black Hills National Forest, September 2011. Photo by Beth Doten, U.S. Forest Service, Black Hills National Forest.

Forest Land Area

Background

Area estimates are the most basic and frequently cited of all forest inventory estimates. They are essential in assessing the status of a region's forest ecosystems. Fluctuations in forest land area estimates may indicate changing land use or forest health conditions, or in the case of a national forest, they may be the result of a land acquisition, sale, or swap.

What we found

The forest land area of the BHNF was estimated to be more than 1.16 million acres, roughly 1 percent of which is reserved as part of the Black Elk Wilderness Area (Fig. 1). The ponderosa pine forest-type group makes up much (~ 76 percent) of the total forest land (Fig. 2). The aspen/birch and spruce/fir forest-type groups, at an estimated 93,400 acres and 51,600 acres, respectively, are the only other groups on the BHNF that cover at least 50,000 acres. The area of timberland was estimated at 1.14 million acres. Timberland, a subset of forest land, is defined as forested area capable of growing a minimum of 20 cubic feet/acre per year (at culmination of mean annual increment) and is not reserved from harvest by law or statute, such as a wilderness area. Sawtimber-size stands dominate timberland area, covering about 752,400 acres (Fig. 3). Although the ponderosa pine forest-type group makes up the overwhelming majority of the sawtimber- and poletimber-size stands, it is only 50 percent of the sapling-seedling-size stands.

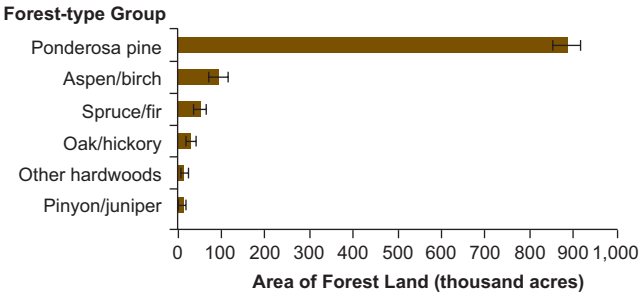

Figure 2.—Area of forest land by forest-type group, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota). Error bars show the 68 percent confidence interval.

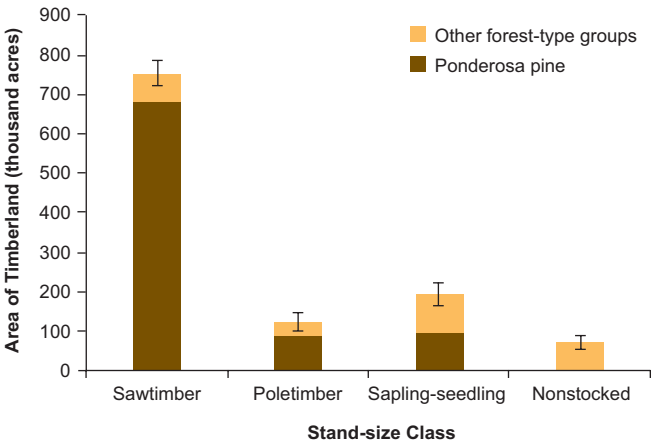

Figure 3.—Area of timberland by forest-type group and stand-size class, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota). Error bars show the 68 percent confidence interval. Note: error bars are for the total area of timberland in each stand-size class.

What this means

The 1.14 million acres of timberland represent 98 percent of the total forest land in the BHNF. With most of that area covered by stands in the large-diameter class, it has good prospects for potential timber production. Although the BHNF is known for its vast forests of ponderosa pine, its areas of aspen/birch, spruce/fir, and other forest-type groups should not be overlooked for their contributions to timber, wildlife habitat, and other benefits. The high proportion of area in the large-diameter stand class means the forest is mature, but the plentiful area in the medium and small classes signifies adequate reproduction. However, the high proportion of small-diameter stands that are in forest-type groups other than ponderosa pine may be of concern. Large numbers of ponderosa pines killed by the mountain pine beetle (MPB; *Dendroctonus ponderosae*) may be replaced by other species.

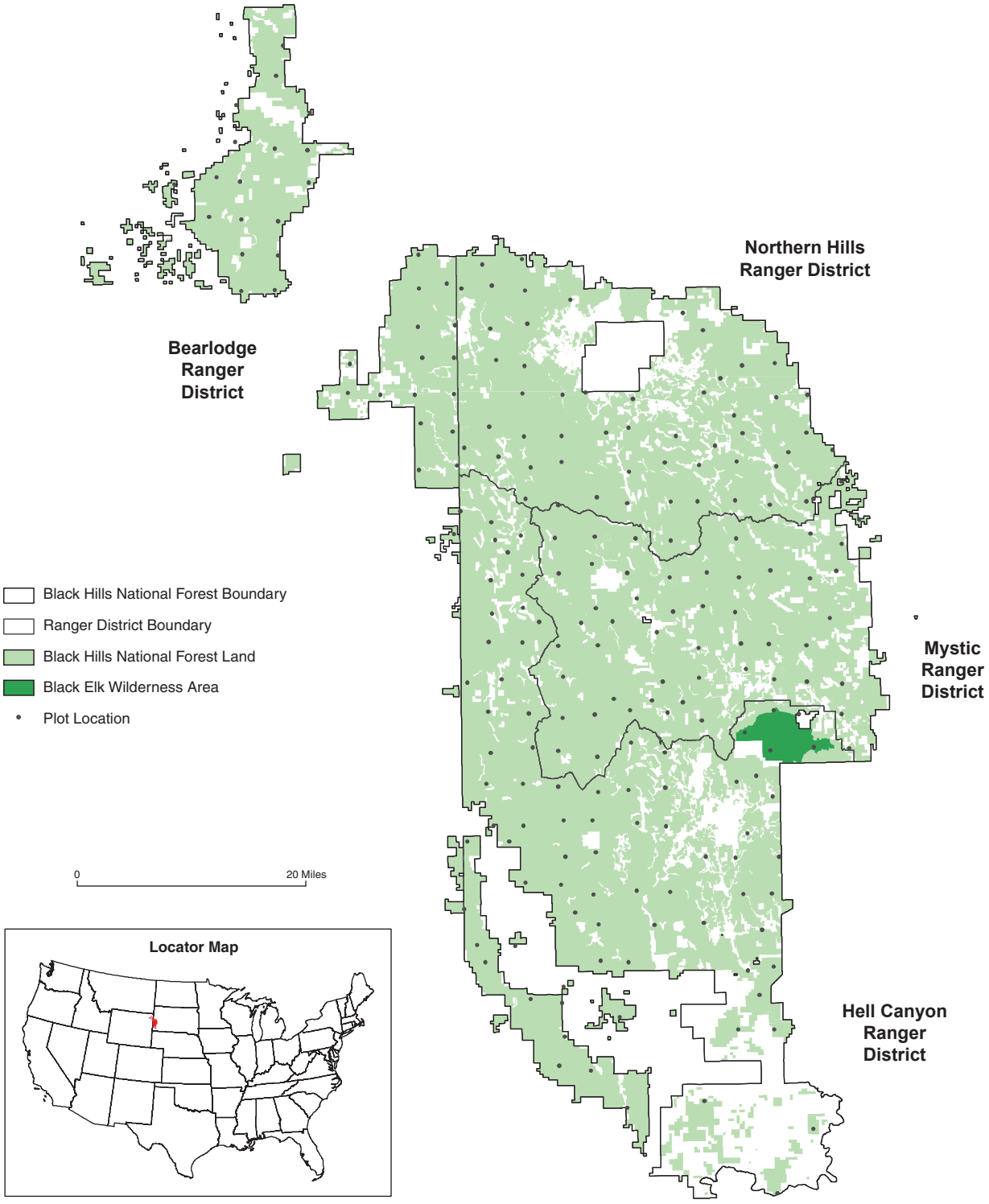

Figure 1.—Map of the Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota). Plot locations are approximate.

Biomass and Volume

Background

As with measures of the BHNF acreage, measuring total tree biomass and all tree volume helps us understand the components of a forest stand and the resources available for different uses (e.g., wildlife habitat, carbon sequestration, biofuels). Historically, volume has been reported as either growing stock or sawtimber, ignoring volume found in noncommercial, rotten, rough, or salvable dead trees that have potential value as wood fiber or fuelwood. With interest increasing in FIA data from an ecological perspective, a greater focus has been placed on all tree volume in addition to biomass.

What we found

Live aboveground tree (at least 1 inch d.b.h./d.r.c.) biomass on forest land was estimated at more than 30.2 million oven-dry short tons. Softwoods made up a large majority of the total, 28.9 million dry short tons, 95 percent of which is ponderosa pine (Fig. 4). Most of the biomass is in the boles of growing-stock trees, followed by growing-stock tree stumps, tops, and limbs and trees less than 5 inches d.b.h./d.r.c. (Fig. 5). All tree volume (at least 5 inches d.b.h./d.r.c.) was estimated at 1.6 billion cubic feet, an average of 1,378 cubic feet of volume per acre of forest land. Ponderosa pine accounted for 94 percent of the total (Fig. 6). Volume from non-growing-stock trees amounted to 127 million cubic feet, just under 8 percent of all tree volume (Fig. 7).

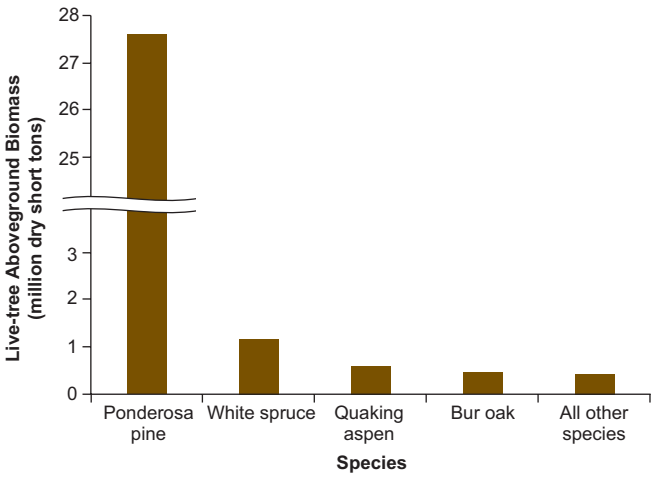

Figure 4.—Live-tree aboveground biomass on forest land by species, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

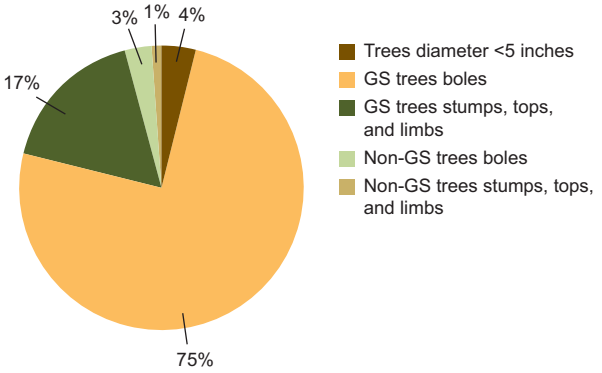

Figure 5.—Live-tree aboveground biomass on forest land by tree component, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota). (Note: GS refers to growing-stock trees and non-GS refers to non-growing-stock trees at least 5 inches d.b.h./d.r.c.).

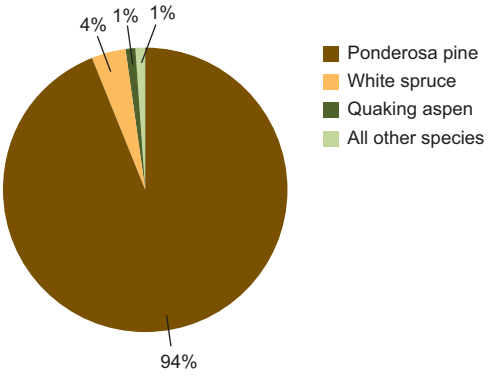

Figure 6.—Net volume (thousand ft³) of all trees (at least 5 inches d.b.h./d.r.c.) on forest land by species, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

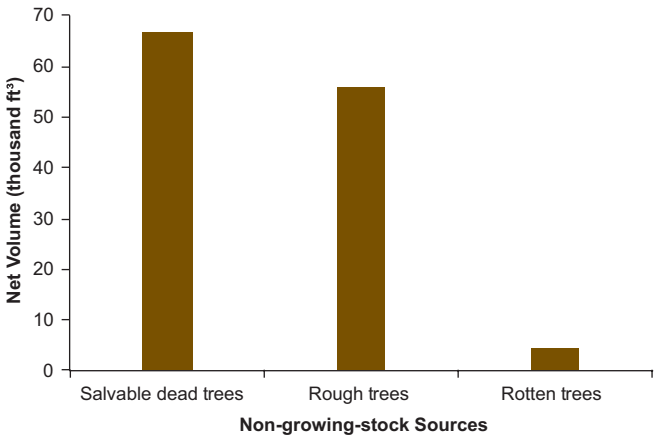

Figure 7.—Net volume of non-growing-stock trees (at least 5 inches d.b.h./d.r.c.) on forest land, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

What this means

The total live-tree biomass on the BHNF is a tremendous resource both in terms of economic and environmental importance. The potential for expanding woody biomass for energy production makes knowledge of the resource amount vital to additional demands on forest planning and management. Likewise for all volume, while growing-stock volume is important, knowing how much non-growing-stock volume is in the BHNF potentially opens that resource to be managed for timber, pulp, or non-timber products.

Tree Species Composition

Background

The species composition of a forest drives the dynamics of its growth, development, and ecosystem function. Some forests are composed of a diverse set of tree species while others are composed of very few different species or dominated by a single species. Both types of forests provide a variety of ecological niches that various plant and animal communities require. Although diverse forests are not completely free of forest health problems, they are less likely to be devastated by insect or disease attacks than a forest composed of a single species or narrow group of species. The Shannon Diversity Index is a good measure of species diversity because it combines measures of the number of species present and the relative distribution of those species (Magurran 1988). Knowledge of current species compositions and diversity allows us to quantify the character of current and potential future forest ecosystems.

What we found

The BHNF contains more than 405 million trees (at least 1 inch d.b.h./d.r.c.) representing 11 different tree species that were documented during this inventory. Ponderosa pine was by far the most common species; with more than 285 million trees, it made up 70 percent of the total number of trees (Fig. 8). Quaking aspen was the next most abundant species on the forest with 40 million trees, or about 10 percent of all trees. The Shannon Diversity Index value for the BHNF as a whole was 1.13, where a value of 0 would be no diversity (i.e., a single species covering the entire forest) and the value increases with more species present and distributed evenly. For reference, the Shannon Index for the Monongahela National Forest, containing a diverse mix of central Appalachian hardwoods, is 2.91.

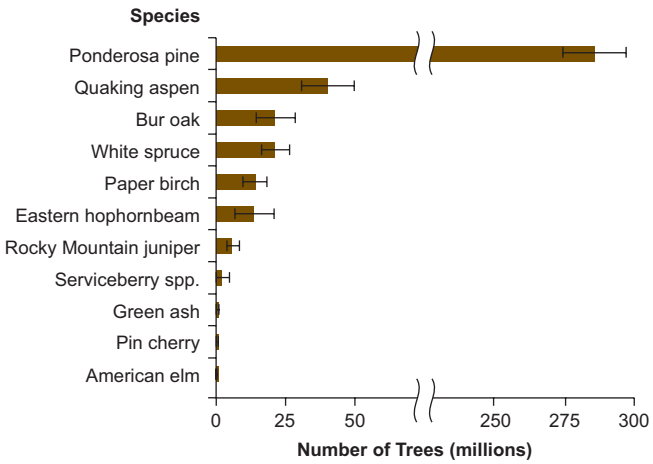

Figure 8.—Number of live trees on forest land by species, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota). Error bars show the 68 percent confidence interval.

As elevation changes, so does the diversity of the forest land. Elevation is associated with variations in local climate, having considerable impact on the ability of a tree species to compete with other species. The most diverse range in elevation occurred at 4,000 to 4,999 feet. The Shannon value was 1.17, and there were seven species present (Fig. 9). Ponderosa pine was the most abundant species at all elevation ranges; above 7,000 feet, it was the only species present. Below 5,000 feet, bur oak was the second most abundant species present; above 5,000 feet, quaking aspen was the second most abundant species.

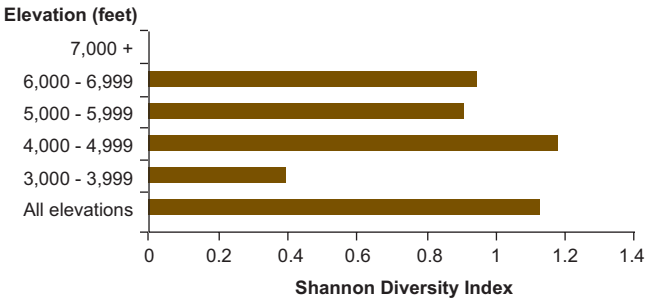

Figure 9.—Shannon Diversity Index by elevation, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

What this means

Because ponderosa pine is the major tree species on the BHNF, much of the forest ecology is based around it. A big disadvantage to having a forest with so many trees from one species is susceptibility to attack by forest pests. That scenario has played out many times on the BHNF through its history with MPB outbreaks, including another major epidemic cycle that significantly increased in intensity during the mid- to late-1990s.

Density of Ponderosa Pine Forests

Background

The relative density of a forest indicates the current phase of stand development and has implications for diameter growth, tree mortality, and yield. Relative density, a measure of a forest's current stocking of trees per unit area relative to a maximum, represents the degree of tree occupancy required to fully utilize the growth potential of the land. A relative density between 0.30 and 0.60 can suggest full site occupancy, while relative density exceeding 0.60 often indicates imminent mortality. Relative density was calculated using Stand Density Index (Long 1985). Because the ponderosa pine forest type dominates much of the BHNF's landscape, assessing its current level of stocking relative to its maximum can indicate future trajectories of stand development.

What we found

Most of the ponderosa pine forests of the BHNF are at full site occupancy (Fig. 10). Only the youngest stands (< 25 years in age), with relative density approximately 0.15, are substantially below full site occupancy. There is no evidence of stand stocking increasing with stand age once stand age exceeds 25 years. In contrast to stand age, as ponderosa pine stands develop and more fully occupy BHNF sites, their gross live-tree volume nearly quadruples from nearly 500 cubic feet/acre in stands with relative density below 0.10 to nearly 4,000 cubic feet/acre in stands with relative density between 0.70 and 0.80 (Fig. 11). It should be noted that the mean live-tree gross volume drops to nearly 3,500 cubic feet/acre at the highest levels of relative density.

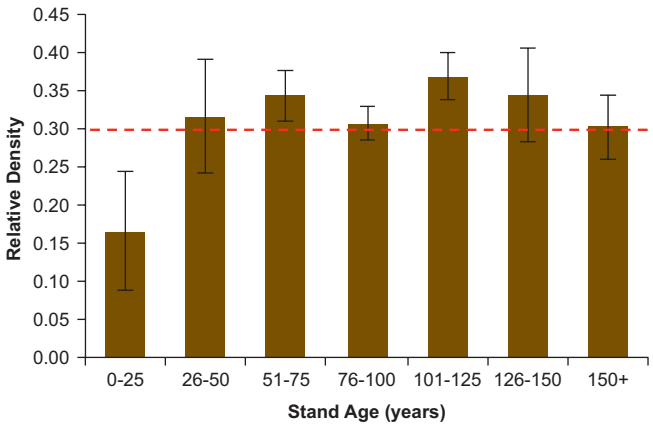

Figure 10.—Mean relative density and associated standard errors of ponderosa pine forest type on forest land by classes of stand age, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota) (Note: dashed red line indicates full site occupancy).

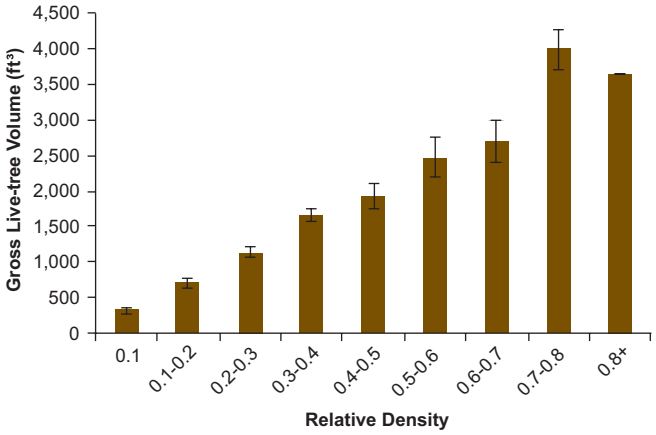

Figure 11.—Mean live-tree gross volume and associated standard errors of the ponderosa pine forest type by classes of relative density on forest land, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

What this means

The dynamics between the relative density (i.e., live-tree stocking), stand age, and total live-tree volumes per acre presents evidence of a maturing forest resource across the BHNF. Unless disturbances (i.e., tree mortality/removal) occur, either human-induced or natural, it should be expected that this trend will continue until ponderosa pine stands reach a state of senescence (i.e., overstocking with substantial self-thinning). Although many of BHNF's ponderosa pine stands have reached relative densities just at the minimum level of full stocking suggestive of minimal impending mortality, as these stands are fully stocked they can be more susceptible to the effects of droughts or MPB attacks. Compared to relative densities across forests of the U.S. (Woodall et al. 2006), the stocking of ponderosa pine forests of the BHNF is not excessive, although most forests in the U.S. do not face the same unique disturbance events (e.g., wildfire) as those in the BHNF.

Forest Growth, Removals, and Mortality

Background

Forest health, vigor, and the rate of woody biomass accretion and depletion are all influenced by the dynamic relationship between tree growth, mortality, and removals (i.e., harvests and land use change). A stand's capacity for growth is an indication of the overall condition of the forest and more specifically of tree vigor, forest health, and successional stage. Forest growth is measured as average annual net growth, where net growth is equivalent to gross growth minus mortality. Mortality can be caused by insects, disease, adverse weather, succession, competition, fire, old age, or human or animal activity, and is often the result of a combination of these factors. Growing-stock mortality estimates represent the average cubic-foot volume of sound wood in growing-stock trees that died each year as an average for the years between inventories. Changes in the quantity of growing stock removed help identify trends in land use change and forest management. Because removals are generally recorded on a limited number of plots, the estimates for removals show greater variance than those for growth, mortality, or area. Because the BHNF spans two states with varying periodic and annual inventories, change estimation is based on two full cycle periodic inventories in Wyoming (2000 and 2005) and two full cycle annual inventories in South Dakota (2002-2006 and 2007-2011).

What we found

Ponderosa pine dominates the average annual net growth of growing stock across the BHNF, exceeding 21 million cubic feet/year on timberland (Fig. 12). At a distant second place is white spruce at about 1 million cubic feet/year. Given the fairly limited tree species diversity in the BHNF, no other tree species demonstrated appreciable growth (e.g., bur oak and green ash (*Fraxinus pennsylvanica*)). It should be noted that given the relatively high mortality rates of quaking aspen, this species had negative net average annual growth. Quaking aspen had average annual mortality exceeding that of white spruce, 970,000 versus 826,000 cubic feet/year, respectively (Fig. 13). Ponderosa pine had average annual mortality at approximately 14 million cubic feet/year, less than half of the gross growth within the BHNF. Removals (i.e., harvests or land use change) are dominated by white spruce and ponderosa pine on timberland in the BHNF at about 1 and 24 million cubic feet/year, respectively (Fig. 14). The net growth to removals ratio of ponderosa pine of growing-stock volume on timberland in the BHNF is 0.88. When growth/removals/mortality are viewed on a relative basis compared to total growing-stock volume, ponderosa pine trends are sustainable given the species' tremendous total volume (Fig. 15). In contrast, species such as quaking aspen and paper birch have high mortality rates compared to their total volumes. Green ash and white spruce have the highest relative rates of growth and removals, respectively.

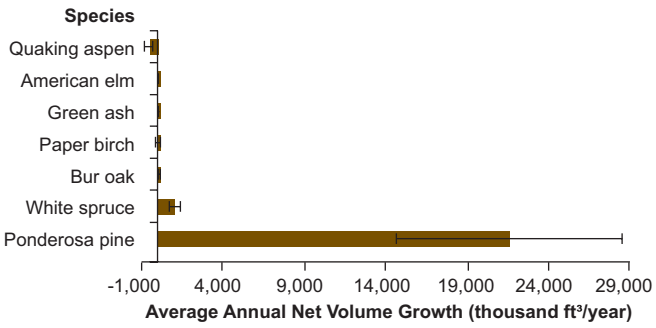

Figure 12.—Top species in terms of average annual net (gross growth minus mortality) growing-stock volume growth on timberland, Black Hills National Forest, 2000 to 2005 (Wyoming) and 2002-2006 to 2007-2011 (South Dakota). (Note: negative net growth indicates mortality exceeded gross growth). Error bars show the 68 percent confidence interval.

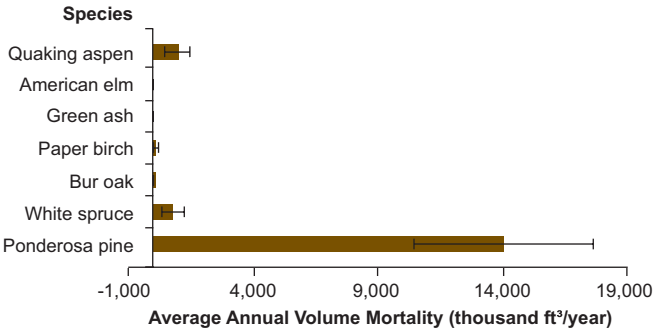

Figure 13.—Top species in terms of average annual net growing-stock volume mortality on timberland, Black Hills National Forest, 2000 to 2005 (Wyoming) and 2002-2006 to 2007-2011 (South Dakota). Error bars show the 68 percent confidence interval.

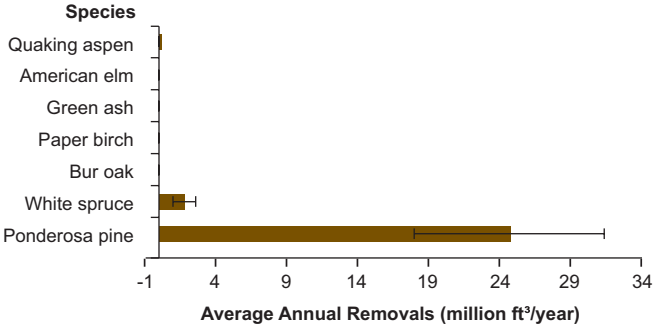

Figure 14.—Top species in terms of average annual net growing-stock volume removals per acre of timberland, Black Hills National Forest, 2000 to 2005 (Wyoming) and 2002-2006 to 2007-2011 (South Dakota). Error bars show the 68 percent confidence interval.

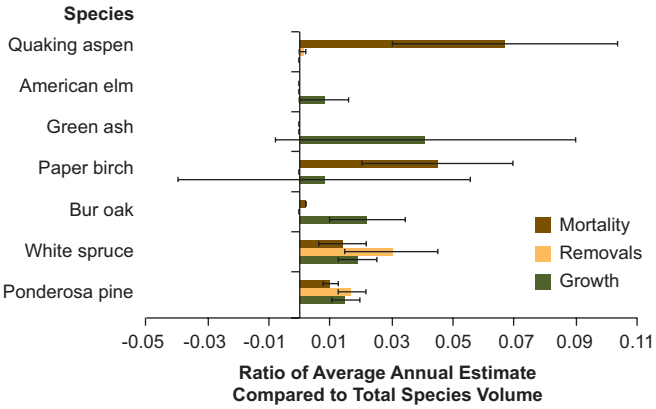

Figure 15.—Top species in terms of average annual net volume growth, mortality, and removals as a percent of total growing-stock volume on timberland, Black Hills National Forest, 2000 to 2005 (Wyoming) and 2002-2006 to 2007-2011 (South Dakota). Error bars show the 68 percent confidence interval.

What this means

Ponderosa pine fully dominates trends in growth, mortality, and removals in the BHNF. Given concerns about the stocking of ponderosa pine forests in light of wildfire and insect risks, active management in portions of the BHNF (e.g., salvage logging and density reduction harvests) has reduced stocking levels, resulting in a growth to removal ratio below 1, which may be reflected in the relatively low levels of ponderosa pine mortality compared to other species such as quaking aspen. The average annual mortality rate of ponderosa pine is less than that of growth and removals individually. Given the rates of mortality in species such as quaking aspen and paper birch, we would expect reductions in their contribution to overall tree species diversity into the future. In contrast, hardwood species such as bur oak and green ash have relatively high levels of growth in the context of their being a small component of overall BHNF volume, and could constitute larger portions of growing-stock volume in the distant future.

Carbon

Background

Collectively, forest ecosystems represent the largest terrestrial carbon sink on Earth. The accumulation of carbon in forests through sequestration helps to mitigate emissions of carbon dioxide to the atmosphere from sources such as forest fires and burning of fossil fuels. The FIA program does not directly measure forest carbon stocks in the BHNF. Instead, a combination of empirically derived carbon estimates (e.g., standing live trees) and models (e.g., carbon in soil organic matter based on stand age and forest type) are used to estimate the BHNF's forest carbon. Estimation procedures are detailed by Smith et al. (2006) and Woodall et al. (2011).

What we found

The BHNF currently contains more than 55 million tons of carbon. Soil organic matter (SOM) represents the largest forest ecosystem carbon stock in the BHNF at more than 24 million tons, followed by live trees, woodland species, and saplings at more than 18 million tons (Fig. 16). Within the live-tree, woodland species, and sapling pool, merchantable boles contain the bulk of the carbon (~ 11.7 million tons) followed by roots (~ 3.4 million tons) and stumps, tops, and limbs (~ 2.7 million tons). The majority of the BHNF's forest carbon stocks are found in moderately aged stands, 61 to 100+ years old (Fig. 17). Early in stand development, most of the forest ecosystem carbon is in the SOM and belowground tree components. As forest stands mature, the ratio of aboveground to belowground carbon shifts, and by the 81 to 100 age class the aboveground components represent the majority of ecosystem carbon. This trend continues well into stand development as carbon accumulates in live and dead aboveground components. A look at carbon by forest-type group on a per unit area basis found that six of the seven types have between 40 and 60 tons of carbon per acre (Fig. 18). Despite the similarity in per acre estimates, the distribution of forest carbon stocks by forest type is quite variable. In the ponderosa pine group, for example, 39 percent

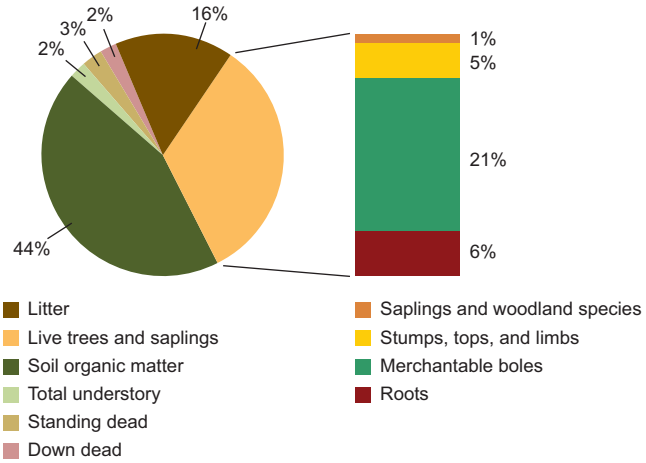

Figure 16.—Total carbon stocks on forest land by forest ecosystem component in the Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

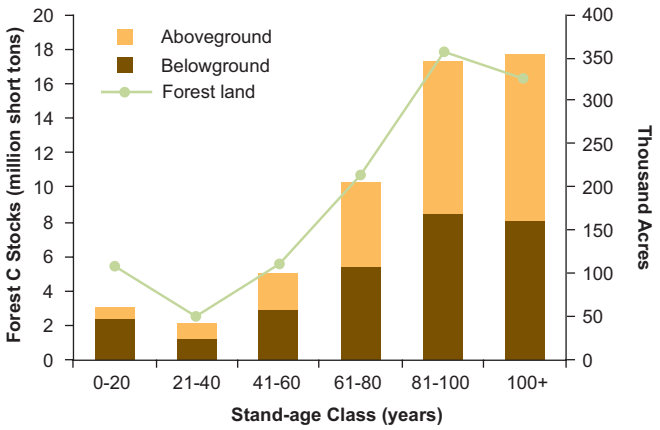

Figure 17.—Aboveground and belowground carbon stocks on forest land by stand-age class, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

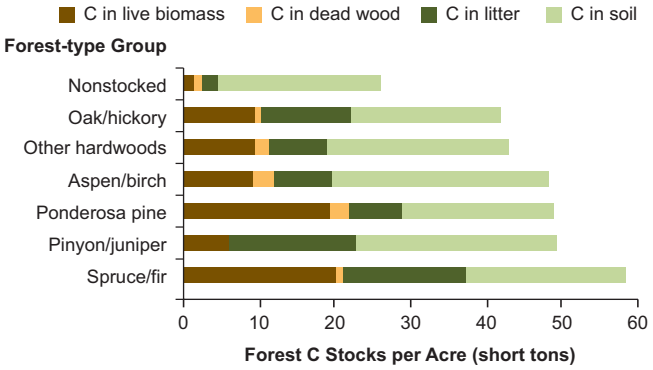

Figure 18.—Carbon stocks by forest-type group and carbon pool per acre of forest land, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

(~ 19 tons per acre) of the forest carbon is in the live biomass, but in the pinyon/juniper group only 12 percent (~ 6 tons per acre) is in the living material.

What this means

Carbon stocks in the forested components of the BHNF have increased substantially over the last several decades. The majority of forest carbon in the BHNF is found in moderately aged stands dominated by a relatively long-lived conifer species. This finding suggests that the BHNF forest carbon is generally expected to continue to increase as stands mature and accumulate carbon in aboveground and belowground components. Given the age class structure and species composition of forests in the BHNF, there may be opportunities to increase forest carbon stocks.

Standing Dead Trees (Snags)

Background

Standing dead trees (snags), from the time they die until they are fully decomposed, contribute to the structure and function of forest ecosystems. Snags are created naturally by extreme weather events, fire, insects, and pathogens, and these same biotic and abiotic agents contribute to the decomposition of standing dead wood. Until recently, the FIA program did not directly measure standing dead trees in the BHNF. Instead, estimates of standing dead tree biomass were modeled using geographic area, forest type, and growing-stock volume (Woudenberg et al. 2010). Standing dead trees are now measured directly and estimates of aboveground biomass are adjusted to account for density reductions and structural loss by decay class (Domke et al. 2011).

What we found

The nearly 20 million standing dead trees (at least 5 inches d.b.h./d.r.c.) in the BHNF contain more than 2.4 million tons of aboveground biomass. The majority of snag biomass (1.7 million oven-dry short tons) is found in the early stages of decomposition (see Domke et al. 2011 for a description of decay classes) in decay classes 1 to 3 (Fig. 19). Not surprisingly, the ponderosa pine forest-type group represents the largest proportion (62 to 88 percent) of biomass in each decay class. The majority (61 percent) of standing dead trees are found in the smallest diameter classes (5.0 to 9.0 inches d.b.h.); however, the bulk of the aboveground biomass is found in slightly larger diameter classes (7.0 to 15.0 inches d.b.h.) (Fig. 20). Ponderosa pine is the dominant forest type across diameter classes, and the proportion of the ponderosa pine type generally increases with increasing diameter. A look at the number of standing dead trees

per unit area across the elevation gradient in the BHNF suggests, in general, that the number of standing dead trees per acre increases with increasing elevation (Fig. 21). Furthermore, the ratio of live to standing dead aboveground biomass decreases with increasing elevation, suggesting that standing dead trees, while present at all elevations, make up a much larger proportion of high elevation forests in the BHNF.

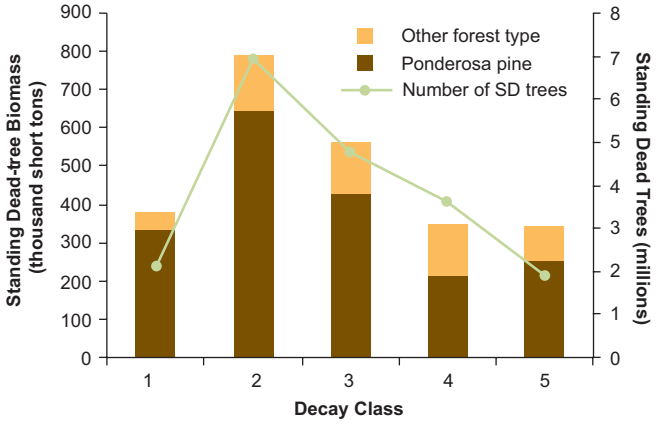

Figure 19.—Number of standing dead trees and aboveground biomass (oven-dry short tons) by decay class, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

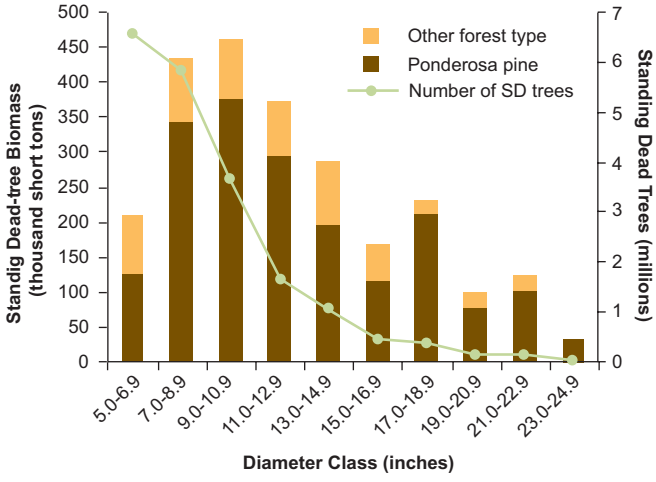

Figure 20.—Number of standing dead trees and aboveground biomass by diameter (d.b.h./d.r.c.) class, Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

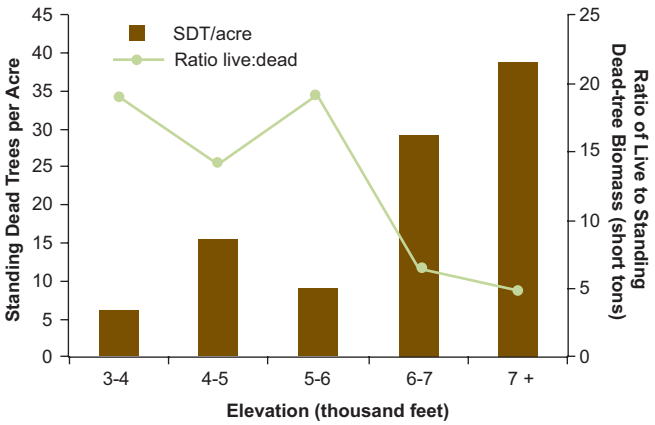

Figure 21.—Number of standing dead trees per acres by elevation and the ratio of live to standing dead tree biomass (short tons) in the Black Hills National Forest, 2005 (Wyoming) and 2007-2011 (South Dakota).

What this means

The MPB, once called the Black Hills beetle, has led to documented large-scale tree mortality pre-dating the establishment of the BHNF. Given the large proportion of ponderosa pine in the BHNF and the cyclical nature of MPB outbreaks as well as other mortality agents such as fires that have resulted in about 25 percent of the BHNF burned at some level since 2000, it is not surprising that there is a substantial amount of standing dead tree biomass across all stages of decay. The majority of standing dead trees in the BHNF are small and in the early stages of decay, suggesting relatively recent mortality. Early thinning treatments aimed at capturing mortality, decreasing fuel loads, and reducing stem density, particularly at high elevations, in stands that have historically been deemed sub-merchantable may now be an option given renewed interest in biomass utilization for energy. The MPB and fire, among other biotic and abiotic agents, are important to the structure and function of forest ecosystems in the BHNF. In the face of global change, maintaining a balance between standing dead tree structural attributes and fire danger will continue to require specific planning considerations and creative silviculture.

Down Woody Materials

Background

Down woody materials, in the various forms of fallen trees and litter fall, provide numerous ecological niches in the BHNF (e.g., wildlife habitat and stand structural diversity) while contributing toward forest fire hazards via surface woody fuels.

What we found

The down woody materials in the BHNF are dominated by litter and coarse woody debris (down dead wood with a minimum diameter of 3 inches and minimum length of 3 feet) (Fig. 22). The percentages of the total down woody materials represented by fine woody debris, coarse woody debris, duff, and litter were 10, 26, 13, and 51 percent, respectively. The fuel loadings of down woody materials (time-lag fuel classes) in ponderosa pine forests of the BHNF were compared to the same forest type in the neighboring state of Montana (for fuel definitions see Woodall and Monleon 2008) (Fig. 23). Given the large sampling errors associated with the estimates, we cannot make definitive conclusions, but we can say that loadings of coarse woody debris and litter in the ponderosa pine forests of the BHNF were nearly four times larger than Montana's.

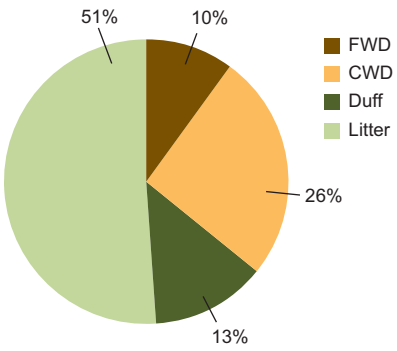

Figure 22.—Proportion of total down woody material biomass by down woody material component on forest land, Black Hills National Forest, 2005 (Wyoming) and 2006-2011 (South Dakota).

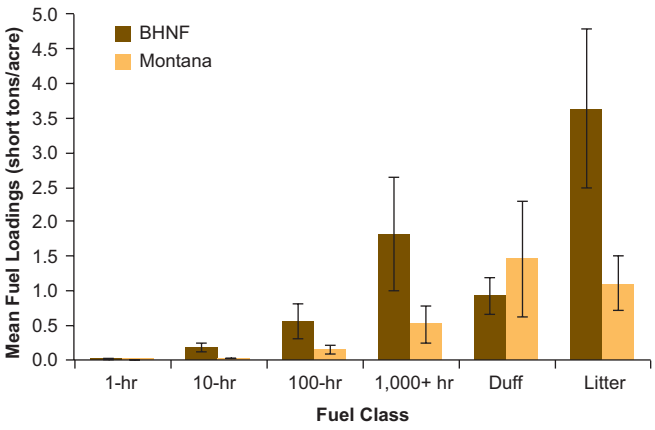

Figure 23.—Mean fuel loadings (tons per forest land acre) and associated sampling errors by fuel class of ponderosa pine forests in Black Hills National Forest and Montana, 2005 (Wyoming) and 2006-2011 (South Dakota and Montana).

What this means

The BHNF's fuel loadings may be viewed as moderate within the larger context of national forests of the U.S., despite having down dead wood fuel loadings potentially larger for some fuel categories (e.g., litter) than ponderosa pine forests in Montana, a neighboring western state. Fuel loads typically increase in response to disturbances such as wind or mortality events; however, despite the many years of mortality from MPB the BHNF fuel load does not appear to be excessive when compared to other disturbance events. A blowdown disturbance in the Superior National Forest of Minnesota produced fuel loads five times greater than seen in the BHNF (Woodall and Nagel 2007). However, the combination of continuing tree mortality, coupled with the potential for drought in the BHNF, suggests the need for continued monitoring and potential mitigation of fire hazards (i.e., down woody material fuels) in varying areas of the BHNF landscape.

Forest Economics

Sunday Gulch Timber Sale, 2010. Photo by Beth Steinhauer, U.S. Forest Service, Black Hills National Forest.

Growing-Stock and Sawtimber Volume

Background

Growing-stock volume is the amount of merchantable wood in live commercial tree species that are sound, reasonably straight, and 5 inches d.b.h. or greater. This measure has traditionally been used to estimate the volume of wood material available for the manufacture of timber products. Sawtimber trees are live trees of commercial species that contain either one 12-foot or two noncontiguous 8-foot logs that are free of defect. Hardwoods must be at least 11 inches d.b.h. and softwoods must be 9 inches d.b.h. to qualify as sawtimber. Sawtimber volume is defined as the net volume of the saw log portion of a tree, measured in board feet, from a 1-foot stump to the merchantable top (9 inches for hardwoods and 7 inches for softwoods). Estimates of sawtimber volume are used to determine the monetary value of wood volume and to identify the quantity of merchantable wood. Knowing both measures of volume is important for economic planning and development, and are essential when evaluating sustainable forest management.

A system of standards, called tree grades, are used to rate the quality of a tree for producing forest products. The meanings differ by species group, but grade one is the highest quality. The quality decreases as the grade number increases up to grade five. Many factors affect the grading including defects, curvature, and length of usable sections in the saw log portion. See U.S. Forest Service (2010), Appendix E, for the grading specifications.

What we found

The net volume of growing stock on timberland in the BHNF was estimated at 1.51 billion cubic feet, or 1,325 cubic feet of growing stock per acre of timberland. The spruce/fir forest-type group had the highest volume of growing stock per acre of timberland, despite being a distant second place behind the ponderosa pine group in terms of net growing-stock volume (Fig. 24). Not surprisingly, ponderosa pine trees accounted for more than 1.43 billion cubic feet (94 percent) of the total growing-stock volume. All hardwood species combined for 22.6 million cubic feet. Quaking aspen made up 63 percent of the total hardwood growing-stock volume.

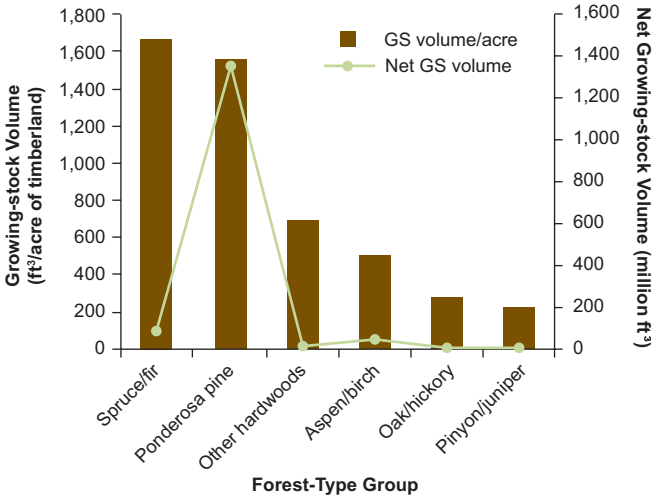

Figure 24.—Net volume of growing stock per acre of timberland and net growing-stock volume on timberland by forest-type group, Black Hills National Forest, 2005 (Wyoming) and 2006-2011 (South Dakota).

The net sawtimber volume on BHNF timberland was estimated at more than 4.98 billion board feet (Scribner rule), which includes volume that may be located on inaccessible sites (e.g., steep slopes or access restrictions due to private land). More than one-third of the total sawtimber volume was in the 13.0- to 14.9-inch and 15.0- to 16.9-inch diameter classes (Fig. 25). In terms of sawtimber quality, 72 percent of sawtimber volume came from grade three trees while only slightly more than 1 percent of the volume was graded less than grade three (Fig. 26). For white spruce, 83 percent of total sawtimber volume came from grade one trees.

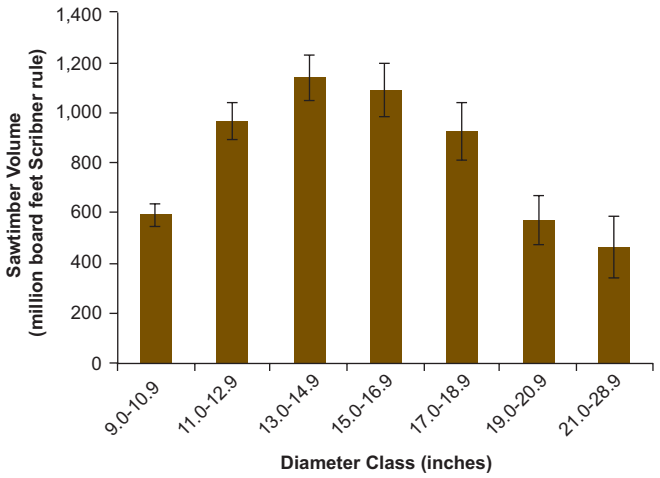

Figure 25.—Sawtimber volume (Scribner rule) on timberland by diameter class, Black Hills National Forest, 2005 (Wyoming) and 2006-2011 (South Dakota). Error bars show the 68 percent confidence interval.

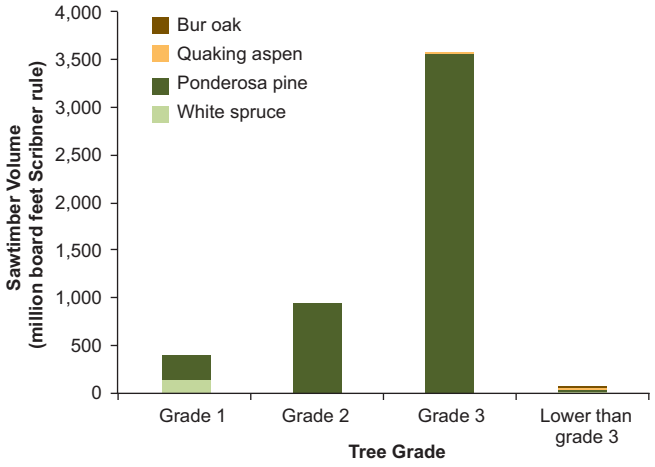

Figure 26.—Sawtimber volume (Scribner rule) by species and tree grade, Black Hills National Forest, 2005 (Wyoming) and 2006-2011 (South Dakota).

What this means

Although the BHNF is currently experiencing a MPB epidemic that is increasing tree mortality, abundant live growing-stock and sawtimber volume is still available. While a majority of sawtimber is not in the top quality grade, it is still an important asset to the timber products industry of the surrounding Black Hills region.

Timber Products Output

Background

The harvesting and processing of timber products produces a stream of income shared by timber owners, managers, marketers, loggers, truckers, and processors. In 2007, the wood products and paper manufacturing industries (NAICS codes 321 and 322) in South Dakota, where most of the BHNF is located, employed about 2,470 people, with an average annual payroll of $86.1 million and total value of shipments of $560.9 million (U.S. Census Bureau 2007). To strengthen the commercial wood production portion of multiple use management of the BHNF, it is important to know the species, amounts, and locations of timber being harvested.

In 2009, a cooperative effort between the South Dakota Department of Agriculture, Resource Conservation and Forestry Division (SDRCF) and the Northern Research Station (NRS-FIA) used a questionnaire designed to determine the size and composition of South Dakota's forest products industry, its use of roundwood (round sections cut from trees), and its generation and disposition of wood residues. SDRCF personnel contacted via mail and telephone all primary wood-using mills in the State. Completed questionnaires were sent to NRS-FIA for processing. To compile data to include in this report, mills were later contacted and asked what percent of the wood processed at the mill came from the BHNF. A similar study was conducted for the mills in Wyoming in 2010 by the University of Montana's Bureau of Business and Economic Research, Forest Industry Research program. As part of data processing, all industrial roundwood volumes reported were converted to standard units of measure using regional conversion factors. Data on industrial roundwood receipts at mills drawing from the BHNF were added to a regional timber removals database to provide a complete assessment of the BHNF's timber products output.

What we found

In 2009, there were 14 active primary wood-using mills that processed 29.3 million cubic feet of industrial roundwood from the BHNF into lumber, particleboard, posts, and other wood products. Eighty-two percent of the total was harvested in the South Dakota portion of the forest, and the remainder was processed in Wyoming. The BHNF is so important to South Dakota's forest products industry that more than 80 percent of the industrial roundwood processed in the State came from the BHNF. Saw logs accounted for 97 percent of the industrial roundwood harvested from the BHNF (Fig. 27). Other products harvested were posts, pulpwood, and cabin logs. Ponderosa pine accounted for 99 percent of the industrial roundwood. A small amount of white spruce was also harvested.

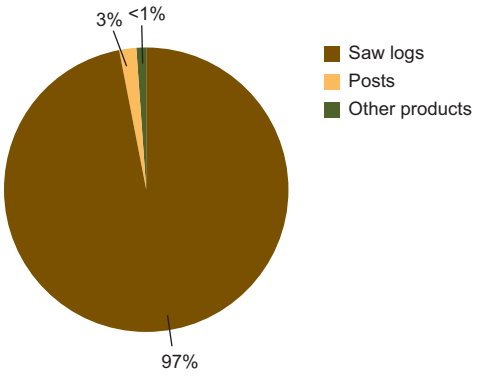

Figure 27.—Industrial roundwood products harvested from the Black Hills National Forest, 2009.

What this means

Harvesting of industrial roundwood on the BHNF provides not only forest products, but also an economic means to thin dense stands that are susceptible to MPB and forest fires. Some forest stands are being thinned without markets for the wood in an attempt to reduce the potential for MPB to access certain areas across the landscape during the current epidemic that has been affecting the BHNF for a decade or more, while also reducing forest fire hazards. This requires that the wood be stacked and burned to potentially reduce the severity of and aid in suppressing potential future wildfires. An improvement in the economy may lead to an increase in the markets for this unused wood material. This material could also be a supply source for a small, local biomass-based facility (e.g., wood pellets).

Data Sources and Techniques

Aerial photography of Inyan Kara Mountain, Bearlodge Region of the Black Hills National Forest.
Photo by Gary Chancey, U.S. Forest Service, Black Hills National Forest.

Forest Inventory

Information on the condition and status of forests in the Black Hills National Forest was obtained from the Northern Research Station's Forest Inventory and Analysis (NRS-FIA) program. The inventory in South Dakota was performed under an annual inventory system in which one-fifth of the field plots (considered one panel) in the State are measured each year. The entire inventory is completed every 5 years. Annual inventory has been done in South Dakota since 2001. Historically, FIA inventoried each state on a periodic cycle that averaged about 12 years. The need for timely and consistent data across large geographical regions along with national legislative mandates resulted in the annual inventory program. As of yet, an annual inventory has not been completed in the state of Wyoming, making an inventory of the BHNF an especially challenging endeavor. The last periodic inventory occurred in Wyoming in the year 2000 and was performed by the Interior West Forest Inventory and Analysis (IW-FIA) program. In cooperation with the BHNF, field crews from NRS-FIA measured 35 plots in the BHNF on the Wyoming side in 2005 so a complete report could be compiled. Data for this report include the most recent 5-year inventory period for the South Dakota portion of the BHNF, 2007–2011 and the 2005 Wyoming data. Growth, removals, and mortality (GRM) estimates were made using the 2002–2006 South Dakota inventory and the 2000 Wyoming inventory. The 2000 periodic inventory for Wyoming was valid for GRM estimation because the plot design was similar to the national annual inventory plot design; however, because of regional differences in data compilation between NRS-FIA and IW-FIA, unique data compilation procedures had to be developed.

Inventories are conducted in three phases. During the first phase, aerial photographs, digital orthoquads (DOQs), and satellite imagery are used for initial plot measurement via remotely sensed data and stratification. Analysts determine a digitized geographic location for each field plot and a human interpreter assigns the plot a land cover/use. All plot locations that could possibly contain accessible forest lands that satisfy FIA's definition of forest land are selected for further measurement via field crew visits.

The second phase of the inventory consists of measuring the annual sample of field plots. Current FIA precision standards require a sampling intensity of one plot for approximately every 6,000 acres. FIA has divided the entire area of the United States into nonoverlapping hexagons, each of which contains 5,937 acres (McRoberts 1999). The total Federal base sample of plots was systematically divided into five interpenetrating, nonoverlapping subsamples or panels. Each year the plots in a single panel are measured, and panels are selected on a 5-year, rotating basis. For estimation purposes, the measurement of each panel of plots may be considered an independent systematic sample of all land in a state. Field crews measure vegetation on plots forested at the time of the last inventory and on plots currently classified as forest by trained photointerpreters using aerial photos or DOQs. In this BHNF inventory only plots from the South Dakota inventory that were completely or partially on BHNF land were included in the data compilation in addition to the supplemental Wyoming plots that were all completely on BHNF land.

The overall Phase 2 (P2) plot layout consists of four subplots. The centers of subplots 2, 3, and 4 are located 120 feet from the center of subplot 1. The azimuths to subplots 2, 3, and 4 are 0, 120, and 240 degrees, respectively. Trees with a d.b.h./d.r.c. 5 inches and larger are measured on a 24-foot-radius (1/24 acre) circular subplot. All trees less than 5 inches d.b.h. are measured on a 6.8-foot-radius (1/300 acre) circular microplot located 12 feet east of the center of each of the four subplots. Forest conditions that occur on any of the four subplots are recorded. Factors that differentiate forest conditions are changes in forest type, stand-size class, land use, ownership, and density.

The third phase focuses on forest health. Phase 3 (P3) plots consist of a 1:16 subset of P2 plots with one P3 plot for about every 95,000 acres. Measurements on these plots are obtained by field crews during

the growing season and include an extended suite of ecological data such as down woody material. Further information about P2 and P3 data collection can be found at http://fia.fs.fed.us/library/fact-sheets/.

A Comparison of Volume Models for Ponderosa Pine

The volume of a tree can be precisely determined by immersing it in a pool of water and measuring the amount of water displaced. Because such a process is destructive and cost prohibitive, models of tree volume based on tree metrics (e.g., tree diameter) must be used to estimate volume. Often, there are a variety of tree volume models for common tree species. For ponderosa pine in the BHNF, FIA-NRS uses tree volume equations based on Myers (1964).

Other tree volume equations have been developed for ponderosa pine in the BHNF, most notably, the Flewelling profile model (based on work presented in Flewelling and Raynes 1993 and Flewelling 1993) and the Czaplewski profile model (Czaplewski et al. 1989). The Myers volume equation relies on species, d.b.h., and total height to calculate tree net volume (from a 1-foot stump to a 4-inch top); the Flewelling and Czaplewski profile models also require the height to the merchantable top (4.0 inches). To compare the Myers tree volume equation to the Flewelling and Czaplewski versions, Microsoft Excel Volume Functions were installed from the National Volume Estimator Library (NVEL) Web site located at: http://www.fs.fed.us/fmsc/measure/volume/nvel/index.php. The NVEL Excel Volume Functions allow tree volumes to be calculated using different volume equations.

NRS-FIA estimated that the net volume of live ponderosa pine trees 5 inches in diameter or greater on forest land in the BHNF was 1.5 billion cubic feet using the Myers tree volume equations (Fig. 28). The NVEL Excel Volume Functions produced an estimate of 1.6 billion cubic feet using the Czaplewski profile model (a difference of 6 percent) and 1.4 billion cubic feet using the Flewelling profile model (a difference of -9 percent).

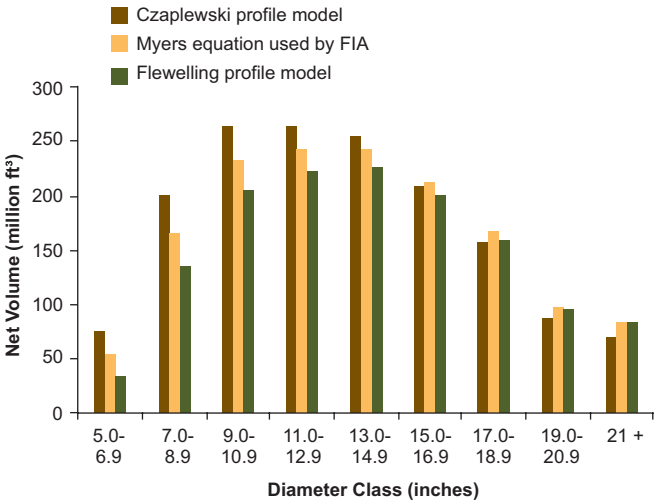

Figure 28.—Net volume of live ponderosa pine trees (at least 5 inches d.b.h./d.r.c.), in million cubic feet, on forest land by diameter class and volume equation model, Black Hills National Forest, 2005 (Wyoming) and 2006-2011 (South Dakota).

When looking at the estimated tree volumes among a variety of models, it is important to assess differences across a range of diameters. For ponderosa pine in South Dakota, the Czaplewski profile model appears to provide larger estimates of small-diameter tree volume and smaller estimates of large-diameter tree volume compared to the Myers volume equation. On the other hand, the Flewelling profile model had smaller estimates of small-diameter tree volume when compared with the Myers volume equation; however, as the tree diameter became larger, the difference between the two was reduced. The difference between the total net volume of ponderosa pine trees 21 inches or greater using Myers volume equations and the Flewelling profile model was less than 0.5 percent.

Glossary

All live tree: All living trees. All size classes, all tree classes, and both saw log and non-saw log species are included.

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

Average annual net growth: The average annual change in the volume of trees between inventories. Components include the change in volume of trees that have met the minimum size requirements over the inventory period, plus the volume of trees reaching the minimum size during the period (ingrowth), minus the volume of trees that died during the period, minus the volume of cull during the period. Mortality removals (trees killed in the harvesting process and left on site) and diversion removals (trees removed from the forest land base due to a change from forest to nonforest land) are not included. This estimate can be provided in cubic feet for live and growing-stock trees or in board feet for sawtimber trees.

Average annual removals: The average annual change in removals of trees between inventories. The estimate includes harvest removals, mortality removals (trees killed in the harvesting process and left on site), and diversion removals (trees removed from the forest land base due to a change from forest to nonforest land). This estimate can be provided in cubic feet for live and growing-stock trees or in board feet for sawtimber trees.

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

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

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

1-to 5-inch trees: Total aboveground biomass of a tree from 1 to 5 inches d.b.h.

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

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

Coarse woody debris (CWD): Dead branches, twigs, and wood splinters 3.0 inches in diameter and larger measured at the smallest end.

Commercial species: Tree species suitable for industrial wood products.

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

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

Diameter at breast height (d.b.h.): The diameter of a tree stem, located at 4.5 feet above the ground (breast height) on the uphill side of a tree. The point of diameter measurement may vary on abnormally formed trees.

Diameter at root collar (d.r.c.): The diameter of a tree (usually a woodland species), measured outside of the bark at the ground line or stem root collar.

Diameter class: A classification of trees based on d.b.h./d.r.c. With 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches d.b.h.

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

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

Duff: A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) no longer can be identified.

Epidemic: (1) Entomology: pertaining to populations of plants, animals, and viruses that build up, often rapidly, to unusually and generally injuriously high levels. Synonym: outbreak. Many insect and other animal populations cycle periodically or irregularly between endemic and epidemic levels. (2) Pathology: a disease sporadically infecting a large number of hosts in an area and causing considerable loss (Helms 1998).

Fiber products: Products derived from wood and bark residues, such as pulp, composition board products, and wood chips.

Fine woody debris (FWD): Dead branches, twigs, and wood splinters 0.1 to 2.9 inches in diameter.

Forest land: Land at least 10 percent stocked by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with trees and forest areas adjacent to urban and builtup lands. Also included are pinyon-juniper and chaparral areas and afforested areas. The minimum area for classification of forest land is 1 acre and 120 feet wide measured stem-to-stem from the outermost edge. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest type: A classification of forest land based on the species presently forming a plurality of the live-tree stocking. If softwoods predominate (50 percent or more), then the forest type will be one of the softwood types and vice versa for hardwoods.

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

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

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

100-hour fuels: Fine woody debris with a transect diameter between 1.0 and 2.9 inches.

10-hour fuels: Fine woody debris with a transect diameter between 0.25 and 0.9 inches.

1-hour fuels: Fine woody debris with a transect diameter < 0.24 inches.

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

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

Soft hardwoods: A category of hardwood species with wood generally of low specific gravity (less than 0.5). Notable examples include red maple, paper birch, quaking aspen, and American elm.

Hard hardwoods: A category of hardwood species with wood generally of high specific gravity (greater than 0.5). Notable examples include sugar maple, yellow birch, black walnut, and oaks.

Industrial wood: All commercial roundwood products except fuelwood.

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

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

Mean annual increment (MAI) at culmination: A measure of the productivity of forest land expressed as the average increase in cubic feet of wood volume per acre per year. For a given species and site index, the mean is based on the age at which the MAI culminates for fully stocked natural stands. The MAI is based on the site index of the plot (Azuma et al. 2004).

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

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

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

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

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

Nonstocked areas: Timberland less than 10 percent stocked with live trees.

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

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

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

Reserved forest land: Forest land withdrawn from timber utilization through statute, administrative regulation, or designation without regard to productive status.

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

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

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

Roundwood products: Logs, bolts, and other round timber generated from harvesting trees for industrial or consumer use.

Salvable dead tree: A downed or standing dead tree considered currently or potentially merchantable by regional standards.

Sampling error: Difference between a population value and a sample estimate that is attributable to the sample, as distinct from errors due to bias in estimation, errors in observation, etc. Sampling error is measured as the standard error of the sample estimate (Helms 1998).

Saplings: Live trees 1.0 inch through 4.9 inches d.b.h.

Saw log: A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards.

Sawtimber tree: A live tree of commercial species containing at least a 12-foot saw log or two noncontiguous saw logs 8 feet or longer, and meeting regional specifications for freedom from defect. Softwoods must be at least 9.0 inches d.b.h. Hardwoods must be at least 11.0 inches d.b.h.

Sawtimber volume: Net volume of the saw log portion of live sawtimber in board feet, International ¼-inch rule (unless specified otherwise), from stump to a minimum 7.0 inches top d.o.b. for softwoods and a minimum 9.0 inches top d.o.b. for hardwoods.

Seedlings: Live trees less than 1.0 inch d.b.h. and at least 1 foot in height.

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

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

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

Stand age: A stand descriptor that indicates the average age of the live dominant and codominant trees in the predominant stand-size class of a condition.

Stand origin: A classification of forest stands describing their means of origin.

Planted: Planted or artificially seeded.

Natural: No evidence of artificial regeneration.

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

Sawtimber: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of sawtimber is at least equal to that of poletimber.

Poletimber: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of poletimber exceeds that of sawtimber.

Seedling-sapling: Forest land stocked with at least 10 percent of full stocking with live trees with half or more of such stocking in seedlings or saplings or both.

Nonstocked: Forest land stocked with less than 10 percent of full stocking with live trees. Examples are recently cutover areas or recently reverted agricultural fields.

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

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

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

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

Tree grade: A classification of the sawlog portion of sawtimber trees based on (1) the grade of the butt log, or (2) the ability to produce at least one 12-foot or two 8-foot logs in the upper section of the sawlog portion. Tree grade is an indicator of quality; grade one is the best quality (see U.S. Forest Service 2010, Appendix E for grading specifications).

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

Sawtimber-size trees: Softwood timber species ≥ 9.0 inches d.b.h., and hardwood timber species ≥ 11.0 inches d.b.h.

Poletimber-size trees: Softwood timber species 5.0 to 8.9 inches d.b.h. and hardwood timber species 5.0 to 10.9 inches d.b.h.

Saplings: Live trees 1.0 inch through 4.9 inches d.b.h.

Seedlings: Live trees less than 1.0 inch d.b.h. and at least 1 foot in height.

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

Upper stem portion: Portion of a sawtimber tree that is above the saw log portion. Begins at a top of 7 inches d.o.b. for softwoods and 9.0 inches d.o.b. for hardwoods, or where the central stem breaks into limbs.

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Tables

Table 1.—Area of forest land, in thousand acres, by forest-type group, forest type, and owner category, Black Hills National Forest, 2011

Forest-type group/forest type	Owner category			
	All owners	Public	Private	Unidentified owner
Softwood type groups				
Spruce / fir group				
White spruce	51.6	51.6	--	--
All forest types	51.6	51.6	--	--
Pinyon / juniper group				
Rocky Mountain juniper	11.3	11.3	--	--
All forest types	11.3	11.3	--	--
Ponderosa pine group				
Ponderosa pine	884.9	881.4	3.6	--
All forest types	884.9	881.4	3.6	--
All softwood groups	947.9	944.3	3.6	--
Hardwood type groups				
Oak / hickory group				
Bur oak	25.1	25.1	--	--
Mixed upland hardwoods	5.7	5.7	--	--
All forest types	30.8	30.8	--	--
Aspen / birch group				
Aspen	83.8	83.8	--	--
Paper birch	5.3	5.3	--	--
Pin cherry	4.3	4.3	--	--
All forest types	93.4	93.4	--	--
Other hardwoods group				
Other hardwoods	15.8	15.8	--	--
All forest types	15.8	15.8	--	--
All hardwood groups	140	140	--	--
Nonstocked	75.2	75.2	--	--
All forest groups	1,163.2	1,159.6	3.6	--

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 2.—Area of timberland, in thousand acres, by major forest-type group, stand origin, and owner category, Black Hills National Forest, 2011

Major forest-type group and stand origin	Owner category			
	All owners	Public	Private	Unidentified owner
Softwood type groups				
Natural	928.2	924.6	3.6	--
Planted	6.1	6.1	--	--
All softwood types	934.3	930.7	3.6	--
Hardwood type groups				
Natural	128.7	128.7	--	--
Planted	5.7	5.7	--	--
All hardwood types	134.4	134.4	--	--
Nonstocked	70.1	70.1	--	--
All groups	1,138.7	1,135.2	3.6	--

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 3.—Area of timberland, in thousand acres, by forest-type group, forest type, and stand-size class, Black Hills National Forest, 2011

Forest-type group/forest type	Stand-size class				
	All stands	Sawtimber	Poletimber	Sapling-seedling	Nonstocked
Softwood type groups					
Spruce / fir group					
White spruce	51.6	51.6	--	--	--
All forest types	51.6	51.6	--	--	--
Pinyon / juniper group					
Rocky Mountain juniper	11.3	11.3	--	--	--
All forest types	11.3	11.3	--	--	--
Ponderosa pine group					
Ponderosa pine	871.3	683.8	90.6	96.9	--
All forest types	871.3	683.8	90.6	96.9	--
All softwood groups	934.3	746.7	90.6	96.9	--
Hardwood type groups					
Oak / hickory group					
Bur oak	25.1	--	--	25.1	--
Mixed upland hardwoods	5.7	--	--	5.7	--
All forest types	30.8	--	--	30.8	--
Aspen / birch group					
Aspen	78.2	5.7	26.5	46.0	--
Paper birch	5.3	--	5.3	--	--
Pin cherry	4.3	--	--	4.3	--
All forest types	87.8	5.7	31.9	50.2	--
Other hardwoods group					
Other hardwoods	15.8	--	--	15.8	--
All forest types	15.8	--	--	15.8	--
All hardwood groups	134.4	5.7	31.9	96.8	--
Nonstocked	70.1	--	--	--	70.1
All forest groups	1,138.7	752.4	122.5	193.8	70.1

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 4.—Net volume of live trees (at least 5 inches d.b.h./d.r.c.), in thousand cubic feet, on forest land by species group, species, and owner category, Black Hills National Forest, 2011

Species group/species	Owner category			
	All owners	Public	Private	Unidentified owner
Softwoods				
Ponderosa and Jeffery pines				
Ponderosa pine	1,497,487	1,490,821	6,666	--
All species	1,497,487	1,490,821	6,666	--
Engelmann and other spruces				
White spruce	66,650	66,650	--	--
All species	66,650	66,650	--	--
Woodland softwoods				
Rocky Mountain juniper	5,815	5,815	--	--
All species	5,815	5,815	--	--
Total softwoods	1,569,953	1,563,287	6,666	--
Hardwoods				
Cottonwood and aspen				
Quaking aspen	21,383	21,383	--	--
All species	21,383	21,383	--	--
Other western hardwoods				
Paper birch	4,467	4,467	--	--
Green ash	656	656	--	--
Eastern hophornbeam	175	175	--	--
Bur oak	7,284	7,284	--	--
American elm	281	281	--	--
All species	12,864	12,864	--	--
Total hardwoods	34,246	34,246	--	--
All species groups	1,604,199	1,597,533	6,666	--

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 5.—Net volume of live and salvable dead trees (at least 5 inches d.b.h./d.r.c.), in thousand cubic feet, on timberland by class of timber and softwood/hardwood species category, Black Hills National Forest, 2011

Class of timber	All species	Softwood species	Hardwood species
Live trees			
Growing-stock trees			
Sawtimber			
Saw log portion	1,093,999	1,092,200	1,799
Upper stem portion	182,432	181,762	670
Total	1,276,431	1,273,961	2,470
Poletimber	235,971	215,817	20,154
All growing-stock trees	1,512,402	1,489,779	22,624
Cull trees			
Rough trees[a]			
Sawtimber size	39,651	39,276	375
Poletimber size	16,237	10,159	6,078
Total	55,888	49,435	6,453
Rotten trees[a]			
Sawtimber size	3,320	2,049	1,271
Poletimber size	1,312	--	1,312
Total	4,632	2,049	2,583
All live cull trees	60,520	51,484	9,036
All live trees	1,572,922	1,541,262	31,660
Salvable dead trees			
Sawtimber size	45,982	45,982	--
Poletimber size	20,517	17,071	3,445
All salvable dead trees	66,498	63,053	3,445
All classes	1,639,420	1,604,315	35,105

All table cells without observations in the inventory sample are indicated by --. Table value of 0 indicates the volume rounds to less than 1 thousand cubic feet. Columns and rows may not add to their totals due to rounding.
[a]Includes noncommercial species.

Table 6.—Net volume of growing-stock trees (at least 5 inches d.b.h./d.r.c.), in thousand cubic feet, on timberland by forest-type group, forest type, and softwood/hardwood species category, Black Hills National Forest, 2011

Forest-type group/forest type	All species	Softwood species	Hardwood species
Softwood type groups			
Spruce / fir group			
White spruce	85,943	84,169	1,774
All forest types	85,943	84,169	1,774
Pinyon / juniper group			
Rocky Mountain juniper	2,551	2,551	--
All forest types	2,551	2,551	--
Ponderosa pine group			
Ponderosa pine	1,356,944	1,347,796	9,147
All forest types	1,356,944	1,347,796	9,147
All softwood groups	1,445,438	1,434,517	10,921
Hardwood type groups			
Oak / hickory group			
Bur oak 4,696	3,560	1,136	
Mixed upland hardwoods	3,911	3,870	41
All forest types	8,607	7,430	1,177
Aspen / birch group			
Aspen 41,533	32,234	9,300	
Paper birch	2,104	1,223	882
Pin cherry 489	489	--	
All forest types	44,127	33,946	10,181
Other hardwoods group			
Other hardwoods	10,956	10,647	309
All forest types	10,956	10,647	309
All hardwood groups	63,690	52,023	11,668
Nonstocked	3,274	3,239	35
All forest groups	1,512,402	1,489,779	22,624

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 7.—Net volume of growing-stock trees (at least 5 inches d.b.h./d.r.c.), in thousand cubic feet, on timberland by species group, species, and diameter class, Black Hills National Forest, 2011

	Diameter class (inches at breast height)										
Species group/species	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	21.0-28.9	29.0+
Softwoods											
Ponderosa and Jeffery pines											
Ponderosa pine	1,432,614	48,433	156,770	219,402	235,267	235,013	201,322	162,759	97,222	76,427	--
All species	1,432,614	48,433	156,770	219,402	235,267	235,013	201,322	162,759	97,222	76,427	--
Engelmann and other spruces											
White spruce	57,164	4,161	6,453	9,043	9,323	9,383	11,371	5,491	1,940	--	--
All species	57,164	4,161	6,453	9,043	9,323	9,383	11,371	5,491	1,940	--	--
Total softwoods	1,489,779	52,594	163,223	228,444	244,591	244,396	212,693	168,250	99,162	76,427	--
Hardwoods											
Cottonwood and aspen											
Quaking aspen	14,451	3,675	7,601	2,241	934	--	--	--	--	--	--
All species	14,451	3,675	7,601	2,241	934	--	--	--	--	--	--
Other western hardwoods											
Paper birch	3,064	1,619	1,446	--	--	--	--	--	--	--	--
Green ash	532	--	532	--	--	--	--	--	--	--	--
Bur oak	4,457	996	1,019	907	927	608	--	--	--	--	--
American elm	119	--	119	--	--	--	--	--	--	--	--
All species	8,172	2,615	3,115	907	927	608	--	--	--	--	--
Total hardwoods	22,624	6,290	10,716	3,148	1,861	608	--	--	--	--	--
All species groups	1,512,402	58,884	173,939	231,592	246,452	245,005	212,693	168,250	99,162	76,427	--

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 8a.—Net volume of sawtimber trees, in thousand board feet (International ¼-inch rule), on timberland by species group, species, and diameter class, Black Hills National Forest, 2011

Species group/species	Diameter class (inches at breast height)								
	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	21.0-28.9	29.0+
Softwoods									
Ponderosa and Jeffery pines									
Ponderosa pine	5,547,481	555,517	923,216	1,097,763	1,044,370	901,655	561,617	463,343	--
All species	5,547,481	555,517	923,216	1,097,763	1,044,370	901,655	561,617	463,343	--
Engelmann and other spruces									
White spruce	196,384	37,950	38,959	39,605	48,325	23,023	8,522	--	--
All species	196,384	37,950	38,959	39,605	48,325	23,023	8,522	--	--
Total softwoods	5,743,864	593,468	962,175	1,137,368	1,092,694	924,678	570,139	463,343	--
Hardwoods									
Cottonwood and aspen									
Quaking aspen	4,281	--	4,281	--	--	--	--	--	--
All species	4,281	--	4,281	--	--	--	--	--	--
Other western hardwoods									
Bur oak	7,309	--	4,398	2,911	--	--	--	--	--
All species	7,309	--	4,398	2,911	--	--	--	--	--
Total hardwoods	11,590	--	8,679	2,911	--	--	--	--	--
All species groups	5,755,454	593,468	970,854	1,140,278	1,092,694	924,678	570,139	463,343	--

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 8b.—Net volume of sawtimber trees, in thousand board feet (Scribner rule), on timberland by species group, species, and diameter class, Black Hills National Forest, 2011

Species group/species	Diameter class (inches at breast height)								
	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	21.0-28.9	29.0+
Softwoods									
Ponderosa and Jeffery pines									
Ponderosa pine	4,803,253	434,970	765,069	941,551	917,375	806,530	509,892	427,866	--
All species	4,803,253	434,970	765,069	941,551	917,375	806,530	509,892	427,866	--
Engelmann and other spruces									
White spruce	166,749	29,715	32,285	33,969	42,448	20,594	7,737	--	--
All species	166,749	29,715	32,285	33,969	42,448	20,594	7,737	--	--
Total softwoods	4,970,002	464,685	797,354	975,520	959,823	827,124	517,629	427,866	--
Hardwoods									
Cottonwood and aspen									
Quaking aspen	3,560	--	3,560	--	--	--	--	--	--
All species	3,560	--	3,560	--	--	--	--	--	--
Other western hardwoods									
Bur oak	6,165	--	3,658	2,506	--	--	--	--	--
All species	6,165	--	3,658	2,506	--	--	--	--	--
Total hardwoods	9,725	--	7,219	2,506	--	--	--	--	--
All species groups	4,979,727	464,685	804,573	978,027	959,823	827,124	517,629	427,866	--

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 9.—Aboveground dry weight of live trees (at least 1 inch d.b.h./d.r.c.), in thousand dry short tons, on forest land by owner category, softwood/hardwood species category, and tree component, Black Hills National Forest, 2011

Owner category and softwood/hardwood Category	Tree biomass component							
			Growing-stock trees			Non-growing-stock trees		
	All Components	All live 1-5 inch trees	Total	Boles	Stumps, tops, and limbs	Total	Boles	Stumps, tops, and limbs
Public								
Softwoods	22,762	698	27,159	22,184	4,975	905	670	235
Hardwoods	1,379	602	549	381	168	228	157	71
Total	30,140	1,300	27,707	22,565	5,143	1,133	827	306
Private								
Softwoods	121	--	121	98	22	--	--	--
Total	121	--	121	98	22	--	--	--
All ownerships								
Softwoods	28,882	698	27,280	22,282	4,997	905	670	235
Hardwoods	1,379	602	549	381	168	228	157	71
Total	30,261	1,300	27,828	22,663	5,165	1,133	827	306

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 10.—Average annual net growth of growing-stock trees (at least 5 inches d.b.h.), in thousand cubic feet, on timberland by species group, species, and owner category, Black Hills National Forest, Wyoming 2000-2005, South Dakota 2002-2006: 2007-2011

Species group/species	Owner category			
	All owners	Public	Private	Unidentified owner
Softwoods				
Ponderosa and Jeffery pines				
Ponderosa pine	21,771	21,708	63	--
All species	21,771	21,708	63	--
Engelmann and other spruces				
White spruce	1,074	1,074	--	--
All species	1,074	1,074	--	--
Total softwoods	22,845	22,782	63	--
Hardwoods				
Cottonwood and aspen				
Quaking aspen	-546	-546	--	--
All species	-546	-546	--	--
Other western hardwoods				
Paper birch	23	23	--	--
Green ash	22	22	--	--
Bur oak	99	99	--	--
American elm	1	1	--	--
All species	144	144	--	--
Total hardwoods	-402	-402	--	--
All species groups	22,444	22,381	63	--

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 11.—Average annual removals of growing-stock trees (at least 5 inches d.b.h.), in thousand cubic feet, on timberland by species group, species, and owner category, Black Hills National Forest, Wyoming 2000-2005, South Dakota 2002-2006: 2007-2011

Species group/species	Owner category			
	All owners	Public	Private	Unidentified owner
Softwoods				
Ponderosa and Jeffery pines				
Ponderosa pine	24,663	24,663	--	--
All species	24,663	24,663	--	--
Engelmann and other spruces				
White spruce	1,712	1,712	--	--
All species	1,712	1,712	--	--
Total softwoods	26,375	26,375	--	--
Hardwoods				
Cottonwood and aspen				
Quaking aspen	12	12	--	--
All species	12	12	--	--
Total hardwoods	12	12	--	--
All species groups	26,387	26,387	--	--

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 12.—Average annual mortality of growing-stock trees (at least 5 inches d.b.h.), in thousand cubic feet, on timberland by species group, species, and owner category, Black Hills National Forest, Wyoming 2000-2005, South Dakota 2002-2006: 2007-2011

Species group/species	Owner category			
	All owners	Public	Private	Unidentified owner
Softwoods				
Ponderosa and Jeffery pines				
Ponderosa pine	14,046	14,046	--	--
All species	14,046	14,046	--	--
Engelmann and other spruces				
White spruce	826	826	--	--
All species	826	826	--	--
Total softwoods	14,873	14,873	--	--
Hardwoods				
Cottonwood and aspen				
Quaking aspen	970	970	--	--
All species	970	970	--	--
Other western hardwoods				
Paper birch	137	137	--	--
Bur oak	8	8	--	--
All species	146	146	--	--
Total hardwoods	1,115	1,115	--	--
All species groups	15,988	15,988	--	--

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.

Walters, Brian F.; Woodall, Christopher W.; Piva, Ronald J.; Hatfield, Mark A.; Domke, Grant M.; Haugen, David E. 2013. **Forests of the Black Hills National Forest 2011**. Resour. Bull. NRS-83. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 36 p.

This inventory of the Black Hills National Forest (BHNF) covers the years 2007-2011 on the South Dakota portion of the forest and 2005 on the Wyoming portion. It reports more than 1.16 million acres of forest land dominated by ponderosa pine. Forest features reported on include volume, biomass, growth, removals, mortality, carbon, snags, and down woody material, along with information on forest economics. This report provides the public with a set of forest statistics that may be used in the Black Hills' land management decisionmaking.

KEY WORDS: inventory, forest statistics, forest land, volume, biomass, carbon, growth, removals, mortality, forest health

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