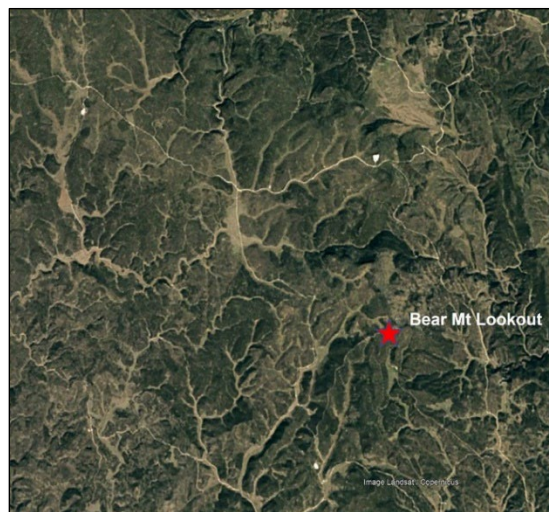




Black Hills National Forest

Revised Forest Assessments: Timber



Forest conditions west of Custer (junction of Ditch Creek and Six Mile roads), 1997 (top) and 2020 (bottom).

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Chapter 1. Introduction

There is a need to re-evaluate the timber program level authorized by the 1997 Forest Land and Resource Management Plan (forest plan) for the Black Hills National Forest, management practices, product mixes, and metrics that inform desired forest management. There have been major changes to the national forest since 1996 when an increase in mountain pine beetle (MPB) populations was first detected. These changes are related to the major ecosystem drivers and stressors for the national forest, timber production, MPB epidemics, and wildfire. This assessment highlights changes to key forest vegetation characteristics that influence sustainable timber program levels.

Federal Laws, Regulations, and Policy

Sustainable production of timber on national forest lands is guided by two primary laws, the Multiple-Use Sustained Yield Act (MUSYA) of 1960 and the National Forest Management Act (NFMA) of 1976. The MUSYA authorizes and directs national forests to be managed under principles of multiple use and to produce a sustained yield of products and services. The NFMA limits the sale of timber from each national forest to a quantity equal to or less than a quantity that can be removed in perpetuity on a sustained-yield basis.

The timber program for the 1997 forest plan (table 1) was developed per the 1982 Planning Rule. The sustainable timber program for the revised forest plan will be developed per direction from the 2012 Planning Rule. There are key differences between the 2012 and 1982 Planning Rules regarding timber production.

- The ***Sustained Yield Limit*** (SYL, 2012 Planning Rule) vs. the ***Long Term Sustained Yield Capacity*** (1982 Planning Rule, LTSYC)

The SYL replaces the LTSYC and is the volume that may be produced in perpetuity on lands tentatively suitable for timber production (now called “may be suitable”). Both estimates are hypothetical growth and yield thresholds that limit timber production on national forest lands. LTSYC was an estimate for the volume that may be produced in perpetuity from the planning area. LTSYC was unique for each Alternative considered in the planning process and was limited by the same resource constraints as the Alternative. SYL, unlike LTSYC, is not limited by multiple-use objectives (forest plan resource desired conditions, goals, objectives, standards, and guidelines). In theory, the SYL may be higher than the LTSYC if similar variables such as the total area for may be suitable lands and net growth (gross growth minus mortality) are constant. The LTSYC determined for the 1997 forest plan was 242,000 CCF per year. Note that this is the long-term sustainable volume and is not necessarily achievable or sustainable within the planning period. Rather, the Allowable Sale Quantity is the volume that can be achieved during the plan implementation period.

- The ***Allowable Sale Quantity*** (ASQ, 1982 Planning Rule) and ***Total Sale Program Quantity*** (USDA 1997 and Record of Decision).

Allowable Sale Quantity (ASQ) was the 1997 estimate of the sustainable yield of commercial material per utilization specifications for sawtimber¹ and products other than logs² (POL) from lands designated as suitable for timber production only. This material was included in the LTSYC but was less than or equal to the LTSYC. ASQ included constraints to achieve forest plan desired conditions, goals, objectives, standards, and guidelines. ASQ was applied on a decadal basis and was a limit on

¹ Sawtimber: trees ≥ 9.0 inches diameter at breast height (dbh). DBH is measured at 4.5 feet above ground level.

² Products other than logs (POL): posts, poles, and fiber from trees or parts of trees less than sawlog size. POL typically includes trees ≥ 5 inches dbh and < 8.9 inches dbh, with tops of trees > 4 to < 6 inches in diameter. The current forest utilization practice for pole material is trees ≥ 7.0 and < 9.0 inches dbh.

timber production from suitable lands. The 1997 Record of Decision also discloses a “Total Sale Program Quantity” to include incidental volume from unsuitable land. This added approximately 1 million board feet per year to the ASQ, for a total cubic foot volume of 204,000 CCF annually for the first decade of the 1997 plan implementation. The ASQ is not recognized by plans revised under the 2012 Planning Rule. Rather, the Projected Timber Sale Quantity and Projected Wood Sale Quantities are used.

- The ***Projected Timber Sale Quantity/Projected Wood Sale Quantity*** (PTSQ/PWSQ³ 2012 Planning Rule) vs. the Allowable Sale Quantity

Projected Timber Sale Quantity (PTSQ) and Projected Wood Sale Quantity (PWSQ) estimates are annual averages for a decade during the planning period (15-20 years) of a plan revised under the 2012 Planning Rule. PTSQ is the estimated quantity of timber meeting applicable utilization standards. PWSQ includes timber and all other wood products expected to be sold. They are not limited to lands designated as suitable for timber production but will be based primarily on products from suitable lands. These estimates are also based upon existing forest conditions and must be consistent with forest plan desired conditions, goals, objectives, standards, and guidelines. One notable difference between the PTSQ and the ASQ is that the PTSQ is based on the planning unit’s fiscal capability and organizational capacity.

For the 1997 forest plan, the ASQ guideline 2402 limited the program level to 202,000 CCF in the second decade and included an incidental amount of volume produced from unsuitable lands (USDA Forest Service 2005).

The ASQ set the limit for timber production from suitable lands by decade for the 1997 forest plan timber program. The 2012 Planning Rule does not contain a metric that is equivalent to the ASQ. The SYL is now the long-term limit for timber production on national forest lands that applies to entire forest rotations and cycles. The estimates for PTSQ/PWSQ are produced for the duration of the new forest plan. Although PTSQ and PSWQ are not targets nor limitations on timber production, they are constrained by the SYL (except when the plan allows for a departure), existing forest conditions, plan components, fiscal capability, and organizational capacity.

The 1997 Forest Plan Timber Program Assumptions

In 1997 the standing inventory (sawtimber and POL) was predicted to increase over the next 50 years because net growth was expected to exceed timber production levels (ASQ) (table 1). The predicted growth rates that were used to calculate ASQ were higher than actual growth that has occurred since the 1997 plan. Mortality rates incorporated into the 1997 ASQ were not representative of the actual MPB and wildfire mortality that would occur over the next 25 years.

³ The PTSQ is the estimated amount of timber meeting utilization standards for the period covered by the forest plan (sawtimber and pole-sized material). PWSQ is the estimated amount of all other wood products such as fuelwood and biomass.

Table 1. Estimated average annual sustainable harvest levels, 1997 forest plan, decades 1 through 5, Black Hills National Forest, 1982 Planning Rule

[Source: USDA Forest Service 1996. The 202,000 CCF ASQ for decades 1-3 = 181,000 CCF of sawtimber and 21,000 CCF of POL. CCF = 100 cubic feet.]

Estimate	Land Base	Constraints	Decade 1 (CCF)	Decade 2 (CCF)	Decade 3 (CCF)	Decade 4 (CCF)	Decade 5 (CCF)
Allowable Sale Quantity	Suitable	Forest plan direction	202,000	202,000	202,000	220,000	221,000

Sustainable timber program levels for the revised forest plan will be affected by changes to the following forest vegetation characteristics:

1. Net growth: Long-term gross growth and mortality rates that are representative of timber production and natural disturbance cycles (SYL)
2. The area of timberlands by forest type (SYL)
3. The existing standing inventory (PTSQ/PWSQ)
4. The existing forest structure (size class and density) (PTSQ/PWSQ)

Data Sources

A forest-wide comparison of the standing commercial forest inventory and area by age class using Forest Inventory and Analysis (FIA) data was made using: the 2000 periodic inventory for Wyoming and the 2001-2005 annual inventory for South Dakota (Measurement 1); and the 2017-2019 forest-wide inventory (Measurement 2) for available⁴ timberlands and lands designated as suitable for timber production in the 1997 forest plan. Output from this inventory comparison was not available when the draft report was released to the public on June 17, 2022. Timberlands are defined as forest lands that can grow a minimum of 20 cubic feet per acre per year (FIA definition). Lands designated as suitable for timber production are a subset of timberlands. This is the land base that is appropriate for timber production per 1997 forest plan management direction. This comparison was intended to identify change to the forest standing inventory during the implementation of the 1997 Forest Plan. These inventories represent the earliest and latest FIA inventories available for this period. The Measurement 1 inventory estimates for both SD and WY utilize data from the plots were incorporated into the 2002 DeBlander inventory report which were retained for future measurements. The 2001-2005 annual inventory for South Dakota provides estimates per measurements that precede the data that was incorporated into the 2013 inventory report by Walters et al. Comparisons were made using repeat measurements only since this approach is ideal for assessing change over time.

The sampling intensity of the 2017-2019 FIA inventory was doubled per the forest request to include plots that were measured for the first time to increase sampling precision. Output that is available to the forest and the public from the 2017-2019 inventory is derived from this intensified sample. Consequently, it was necessary to request custom work by the Rocky Mountain Research Station, Forest Sciences Lab, Interior West FIA, Ogden, UT, to produce comparisons from Measurement 1 to Measurement 2 using repeat measurements only and to stratify output by lands designated as suitable for timber production. This stratification is not standard FIA protocol.

⁴ Land that is not withdrawn by law(s) prohibiting the management of land for the production of wood products (USDA Forest Service 2019).

Other data such as forest vegetation inventory databases (RIS, July 10, 1995, FSveg, November 3, 2021), the forest activity tracking database (FACTS, December 10, 2021) and forest timber sale records (periodic timber sale accomplishment reports and cut and sold reports) were assessed to identify trends for forest types, forest structure and density, stocking, management practices, and cut and sold volume. Forest Health Protection Aerial Detection Survey data, 1996 to 2021, were used to assess the scale of the MPB epidemic on national forest lands. The large wildfire history inventory (April 5, 2022) was used to assess the scale of wildfire affected acres.

In 2023, a decision was made to collect lidar data across the entire Black Hills National Forest to provide additional information for the forest plan revision process and future plan implementation. Lidar, or light detection and ranging, is a remote sensing technology that actively emits pulses of light to measure distances to target surfaces. By calculating the time it takes lidar pulses to hit a surface and return to the lidar sensor, objects can be precisely located in three-dimensional space. With each pulse, the lidar sensor records several points of contact, and with millions of pulses in a lidar acquisition, the result is a dense point cloud that reveals the forest and the ground beneath it. Lidar data can be used to measure vegetation height, canopy cover, and canopy gaps, as well as to create digital elevation models. Together with field sampling and modeling, we can use lidar to estimate forest structure metrics like basal area, volume, and biomass. In the development phase, lidar data could potentially be used to develop detailed maps of vegetation cover, forest structure, and topography. This information could be used to consider different management scenarios and evaluate the potential impacts of those scenarios on various ecological values.

Discussions of timber industry and timber-related employment are included in the Socioeconomics Assessment.

Chapter 2. National Forest Land Classification for Timber Production

Changes to “May be Suitable” and “Suitable” Lands

May be suitable lands are timberlands designated as potentially suitable for timber production that are not withdrawn by statute, executive order, or regulations; not withdrawn by the Secretary of Agriculture or Chief of the Forest Service; excluding lands where the technology is not currently available for conducting timber harvest without causing irreversible damage to soil, slope, or other watershed conditions; excluding lands where there is no reasonable assurance that these lands can be adequately restocked within 5 years following a regeneration harvest; and excluding non-forest lands (USDA Forest Service 2015).

Land classifications are updated on an ongoing basis in the national forest FSveg database per site-specific planning and implementation efforts. Changes since 1997 have resulted in a reduction of 86,618 acres in timber suitability in 2021. The classification of national forest acres for the suitability of timber production in 1997 are compared with the draft 2021 FSveg classifications in table 2. The 2021 acres are based on implementation of the 1997 forest plan. Timber suitability under the 2012 planning rule will be analyzed during the plan development phase of forest plan revision and will likely vary among alternatives.

Table 2. Timber suitability classification for the Black Hills National Forest, 1997 and 2021.

[Source: 1995 RIS inventory and draft 2021 FSVeg inventory.]

Timber Suitability Classification Factors	1997 Forest Plan Alternative G (acres)	2021 (acres)
Net National Forest Acres	1,242,713	1,253,002
Less Non-forested Acres	117,988	117,521
Administratively Withdrawn, not technologically feasible, can't be restocked within 5 years	55,979	74,376
Tentatively Suitable (now "may be suitable")	1,068,746	1,061,105
Less Areas Incapable of Producing Industrial Wood	60,271	63,618
Less Areas with Low Productivity	43,935	40,754
Less Experimental Forest and Research Watershed	4,254	6,058
Less Inyan Kara Mountain and Administrative Sites	1,171	1,170
Lee Administrative Sites and Campgrounds	1,252	7,639
Less Critical Game Habitat	0	437
Less Late Succession	38,931	45,014
Less Remaining Portions of Areas Managed for other Multiple Uses	41,116	39,908
Less Uneconomical for Timber Harvest	11,926	21,710
Less Other (superfund, land exchange)	0	1,648
Suitable and Available Acres (includes non-stocked areas)	865,890	833,148
Less non-stocked acres, ponderosa pine forest	13,022	66,898
	852,868	766,250

Complete changes in land class status are described in table 13 in the appendix A. Changes reflect both updates to land classification as well as more current information collected from activities such as on the ground inventories. Key administrative, economic, and feasibility changes from 1997 to 2021 include:

- An increase to the Black Elk Wilderness, (administratively withdrawn) (3,337 acres)
- An increase in areas considered inaccessible (not technically feasible) (15,481 acres)
- The addition of research natural areas (research watershed) (1,806 acres)
- An increase in developed recreation sites (administrative sites and campground) (6,469 acres)
- An increase in areas classified as isolated patches (uneconomical for timber harvest) (6,504 acres)

These changes reduce the area designated as suitable for timber production. Changes to forest cover, including non-stocked ponderosa pine forests, are discussed in Chapters 3 and 4.

Classification Direction for Suitable Lands

Current direction per the 2012 Planning Rule requires the following factors to be deducted from national forest lands to determine lands that are suitable for timber production:

- i. Statute, Executive order, or regulation prohibits timber production on the land,
- ii. The Secretary of Agriculture or the Chief of the Forest Service has withdrawn the land from timber production,

- iii. Timber production would not be compatible with the achievement of desired conditions and objectives established by the plan for those lands,
- iv. The technology is not currently available for conducting timber harvest without causing irreversible damage to soil, slope, or other watershed conditions,
- v. There is no reasonable assurance that such lands can be adequately restocked within 5 years after final regeneration harvest, or
- vi. The land is not forest land.

Factors i, ii, iv, v, and vi are deducted from national forest lands to determine the total may be suitable area.

In a second step, Factor iii, which examines the compatibility of timber production with the desired conditions and objectives for those lands, is deducted from may be suitable acres to derive the total area that is suitable for timber production.

Chapter 3. Key Ecosystem Drivers and Stressors

Ecosystem drivers are factors or processes that affect ecosystem characteristics and contribute to the natural range of variation. Stressors are defined as factors that may directly or indirectly degrade ecosystem composition, structure, or processes in a manner that may impair its ecological integrity (36 CFR 219.19). Many system drivers can be stressors if they are operating in atypical ways, outside of their natural range of variation. Management influences can be drivers or stressors.

The actual commercial timber production footprint from 1997 to 2021 (table 16), MPB affected acres from 1996 to 2020 (table 17), and wildfire affected acres from 1997 to 2021 are shown in figures 4-6 in appendix A. An estimated 200,000 acres of the commercial timber footprint does not overlap with the MPB affected areas and the wildfire affected areas. More than 60%, 750,000 acres, of all national forest lands on the Black Hills National Forest, 1,253,002 acres, have been affected by these drivers and stressors.

Timber Production and Management Practices

Since implementation of the 1997 forest plan, the Forest has sold 3,800,000 (93.5%) CCF of sawtimber, 263,000 CCF of POL (6.5%), implemented commercial treatments on approximately 550,000 acres (tables 3, 4, and 5), pre-commercially thinned 250,000 acres, successfully regenerated 300,000 acres through natural seeding, and planted approximately 8,000 acres. The Hell Canyon and Northern Hills Ranger Districts have produced the highest level of commercial timber. The Bearlodge Ranger District has had the smallest program but the highest average value for volume sold since 2013.

The average annual output of sawtimber, POL, and firewood from 1997 to 2021, 162,409 CCF, represents 80% of the 1997 forest plan ASQ. Timber production increased in response to the MPB epidemic starting in 2004. Annual sold and cut volumes by product are listed in tables 3 below and table 15 in appendix A.

Table 3. Average annual volume sold by decade by product, Black Hills National Forest

[Source: Periodic timber sale accomplishment reports and cut and sold reports.]

Fiscal Year	Sawtimber (CCF)	POL (CCF)	Firewood (CCF)	Add Volume (sawtimber, CCF)	Total (CCF)
Decade 1: 1997-2006	117,388	3,194	5,522	0	126,104
Decade 2: 2007-2016	181,709	5,912	6,582	512	194,715
Decade 3: 2017 through 2021 only	152,015	2,684	7,450	8,258	170,407
Annual Average: 1997-2021	150,042	4,179	6,331	1,856	162,409

Average annual cut levels, total and by decade (table 4), exceed the amount of volume sold. The cut rate can exceed the total amount sold should timber cruise total overruns exceed underruns. Volume can also be added to contracts post award. Examples of situations which would generate “add-on” volume include tree felling and removal per operational and safety considerations or the need for the sanitation or salvage of trees that were impacted post award by insects, disease, or other disturbance events such as wildfire.

Discussions with Industry and Forest Service entomologists during the MPB epidemic led to the Black Hills National Forest deciding to emphasize the sanitation logging and preventative thinning of live trees with the intent to reduce the spread and severity of beetle infestations instead of the salvage logging of dead trees. Sanitation logging is defined as “the removal of trees to improve stand health by stopping or reducing the actual or anticipated spread of insects and disease” (Helms). This emphasis resulted in the Black Hills National Forest timber sale contracts defining live trees as having at least one green needle and dead trees as having no green needles. All “live” trees were sold according to the Advertised Rate per the Regional Bulletin and not at the Adjusted Base Period Price of \$3.00/CCF for dead sawtimber. In addition, the prospectus for each timber sale during this timeframe contained a statement that the deterioration or loss of timber value due to the MPB would not be considered as an unexpected event under B8.12 Liability for Loss. Consequently live, green-needled trees were predominantly harvested during the MPB epidemic, regardless of their MPB infestation status. The salvage logging of recently killed, or older mortality trees, to recover economic value was infrequent due to rapid wood deterioration. The combination of unharvested MPB mortality and the harvest of primarily live trees intensified net change trends.

Table 4. Average annual volume cut by decade by products, Black Hills National Forest

[Source: Periodic timber sale accomplishment reports and cut and sold reports.]

Fiscal Year	Sawtimber (CCF)	POL (CCF)	Firewood (CCF)	Total (CCF)
Decade 2: 2007-2016	197,584	6,931	6,803	211,318
Decade 3: 2017 through 2021 only	165,111	4,101	7,529	176,741
Annual Average: 1997-2021	165,977	5,457	6,235	177,669

The standard silvicultural practice at the beginning of the MPB epidemic, commercial thinning mature stands of ponderosa pine to a residual density of 80 square feet of basal area⁵, was determined to be ineffective for mitigating MPB mortality. As a result, the primary practices became commercial thinning to a 60 basal area, a density reduction method, and shelterwood establishment cutting, a regeneration method (appendix B). These treatments reduced residual densities to 30 to 60 square feet of basal area, creating open conditions that are ideal for seed dissemination, seed germination, and early stand development. Regeneration treatments create new age classes. Thinning cuts, unlike regeneration treatments, alter existing stand densities and structure and are generally not intended to create new age classes. These treatments did, however, result in the establishment of low to moderate levels of natural regeneration.

Overstory removals have replaced shelterwood establishment cuts as the primary silvicultural practice starting with the implementation of the Black Hills Resilient Landscapes Project in 2018. These treatments remove the overstory that was retained via the shelterwood establishment cuts to release the new age class in the understory. This transition occurred following the end of the MPB epidemic in 2016 because the levels of dense (Habitat structural state (HSS)4C) or moderately dense (HSS4B), mature ponderosa pine stands were below desired levels per forest plan objectives or were reserved to meet other resource objectives. The total area of open stands (SS4A) exceeded desired levels (Section 4, Habitat Structural Stage (HSS) (Size Class and Density)). Cut volume per acre has decreased from an average of 8.0-10.0 CCF produced via shelterwood establishment cuts and commercial thinning to an average of 6.0 CCF produced via overstory removals. The total commercial acreage treated is listed by district for 1997-2021 in table 5.

Table 5. Total commercial acreage treated by district, Black Hills National Forest, 1997-2021

[Includes overlapping acres for forest stands that have been treated multiple times during this period. See Table 16 in the appendix A for annual numbers by silvicultural method. Source: FACTS database.]

	Bearlodge (acres)	Hell Canyon (acres)	Mystic (acres)	Northern Hills (acres)	Total
Decade 1: 1997-2006	21,741	60,412	65,486	53,745	201,384
Decade 2: 2007-2016	29,758	81,554	53,878	68,664	233,854
Decade 3: 2017 through 2021 only	26,126	28,282	24,030	33,945	112,383
Annual Average: 1997-2021	3,105	6,810	5,736	6,254	21,905

Mountain Pine Beetles

The forest condition in 1997 consisted of a high level of mature, dense ponderosa pine forest stands (see Chapter 4, Habitat Structural Stage) that was highly susceptible to MPB activity when combined with drought and warmer weather. The increase in MPB populations from endemic to epidemic levels was first recognized in 1996 (table 6). Between 1996 and 2009 affected areas were delineated by observers in small aircraft (Forest Health Aerial Detection Survey Program) which produced a range of results regarding precision. In 2010 survey protocol for the forest shifted to a more accurate method using high-resolution aerial photography. Following this change in survey methods, the highest level of MPB affected acres was detected in 2011 (appendix A, table 17). MPB-related mortality peaked in 2013 and MPB populations returned to endemic levels in 2016.

⁵ The area of the cross section of a tree stem including the bark, generally at breast height (4.5 feet above the ground).

During the epidemic, MPB impacts occurred on an estimated 412,500 acres of national forest lands (both survey methods, adjusted for overlap between survey years). Based on the cumulative results for affected acres and mortality acres, MPB-related mortality occurred on approximately 50% of the affected acres. MPB impacts were lower in Wyoming than in South Dakota.

Table 6. Aggregate acreage (no overlap between survey years) affected by MPB mortality by district, Black Hills National Forest, 1996-2021

[Source: Forest Health Protection Aerial Detection Surveys.]

	Bearlodge	Hell Canyon	Mystic	Northern Hills	Totals
Area affected by MPB (acres)	28,167	100,927	131,620	151,785	412,500
Ponderosa pine forest type (acres)	135,728	367,004	266,212	259,731	1,028,675
Percentage of ponderosa pine forest affected	21%	27%	49%	58%	40%

Forest silvicultural practices have developed primarily even-aged stands (those stands with single or two-age classes) from 1997 to 2021 (95%) (appendix A, table 16). Uneven-aged silvicultural methods are intended to create forest stands with a minimum of three age classes and more complex structure. A high level of even-aged management creates a landscape that is more susceptible and less resilient to MPB mortality when majority of the ponderosa pine forest is mature. This increased risk and reduced potential for recovery is due to the high level of forest stands with more susceptible trees (sawtimber sized trees), greater continuity of susceptible trees, an increased potential for hazardous fuels levels following MPB-related mortality, greater loss of seed sources, and lower potential for replacement trees following MPB events, in comparison with a landscape that contains a higher level of uneven-aged structure. See Chapter 5, Silvicultural Practices, Uneven-aged Management, Bark Beetle Susceptibility for additional discussion.

Wildfire

Since 1997, wildfires have burned approximately 172,000 acres on the Black Hills National Forest. The total burn area that does not overlap with MPB affected acres or that burned multiple times is 152,356 acres (table 7). The majority of these wildfires occurred in South Dakota. Changes in the growing season and precipitation in the winter type due to warmer temperatures throughout the year may increase fire frequency, increase wildfire extents, and prolong the fire seasons (Graham et al. 2021). These changes may diminish the potential for forest regeneration and growing stock potential (Graham et al. 2021). Severe events such as the 2000 Jasper wildfire which burned 83,511 acres, primarily on the Hell Canyon Ranger District, have converted approximately 51,690⁶ acres of ponderosa pine forest on suitable lands to grasslands for the foreseeable future. This will have long-term impacts without management intervention on a scale comparable to the disturbance event. On the Black Hills National Forest, an average of 430 acres per year have been planted with ponderosa pine trees in the Jasper burn area since 2003.

⁶ Source: 2021 FSVeg inventory

Table 7. Aggregate wildfire acreage by district on national forest lands in the Black Hills National Forest, 1997 to 2021

[Includes overlapping acres for areas that burned more than once during this period. Source: Forest large fire history inventory.]

	Bearlodge	Hell Canyon	Mystic	Northern Hills	Total
Area affected by wildfire (acres)	1,478	108,286	34,218	8,374	152,356
National forest lands (acres)	169,865	459,471	309,879	313,787	1,253,002
Percentage of national forest lands affected	0.9%	23.6%	11.0%	2.7%	12.2%

Chapter 4. Inventory Trends

Net Growth and Net Change

Net growth is defined as gross growth minus natural mortality over a specified time period (Graham et. al 2021). Net growth estimates for long-term forest cycles and rotations⁷ per likely management scenarios determine sustainable timber program levels. Net growth that occurred between 1997 and 2021 was lower than what was predicted in 1997.

Net change in forest inventory is net growth less removals (Graham et. al 2021). Negative net change on the forest was initially identified by forest staff in 2012 per a draft of NRS-81, South Dakota's Forests 2010 (Piva et al. 2013) and confirmed by the publication in 2013 of NRS-83 Forests of the Black Hills National Forest (Walters et al. 2013).

Ponderosa Pine

Annual NRS FIA inventories, 2006-2020 for the forest in South Dakota (timberlands, public Evaluator 2.0) indicate that net growth for ponderosa pine sawtimber has been negative since the 2009-2014 repeat measurements and net change has been negative since the earliest available measurement period 2006-2010 (applying forest annual sawtimber cut data, appendix A, Table 16). Net growth of ponderosa pine shifted from positive to negative as a percentage of standing inventory (from + 2.20% or greater to - 0.75%, growing stock, various inventories (figure 1), from 1999 to 2019). This decline in net growth is primarily due to increased MPB-related mortality (from 0.27% to 3.07%); however, weather and fire-related mortality has also increased (from 0.21% to 0.40%) (figure 2).

This 20-year trend is important because this cycle of change from positive to negative net growth may repeat several times during a 120- to 150-year rotation or series of cutting cycles for ponderosa pine. Between 1896 and 2012 there have been six MPB epidemics of various severities despite the implementation of a variety of direct and indirect control methods and silvicultural practices. This is a frequency of an epidemic every 20 years (Graham et al. 2016). Inventory levels have also fluctuated during this period. These fluctuations highlight why sustainable timber harvest limits are based on representative rates for entire forest cycles and rotations. Rates from annual or periodic inventories are just snapshots and can be higher or lower than rates for entire rotations or cutting cycles.

Graham et al. (2021) found that a sustainable net change or any increase in inventory would only occur with positive net growth of the standing inventory and a reduction of the timber program level for both short-term (5 and 20 years) and long-term projections (80 years). Timber program levels incorporated into

⁷ Cycle applies to both natural disturbance cycles and uneven-aged forest management. Rotation applies to even-aged forest management. See Silviculture Terminology in the appendix.

sustainable scenarios in this study range from 72,400 CCF to 126,700 CCF per year depending upon the net growth percentage applied to each scenario. Sustainable scenarios incorporated net growth values that ranged from 1.21% to 2.47% of the standing sawtimber inventory for both short-term and long-term scenarios. Additionally, all the program levels discussed in Graham et al. 2021 are based upon net growth only. No deductions were made for net growth that is reserved from timber production to meet other resource objectives per the forest plan. As the new forest plan is developed, planned timber program levels will need to factor in other resource objectives as described in USDA Forest Service 2015.

The findings of Graham et al. 2021 are based on an estimated 765,733 acres from the 2017-2019 intensified FIA inventory and represent estimates for ponderosa pine sawtimber on 100% of 2021 draft suitable lands when non-stocked areas are deducted (Table 2). These findings also represent 77% (based on 994,207 acres) of 2021 draft may be suitable lands (Table 2) when non-stocked areas are deducted. The deduction of non-stocked areas adjustment is consistent with FIA protocol which, unlike forest inventory data, separates non-stocked areas from conifer and hardwood forest types.

Table 4—Merchantable volume of ponderosa pine trees (> 5 inches d.b.h.), in CCF, on suitable timberland of the Black Hills National Forest. See Box 1 for a description of gross growth as described by FIA.

Date	Average annual volume (CCF)					Standing live inventory (CCF)
	Gross growth	Mortality	Net growth	Harvest ^a	Net change	
1962 ^b	213,010	12,180	200,830	109,780	91,050	7,810,000
1984 ^c	339,540	34,910	301,660	199,540	102,120	13,449,000
1999 ^d	380,000	42,120	337,880	204,628	133,252	15,353,000
2011 ^e	358,170	140,460	217,710	246,630	-28,920	13,477,960
2017 ^f	247,768	246,122	1,646	261,721	-260,075	9,050,031
2019 ^f	185,049	244,703	-59,654	183,592	-244,804	7,958,314
Average annual volume (% of inventory)						
1962 ^b	2.73	0.16	2.57	1.41	1.17	—
1984 ^c	2.52	0.26	2.24	1.48	0.78	—
1999 ^d	2.48	0.27	2.20	1.33	0.87	—
2011 ^e	2.66	1.04	1.62	1.83	-0.21	—
2017 ^f	2.74	2.72	0.02	2.89	-2.87	—
2019 ^f	2.33	3.07	-0.75	2.31	-3.08	—

^aTo ensure consistency in calculations, FIA estimates of harvest levels were reported in the table. The United States Forest Service utilizes a series of systems: Timber Information Manager (TIM) and Forest Products Financial System (FPFS) for a more accurate record of sold and cut volume (<https://www.fs.fed.us/forestmanagement/products/cut-sold/index.shtml>). Note: Sawtimber utilization standards for FIA estimates use a 7 inch top and current utilization on the BHNF use a 6 inch top.

^bEstimates are for softwoods on timberlands (commercial lands) within the Black Hills and Custer National Forest portions of South Dakota only. Softwoods include ponderosa pine and white spruce (Choate and Spencer 1969). Area of commercial forest land estimated for the National Forest was 957,000 acres, but it was not apparent how many acres were classified as suitable timberland.

^cEstimates are for softwoods on timberlands within the Black Hills and Custer National Forest portions of South Dakota only. Softwoods include ponderosa pine and white spruce. Area of timberland for the national forest was 952,500 acres, but it was not clear if timberlands included lands withdrawn by statute or administrative regulation or which were classified as suitable timberland (Collins and Green 1988).

^dEstimates are for ponderosa pine on forest land within the Black Hills National Forest including South Dakota and Wyoming. These estimates included values from all forest lands administered by the Black Hills National Forest, including reserved lands, which make up 1% of the total land base. Area of total forest lands for the National Forest was 1,150,627 acres, but it was not clear which lands were classified as suitable timberland (DeBlender 2002).

^eEstimates are for ponderosa pine on timberlands within the Black Hills National Forest including South Dakota and Wyoming. Area of timberlands estimated for the National Forest was 1,135,200 acres, but it was not clear which lands were classified as suitable timberland (Walters et al. 2013).

^fEstimates are for ponderosa pine on timberlands within the Black Hills National Forest including South Dakota and Wyoming. Area of total timberland was 1,062,776 acres, of which 765,734 were classified as suitable timberland.

Figure 1. Image of Table 4 from Graham et al. 2021 showing merchantable volume of ponderosa pine trees (>5 inches dbh), in CCF, on suitable timberland of the Black Hills National Forest.

Table shows dates on left side with data regarding gross growth, mortality, net growth, harvest, net change, and standing live inventory as well as average annual volume as a percentage of inventory. Years lists include 1962, 1984, 1999, 2011, 2017, and 2019.

Table 1—Volume mortality rates based on standing live volume of growing stock trees (> 5 inches d.b.h.), throughout the last several decades in the Black Hills region. Values of mortality category (rounded to 2 significant digits) are based on the proportion that each disturbance contributed to the overall total mortality rate. Values might not add up due to rounding.

Year	Mortality rate (%)	Insect (%)	Fire (%)	Disease (%)	Weather (%)	Other (%)	Mortality (%) without insect included
1962 ^a	0.15	0.03	0.00	0.08	Not reported	0.03	0.12
1984 ^b	0.26	0.03	0.03	0.00	0.17	0.03	0.23
1999 ^c	0.27	0.03	0.03	0.03	0.19	0.00	0.24
2011 ^d	1.24	0.80	0.13	0.00	0.27	0.04	0.44
2019 ^e	3.07	2.60	0.20	0.05	0.20	0.02	0.47

^a1962: Mortality and standing live volume based on softwoods across all land ownerships in South Dakota on suitable timberlands (data source: Choate and Spencer 1969).

^b1984: Mortality and standing live volume based on ponderosa pine across all land ownerships in South Dakota on suitable timberlands (data source: Collins and Green 1988). Mortality by disease was 0.002.

^c1999: Mortality and standing live volume based on ponderosa pine on the Black Hills National Forest (South Dakota and Wyoming) on suitable timberlands (data source: DeBlander 2002). Mortality by disease was 0.025 and fire was 0.025.

^d2011: Mortality rate was based on ponderosa pine on the Black Hills National Forest in South Dakota on suitable timberlands. Walters et al. 2013 reported mortality of 1.04%, which included Wyoming and South Dakota; however, when FIA provided the values for 2011 by mortality category, it was only for South Dakota lands.

^e2019: Mortality and standing live volume based on ponderosa pine on the Black Hills National Forest (South Dakota and Wyoming) on suitable timberlands (source: USDA FS 2021).

Figure 2. Image of Table 1 from Graham et al. 2021 portraying volume mortality rates based on standing live volume of growing stock trees (>5 inches dbh) throughout the last several decades in the Black Hills Region.

Table shows values of mortality category (rounded to 2 significant digits) are based on the proportion that each disturbance contributed to the overall total mortality rates. Values might not add up due to rounding. The table shows years (1962, 1984, 1999, 2011, 2019) in left column and percentages for mortality rate, insect, fire, disease, weather, other, and mortality without insect included.

White Spruce

Net growth of white spruce on the Black Hills National Forest has remained positive, from 10,500 CCF per year (2006 to 2010) to 6,700 CCF per year (2017 to 2019)⁸. Despite conditions that favor positive net growth, the above levels represent a small proportion of the white spruce inventory, less than 2%. Overall changes to the white spruce inventory will continue to be gradual without a future increase in mortality and/or increased management of this forest type.

Commercial Forest Type Area

The total commercial forest area (ponderosa pine and white spruce forest types) is a key variable for sustainable timber program estimations, at both the SYL and PTSQ/PWSQ levels. Changes to this area will affect volume estimates. A comparison of the 1995 RIS and the 2021 FS Veg forest inventories (table 8) indicates that stocked ponderosa pine forest area has decreased by 78,500 acres. This decrease is due to

⁸ Net growth estimates for white spruce were not available from the 2001-2005 FIA inventory.

an increase in non-commercial forest types and the conversion of forested areas to grasslands due to wildfire (a 66,000-acre increase).

Table 8. Forest land area by forest type, Black Hills National Forest, 1995 to 2021

[Source: 1995 RIS inventory and 2021 FSVeg inventory.]

Forest Type	1995 (acres)	2021 (acres)	Change (acres)
<i>Non-commercial, Aspen</i>	48,225	42,250	-5,975
<i>Non-commercial, Bur Oak</i>	9,190	14,154	4,963
<i>Non-commercial, Conifer/Hardwood Mix</i>	0	7,532	7,532
<i>Non-commercial, Other Hardwoods</i>	690	5,522	4,831
<i>Non-commercial, Other Softwoods</i>	153	159	6
<i>Non-commercial, Paper Birch</i>	2,623	1,757	-866
<i>Non-commercial, Rocky Mountain Juniper</i>	494	1,109	615
<i>Non-commercial, Subtotal</i>	61,375	72,482	11,107
<i>Commercial, Ponderosa Pine</i>	1,017,981	939,693	-78,288
<i>Commercial, White Spruce</i>	21,737	33,700	11,963
<i>Commercial, Subtotal</i>	1,039,719	973,393	-66,326
<i>Non-stocked ponderosa pine</i>	23,502	88,982	65,480
<i>Total</i>	1,124,596	1,134,857	10,261

Changes to total forest land area are also discussed in the *Forested Ecosystems Assessment*. This comparison, using the same FIA repeat measurements, shows similar trends but at a greater magnitude. The FIA results also indicate that the total non-commercial area is much larger than the area designated as non-commercial per the forest inventory data (the 2000-2005 FIA estimate is 101,446 acres and the 2017-2019 FIA estimate is 142,308 acres⁹. This inconsistency is likely due to differences in forest type classification protocols and the high sampling errors (low plots counts) associated with hardwoods, mixed stands, and other softwoods for the FIA data or a combination of both factors. Non-stocked areas have increased; however, the inventory data used for the FIA comparison was collected after the Jasper wildfire in 2000, so the estimated increase is lower.

The increase in non-stocked commercial forest is significant because portions of forest area that have been converted from forest to grasslands by wildfire will not naturally regenerate for decades or centuries due to the loss of conifer seed sources and competition from non-forest vegetation. Planted areas may be included in SYL calculations but will not contribute to shorter-term timber program product estimates.

Lands that were formerly occupied by tree cover, but do not presently have tree cover, should be identified as non-forest lands unless the land will be naturally or artificially regenerated into forest cover in the near future (example: clearcut lands) (USDA Forest Service 2015).

⁹ Forested Ecosystems Assessment, Table 2b, sum of aspen, bur oak, paper birch, rocky mountain juniper and other forested vegetation.

Standing Inventory

Inventory comparisons were produced for the forest standing inventory (live trees) for timberlands and for lands designated as suitable for timber production. Measurement 1¹⁰ = Inventory Year 2000 for WY, 2001-2005 SD, Measurement 2 = 2017-2019 for the entire forest. These comparisons are for growing stock trees ≥ 5.0 inches diameter breast height (dbh). The unit of measure varies by size class; volume for the POL size classes (trees 5.0 to 8.9 inches dbh) is in merchantable bole volume¹¹ in CCF; volume for the sawtimber size class (trees ≥ 9.0 inches dbh) is in net sawlog volume¹² in CCF.

Changes to the standing inventory on lands designated as suitable for timber production are greater because this is the area where commercial timber production is concentrated. Changes to ponderosa pine standing inventory in Wyoming will be more moderate than changes in South Dakota due to a smaller commercial timber program and fewer acres affected by bark beetles and wildfire.

Changes in standing inventory by diameter class for ponderosa pine are listed in Table 19 in appendix A. Changes in standing inventory by product class for white spruce are listed in Table 20 in appendix A.

Ponderosa Pine

The total ponderosa pine sawtimber standing inventory on suitable lands decreased by 21% (figure 3, table 18 in appendix A). The total sawtimber standing inventory on timberlands outside of suitable lands decreased by 3%. Removals of sawtimber from 1997 to 2021 have been concentrated in the 12.0- to 14.0-inch dbh diameter classes. Sawtimber volume in the 9.0- to 14.9-inch dbh diameter classes decreased by 32 to 43% on suitable lands. Change to ponderosa pine volume in the same diameter classes on timberlands outside of suitable lands, range between an increase of 11% in 11.0-12.9 class and decreases of 27% to 30% in the 9.0-10.9 and 13.0-14.9 classes.

Changes to the standing inventory measured by volume per acre are listed in Table 19 in appendix A. For these comparisons volume per acre was also assessed for each area category, timberlands, suitable lands, and timberlands outside of suitable lands. The total area by category includes all forest types and non-stocked areas to account for all volume trends for ponderosa pine volume from measurement 1 to

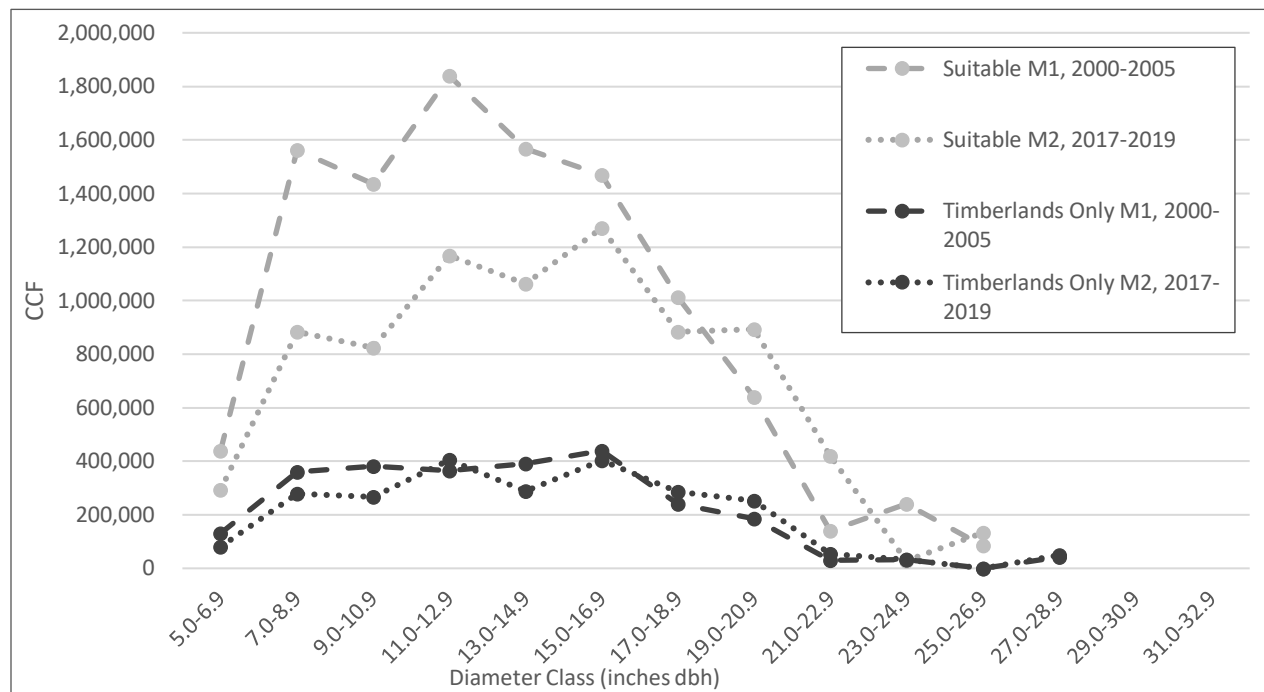
¹⁰ Sampling errors for lands that are designated as suitable for timber production for both measurement periods assessed in this report are not yet available from the Rocky Mountain Research Station, Forest Sciences Laboratory, Interior West FIA. The sampling error for both measurement periods will be higher than the sampling error for the intensified 2017-2019 inventory since this comparison was made using repeat plots only and does not include the additional plots that were measured for the first time 2017-2019. For example, the sampling error for the 2000 forest inventory for ponderosa pine sawtimber on timberlands in WY and the 2001-2005 forest inventory for South Dakota (public FIA Evaluator 2.0.3) was 5.99% (Confidence Interval of 68%, 186 plots) with sampling errors by diameter class starting at 7.5% for the 9.0- to 10.9-inch dbh diameter class and increasing as diameter classes increase due to a diminishing population sample. The sampling error for the 21.0- to 28.9-inch diameter class is 28.105%. By comparison the sampling error for ponderosa pine sawtimber on timberlands for the intensified 2017-2019 forest inventory is 4.76% (CI of 68%, 346 plots) with sampling errors by diameter class starting at 6.67% for the 9.0- to 10.9-inch dbh diameter class increasing up to 15.17% for the 21.0- to 28.9-inch dbh diameter classes.

¹¹ Merchantable bole volume, cubic foot, is defined as the amount of wood contained in a cube 1x1x1 foot. Cubic-foot volume is computed for the merchantable portion of a timber species tree; the merchantable portion includes that part of a bole from a 1-foot stump to a minimum 4-inch top, DOB (diameter outside bark). CCF = 100 cubic feet. Periodic Mapped-plot Design Inventory Terminology. Interior West Forest Inventory and Analysis (IWFIA) Program USDA Forest Service, Rocky Mountain Research Station, Ogden, Utah.

¹² Net sawlog volume is defined as the net volume of wood in the central stem of a timber species tree of sawtimber size (9.0 inches dbh minimum), from a 1-foot stump to a minimum top diameter of 7.0 inches or to where the central stem breaks into limbs, all of which are less than the minimum top diameter. CCF = 100 cubic feet. Periodic Mapped-plot Design Inventory Terminology. Interior West Forest Inventory and Analysis (IWFIA) Program USDA Forest Service, Rocky Mountain Research Station, Ogden, Utah.

measurement 2 and not just trends for the ponderosa pine forest type. Comparisons using these units show trends that are similar to the total standing inventory comparisons described above. Little change has occurred for sawtimber volume per acre outside of suitable lands. Sawtimber per acre on suitable lands has decreased from 9.5 to 7.6 CCF per acre, a decrease of 20%.

Volume in the POL diameter classes has decreased for all area categories, 41% on suitable lands, 27% on timberlands outside of suitable lands, and 38% on total timberlands (appendix A, Table 18).



Source: Forest Inventory and Analysis inventory data, 2000 to 2005 and 2017 to 2019.

Figure 3. Ponderosa pine volume (CCF) by diameter class (inches dbh) on lands designated a suitable for timber production and on timberlands outside of suitable lands, Black Hills National Forest.

White Spruce

The white spruce forest type occurs in South Dakota only. Mortality due to natural ecosystem stressors in the white spruce forest has been limited (USDA Service 2019). Since 1997, spruce sawtimber has primarily been harvested from pine-dominated stands (improvement cutting), aspen stands (hardwood restoration cutting), and meadows (meadow restoration cutting). These treatments have been concentrated on suitable lands. The FIA inventory comparison indicates that white spruce sawtimber has decreased on suitable lands only while the overall trend for POL has been an increase (appendix A, Table 20). Spruce sawtimber volume on timberlands outside of suitable lands shows little change. It is important to consider that inventory estimates for white spruce are less reliable than estimates for ponderosa pine due to the low number of FIA plots located in the spruce forest (11 plots, repeat measurement only).

Habitat Structural Stage (Size Class and Density)

The forest plan (as amended in 2005) directs the Black Hills National Forest to manage for a specific distribution of habitat structural stages (HSS) for the ponderosa pine forest across five management areas:

4.1: Limited Motorized Use and Forest Product Emphasis

5.1: Resource Production Emphasis

5.4: Big Game Winter Range Emphasis

5.43: Big Game and Resource Production

5.6: Forest Products, Recreation, and Big Game Emphasis

(Forest plan objectives 4.1-203, 5.1-204, 5.4-206, 5.43-204, 5.6-204).

Habitat structural stages are defined in table 9. The change in HSS for ponderosa pine forest type for 1995 and 2021 is shown in table 10.

The total area for these management areas is currently 876,500 acres (draft 2021). This includes 112,181 acres of lands that are designated as unsuitable for timber production. A lower level of forest management occurs on unsuitable lands; however, the HSSs in these areas do contribute to the desired distribution of acres. Managing for the desired distribution of HSSs is intended to ensure an even flow of age and size classes in perpetuity, which should maintain habitat for a range of wildlife species.

Table 9. Habitat structural stage definitions

[In 1995, the threshold between HSS classes 3 and 4 was 8.0 inches dbh. This change in protocol 1995 to 2021 will affect comparisons between areas by size class but not by density class.]

Habitat Structural Stages	Size Class (inches dbh)	Density Class canopy cover (cc)	Other Criteria
HSS1 – grass/forb stage	n/a	< 10% cc	
HSS2 – shrub/seedling stage	trees < 1.0	≥ 10% cc	≥ 150 pine seedlings per acre
HSS3 – sapling/pole stage	trees ≥ 1.0 and < 9.0	A = cc < 40%	
HSS3 – sapling/pole stage	trees ≥ 1.0 and < 9.0	B = cc ≥ 40 and < 70%	
HSS3 – sapling/pole stage	trees ≥ 1.0 and < 9.0	C = cc > 70%	
HSS4 - mature stage	trees ≥ 9.0	A = cc < 40%	
HSS4 - mature stage	trees ≥ 9.0	B = cc ≥ 40 and < 70%	
HSS4 - mature stage	trees ≥ 9.0	C = cc > 70%	
HSS5 – late successional	10 trees ≥ 16.0	≥ 10%	10 trees ≥ 160 years

There are several limitations to the current forest use of this metric. Habitat structural stage can be calculated via different methods: by relative density or by percentage of area cover. There are also different interpretations across the national forest regarding how canopy cover is applied by canopy layer to determine density classes for HSS classes 3 and 4.

HSS is a metric intended to identify changes to size class and density for even-aged forest stands. HSS is not a descriptive metric for determining the scale of uneven-aged forest conditions regardless of the method utilized because the number of canopy layers is not included. HSS class 3 is also a wide-diameter class range that is not informative for identifying specific thinning needs for POL or smaller size class forest stands.

Table 10. Change in HSS for ponderosa pine forest type in Management Areas 4.1, 5.1, 5.4, 5.43, and 5.6), 1995 to 2021.

[Source: 1995 RIS inventory and 2021 FSVeg inventory.]

HSS	Percent of Total Area (1997 Forest Plan Objective)	1995 (acres)	2021 (acres)	Change in Acres	1995 (percent of total management area)	2021 (percent of total management area)
1	5%	13,050	71,463	58,413	1.5%	8.2%
2	5%	9,738	51,694	41,955	1.1%	5.9%
3A	10%	83,822	83,060	-762	9.4%	9.5%
3B	15%	120,899	42,875	-78,024	13.5%	4.9%
3C	5%	41,049	23,899	-17,150	4.6%	2.7%
4A	25%	301,701	350,537	48,836	33.8%	40.0%
4B	25%	220,812	162,260	-58,553	24.7%	18.5%
4C	5%	86,287	86,009	-278	9.7%	9.8%
5	5%	16,480	4,704	-11,776	1.8%	0.5%
Total	100%	893,839	876,500	-17,339	100.0%	100.0%

Table 11. Change in HSS by density class, ponderosa pine forest type, Management Areas 4.1, 5.1, 5.4, 5.43, and 5.6), 1995 to 2021

Source: 1995 RIS inventory and 2021 FSVeg inventory.]

Density category	Habitat structural Stage	1995	2021	Change in Acreage
Open density	1 – Non-stocked areas, previously forest cover	13,050	71,463	58,413
Open density	2 – Recently regenerated, shrubs/seedlings	9,738	51,694	41,955
Open density	3A – Intermediate stands, saplings/poles	83,822	83,060	-762
Open density	4A – Mature stands	301,701	350,537	48,836
Open density	Subtotal for open density	408,311	556,754	148,442
Moderate to closed density	3B and 3C – Intermediate stands, saplings/poles	161,948	66,774	-95,174
Moderate to closed density	4B and 4C – Mature stands	307,100	248,269	-58,831
Moderate to closed density	Subtotal for moderate to closed density	469,048	315,043	-154,005
Variable density	5 – Late successional stands	16,480	4,704	-11,776
Variable density	Subtotal for variable density	16,480	4,704	-11,776
All densities/ Total	Total	893,839	876,500	-17,339

- The forest is now more open (table 11).
- Non-stocked areas (HSS1) and recently regenerated forest stands (HSS2) have increased by 100,000 acres.
- Total forest areas designated as open density has increased by 148,500 acres (HSS1, HSS2, HSS3A, HSS4A).
- Moderately closed and closed HSSs (3B, 3C, 4B, 4C) are all below forest plan objectives except for HSS4C. This surplus of HSS4C, 5%, was identified by the 2018 Black Hills Resilient

Landscapes Project decision as ideal growth into the HSS5 class in the future. HSS5 was below the forest plan objective in 1995 and has decreased by 12,000 acres due to MPB mortality.

- The biggest surplus occurs in HSS4A, 15%. This surplus was created via commercial thinning and shelterwood establishment cuts that were implemented to mitigate the impacts of the MPB epidemic.

Age Classes

The forest now contains a higher level of young forest per the FIA inventory comparison data (table 12). Notable changes have been an increase of forest younger than 60 years and a decrease of forest in the 60 to 120-year age classes. Young forest stands have increased by a total of +91,560 acres on all timberlands (+69,240 acres on suitable lands and +22,320 acres on timberlands outside of suitable lands). Forest area in the 60 to 120-year classes has decreased by a total of -192,815 acres (-157,318 acres on suitable lands and -35,497 acres on timberlands outside of suitable lands). These changes are attributable to bark beetle mortality, wildfire impacts, timber production, and growth into the 120 to 140-year age classes.

There has been a minor increase in area for stands that are 160 years or older which is one of the key criteria for the designation of late successional ponderosa pine stands. The total area in the 160 to 180-year age range increased due to growth from stands in the 140 to 160-year class however 70% of this increase was offset by decreases in the 180-year and greater age class range due to MPB and wildfire impacts.

The NFMA established a requirement that the regeneration harvest of timber must occur at or later than the culmination of the mean annual increment (CMAI) of growth which is defined as the age in the growth cycle of an even-aged stand at which the average annual rate of increase of volume is at a maximum (USDA Forest Service 2015). Ponderosa pine forest stands generally reach CMAI between 100 to 120 years on the Black Hills National Forest. The NFMA also established exceptions to the requirement including salvage and sanitation harvesting in stands damaged by fire, wind throw, or other catastrophe; or stands which are in imminent danger from insect or disease attack; harvest on lands not suited for timber production to protect multiple use values; or to meet forest plan desired conditions and objectives (USDA Forest Service 2015). Forest plan desired conditions may be the primary limiting factor for the regeneration of forest stands per the next forest plan, not the CMAI requirement. Objectives that call for a more open forest will prompt managers to plan and implement a higher level of regeneration treatments in pre-CMAI stands than management associated with a higher level of moderately closed and closed forest conditions.

Table 12. Change in area by 20-year age classes, from M1 to M2, ponderosa pine forest type and non-stocked areas, for suitable lands, timberlands outside of suitable lands, and total timberlands.

[Measurement 1 (M1) = Inventory Year 2000 for WY, 2001-2005 SD to Measurement 2 (M2) = 2017-2019 for the entire forest]

Age Class	Suitable (within timberlands) Acres	Suitable (within timberlands) %	Timberlands only (outside of timberlands) Acres	Timberlands only (outside of timberlands) %	Total Timberlands (including suitable lands) Acres	Total Timberlands (including suitable lands) %
0-20	61,870	7.9%	10,178	4.9%	72,048	7.3%
20-40	2,165	0.3%	5,816	2.8%	7,981	0.8%
40-60	5,205	0.7%	6,326	3.1%	11,531	1.2%
60-80	(69,436)	-8.9%	(11,632)	-5.6%	(81,068)	-8.2%
80-100	(81,446)	-10.4%	(7,567)	-3.7%	(89,013)	-9.0%
100-120	(6,436)	-0.8%	(16,298)	-7.9%	(22,734)	-2.3%
120-140	45,585	5.8%	0	0.0%	45,585	4.6%
140-160	5,157	0.7%	(11,632)	-5.6%	(6,475)	-0.7%
160-180	22,847	2.9%	11,632	5.6%	34,479	3.5%
180-200	(14,540)	-1.9%	(5,816)	-2.8%	(20,356)	-2.1%
200-220	(7,270)	-0.9%	3,353	1.6%	(3,917)	-0.4%
Total Acres M1	779,608		206,468		986,076	
Total Acres M2	743,308		190,828		934,137	

Chapter 5. The Need for Change

Timber Program Levels

The gross growth and mortality rates (net growth) applied to sustainable timber program calculations are averages for entire rotations or cutting cycles that account for multiple disturbance cycles. The 1997 forest plan timber program was based on net growth that assumed an increase of the standing inventory for the next five decades. However, the actual net growth between 1996 and 2021 was lower than expected, and the 1997 LTSYC, ASQ, and TSPQ estimates should be revisited. The combination of the major ecosystem drivers and stressors, timber production, bark beetles, and wildfire during this time have caused long-term changes to the forest.

The standing inventory trends identified per the FIA data comparison indicate that volume in the 5.0 to 14.9-inch dbh diameter classes has decreased by an estimated 32-43% on lands suitable for timber production (table 18). This change indicates that the 1997 ASQ and actual average annual program levels of 162,500 CCF sold and 178,000 CCF cut, 1997 to 2021 may not be achievable in the future. Graham et al. 2021 also identified the need to revisit future harvest levels. The timber program increases in response to the MPB epidemic in decade 2, 2007 to 2016, were necessary to mitigate the severity of the MPB epidemic but represent a short-term departure from sustainable levels only and not a realistic long-term sustainable program level.

Near-term harvest levels have been set through 2027. In September 2020 the Black Hills National Forest Advisory Board (NFAB) approved a recommendation by the NFAB Timber Sustainability Working Group to initiate forest plan revision due to changed conditions since 1997 resulting from the effects of the MPB

epidemic, extreme weather events, and wildfire. In October 2020, the NFAB approved a recommendation by the NFAB Timber Sustainability Working Group to maintain an annual commercial sawtimber program of 181,000 CCF for fiscal years 2022 through 2027. These recommendations, dissenting working group recommendations, and a forest critique of the NFAB recommendation are available to the public on the Black Hill National Forest public website:

<https://www.fs.usda.gov/detail/blackhills/landmanagement/resourcemanagement/> (Go to Timber Sustainability on the Black Hills National Forest, National Forest Advisory Board (NFAB))

Suitable Forest Area

The total area for lands designated as may be suitable and suitable for timber production has decreased due to an increase in the net area of non-commercial forest (hardwoods) and non-stocked areas, some of which have been converted to grasslands for decades or centuries due to wildfire. Other reductions in suitable area are due to administrative changes such as the expansion of the Black Elk Wilderness, an increase in developed recreation sites, an increase in inventoried roadless areas and research natural areas, and an increase in areas designated as uneconomical or infeasible for timber production (table 2). Some of these changes are the result of more accurate mapping and the fact that more of the national forest has been surveyed due to the management response to the MPB epidemic. The public will have the opportunity to comment on draft timber suitability classifications during the development phase of forest plan revision.

This decrease in area suitable for timber production will likely reduce long-term volume yield estimates (SYL) and short-term program levels (PTSQ/PWSQ) without an increase in stocked commercial forest type area, and changes to desired future conditions and management objectives.

Habitat Structural Stage

The ponderosa pine forest in the Forest Products Management Areas (4.1, 5.1, 5.4, 5.43, and 5.6) is now more open with a greater proportion of young forest. Older, denser forest structure has shifted by about 150,000 acres to non-stocked areas, recently regenerated forest stands (HSS2), young, open stands (HSS3A) or open, mature stands (HSS4A). Following implementation of the overstory removal treatments authorized by the 2018 Black Hills Resilient Landscapes Project decision, commercial timber production in these areas will be limited for the next two decades to primarily low yield thinning and uneven-aged practices that enhance late successional conditions in the mature, moderate closed (HSS4B), and closed stands (HSS4C) without a change to forest plan desired conditions that prescribes a more open forest than current direction. Barring this type of change to the forest plan, much of the net growth in the mature ponderosa pine forest will occur on trees that may be reserved to meet multiple use objectives.

Objectives

The forest plan habitat structural stage objectives may limit adaptive management responses to unforeseen events if these objectives are interpreted as static targets that do not allow forest managers to adjust for changed conditions. Key stressors that cause large-scale disturbance events during forest cycles may require deviation from any desired size class and density distribution. Examples where deviation may be essential include the need to reserve surplus HSS4B and HSS4C stands to support promotion of late successional forest and meet changing wildlife habitat management strategies, the need to reserve additional HSS4A to promote the development of uneven-aged conditions, or the need to manage for higher levels of open conditions (HSS3A and HSS4A) in areas adjacent to communities or areas containing water sources and infrastructure to reduce the risk of extreme wildfire behavior.

HSS Definition

The HSS system that was incorporated into modeling for the development of the 1997 forest plan needs to be defined consistently across different resource areas to ensure that forest management planning and implementation aligns with stated forest plan objectives and desired conditions. There are inconsistent field interpretations and protocols for determining density classes. The current classification for sapling- and pole-size material (HSS3 classes), 1.0 to 8.9 inches dbh, is too broad to adequately identify management needs in the younger ponderosa pine forest. Finally, the 1997 forest plan HSS metric is not useful for monitoring levels of uneven-aged structure and therefore has limited value to assess consistency with desired conditions for wildlife habitat.

Silvicultural Practices

Uneven-aged Management

Current forest management practices and associated forest structure on the Black Hills National Forest are predominantly even-aged. The current level of uneven-aged management forest-wide is 5% of all commercial silvicultural treatments implemented from 1997 to 2021. Expanding the use of uneven-aged management could increase forest resiliency to large-scale MPB epidemics and better meet other resource needs such as enhancing wildlife habitat for species that rely on forest conditions with complex, heterogenous structure such as the northern goshawk (*Accipiter gentilis*).

Historical Fire Regime and Stand Structure

The fire regime for the Black Hills National Forest was likely mixed severity with forest vegetation influenced by both frequent, low intensity events and larger scale, less frequent stand replacement events.

“Twelve fire history studies covering 27 sites indicate that historical mean fire-return intervals for low-severity fires ranged from about 5 to 33 years in these communities, and that fire frequency generally increased, and fire severity was more variable with increasing elevation and moisture availability. Low-severity surface fires were most frequent in low-elevation ponderosa pine savannas, somewhat less frequent in low- to mid-elevation ponderosa pine woodlands and forests, and least frequent in high-elevation ponderosa pine and white spruce forests in the Black Hills region. Occasional mixed-severity fires likely occurred in the two higher elevation community types when, during low-severity surface fires, small patches (<250 acres (100 ha)) sometimes burned with high-severity. Frequent fire in ponderosa pine forests and woodlands maintained considerable structural and spatial heterogeneity.” (USDA Forest Service 2017)

Brown and Cook found that much of the historical fire regime and resulting forest structure that has been reconstructed for the Black Hills National Forest fits with the dominant model of the ponderosa pine ecosystems in the Southwest. In this model surface fires were a common mode of disturbance and resulted in broad areas of open, multi-aged forest stands often composed of larger and often older trees than those found today because of timber harvest (Fulé et al. in Brown and Cook). Reynolds et al. (2013) found that the structure of ponderosa pine forests in the Southwest that are associated with frequent, low intensity disturbances are typically open, with patches of tree groups with variable densities, openings, and scattered individuals.

Forest structure that is associated with a mixed and high severity fire regime has a higher tendency towards even-aged patches representing various stages of recovering following fire. This structure is characterized by large, high-density tree patches, the presence of large openings, and a high juxtaposition of early and late-seral vegetation with a high amount of edge between seral stages (Kaufmann et al. 2006, Veblen and Donnegan 2005, and Veblen et al. 2012, in Addington et al. 2018). This forest structure is more conducive to large scale, infrequent, severe disturbance than structure that has developed from a

frequent, low severity fire regime. Churchill et al. state that frequent-fire forests are complex mosaics of individual trees, tree clumps, and openings and that there is broad scientific consensus that forest management should seek to restore this mosaic to restore resilience and maintain ecosystem function. Restoring the composition and structure in frequent fire forests should result in more open forest structure and decrease the potential for epidemic outbreaks of insect and diseases and stand replacing fire (Fitzgerald 2005; Fulé et al. 2002, 2004; Graham et al 2004; Roccaforte et al. 2008; Strom and Fulé 2007; in Reynolds et al 2013). Heterogeneous stand structures also impede the buildup of epidemic insect outbreaks by disrupting pheromone plumes and breaking up the continuity of susceptible species, as well as age and size classes (Fettig et al., 2007).

Attaining Desired Stand Structure Through Uneven-aged Management

Even-aged stands typically have low structural diversity and homogenous spatial patterns at both the landscape level and at the stand scale. These conditions are not representative of historical patterns or disturbance regimes. A higher level of uneven-aged management can accelerate the recovery of forest stands post-disturbance. According to O'Hara, complex multiage stands may have greater resilience than simpler stand structures because the multiple age classes have variable susceptibilities and offer multiple pathways for recover after disturbance. Post-disturbance, multi-aged stands, because of their range of tree sizes and ages, will also potentially retain many pre-disturbance functions. Puettmann et al. state that forests that have developed heterogenous structure, function, and compositions rather than being managed to a specific, narrow set of stand structures tend to be better able to adapt to changing abiotic and biotic conditions and that this adaptability is especially critical because of the rapid pace of climate change and species invasions.

Forest structure that is beneficial for wildlife varies by species. Both even-aged and uneven-aged silvicultural systems and associated forest structures have advantages and disadvantages for wildlife habitat and management practices that focus exclusively on one system are unlikely to meet management objectives and desired conditions. McAnich, Hoover, and Kufeld (in Hoover and Wills) concluded that conditions associated with uneven-aged management are beneficial to many species of non-game birds but are not ideal for other species of birds and mammals. Even-aged management also has positive and negative impacts on wildlife but tends to have a higher degree of surface disturbance and can produce long lasting effects.

The northern goshawk (*Accipiter gentilis atricapillus*), a Rocky Mountain Region sensitive species, would benefit from an increase in uneven-aged management. A recent study for the South Dakota Department of Game Fish and Parks (Bruggeman, J.E. and P.L. Kennedy) reported that:

“Through a combination of timber harvest practices and unpredictable natural disturbances, our results suggest the BHNF has lost much of its high-quality Goshawk nesting habitat over the past 30 years. Furthermore, the remaining high-quality habitat has become increasingly fragmented. Given the loss of high-quality habitat and limited data documenting Goshawk use of lower-quality habitat, the BHNF may be moving away from management objectives established to ensure Goshawk population viability.”

Reynolds et al. 1992 proposed a combination of thinning from below, irregular shelterwood, and group selection treatments in the 420-acre Post Fledging-Family Areas (PFAs) to create a variety of forest conditions and prey habitat attributes. Interspersed small openings, snags, downed logs, and woody debris are critical PFA attributes. Irregular shelterwood treatments are similar to uneven-aged, selection silvicultural methods (Smith 1986):

“Irregular shelterwood treatments differ from other shelterwood methods in that the regeneration period is extended so long that the new stand is not really even-aged. This does not mean that it has three or more age classes that denote the uneven-aged conditions. It does, however, mean that the stand will include two age classes for long periods and sometimes even for a whole rotation. The adjective “irregular” refers to the variations in tree heights within the new stand.”

In 2003, Shepperd and Battaglia promoted the management suggestions by Reynolds for the Black Hills pending additional studies and stated that continuous management will be needed to obtain and maintain various HSSs across the landscape and that management that results in large areas of the same HSS should be avoided. Uneven-aged group and irregularly spaced individual-tree selection systems were identified as well suited to accomplish and maintain goals proposed by Reynolds and Graham for goshawk management in the Black Hills National Forest.

More recent management suggestions (Graham et al. 2015) proposed an uneven-aged selection prescription that could create and maintain forest conditions for both the goshawk and its prey by converting two aged forest stands to uneven-aged conditions. These treatments would maintain high forest cover and reduce the high level of homogenous conditions. This selection prescription and other uneven-aged methods are the current recommended practice for treatments in PFAs and Forage areas near nest sites (USDA Forest Service 2021). This type of forest management would create diverse habitat for prey species by creating a mosaic of HSSs in small patches. Goshawks use a variety of prey, and a mosaic of vegetation structure provides for the most prey species.

Bark Beetle Susceptibility

Silvicultural practices can be designed to reduce the susceptibility of the forest to bark beetle infestations. The majority of the silvicultural practices on the Black Hills National Forest are considered even-aged, which create conditions that are less resilient to severe bark beetle events. Potential effects include the greater loss of large-diameter forest structure, higher hazardous fuel loads, and longer intervals to re-stock stands due to lower numbers of replacement trees and fewer seed sources.

Since most studies that have examined forest susceptibility to mountain pine beetle have been conducted in even-aged stands confusion may exist regarding how silvicultural systems relate to lower bark beetle susceptibility. Susceptibility is based on stand density and tree diameter. Negrón et al (2008) found that the basal area of ponderosa pine in uneven-aged stands in trees ≥ 25.4 cm (10-inches) diameter at breast height (dbh) and total ponderosa pine stand density index were correlated with mountain pine beetle attack:

“The estimated probability of individual tree attack increased with tree diameter in infested plots, but it was also influenced by stand density. A tree of a given diameter size is more likely to be infested in a denser stand. In plots with of similar stand density, those with a higher basal area in trees in mid to large size classes, as compared to those with a higher proportion in small dbh trees, are more susceptible to mountain pine beetle attack.”

A more recent study by Negrón et al. (2017) conducted in thinned and unthinned even-aged stands produced similar results indicating that bark beetle susceptibility was greater in unthinned stands that contained higher number of trees ≥ 25.4 cm (10.0) inches dbh and higher stand densities in these diameter classes. The densities of the more susceptible, unthinned stands were approaching a relative stand density index (SDI) of 55% which is considered to the threshold for the lower level of self-thinning. Less susceptible thinned stands had relative SDI values well below 25% which is considered to the threshold for the onset of competition. Forest stands below these density thresholds, both even-aged and uneven-aged, will presumably be more vigorous which translates to higher tree resistance to bark beetle attacks Larsson et al. 1983, Waring and Pitman 1985 cited in Negrón et al 2017).

Stands can be commercially thinned to reduce density and thus lower the risk of beetle mortality in both even-aged and uneven-aged stands. Uneven-aged stands with a balanced diameter distribution (reverse-J curve, see Figure 8 in Appendix A) of trees by diameter class will have fewer large diameter susceptible trees and more smaller diameter trees that are considered low to moderate risk for bark beetle infestation at comparable densities with even-aged stands. These low to moderate risk trees can serve as replacement trees when overstory trees are killed by bark beetles.

Fuels Reduction

Uneven-aged treatments designed to increase horizontal and vertical complexity at low to moderate residual densities in ponderosa pine in the western United States are typically considered restoration treatments that create conditions that are consistent with the natural range of variation. These treatments may reduce the potential for severe wildfire behavior if designed appropriately concerning overall residual density, residual stocking by size class, tree spacing, and ladder fuels. From Reynolds et al. 2013:

A landscape mosaic of tree groups and scattered individual trees within an open, grass, forbs, shrub matrix, along with snags, logs, and woody debris, provides for the predominance of surface fire, mixed with small-scale, variable fire behavior (e.g, torching). An open or grouped spatial structure reduces canopy continuity, decreasing a stand's vulnerability to active crown fire (Fitzgerald 2005; Fulé et al. 2004; Roccaforte et al. 2008; Stephens et al. 2009).

Ziegler et al. found that restoration driven, variable retention harvests on structural complexity, both of horizontal and vertical dimensions, and potential fire behavior can simultaneously fulfill objectives of altering structural complexity and of reducing fire behavior but did recommend further research on desired ranges of vertical complexity to inform treatment design.

Hunter et al. indicate that both even-aged and uneven-aged methods can be effective fuels reduction treatments but recommend uneven-aged management to create structure that is consistent with relatively frequent, low-intensity surface fires that act as a natural thinning agent by reducing litter, burning small trees, and reducing ladder fuels. Regarding treatment design, uneven-aged treatments that emphasize the removal of small diameter trees are likely to reduce the potential for crown fire spread.

Pre-commercial Thinning

The total ponderosa pine area designated as a seedling habitat structural stage (HSS2) has increased from 9,700 acres to 51,700 acres (42,000 acre increase; table 10). There are currently 67,000 acres of dense sapling- and pole-size stands (HSS3B and HSS3C) stands. The majority of the seedling/sapling/pole stands are considered overstocked and will benefit from pre-commercial thinning.

Pre-commercial thinning needs will continue to increase over the next decade.¹³ Recent average annual treatments from 2017 to 2021 have occurred on 8,953 acres (FACTS database). Projected needs range from 13,000 to 15,000 acres per year. The Forest Service has recently requested additional funding to increase the level of pre-commercial thinning via service and stewardship contracting.

Reforestation

The planting program (430 acres per year since 2003) is inadequate to restock burn areas that have no or very limited potential for natural regeneration over the next two decades. Areas that will not be restocked within the next two decades should be deducted from sustainable timber program calculations (SYL and PTSQ/PWSQ) for the next forest plan. Opportunities for increasing the annual planting program, current forest capacity, and additional funding opportunities are currently being evaluated.

Late Successional Stands

The total area considered late successional ponderosa pine forest (HSS5) was below the 1997 forest plan objective (5% of Management Areas 4.1, 5.1, 5.4, 5.43, and 5.6) initially and has declined during the

¹³2020 Forest Stand Improvement Report to the Regional Office. These estimates fluctuate as they are updated annually.

MPB epidemic. There is a need to inventory and monitor forest stands that currently contain late successional characteristics or forest stands that are progressing towards these conditions in the short-term (HSS4B and HSS4C) and would benefit from management designed to promote desired conditions.

In addition, the 1997 forest plan definition of HSS5, derived from Mehl (Kaufman et al. 1992), is descriptive of even-aged forest stands. Other criteria may need to be considered in conjunction with a general assessment of HSS metrics.

Product Mixes

There is an increased need for the Black Hills National Forest to treat smaller diameter material and young forest stands based on changes to size and density classes from 1997 to 2021. The average cut tree diameter for commercial sales of sawtimber, typically in the 12- to 14-inch dbh range, is expected to decrease following implementation of overstory removal treatments per the 2018 Black Hills Resilient Landscapes Project. Program levels for pole-size material and biomass have been minor components of the overall forest program historically and since 1997. Increased commercial utilization of smaller diameter material will increase the cost effectiveness and capacity to promote the growth and resiliency of the young pine forest.

Monitoring

Close monitoring of net growth and net change trends based on a prescribed framework is necessary for maintaining a sustainable forest timber program. Timber program level calculations such as the SYL are based on long-term averages that will fluctuate over time and are unlikely to accurately predict the scale of all natural drivers and stressors through entire rotations or cutting cycles. Short-term adjustments to timber program levels will often be necessary during the life of a forest plan. There is also much uncertainty regarding future growth, mortality, and natural forest regeneration trends that may affect timber program levels due to climate change. Graham et al. (2021) summarizes the need for continuous monitoring and program flexibility based on this uncertainty:

Continuous monitoring and flexibility to adjust harvest levels based on realized mortality rates is crucial if long-term timber sustainability is to continue. In addition, growth rates also need to be adjusted going into the future because there is uncertainty on how climate will specifically influence subsequent disturbance and growth rates. Some assume that, by using harvesting alone, management can control mortality, but disturbances such as drought, tornados, and wildfires are also driven by climate and seasonal weather. If seasonal weather becomes extreme as suggested in the future climate literature (Frankson et al. 2017, Rice et al. 2018), then the potential for weather driven events could increase mortality rates, regardless of harvest levels. In addition, there is still uncertainty in exactly how climate will influence localized disturbances; thus, mortality and growth together will need to be monitored and considered when current and future harvest levels are evaluated. Because forests and disturbances are becoming more dynamic, shifts in harvest levels in the short term and reevaluations through time may be required because of the uncertainty associated with a future climate. In these potentially dynamic forested ecosystems, harvest levels and the forest products industry may also need to reflect a dynamic nature. Short-term monitoring can provide information on changing growth and mortality rates allowing for subsequent harvest levels to be adjusted. These adjustments may need to occur quickly, particularly if there are large stand-replacing wildfires.

A target inventory range that is associated with desired forest structure and species composition would be useful to guide adaptive management decisions per monitoring results. Such a range will inform managers whether to further reduce high levels of standing inventory based on the risk of stand replacement disturbance within parameters that define other multiple-use objectives or to consider a reduction in timber production levels to allow for growth of the standing inventory following a period of negative net change.

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Timber Suitability Classification Category	ALTERN- ATIVE G (1995 Data) Acres Reduced	ALTERN- ATIVE G (1995 Data) Running Total	FSVeg Nov 3, 2021 Acres Reduced	FSVeg Nov 3, 2021 Running Total
h. Less Experimental Forest and Research Watershed				
Experimental Forest (Comp. MA 5.3A)	3,368		3,371	
Research Watershed (Alkali) (Comp. MA 5.3B)	886		881	
Research Natural Area (RNA) (Comp. 811)			1,806	
TOTAL	4,254	960,286	6,058	950,675
i. Less Inyan Kara Mountain (MA 3.2A)	1,171	959,115	1,170	949,505
j. Less Administrative Sites and Campgrounds				
Administrative Sites (Comp. 850)	318		278	
Developed Recreation Sites (Comp. 825)	892		7,361	
Other (Seed Collection Sites, etc.) (Comp. 860)	42		0	
TOTAL	1,252	957,863	7,639	941,866
k. Less Critical Game Habitat				
Within Norbeck (Comp. 805)	0		415	
Other (Comp. 800)	0		22	
TOTAL	0	957,863	437	941,428
l. Less Late Succession (Comp. 701, 702, 801, 802) – Where Otherwise Unsuitable	38,931	918,932	45,014	896,415
m. Less Remaining Portions of Areas Managed for other Multiple Uses				
Botanical Areas (Comp. MA 3.1)	6,075		6,709	
Riparian Areas (Comp. 804)	4,407		273	
Backcountry Recreation Areas (MA 3.31 and 3.32)	12,710		14,919	
Spearfish Canyon (Comp. MA 4.2A)	6,391		4,109	
Southern Hills Comp. MA 5.1A)	11,533		13,899	
TOTAL	41,116	877,816	39,908	856,506
n. Less Uneconomical for Timber Harvest				
Steep Slopes (Comp. 820 and 821)	6,884		8,289	
Topography Prevents Harvest (723)	0		297	
Roading Problems (Comp. 823)	2,461		4,039	
Isolated Patches (Comp. 824)	2,581		9,085	
TOTAL	11,926	865,890	21,710	834,796
Other				
Superfund site (Comp. 806)	0		1,598	
Proposed Land Exchange (Comp. 873)	0		50	
SUITABLE AND AVAILABLE ACRES		865,890	1,648	833,148
Less non-stocked acres, ponderosa pine forest	13,022	852,868	66,898	766,250

Table 14. Annual total volume sold by product, Black Hills National Forest, 1997 to 2021.

[Source: Periodic timber sale accomplishment reports and cut and sold reports.]

Year	Sawtimber	POL	Firewood	Add Volume (sawtimber)	Total
1997 ¹	169,197	3,919	7,643	0	180,759
1998	151,765	2,385	6,927	0	161,077
1999	144,100	856	7,633	0	152,589
2000	74,613	1,695	4,764	0	81,071
2001	19,036	1,689	2,949	0	23,675
2002	89,853	1,359	3,151	0	94,364
2003	78,019	3,424	3,235	0	84,679
2004	160,046	10,987	4,982	0	176,015
2005	141,632	3,451	5,158	0	150,241
2006	145,614	2,176	8,779	0	156,569
2007	174,759	3,119	5,200	0	183,078
2008	238,793	6,416	7,491	0	252,700
2009 ²	194,680	3,523	9,042	0	207,245
2010	181,658	2,609	7,352	0	191,619
2011	161,934	8,072	7,320	0	177,326
2012	164,835	6,421	5,662	0	176,918
2013	161,116	5,997	5,221	0	172,334
2014	159,798	4,349	6,741	0	170,888
2015	183,819	11,125	5,762	0	200,706
2016 ³	195,698	7,492	6,025	5,118	214,334
2017	173,476	6,613	6,740	12,871	199,700
2018	181,053	2,038	7,694	21,251	212,037
2019	163,671	825	8,622	0	173,118
2020	114,306	707	7,451	2,952	125,416
2021	127,571	3,235	6,743	4,215	141,764
Totals	3,751,043	104,482	158,287	46,407	4,060,220

¹All volume was converted from MBF. Volume started being reported in CCF in 1998.

²Previous volume was reported from the old Timber Sale Accounting system. In 2009 and forward, volume was pulled from PTSAR system.

³Add volume started being tracked through Modifications and Agreements.

Table 15. Annual volume cut by product, Black Hills National Forest, 1997 to 2021.

[Source: Cut and sold reports. Volume was converted from MBF to CCF from 1997 to 2007. Cut and sold reports were available in CCF starting in 2008.]

Year	Sawtimber	POL	Firewood	Total
1997	118,620	4,299	6,912	129,830
1998	130,393	2,064	8,303	140,759
1999	140,545	1,365	6,892	148,801
2000	127,846	3,611	6,450	137,907
2001	150,941	4,208	3,202	158,350
2002	118,989	3,237	2,514	124,740
2003	128,895	3,709	2,822	135,426
2004	139,983	7,131	3,415	150,529
2005	145,396	14,305	5,514	165,215
2006	146,412	2,687	4,188	153,286
2007	171,312	5,088	3,836	180,236
2008	201,633	9,029	14,016	224,678
2009	212,532	9,967	6,397	228,897
2010	222,212	8,690	6,722	237,625
2011	221,545	6,826	7,120	235,491
2012	193,848	6,032	6,650	206,530
2013	208,936	9,204	5,093	223,233
2014	171,388	2,067	6,100	179,554
2015	193,427	4,907	6,168	204,502
2016	179,010	7,497	5,925	192,432
2017	175,441	4,893	6,502	186,836
2018	132,751	2,771	9,532	145,054
2019	181,623	4,643	8,314	194,579
2020	172,982	2,681	6,615	182,278
2021	162,757	5,515	6,684	174,956
Totals	4,149,416	136,424	155,883	4,441,724

Table 16. Annual commercial timber acres by silvicultural method, Black Hills National Forest, 1997 to 2021.

[Source: FACTS database, December 10, 2021. All regeneration methods are considered even-aged except for selection methods, which are considered uneven-aged.]

Fiscal Year	Thinning ¹ (acres)	Shelterwood Cut ² (acres)	Overstory Removal ³ (acres)	Clearcut (acres)	Patch Cut (acres)	Hardwood/ Meadow Restoration (acres)	Seed Tree Cut (acres)	Selection (acres)	Improvement Cut (acres)	Sanitation / Salvage (acres)	Total (acres)
1997	4,034	7,403	1,820		414		351	811	470		15,303
1998	4,118	8,012	2,034		344		759	596	1,043	186	17,092
1999	7,216	6,076	2,341		324		682	544	526	112	17,821
2000	5,205	6,190	2,026		425		336	361	198	83	14,824
2001	3,234	3,393	3,647		129		587	323	225	1,583	13,121
2002	7,845	4,931	3,139		436		901	921	409	579	19,161
2003	6,357	3,565	3,283		364		117	684	732	1,460	16,562
2004	11,016	8,254	5,180		1,110		632	682	1,885	239	28,998
2005	12,984	4,864	4,343	16	364		818	471	391	563	24,814
2006	16,985	5,465	7,266	15	597		679	1,396	845	440	33,688
2007	10,306	3,231	3,185		16	13	577	529	448		18,305
2008	17,244	3,355	6,706		96	151	710	343	145	926	29,676
2009	16,987	1,854	3,529	20	27	56	85	803	168	1,053	24,582
2010	8,968	2,834	5,579			52	273	1,025	176	4,592	23,499
2011	8,152	2,115	4,479	10	6	219	331	2,425	7	2,060	19,804
2012	15,428	1,934	4,579			10		811	96	4,320	27,178
2013	11,702	4,272	3,641		64		12	2,297	8	1,573	23,569
2014	7,820	7,008	3,326					716	79	2,571	21,520
2015	9,765	7,378	2,143			2		1,456		419	21,163
2016	14,620	6,306	1,668		20			1,068		876	24,558
2017	9,213	3,397	2,046			23		1,031			15,710
2018	5,469	2,330	7,003		13			2,063		13,083	29,961
2019	4,653	3,354	13,211			547		2,906	381	28	25,080
2020	1,531	1,746	11,293			864		1,494	224	3,019	20,171
2021	4,966	906	8,191	2,227	10	256	213	2,999	154	1,539	21,461
Total	225,817	110,173	115,658	2,288	4,759	2,193	8,063	28,755	8,610	41,304	547,621

¹Many commercial thinning treatments were regeneration treatments, shelterwood establishment cuts, but were coded as thinning per treatment descriptions in the 2012 MPBR Project.

² Includes all entries associated with a shelterwood system except for overstory removals.

³ Includes liberation cuts.

Table 17. Annual acres affected by MPB per aerial detection surveys by district on national forest lands and total mortality acres, Black Hills National Forest, 1996 to 2021.

[Source: Forest Health Protection, Aerial Detection Survey program. Reported affected acres include overlap between surveys years (ongoing mortality can be identified in the same area for multiple years).]

Survey Year	BL	HC	MY	NH	Total	Mortality Acres
1996	385	396	669	634	2,084	-
1997	658	249	708	5,383	6,999	561
1998	1,578	1,040	3,411	7,263	13,293	1,266
1999	857	4,770	3,973	8,584	18,184	807
2000	1,094	4,006	2,366	5,871	13,337	1,988
2001	4,144	17,609	32,247	43,661	97,662	13,614
2002	5,068	24,247	35,532	32,660	97,506	19,023
2003	3,974	45,755	52,556	71,400	173,685	16,549
2004	8,070	14,078	18,256	18,164	58,567	15,048
2005	879	5,830	7,373	4,049	18,130	2,340
2006	890	12,337	15,577	8,211	37,015	3,478
2007	775	5,708	13,535	4,599	24,617	9,010
2008	314	7,231	14,050	2,611	24,206	2,275
2009	208	4,806	11,657	4,965	21,635	2,024
2010	235	6,006	25,501	10,462	42,203	9,500
2011	1,204	8,675	32,602	22,101	64,583	20,000
2012	537	5,374	12,504	11,102	29,518	31,200
2013	509	7,174	16,611	8,112	32,406	34,000
2014	695	5,152	5,627	4,080	15,553	16,500
2015	1,154	4,925	4,428	4,788	15,295	16,500
2016	347	835	355	758	2,296	2,500
2017	1,729	1,967	62	789	4,547	2,900
2018	37	165	15	12	230	230
2019	9	2	2	2	15	20
2020	13	0	0	1	14	10
2021	0	0	0	0	0	0
Total	34,977	187,940	308,947	279,630	811,494	221,343

Note: Affected acres and mountain pine beetle mortality acres from 1996 to 2009 for the Black Hills National Forest were derived from the USDA Forest Service Forest Health Protection Aerial Detection Survey (ADS) program. These surveys are conducted by observers in small aircraft who map areas of forest insect and disease activity using a digital aerial sketch mapping system. Mountain pine beetle affected acres are gross acres that contain both mortality trees that were attacked by beetles the previous year and live trees that were unaffected at the time of each survey. Mortality trees per acre are then estimated for each activity area. Affected acres often contain overlap between survey years. From 1996 to 2009 mortality acres were typically estimated by dividing gross ADS affected acres by mortality trees per acre. Starting in 2010 a more accurate method was implemented. High resolution aerial photography was assessed in GIS software to delineate areas of annual mortality.

Table 18. Ponderosa pine volume (CCF) by size class (inches dbh), on timberlands and lands designated as suitable for timber production, Black Hills National Forest.

[The unit of measure varies by size class: POL size class volume (trees 5.0 to 8.9 inches dbh) is presented in merchantable bole volume; sawtimber size class volume (trees ≥ 9.0 inches dbh) is presented in net sawlog volume. Measurement 1 (M1) = Inventory Year 2000 for WY, 2001-2005 SD, Measurement 2 (M2) = 2017-2019 for the entire forest.]

Diameter Class	Suitable Lands (within timberlands) M1	Suitable Lands (within timberlands) M2	Suitable Lands (within timberlands) Change (CCF)	Suitable Lands (within timberlands) % Change	Timberlands (outside of suitable lands) M1	Timberlands (outside of suitable lands) M2	Timberlands (outside of suitable lands) Change (CCF)	Timberlands (outside of suitable lands) % Change	Total Timberlands (including suitable lands) M1	Total Timberlands (including suitable lands) M2	Total Timberlands (including suitable lands) Change (CCF)	Total Timberlands (including suitable lands) % Change
5.0-6.9	438,224	292,622	(145,602)	-33.2%	130,794	80,014	(50,780)	-38.8%	569,018	372,637	(196,382)	-34.5%
7.0-8.9	1,561,482	883,590	(677,892)	-43.4%	361,161	277,616	(83,545)	-23.1%	1,922,643	1,161,206	(761,437)	-39.6%
9.0-10.9	1,435,539	824,386	(611,153)	-42.6%	381,852	267,119	(114,733)	-30.0%	1,817,391	1,091,505	(725,886)	-39.9%
11.0-12.9	1,839,082	1,167,453	(671,629)	-36.5%	363,721	404,783	41,062	11.3%	2,202,803	1,572,236	(630,567)	-28.6%
13.0-14.9	1,567,937	1,061,954	(505,983)	-32.3%	391,777	287,273	(104,504)	-26.7%	1,959,714	1,349,227	(610,487)	-31.2%
15.0-16.9	1,469,596	1,270,899	(198,697)	-13.5%	439,432	404,019	(35,414)	-8.1%	1,909,029	1,674,918	(234,111)	-12.3%
17.0-18.9	1,011,338	883,525	(127,813)	-12.6%	239,714	284,700	44,986	18.8%	1,251,052	1,168,225	(82,827)	-6.6%
19.0-20.9	640,068	894,107	254,039	39.7%	185,678	253,256	67,578	36.4%	825,745	1,147,362	321,617	38.9%
21.0-22.9	140,763	419,943	279,180	198.3%	29,645	52,868	23,223	78.3%	170,408	472,811	302,403	177.5%
23.0-24.9	241,667	28,169	(213,499)	-88.3%	31,818	32,820	1,002	3.1%	273,485	60,989	(212,497)	-77.7%
25.0-26.9	84,012	133,281	49,269	58.6%	0	0			84,012	133,281	49,269	58.6%
27.0-28.9					42,961	48,864	5,903	13.7%	42,961	48,864	5,903	13.7%
29.0-30.9												
31.0-32.9												
POL	1,999,705	1,176,212	(823,494)	-41.2%	491,955	357,631	(134,325)	-27.3%	2,491,661	1,533,842	(957,818)	-38.4%
Sawtimber	8,430,002	6,683,717 ¹⁴	(1,746,285)	-20.7%	2,106,599	2,035,702	(70,897)	-3.4%	10,536,601	8,719,419	(1,817,182)	-17.2%
Totals	10,429,707	7,859,928	(2,569,779)	-24.6%	2,598,554	2,393,333	(205,222)	-7.9%	13,028,261	10,253,261	(2,775,000)	-21.3%

¹⁴ Total ponderosa pine inventory for both suitable lands and all timberlands will differ from the totals released to the public in January 2020, for the 2017-2019 intensified forest inventory (5,995,428 CCF estimate for suitable lands) because the 2017-2019 intensified inventory estimates are derived from a larger population sample. This intensified inventory is more precise and has a lower sampling error in comparison with inventory estimates presented in table 17.

Table 19. Ponderosa pine volume (CCF) per acre by product classes on timberlands and lands designated as suitable for timber production, all forest types, including non-stocked areas.

[The unit of measure varies by size class: POL size class volume (trees 5.0 to 8.9 inches dbh) is presented in merchantable bole volume; sawtimber size class volume (trees ≥ 9.0 inches dbh) is presented in net sawlog volume. Measurement 1 (M1) = Inventory Year 2000 for WY, 2001-2005 SD, Measurement 2 (M2) = 2017-2019 for the entire forest.]

Area	Measurement	Total Acres	Sawtimber CCF	Sawtimber CCF/Acre	Sawtimber % Change	POL CCF	POL CCF/Acre	POL %Change	Total CCF	Total CCF/Acre	Total %Change
Suitable lands, within timberlands	M1	884,603	8,430,002	9.53		1,999,705	2.26		10,429,707	11.79	
Suitable lands, within timberlands	M2	879,194	6,683,717	7.60	-20.2%	1,176,212	1.34	-40.8%	7,859,928	8.94	-24.2%
Timberlands, outside of suitable lands	M1	241,781	2,106,599	8.71		491,955	2.03		2,598,554	10.75	
Timberlands, outside of suitable lands	M2	234,638	2,035,702	8.68	-0.4%	357,631	1.52	-25.1%	2,393,333	10.20	-5.1%
Total timberlands, including suitable lands	M1	1,126,384	10,536,601	9.35		2,491,661	2.21		13,028,261	11.57	
Total timberlands, including suitable lands	M2	1,113,831	8,719,419	7.83	-16.3%	1,533,842	1.38	-37.7%	10,253,261	9.21	-20.4%

Table 20. White spruce volume (CCF) by product classes on timberlands and lands designated as suitable for timber production, Black Hills National Forest.

[Change in white spruce total volume per size class. The unit of measure varies by size class: POL size class volume (trees 5.0 to 8.9 inches dbh) is presented in merchantable bole volume; Sawtimber size class volume (trees ≥ 9.0 inches dbh) is presented in net sawlog volume. Measurement 1 (T1) = Inventory Year 2000 for WY, 2001-2005 SD, Measurement 2 (T2) = 2017-2019 for the entire forest.]

Diameter Class	Suitable Lands (within timberlands) M1	Suitable Lands (within timberlands) M2	Suitable Lands (within timberlands) Change (CCF)	Suitable Lands (within timberlands) % Change	Timberlands (outside of suitable lands) M1	Timberlands (outside of suitable lands) M2	Timberlands (outside of suitable lands) Change (CCF)	Timberlands (outside of suitable lands) % Change	Total Timberlands (including suitable lands) M1	Total Timberlands (including suitable lands) M2	Total Timberlands (including suitable lands) Change (CCF)	Total Timberlands (including suitable lands) % Change
POL	68,739	83,400	14,661	21.3%	36,688	35,828	-859	-2.3%	105,427	119,228	13,801	13.1%
Sawtimber	322,137	188,575	-133,562	-41.5%	162,715	170,238	7,523	4.6%	484,852	358,813	-126,039	-26.0%
Totals	390,876	271,975	-118,902	-30.4%	199,403	206,066	6,664	3.3%	590,279	478,041	-112,238	-19.0%

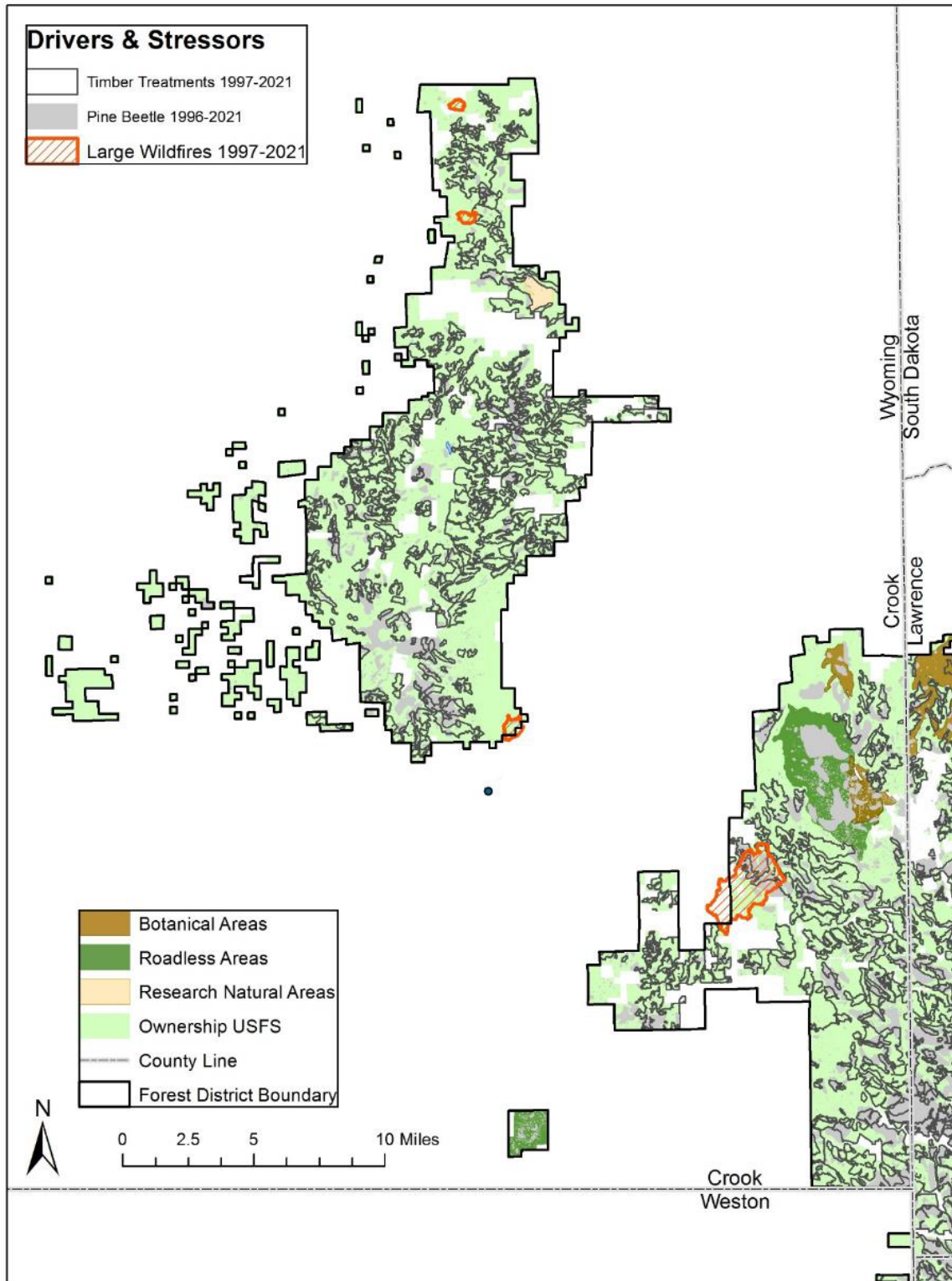


Figure 4. Major drivers and stressors for the Black Hills National Forest, Bearlodge Ranger District, Wyoming, 1996 to 2021.

Image of a portion of the Forest map showing Botanical Areas in brown, Roadless Areas in dark green, Research Natural Areas in beige, USFS ownership in light green, pine beetle affected areas in gray, wildfire affected areas in hashed orange, and county boundaries in dashed line. White areas on map represent non-Forest Service ownership.

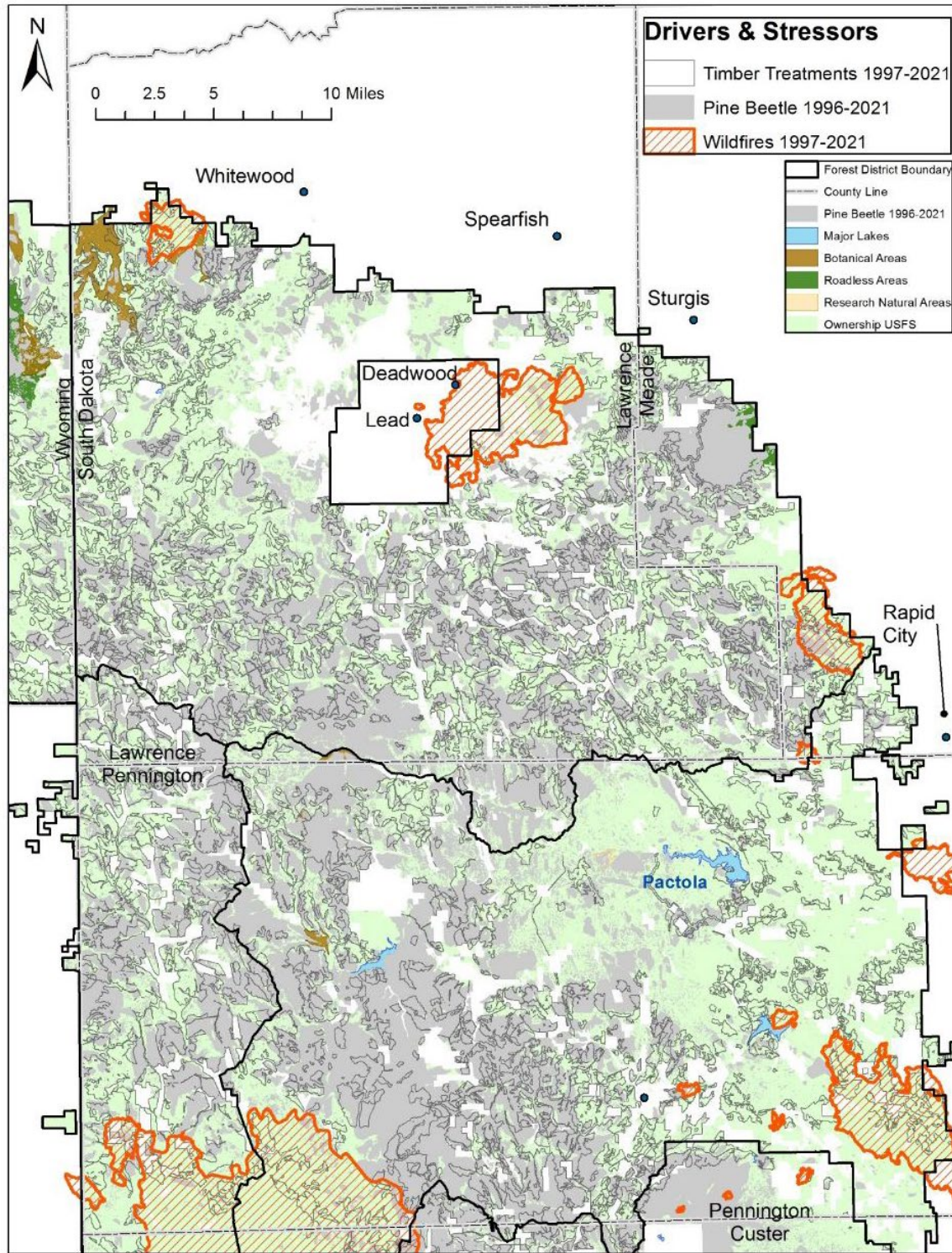


Figure 5. Major drivers and stressors for the Black Hills National Forest, Northern Hills and Mystic Rangers Districts, South Dakota, 1996 to 2021.

Image of a portion of the Forest map showing Botanical Areas in brown, Roadless Areas in dark green, Research Natural Areas in beige, USFS ownership in light green, Pine beetle affected areas in gray, wildfire affected areas in hashed orange, and county boundaries in dashed line. White areas on map represent non-Forest Service ownership.

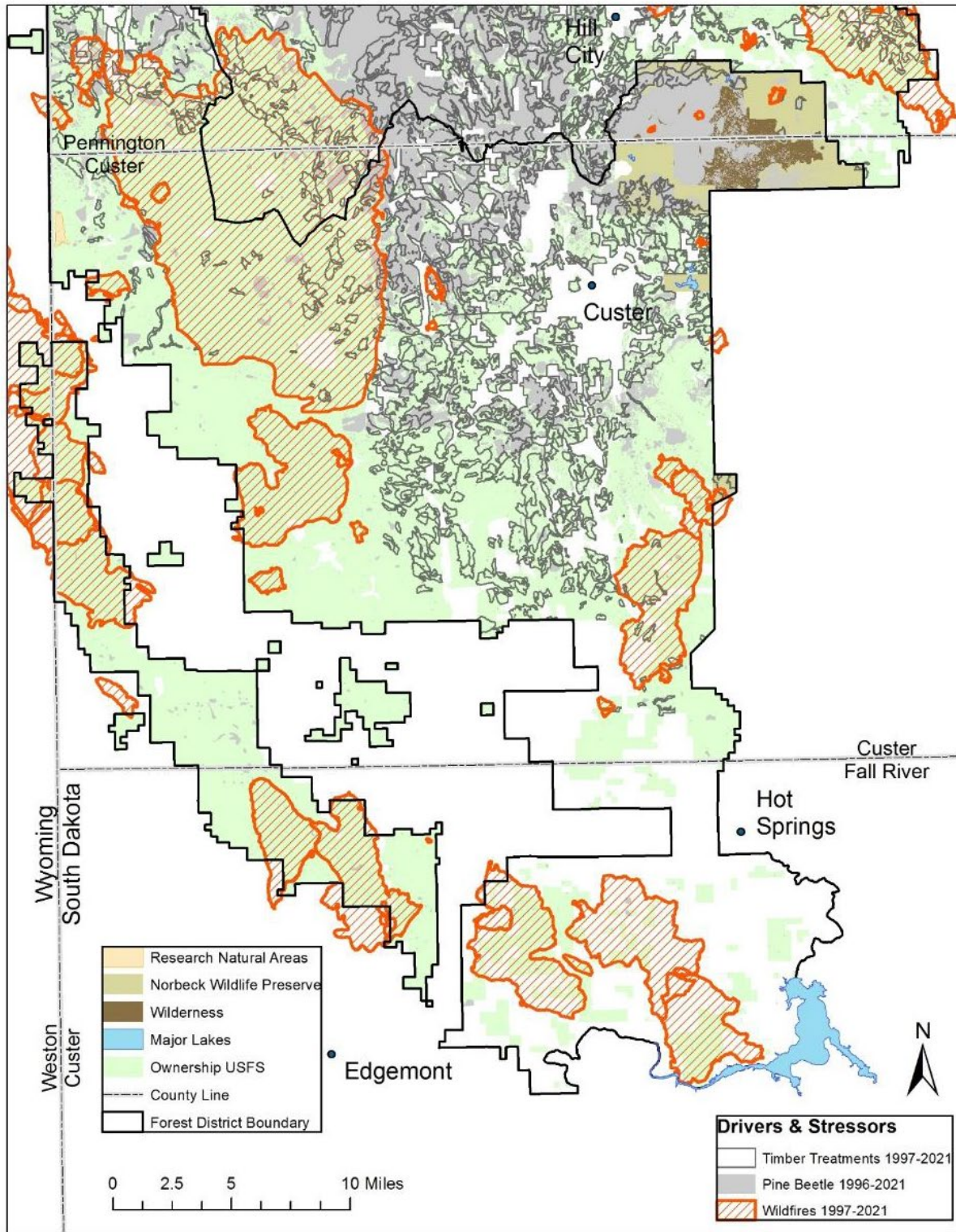


Figure 6. Major drivers and stressors for the Black Hills National Forest, Hell Canyon Ranger District, South Dakota, 1996 to 2021.

Image of a portion of the Forest map showing Botanical Areas in brown, Roadless Areas in dark green, Research Natural Areas in beige, Norbeck Wildlife Preserve in khaki, major lakes in blue, USFS ownership in light green, pine beetle affected areas in gray, wildfire affected areas in hashed orange, and county boundaries in dashed line. White areas on map represent non-Forest Service ownership.

Appendix B - Silviculture Terminology

The source for all definitions is Society of American Foresters (1994) unless noted otherwise.

Cutting Cycle: The planned interval between partial harvests in an uneven-aged stand.

Even-aged Methods: A planned sequence of treatments designed to maintain and regenerate a stand with predominately one age class. The range of tree ages is usually less than 20 percent of the rotation (see clearcutting, seed-tree, shelterwood, and coppice regeneration methods).

Even-aged Stand: A stand of trees composed of a single age class in which the range of tree ages is usually +/- 20 percent of the rotation age.

Hardwood Restoration Cut: The objective of these cuts is to increase the number of acres of hardwoods. This would be accomplished by patch cutting in pine stands with remnant hardwoods or expanding the edges of existing hardwood stands. As described earlier, hardwoods and the mix of tree species are key components of biological diversity (USDA Forest Service 1996).

Improvement Cut: The removal of less desirable tree of any species in a stand of poles or larger trees, primarily to improve composition and quality.

Intermediate Treatment: Any treatment or tending designed to enhance growth, quality, vigor, and composition of a stand after establishment or regeneration and prior to final harvest.

Meadow Restoration Cut: This cut restores meadow acres encroached upon by conifers over the last century. This is accomplished through cutting pine or spruce adjacent to existing meadows. The location and extent of these cuts are determined by soil types and by the use of historic photographs. Meadow restoration is distinct from the removal of small pine trees that have encroached into meadows. Meadows are a key component of the biological diversity being lost as conifer cover expands. (USDA Forest Service 1996).

Overstory Removal: The cutting of trees constituting an upper canopy layer to release trees or other vegetation in an understory.

Precommercial Thinning: The removal of trees not for immediate financial return but to reduce stocking to concentrate growth on the more desirable trees.

Regeneration Method: A cutting procedure by which a new age class is created; the major methods are clearcutting, seed tree, shelterwood, selection and coppice wood.

Rotation: In even-aged systems, the period between regeneration establishment and final cutting.

Shelterwood Establishment Cut: A cut to establish a moderated micro-environment, prepare the seed bed, and create a new age class.

Thinning: A cultural treatment made to reduce stand density of trees primarily to improve growth, enhance forest health, or to recover potential mortality.

Two-Aged Stand: A growing area with trees of two distinct age classes separated in age by more than +/- 20 percent of rotation.

Two-Aged Method: Regeneration and maintenance of stands with two age classes. The resulting stand may be two-aged or tend towards an uneven-aged condition as a consequence of both an extended period of regeneration establishment and the retention of reserve trees (green trees) that may represent one or more age classes.

Uneven-aged Stand: A stand with trees of three or more distinct age classes, either intimately mixed or in small groups.

Uneven-Aged System: A planned sequence of treatments designed to maintain and regenerate a stand with three or more age classes.

Group Selection: Trees are removed and new age classes are established in small groups. *Note 1.* The width of groups is commonly approximately twice the height of the mature trees with small openings providing micro-environments suitable for tolerant regeneration and larger openings providing conditions suitable for more intolerant regeneration. *Note 2.* the management unit or stand in which regeneration, growth, and yield are regulated consists of an aggregation of groups.

Group Selection with Reserves: Some trees within the group are not cut to attain goals other than regeneration withing the group.

Single Tree Selection: Individual trees of all size classes are removed more-or-less uniformly throughout the stand, to promote growth of remaining trees and to provide space for regeneration.



Figure 7. Image of mature, open ponderosa pine forest (trees greater than 9 inches dbh, crown cover 11 to 40%) following a shelterwood establishment-cut (USDA Forest Service 2018).

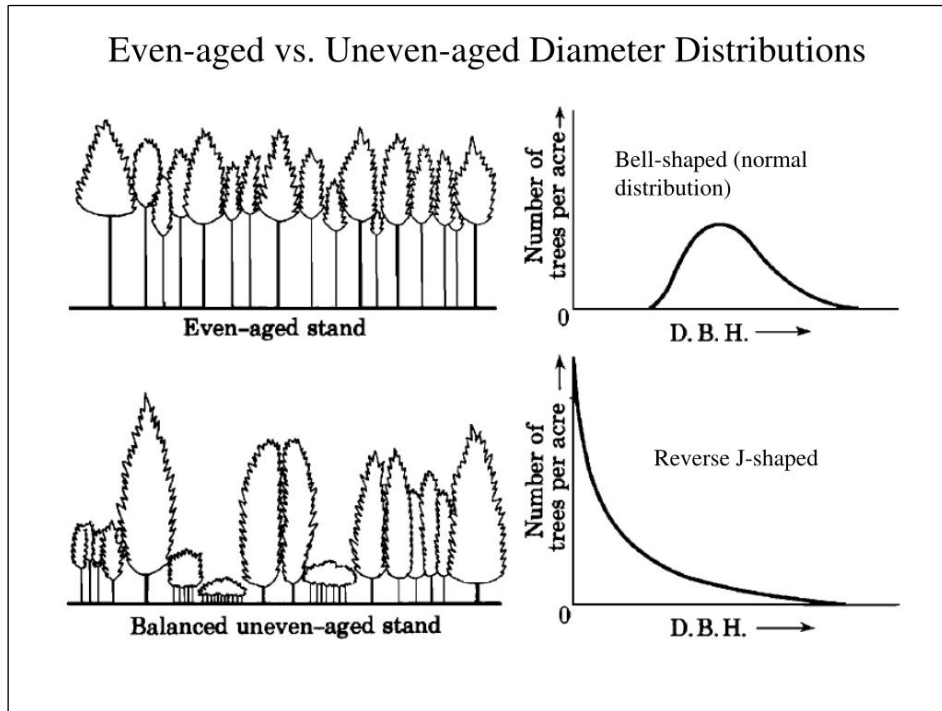


Figure 8. Image of comparison of even-aged and uneven-aged diameter distributions.