



Three Decades of Silviculture in Northern Rocky Mountain Forests, USA: Trends, Practices, and Outcomes

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Received: 2 March 2026 / Accepted: 1 July 2026
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Abstract

The Northern Rocky Mountains region includes 42 million acres of forest land which is diverse in landownership, management objectives, tree species, site productivities, disturbance regimes, and silvicultural practices resulting in a mosaic landscape. Substantial changes in landownership, management objectives, markets, policy, forest conditions, and silvicultural practices have occurred over the last thirty years. This review provides a synopsis of these changes across different forest types in the region. The U.S. Department of Agriculture, Forest Service remains the largest forest management entity in the region, encompassing all forest types. Silvicultural practices have largely shifted towards multiple objective management on federal lands, reflecting broad societal values. This includes restoring historical species composition and enhancing resistance and resilience to natural disturbances, with wildfire a dominant disturbance concern across all forest types. Large corporate landownerships remain concentrated on high productivity sites in the region. Many of these companies are now Timber Investment Management Organizations (TIMOs) and Real Estate Investment Trusts (REITs). The region has seen an uptick in the establishment of high-yield plantations on their land, dominated by Douglas-fir and western larch. State lands continue to manage to meet their endowment mandates with some examples of increased intensification through plantation establishment. Overall, the region is dynamic, and we expect continued emphasis on fuels reduction, timber production, recreation, wildlife habitat, among others, as meeting these objectives will help ensure the sustainability of forests for years to come.

Study Implications This review summarizes changes in forests and silviculture in the Northern Rocky Mountains over the last 30 years. This is in no way prescriptive, but it is valuable for understanding broad forest management objectives and how those influence silvicultural trends in the region and across ownerships. We anticipate this will be helpful for students, managers, researchers, and stakeholders to understand the larger context under which site-specific forest management occurs, improve our capacity to learn from other regions, and help us understand the past to better prepare for the future.

Extended author information available on the last page of the article

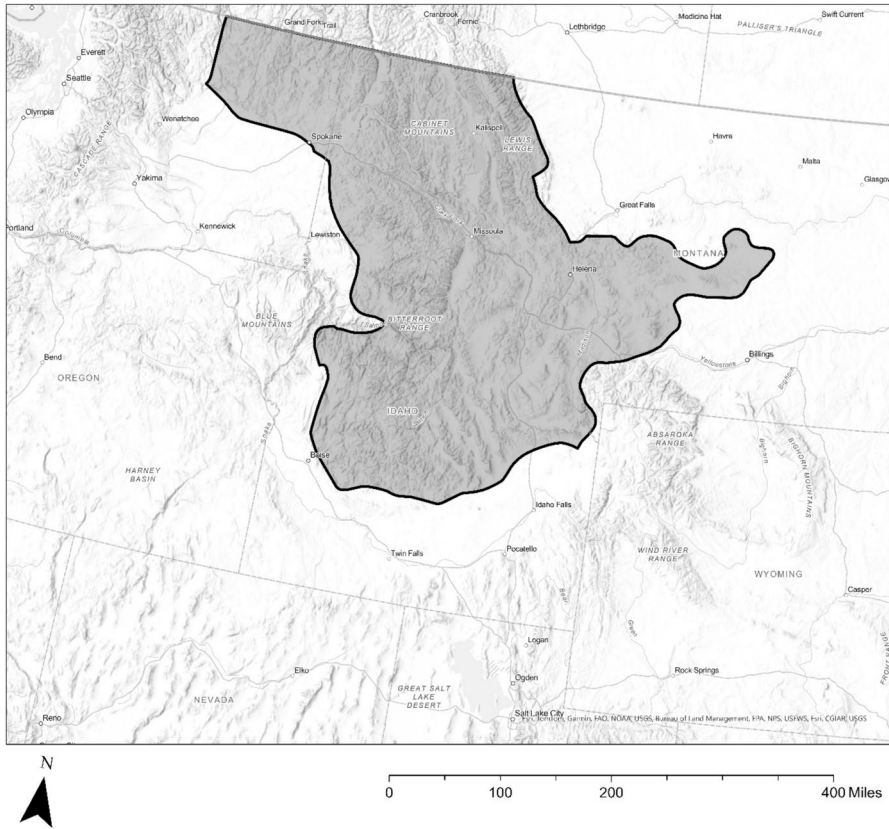


Fig. 1 Range of the Northern Rocky Mountains based on the ecoregion sections developed by Bailey (2016) spanning Northeast Washington, Idaho north of the Snake River Plain, and most of Western Montana. The region aligns with the map provided in Long (1995)

Keywords Moist conifer forest · Dry conifer forest · Cold conifer forest · Idaho · Washington · Montana

Introduction

The Northern Rocky Mountains of the United States span northeastern Washington, Idaho north of the Snake River Plain, and most of western Montana (Fig. 1) (Adams 1995). The region spans approximately 63 million acres with more than two-thirds of this area classified as forest (Table 1) (U.S. Department of Agriculture, Forest Service 2025e). The region encompasses the Northern Rocky Mountain Forest (M333) and Middle Rocky Mountain Steppe (M332) ecoregions (Bailey 2016). Across the forested area, 34.1 million acres are classified as timberland (i.e., forestland capable of producing 20 cubic feet per acre of wood per year) and 8.1 million

Table 1 Forestland classification and net timber volume in the Northern Rocky Mountains, 2009–2015 derived from FIA inventories (Forest Service 2025e) in the M333 and M332 ecoregions of Idaho, Montana, and Washington (Bailey 2016)

State/Entity	Total Land Area (M acres)	Forest Land (M acres)	Timberland (M acres)	Reserved Forest Land (M acres)	Other Forestland *	Other Land **	Net Growing Stock ‡	Net Sawtimber Volume Timberland ‡‡
Idaho	25,958	17,998	13,803	3,695	500	7,960	35,395	185,298
Montana	31,480	19,839	16,106	2,624	1,109	11,641	28,915	125,257
Washington	5,221	4,183	4,023	130	30	1,038	9,021	44,495
National Forest	33,266	29,012	22,401	5,615		4,254	54,231	264,960
Other Federal	5,419	1,953	1,029	1,156		3,466	1,899	8,791
State and Municipal	3,677	2,074	1,971	2,043		1,603	3,957	19,885
Private	20,297	8,981	8,530	8,975		11,316	13,242	61,414
Total	62,659	42,020	34,116	6,449	1,639	20,639	73,329	355,050

State and Municipal includes state- and city-owned lands. Private includes corporate, non-governmental natural resource organizations, unincorporated local partnerships, Native American, and individuals and family lands

* total forest minus timber reserved

** total land minus total forest land

‡ ≥ 5 in DBH Volume on Timberland (MM cubic feet)

‡‡MM board feet Intl 1/4 inch rule

acres are classified as reserve or for purposes other than timber production. The Northern Rocky Mountains contain numerous forest types that are defined by the dominant tree species. Five major forest types were identified in the Northern Rocky Mountain chapter of the Regional Silviculture of the United States, 3rd Edition (Adams 1995), namely western white pine (*Pinus monticola*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), lodgepole pine (*Pinus contorta* var. *latifolia*), ponderosa pine (*Pinus ponderosa*), and Engelmann spruce (*Picea engelmannii*)-subalpine fir (*Abies lasiocarpa*). Two additional forest types are increasingly of regional importance: western larch (*Larix occidentalis*) and whitebark pine (*Pinus albicaulis*).

These forest types vary across topographical and elevation gradients from dry ponderosa pine forests common at low elevations and dry slopes to moist mixed-conifer forests where western white pine historically mixed with other conifer species at mid-elevation sites to lodgepole pine, spruce-fir, and whitebark pine at higher elevations and colder sites.

Three decades ago, Adams (1995) provided an in-depth characterization of regional forests and silviculture of the Northern Rocky Mountains that has served as a foundational text about the region. But substantial changes have occurred in forest ownership, management objectives, policies, markets, forest ecology, and associated silvicultural activities in the last 30 years across the region warranting an updated discussion.

The region has experienced a general shift in management objectives considering environmental drivers when designing silvicultural systems. There is a general recognition that climate change is affecting interactions of insects and diseases with trees, as well as abiotic disturbances such as increased frequency of severe wildfires and droughts (Loehman et al. 2018). In addition, there is evidence that climate change may result in range shifts and alterations to deployed seed sources to match future climatic conditions (Keane et al. 2018). Some private landowners, agencies, and Tribes have started incorporating emerging science on climate-assisted seed transfer guidelines into their management.

The following sections provide an overview of the status of land ownership and management objectives, policies, and markets agnostic to forest type in the Northern Rocky Mountains. We then discuss current conditions, management objectives, and silvicultural practices for the seven major forest types in the region. The paper concludes with a look towards the future in terms of tools to support silvicultural decision-making and expected changes in management objectives and infrastructure that inform silvicultural designs and implementation.

Forest Ownership and Management Objectives

Much of the forestland is managed by federal agencies, primarily the U.S. Department of Agriculture Forest Service (Forest Service) (Table 1), but management objectives and the silvicultural practices used to achieve them have adapted to evolving market conditions, societal expectations, and scientific knowledge over the last 30 years.

One of the biggest changes to the Forest Service in the region has been the merger of many National Forests to improve administrative and operational efficiency. These include the Beaverhead-Deerlodge National Forest (1996), Salmon-Challis National Forest (1998), Caribou-Targhee National Forest (2000), Nez Perce-Clearwater National Forests (2012), and Helena-Lewis and Clark National Forest (2015). Following their mergers, these forests and many other National Forests have revised their management plans to reflect contemporary management goals and design silvicultural systems to meet multiple management objectives based on natural range of variability, historical species composition, and various national level management objectives documented in federal laws such as the Endangered Species Act, The Water Quality Act, and the National Forest Management Act and directed by the 2012 Forest Service Planning Rule. Ranger districts have also consolidated on National Forests resulting in fewer people managing more acres. Multidisciplinary teams (e.g., wildlife, hydrology, soils, botany) have been enhanced, which has made management decisions more complex. There has also been a widespread shift towards custodial management on many National Forests to limit high-severity fire and protect human communities and infrastructure. Much of this occurs within the wildland-urban interface (WUI), which has expanded considerably across the region (Radeloff et al. 2018). These WUI areas are often prioritized for fuels reduction as a primary management objective.

State land area has changed minimally through various land swaps. Management objectives on state lands vary by state and productivity of the forest, but there has been an overall trend of increased plantation establishment and associated silvicultural activities on sites capable of producing timber, while improving forest health, reducing wildfire risk, protecting water quality, maintaining wildlife habitat, and recreation (Eckberg and Holfeltz 2020; Montana DNRC 2020; Washington DNR 2025). Many state lands in Montana, Idaho, and Washington are managed as Trust Lands, where revenue generated from timber sales support K-12 and university educational institutions, and other beneficiaries. In Washington, state forest land management has become contentious with environmental interests and trust beneficiaries, like counties, litigating for less and more timber harvesting respectively (e.g., *Conservation Northwest v. Commissioner of Public Lands* 2022; *County of Skamania v. State* 1984; *Skagit County v. State of Washington* 2020). State wildlife agencies (e.g., Montana Fish, Wildlife and Parks, Idaho Department of Fish and Game, Washington Department of Fish and Wildlife) also manage forest land in the region, often in designated recreation or wildlife management areas, to meet mandates to create and maintain habitat for wildlife species (Idaho DFG 2026; Montana FWP 2026; Washington DFW 2026). These agencies often collaborate with conservation organizations, such as the Rocky Mountain Elk Foundation, to meet their objectives.

Private timberland as defined by the USDA Forest Inventory and Analysis program (FIA; i.e. corporate, non-governmental natural resource organizations, unincorporated local partnerships, Native American, and individuals and families) acreage has remained constant at 25% of total timberland, although there have been considerable changes among land ownership entities within this category. An example is the acquisition of 310,000 acres of land by The Nature Conservancy and The

Trust for Public Land previously owned by Plum Creek Timber in Montana (Trust for Public Land 2026).

Private family forestland owners are a major landownership class in the Northern Rocky Mountains. Across the region, there are approximately 156,000 family forest owners who own 5.15 million acres; average parcel size in Idaho and Montana are 74 and 100 acres, respectively (Rabotyagov et al. 2021; Forest Service 2021a, b). Many family forest landowners indicate that timber production is of little or no importance to them (Rabotyagov et al. 2021). Dominant reasons for owning forests are similar across all three states and include scenery, wildlife habitat, protecting nature and water, and privacy (Rabotyagov et al. 2021; Forest Service 2021a, b).

Company structure of corporate landowners in the region has changed substantially with the near complete transition of forestry corporations from vertically integrated entities to real-estate investment trusts (REITs) and timber investment management organizations (TIMOs). The conversion to REITs and TIMOs occurred in response to a series of changes to US tax rules and the 1974 Employee Retirement Income Security Act (ERISA) law requiring pension funds to diversify beyond stocks and bonds and creating vehicles and incentives for managing timber land as an investment (Baral and Mei 2022; Mendell 2016; Mendell et al. 2008). By the 2010s most corporate landowners in the country were either TIMOs or REITs (Stein 2011). This shift in structure has been accompanied by buying and selling large parcels of land between companies and the emergence of new companies managing the land (Stein 2011). The shift in structure of the companies has also led to diversification of revenue, including real estate developments for high-value parcels, sale of conservation easements, access permitting, and carbon credit schemes (Kaur and Abrams 2026; Sass et al. 2021).

The change in ownership structure of corporate landowners toward REITs and TIMOs has contributed to shifts in silviculture (Stein 2011). Most significantly, the investment models used by TIMOs and REITs emphasize the time value of money which encourages shortened rotations, relative to those that maximize annual volume production, which was historically a greater priority for integrated companies who relied on timberlands to furnish their sawmills, rather than as an investment in their own right (Clutter et al. 2005; Kaur and Abrams 2026; Lacy 2006). These changes may incentivize liquidation of a portion of standing inventory, which combined with substantial reductions in harvest volumes from federal lands likely contributed to large increases in the proportion of timber volume harvested by corporate landowners during the last thirty years (Crandall et al. 2025; Hayes et al. 2021; Kaur and Abrams 2026; Simmons et al. 2024).

Because TIMOs and REITs manage forest land separately from manufacturing interests, there may be less incentive for research and intermediate silvicultural treatments (e.g., pruning) aimed at improving wood quality, particularly if there is a long-time interval to return on investment or inadequate market premiums for timber with desirable traits (Hickman 2007; Lacy 2006). Conversely, the authors of this paper have observed increased interest in silvicultural activities that contribute to shortening rotation lengths, e.g., establishment of plantations with improved genetics, increasing stand uniformity, and using fertilizer. These ownership structures are also more open to alternative revenue streams, even if they reduce timber

production. For instance, a number of TIMOs have entered their lands into improved forest management carbon offset projects, which place restriction on silvicultural practices and typically reduce timber production to increase carbon stored in the forest above base-line scenarios determined by ‘business as usual’ practices of private timber land managers in a given region (Kaur and Abrams 2026; Sass et al. 2021).

Eight Federally recognized Native American Tribes have forested reservation land in the Northern Rocky Mountains. These tribes include Blackfeet Nation, The Coeur d’Alene Tribe, The Confederated Tribes of the Colville Reservation, The Kalispel Tribe of Indians, The Kootenai Tribe of Idaho, Nez Perce Tribe, Confederated Salish and Kootenai Tribes, and Spokane Tribe of Indians. The Tribes collectively have approximately 1.77 million acres of forestland on reservations (Climate Impact Partners 2026; Confederated Salish and Kootenai Tribes 2000; Hokoda 2019; Nez Perce Tribe 2025; The Coeur d’Alene Tribe 2025; United States Bureau of Indian Affairs 2003). Over the past decades tribal self-governance has increased in accordance with the 1975 Indian Self-Determination and Education Assistance Act and 1990 National Indian Forest Resource Management Act, and forest management has shifted away from US Bureau of Indian Affairs (BIA) Forestry toward full self-governance or contracts and compacts of suites and services co-managed with BIA (Indian Forest Management Assessment Team 2023).

Whereas many tribal forestry objectives have been stable over the past decades, the social acceptance and application of Traditional Ecological Knowledge has increased globally (e.g., Cheveau et al. 2008). Cultural goals have expanded from tribal forests to include public and private lands, where landowners and decision-makers are more directly interfacing with Indigenous members (Hoagland 2017; Mason et al. 2012). This combined with a shift from BIA management of tribal forestland in trust towards more autonomous management of forests by the tribes has created new opportunities for integrating cultural resources into silviculture.

Policy and Regulatory Context

In recent decades there have been substantial shifts in the policies and regulations across the region. Following the “Timber Wars” of the 1990s (Proctor 1995), management of forests on federal lands shifted from timber production as the primary management objective to an ecosystem management approach where holistic multi-objective management was identified (Haynes et al. 2001). While much attention on these developments has focused on the northern spotted owl (*Strix occidentalis caurina*) and forests west of the Cascade Mountains and California through the Northwest Forest Plan, in 1993 President Clinton issued a directive for agencies to develop a scientifically based strategy for forests in eastern Oregon and Washington which resulted in new emphasis on ecosystem management and the use of regional and landscape assessments. An example is the Interior Columbia Basin Ecosystem Management Project (ICBEMP), a science-based strategy for ecosystem management for implementation on Forest Service and Bureau of Land Management lands covering the Northern Rocky Mountains and beyond (Haynes et al. 2001).

Policy changes have also influenced interactions of Native American Tribes with federal lands in recent years including the Tribal Forest Protection Act of 2004 and expansion of 638 agreements starting with the 2018 Farm Bill. These policies allow federally recognized tribes to propose projects on Forest Service land to benefit Tribal resources and values while also meeting Forest Service objectives (Agriculture Improvement Act of 2018; Tribal Forest Protection Act of 2004).

Additional policies have been enacted that foster cooperation between state and federal forest management agencies. The primary example is the Good Neighbor Authority program, authorized by Congress in 2014 and expanded in the 2018 Farm Bill, which allows the Forest Service and Bureau of Land Management to enter into agreements with local forestry agencies (i.e., states and counties) to use their resources to do critical forest management on federal land (Agriculture Improvement Act of 2018 115–334 U.S.C. § 8624, 2018; Agriculture Reform Food and Job Act of 2013). These cooperations between Tribes, states, and the federal government have led to many successful projects in the Northern Rocky Mountains including fuels reduction, prescribed fire to improve first foods, and protection of aquatic and terrestrial ecosystems (Idaho Department of Lands 2026; ITC 2026; Montana DNRC 2026; Washington DNRC 2026a).

There were also substantive developments on private lands in the region over this time. Many state forest practice laws were revised in the last 30 years, for instance increasing stream side buffers, managing slash, modifications to restrictions on clear-cut size and reforestation requirements in some states, and requirements for protecting or retaining habitat features during regeneration that have shifted silvicultural activities to conform with law and best management practice guidelines (e.g., Barkley et al. 2015; Ziesak et al. 2015). Also, most large private owners have entered into voluntary sustainability certification schemes, primarily Sustainable Forestry Initiative or Forest Stewardship Council certification (Moore et al. 2012; Washington DNRC 2026b). These certifications systems introduce additional constraints and considerations for silviculture in the region (Fernholz et al. 2011; Gutierrez Garzon et al. 2020).

Markets, Products, and Forestry Infrastructure

The forest products industry of the region has experienced significant structural transformation in recent years. The number of primary wood-processing facilities declined from roughly 400 in the early 1990s to about 170 in the 2020s (Keegan et al. 1995a, b; Keegan et al. 1997; McIver et al. 2013; Scott et al. 2025; Simmons et al. 2014; Smith and Larson 2017). Total timber-processing capacity also declined, but by a much smaller proportion from approximately 2.4 to 1.9 billion board feet Scribner. These changes reflect an industry that has concentrated and modernized, shifting toward fewer and larger mills while maintaining a small group of niche-product operations. Idaho experienced a smaller decline than the rest of the region in both facility count and employment.

Despite these structural adjustments, nominal (not adjusted for inflation) log prices have remained relatively unchanged. Average nominal delivered values

were about \$400 per thousand board feet Scribner in both the 1990s and the 2020s (Bureau of Business and Economic Research 2025), showing little price growth even as operating expenses increased. In contrast, production and transportation costs rose sharply. Ground-based logging operations that averaged around \$75 per MBF in 1991 approached \$250 per MBF in 2023 (Hayes et al. 2023; Keegan III et al. 1995). The cost of hauling a 28-ton truckload 100 miles one way increased from roughly \$400 in 2003 to \$750 in 2023 (Scudder et al. 2024; US Bureau of Labor Statistics 2025a). These trends have reduced the potential real profitability across much of the primary sector, especially for smaller producers with limited economies of scale.

Similar shifts occurred in the regional labor force (Hayes et al. 2021; Scott et al. 2025; Simmons et al. 2024; US Bureau of Economic Analysis 2022, 2025; US Bureau of Labor Statistics 2025b; US Census Bureau 2025). Total private-sector forest-industry employment declined from about 40,000 workers in the 1990s to roughly 26,000 in the 2020s. Within this total, wood-products manufacturing employment dropped from approximately 20,000 to 13,000. Idaho again shows a less pronounced decline, reflecting its more diverse ownership and industrial structure, and possibly its larger area of productive forestland. On the other hand, forestry support and services, such as silvicultural contracting, reforestation, and fuels management, expanded from around 3,500 to 6,000 positions region wide.

Harvesting technology during the 1990s and 2000s remained dominated by conventional whole-tree harvesting systems that expanded during the mechanization era beginning in the 1960s. Whole-tree systems, especially on flatter terrain, offers operators increased efficiency, production rates, and fiber utilization relative to earlier methods (Bolding et al. 2025; Lundbäck et al. 2021). Although cut-to-length (CTL) technology was developed in Scandinavia during the 1970s, adoption outside the Nordic countries remained limited due to terrain, timber size, market logistics, and infrastructure built around whole-tree harvesting (Bolding et al. 2025; Lundbäck et al. 2021). In the western United States, CTL became more closely associated with thinning, restoration forestry, and treatments emphasizing reduced soil disturbance and residual stand protection. At the time of writing, CTL systems still appear to have limited adoption in the Northern Rocky Mountains.

On steeper terrain, however, tethered harvesting systems have expanded rapidly in recent years, representing a major shift away from traditional skyline logging. Hayes et al. (2022) describe tethered logging as a “relatively new form of harvesting” in Montana and northern Idaho, driven largely by labor shortages and worker safety concerns, with contractors increasingly substituting machine capital for labor-intensive cable crews. Additionally, various technologies are used for mastication to achieve a range of objectives from fuels reduction to competition control to site preparation (Jain et al. 2018).

Technological improvements have also enhanced the ability of mills to process smaller-diameter timber. Logs under 10 inches diameter at breast height (DBH) accounted for about 9 percent of inputs in the early 2000s and roughly 15 percent by the 2020s (Simmons et al. 2020). However, residual-fiber markets have weakened as the number of pulp, paper, and board facilities has declined (Brandeis and Guo 2016). More than half of harvested wood fiber enters the residual stream, and the

Fig. 2 Examples of seven forest types in the Northern Rocky Mountains. **A)** shelterwood establishment cut in the western white pine type on Deception Creek Experimental Forest (credit: Andrew Nelson), **B)** commercial thinning in the Douglas-fir type (credit: Andrew Nelson), **C)** aggregate retention as part of variable retention in the lodgepole pine type (credit: Justin Crotteau), **D)** restoration of old-growth characteristics in the ponderosa pine type (credit: Justin Crotteau), **E)** unmanaged stand in the spruce-fir type (credit: Justin Crotteau), **F)** seed-tree establishment in the western larch type (credit: Justin Crotteau), and **G)** daylight thinning in the whitebark pine type (credit: Nicole Mutchler)

shrinking capacity of downstream users highlights the interdependence of production sectors within the regional forest economy.

Along with these broad infrastructure shifts, the tribal forestry workforce has been changing (Indian Forest Management Assessment Team 2023). Greater self-governance and the success of the Confederated Salish and Kootenai College's Forestry degree program (4-year BS degree, first offered in 2005) has enhanced opportunities for Indigenous peoples to enter the tribal forestry workforce.

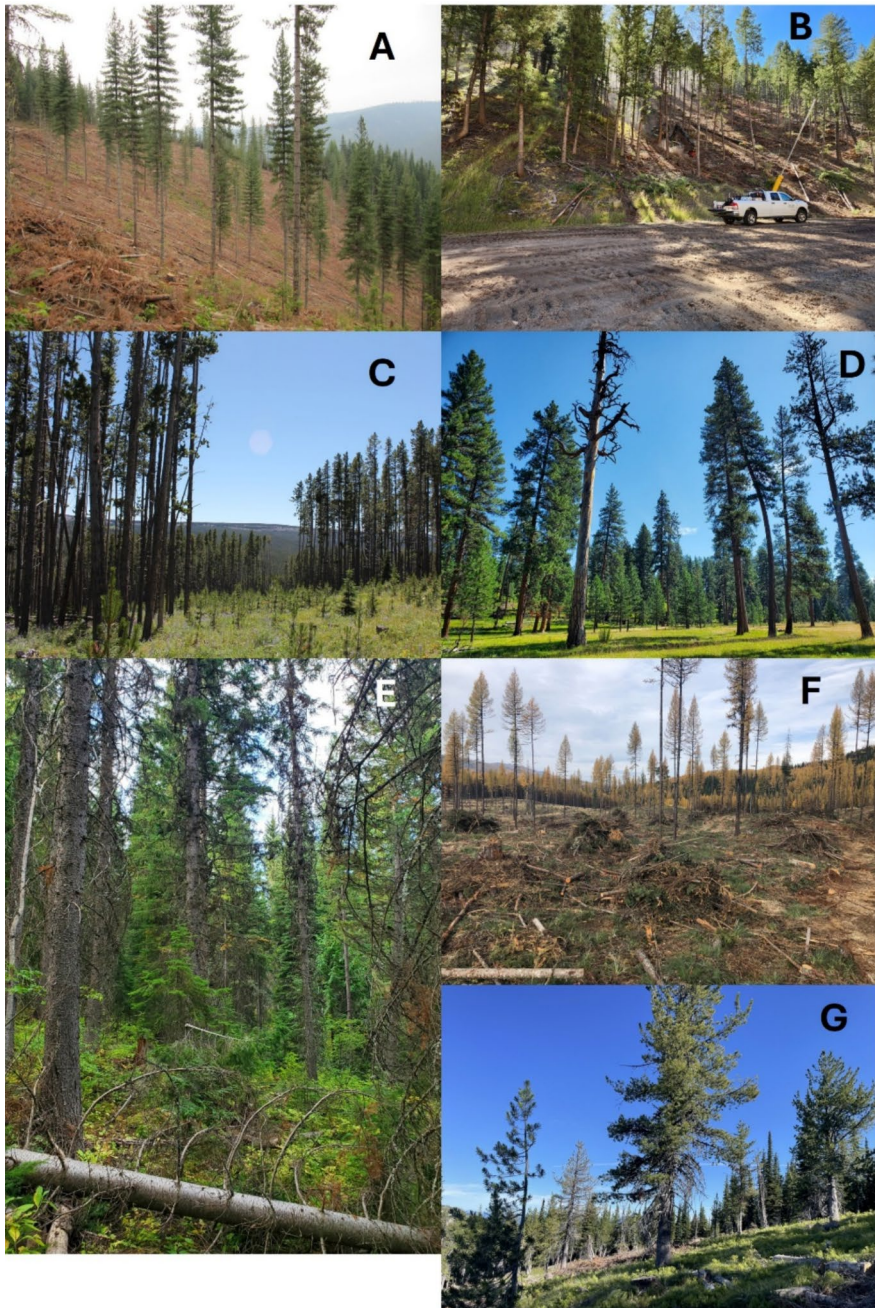
Silviculture of the Major Forest Types

Per Adams (1995), we bin vegetation and strategies by forest cover type rather than potential vegetation classification types. Adams (1995) presented five cover types (western white pine, Douglas-fir, lodgepole pine, ponderosa pine, and spruce-fir) and we present two additional forest types (western larch and whitebark pine) (Fig. 2). Some statements, particularly for management practices on federal lands, derive from communications with federal silviculturists who are cited collectively as (*f.s. pers.comm. 2025*).

Western White Pine Type

The western white pine type was historically dominated by western white pine but also supports the greatest number of tree species across all forest types in the Northern Rocky Mountains including western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), Douglas-fir, grand fir (*Abies grandis*), and many other conifers (Daubenmire and Daubenmire 1968; Haig et al. 1941). Historically, the fire regime was of mixed severity with variable fire return intervals (Agee 1993; Zack and Morgan 1994). Other disturbances historically contributing to stand dynamics include diseases, insects, wind, snow, and ice (Jain and Graham 2005). A wide range of landowners manage forests in this type including a high concentration of corporate landowners.

The loss of western white pine following the introduction of the *Cronartium ribicola* pathogen that causes white pine blister rust followed by landscape-scale salvage harvesting and aggressive fire suppression shifted composition towards other species that are more shade tolerant and less resistant of biotic and abiotic disturbances (Arno 1980; Hann et al. 1997; Neuenschwander et al. 1999). In addition, National Forests in Idaho planted Douglas-fir and grand fir following disturbance in the mid-twentieth century and favored these species in weeding and thinning treatments



during the early days of the blister rust resistance tree improvement program (Ketcham et al. 1968). Douglas-fir and grand fir also readily regenerated naturally (Jain and Graham 2015). The result is a landscape dominated by these species that are

more susceptible to root pathogens (*Armillaria* sp., *Coniferiporia* sp., *Phaeolus schweinitzii*) (Harvey et al. 2008; Neuenschwander et al. 1999).

The legacy of objectives favoring species other than western white pine and mortality from white pine blister rust resulted in western white pine currently comprising a minor component of contemporary Northern Rocky Mountain forests (Reinhardt et al. 2024) (Table 2). The pendulum has swung considerably away from those objectives and associated silvicultural strategies in the last 30 years on National Forests and other ownership classes once the forest health and disturbance resiliency issues were realized and once blister rust resistant genetics were available for planting western white pine (Forest Service 2015a, 2025d).

Natural regeneration silvicultural systems are used to establish new forests in this type. On National Forests, all even-aged systems are still used including clearcutting, shelterwood, and seed-tree, although large dispersed clearcuts are less common (Forest Service 2015a). Even-aged units often retain reserve trees converting stands into two-aged systems. Traditional single-tree selection is not common as it has the propensity to promote shade tolerant species such as western hemlock and grand fir that are less disturbance resilient and have lower timber value than shade intolerant and mid-tolerant species such as western larch, ponderosa pine, and western white pine (Graham et al. 1999). Single-tree selection may be an appropriate system for promoting western redcedar, which has high timber value and shade-tolerance (Haig et al. 1941), although research is lacking. Group selection is a viable option in this forest type where desirable early seral species can be regenerated when opening sizes average 0.6 acres (Smith and Smith 1994). Free selection systems (e.g., Graham and Jain 2005) are being trialed on the Idaho Panhandle National Forest to create landscape heterogeneity and within-stand variability in microsites to increase tree species diversity (*personal observation*).

Table 2 Growing-stock volume on timberland by species derived from FIA inventory data between 2009 and 2015 (Forest Service 2025e) in the M333 and M332 ecoregions of Idaho, Montana, and Washington (Bailey 2016)

Species	Idaho	Montana	Washington	Percent
(Million cubic feet)				
Douglas-fir	9,931	10,497	3,242	32.3
Grand fir	8,291	835	723	13.4
Lodgepole pine	2,322	4,877	588	10.6
Ponderosa pine	2,629	2,105	1,636	8.7
Engelmann spruce	2,727	3,318	297	8.6
Western larch	1,372	2,871	1,160	7.4
Subalpine fir	2,247	2,540	183	6.8
Western redcedar	2,893	579	716	5.7
Western hemlock	1,222	299	300	2.5
Mountain hemlock	1,012	257	-	1.7
Western white pine	333	87	48	0.6
Whitebark pine	125	286	-	0.6
Other hardwood species	166	151	85	0.5
Aspen	48	128	42	0.3
Other softwood species	76	86	-	0.2

Site preparation is common both in natural regeneration silvicultural systems and during plantation establishment to modify microsites and manage surface fuels. A variety of treatments are practiced across ownerships including prescribed fire, mastication, grapple pile and burning of slash (Jain et al. 2020), and on state and private lands, herbicides. Herbicides in particular have been shown to increase tree growth multiple decades after treatment (Cherico et al. 2020), while pile and burning has been shown to increase natural regeneration of multiple species (Jain et al. 2020).

Advances have been made over the last 30 years in the western white pine blister rust resistance breeding programs (Fins et al. 2002). The breeding programs have identified major gene resistance and led to the establishment of seed orchards and the near complete use of blister-rust resistant seed for reforestation (McDonald et al. 2004). Western white pine seedlings are often planted along with western larch, lodgepole pine, ponderosa pine, and western redcedar following harvesting and natural disturbance to achieve desired condition in appropriate potential vegetation type groups on federal land, e.g. as directed in Forest Service Forest Plans (e.g., Forest Service 2015a, 2025d), as well as state and private lands. State and private landowners also establish plantations of Douglas-fir and western larch in this forest type, which are described in their respective sections below.

Tending is widely practiced in this forest type. The most common tending treatment is precommercial thinning to reduce density and control species composition in both naturally regenerated stands and plantations. In western white pine plantations, it is recommended to delay thinning until age 25–30, aiming for 400–500 residual trees per acre, to allow for screening of blister rust resistance and shading of *Ribes*, the primary alternate host of *C. ribicolum* (Graham 1983). Pruning is common in western white pine plantations to reduce the likelihood of infection with *C. ribicolum* from alternate ground vegetation hosts and is often carried out at the time of precommercial thinning (Hagle and Grasham 1988; Hunt 1998).

In plantations of species other than western white pine, thinning treatments typically aim for regular spacing and to reduce density to 100–350 trees per acre, depending on objective and desired species (*personal observation*). Lower densities are favored for shade intolerant and mid-tolerant species, such as western larch, reducing fire hazard and increasing drought resistance. Markets for pulpwood are limited for large portions of the region and supplied primarily by mill residue (Simmons et al. 2024), so commercial thinning is rare. Some landowners perform non-commercial improvement cuts in older stands (i.e., 30–50 years old) where trees are left onsite except for the few areas close to remaining pulp markets (*personal observation*). These treatments shift species composition and/or density to enhance resistance to disease, insects, or abiotic disturbances, to create more structural complexity for habitat and other ecological functions, or attempt to increase growth of remaining trees for enhanced timber value.

Douglas-fir Type

Douglas-fir is the predominant forest type of the Northern Rocky Mountains by area and growing stock and occurs across a wide range of landownership classes (Table 2). The species occurs across a broad range of habitat types in the region

from semiarid areas near the lower treeline to subalpine habitats (Arno 1990). It often mixes with other species but also occurs as pure stands in cold-dry forests of southwestern Montana and eastern Idaho (Joy and Hutton 1990). Over the past century this type has expanded in the absence of disturbance, to the point that it is considered over-represented in areas (Keeling et al. 2006). Many landscape patch sizes have increased in size and homogeneity of structure and age class—a trend driven by fire suppression and management history (Arno et al. 2000; Gruell et al. 1982). In the past decades this type has been substantively impacted by wildfire, drought stress, disease, and insect damage (Fig. 3). A complex of *Armillaria*, *Phellinus*, *Heterobasidium*, and *Phaeolus schweinitzii* affect Douglas-fir forests and decrease productivity, along with dwarf mistletoe (*Arceuthobium douglasii*) (Hawksworth and Wiens 1996; Lockman et al. 2016). Endemic insects such as the western spruce budworm (*Choristoneura occidentalis*) and Douglas-fir beetle (*Dendroctonus*

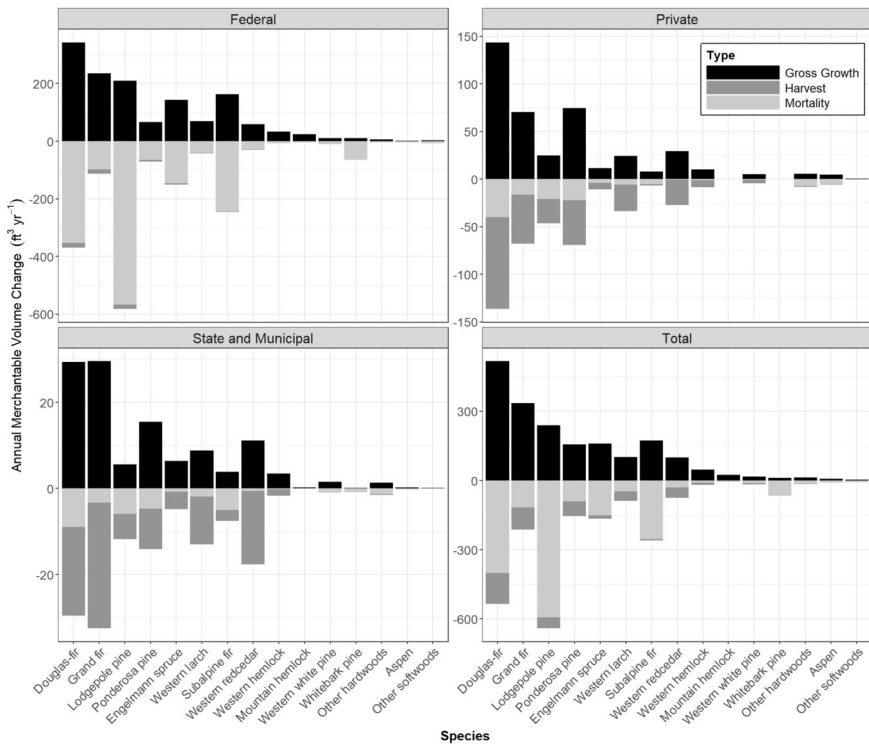


Fig. 3 Components of annual volume change (gross growth, mortality, and harvest) by ownership class and tree species for trees 5.0 inches DBH and greater in million cubic feet per year averaged among years between 2015 and 2025 derived from FIA inventory plots (Forest Service 2025e) in the M333 and M332 ecoregions of Idaho, Montana, and Washington (Bailey 2016). Federal lands (upper left), Private lands (upper right), State and Municipal lands (lower left), and All Ownerships combined (lower right). State and Municipal includes state- and city-owned lands. Private includes corporate, non-governmental natural resource organizations, unincorporated local partnerships, Native American, and individuals and family lands. Gross growth is the annual increase in volume in the absence of cutting and mortality

pseudotsugae) have caused extensive regional damage and mortality in recent years, paving the way for an increase in secondary pests and mortality agents (The Montana DNRC 2025; Forest Service 2025c; Witt et al. 2019).

Considering the accelerated pace of damage in the Douglas-fir type, plus the greater emphasis on managing forests for multiple uses on federal land, many federal forests are promoting early seral species diversity (i.e., western white pine, ponderosa pine, western larch, and lodgepole pine) and practicing ecological forestry with disturbance and warming climate in mind (f.s., pers. comm., 2025; Scott et al. 2013; Forest Service 2025b). This is most evident in Douglas-fir mixed conifer cover types where Douglas-fir is a climax species and other species can maintain dominance with frequent disturbance; Douglas-fir is still preferred in much of its core range with some state and private landowners.

A variety of silvicultural systems are used to manage Douglas-fir forests. Multiple-use forestry on federal lands focuses on objectives to enhance age-class, as well as species, diversity in Douglas-fir forests. Seed tree, shelterwood, two-aged systems, and free selection regeneration methods are used to regenerate Douglas-fir and other species, and improve stand and landscape structural complexity (f.s., pers. comm. 2025). Comparatively, many state and corporate landowners have increased the establishment of Douglas-fir plantations following clearcut harvesting on lands within the historic range of the western white pine type. Greater use of plantations is driven by the value of Douglas-fir for dimensional lumber. Many of these plantations are managed similar to coastal Douglas-fir plantations (Talbert and Marshall 2005), but site productivities are lower and rotation lengths are longer. Desired rotations for Douglas-fir plantations on productive sites are 40–50 years targeting a 12–14-inch quadratic mean diameter and minimum of 250 trees per acre (*C. Brumley*, pers. comm., 2026).

Reforestation has also changed over the past decades. More disturbance tolerant and early seral species are often planted with or in replacement of Douglas-fir on federal lands, as well as some state and private lands. This is driven by the over-representation of Douglas-fir across the landscape and objectives to create heterogeneity in stand composition and structure to increase resilience to warmer temperatures and natural disturbances (e.g., Forest Service 2015b). For example, recommendations for management of root diseases are to plant species less susceptible (Filip et al. 2024; Rippey et al. 2005). Most of the reforestation needs and activity on federal lands now take place on burned areas rather than harvested areas (f.s., pers. comm., 2025). Many plantations on corporate and some state trust lands plant seedlings of first-generation improved seed sources that have been selected and tested by the Inland Empire Tree Improvement Cooperative (IETIC) (Fins 1983). Improved seeds are supplied by private and cooperative IETIC seed orchards. IETIC members recently established second-generation progeny test sites to advance tree improvement efforts (*M. Rust* pers. comm. 2026).

Tending is the most common treatment class in Douglas-fir forests. Where Douglas-fir is the preferred species, managers frequently implement thinning from below (f.s., pers. comm., 2025). This reduces density-dependent competition and ladder fuels, thereby reducing drought stress, improving resistance to Douglas-fir beetle and western spruce budworm, and creating more fire resistant stands (Jain et al.

2012). However, where the forest type is dry mixed-conifer, improvement cuts may be prescribed to increase species diversity to maintain future management options by promoting other long-lived and root-disease-tolerant species such as ponderosa pine and western larch (e.g., Fiedler et al. 1992; f.s., pers. comm., 2025). Care must be taken when thinning root disease infected stands as cut stumps serve as a source of inoculum that can spread infection and increase tree mortality of residual susceptible species and new regeneration (Filip et al. 2024). Many private landowners and states also apply precommercial thinning in Douglas-fir plantations between ages 15 and 20 to maintain optimal density and remove naturally regenerated trees (*personal observation*). Although fertilization is not widely practiced in the region, some landowners do fertilize, particularly towards the end of an even-aged rotation to accelerate volume growth (*personal observation*). Fertilization is recommended on moist sites and when trees are vigorous (Coleman et al. 2014).

Lodgepole Pine Type

Lodgepole pine forests are concentrated on federal lands in the Northern Rocky Mountains. In recent decades, the lodgepole pine type in this region has changed greatly because of high-severity disturbances (2.5 times more mortality than growth) (Fig. 3), but the story starts decades before that. Even-aged management and fire exclusion of this type in the twentieth century homogenized lodgepole pine forests across vast landscapes (Menlove et al. 2012), creating dense forests of similar age classes that were conducive to widespread mountain pine beetle (*Dendroctonus ponderosae*; MPB) outbreak and wildfire. MPB populations irrupted to outbreak levels between 2005 and 2012, killing many mature lodgepole pine overstories (Witt et al. 2019). This resulted in an accumulation of large, downed wood and an increase in shade-tolerant species (Fettig et al. 2022). In addition, recent wildfires have burned 1000s of acres by high severity crown fires (Mietkiewicz and Kulakowski 2016) favoring lodgepole pine regeneration where lodgepole pine is serotinous. This effective recruitment strategy has increased the coverage of this type by simplifying previously mixed species stands to dense lodgepole pine (Larson et al. 2013).

Many forests in this type that were previously managed for timber production are now managed to mitigate wildfire risk, improve resilience to disturbances (i.e. fire and MPB), and improve habitat for Canada lynx (*Lynx canadensis*) (e.g., Forest Service 2025a). One of the primary means of accomplishing these goals is by emulating the structure of mixed-severity disturbances at the landscape scale by diversifying patch patterns, increasing age class diversity, and improving species diversity (Hood et al. 2012; Forest Service 2007). Managers are often charged to elevate fire risk reduction and suppression preparedness in the WUI over other objectives (f.s., pers. comm., 2025). However, forests outside of the WUI and within Canada lynx habitat are often relegated to passive management to maintain dense forest cover.

Even-aged regeneration approaches are still considered in this forest type, though less common in the past 30 years since widespread disturbances reset stand development in many places. Clearcut, seed tree, and shelterwood harvests are options depending on site and objectives, but especially for timber and where mortality hazard from MPB is high (f.s., pers. comm., 2025). Seed tree and shelterwood overwood

density and tree selection must be carefully managed as lodgepole pine trees in dense stands are prone to windthrow once density is reduced and trees infected with dwarf mistletoe can infect regeneration (Alexander et al. 1983). Uniform and group shelterwood with reserves systems are effective at creating two-aged stands that reflect historic mixed-severity disturbance regimes (Hood et al. 2012). Multi-aged approaches are also used in some areas, including group selection, variable retention, free selection, and patch cutting to break up homogeneous stand continuity, improve landscape heterogeneity, facilitate regeneration of diverse species mix, and match local historical disturbance regimes (Crotteau et al. 2018). These approaches can result in more structurally and compositionally diverse stands better equipped to resist fire and insect disturbances and provide a wider range of ecosystem functions (Keyes et al. 2014).

Several forest managers have deemphasized planting lodgepole pine since the species often regenerates prolifically following wildfire where trees are serotinous (*f.s., pers. comm., 2025*). To reduce the number of pure and homogeneous lodgepole pine stands, many managers interplant more long-lived early seral species, including western larch for biodiversity (Forest Service 2022). However, planting lodgepole pine is still needed following disturbance when overstory trees are predominantly non-serotinous.

Lodgepole pine forests in the past were sometimes tended with one or more precommercial thinning, followed by a commercial thinning before final harvest (Alexander et al. 1983). Current practices frequently include a single precommercial thinning and no commercial entry prior to final harvest, or no tending whatsoever to avoid operating in Canada lynx habitat (*f.s., pers. comm., 2025*). The main exceptions are stands managed to reduce fire and bark beetle hazards. Where this forest type interacts with the WUI there has been an increased use of shaded fuel breaks or alternative treatments that double as fuel reduction (Forest Service 2025a). If hazard for MPB-caused mortality is perceived to be high, some managers use relatively low-residual-density (such as 80 ft² ac⁻¹ basal area) tending operations to mitigate risk (Mitchell et al. 1983).

Ponderosa Pine Type

Ponderosa pine forests have not lost as much growing stock as other forests from disturbance agents (Fig. 3), although there has been considerable departure from historic conditions in western Montana (Bollenbacher et al. 2014). Loss is frequently due to succession, insects, and wildfire. Changes on Forest Service land began with fire exclusion in the early twentieth century and the subsequent infilling by more shade-tolerant species (e.g., Douglas-fir and grand fir) (Keeling et al. 2006). This increase in stem density and shift in species composition imposed competitive stress on ponderosa pine trees and created ladder fuels and continuous canopy cover predisposing the ponderosa pine type to mortality at stand and landscape scales (Gruell et al. 1982). The impact has especially been severe for large legacy trees that previously exhibited high resistance to disturbance agents. At a regional scale, the same MPB outbreak that decimated lodgepole pine forests in 2005–2012 also impacted ponderosa pine forests, overwhelming tree defenses especially in

competition-stressed stands (Hood et al. 2016; Witt et al. 2019). More recently there has been substantial damage from secondary pests such as black pine leaf scale (*Dynaspidiotus californicus*) as they complex with extended drought (The Montana DNRC 2016).

Wildfires have become more frequent across the region since the year 2000, driven in part by drought, increasing temperatures, and earlier spring snowmelt (Abatzoglou and Williams 2016; Westerling 2016). Whereas ponderosa pine forests were historically adapted to frequent, low severity fire (Agee 1993), current dense and fuel-laden forests have led to high severity crown fires in many ponderosa pine stands that exceed historic percent replacement severity (Parks et al. 2023).

With the increase in disturbance, the slow decline of the regional timber economy, and the greater emphasis on designing silviculture systems to meet multiple management objectives, management has substantially changed over the past decades in the ponderosa pine forest type. On many acres, ponderosa pine forests are no longer managed for maximized economic value (*f.s., pers. comm., 2025*). Intensive management is often concentrated in the WUI and is most typically characterized as custodial in nature (Forest Service 2024). Management intent is often either an explicit fuels reduction and fire hazard treatment or incorporates fuel reduction (Stephens et al. 2016). However, many landowners also frame activities as restoration, whether that is restoration of historical stand composition and density, or toward a future-adapted state. Cultivating historical low density spatial patterns, large trees, low fuel loads, and fire adaptation have been common themes in recent management (Graham and Jain 2005; Larson and Churchill 2012), and recent evidence suggests managing below stand density index of 100 provides the greatest resistance to MPB-caused mortality amid contemporary arid conditions (Fettig et al. 2022). There have likewise been recommendations among agencies and non-governmental organizations to expand this forest type upslope because of projected temperatures and fire predictions (Scott et al. 2013). While this intent is shared by many managers (*f.s., pers. comm., 2025*), the market for ponderosa pine is weak and resources are limited, which disincentivizes proactive stewardship opportunities.

Clearcutting is less common in ponderosa pine forests of the Northern Rocky Mountains in recent years. Federal land managers often elect seed-tree harvests when the only choice is to reset the stand with higher quality stems (*f.s., pers. comm., 2025*). Some managers in the region have successfully made multi-aged management entries using single-tree and group selection harvests (or hybrids thereof), or free selection, where regeneration is formally intended and expected (*personal observation*). These actions reflect the growing interest to transition even-aged stands to multi-aged stands on federal and conservation lands in this type to meet objectives for a variety of desired future conditions (Williams et al. 2026). Other common activities associated with harvest include site preparation treatments such as masticating, piling and burning woody materials, and broadcast burning (Jain et al. 2012).

Reforestation in this type is frequently done via planting, though many even aged to multi-aged harvests intend for natural regeneration. Reforestation need is greatest in areas burned with high severity fire due to long distances from living seed sources and hot and dry post-fire site conditions (Holden et al. 2025). Sites in lower

elevation, south-facing, or with edaphically constrained water limitations have abundant grass that compete with seedlings and often lead to seedling mortality (Davis et al. 2020b), reflecting the need to mitigate competition, provide shade, and choose planting sites wisely. On these sites, reforestation is frequently conducted where sites are accessible and where the goal is to meet multiple management objectives such as timber and restoration to historic conditions (*f.s., pers. comm., 2025*). More ponderosa pine is being planted on mesic, mixed conifer sites to improve future stand resistance to disease, wildfire, and drought (Keane et al. 2018). Limited afforestation of low elevation ponderosa pine on marginal sites has also been carried out as part of the USDA Conservation Reserve Program, while marginal sites deforested by fire are sometimes left to convert to grass or shrubland.

Most of the active forest management in this type is considered tending. Tending ponderosa pine forests frequently take the form of fuel treatments, which may include noncommercial slashing, thinning from below (commercial or noncommercial), weeding out more shade-tolerant species such as Douglas-fir and grand fir, or improvement cutting that targets more resilient species composition and spatial structure (*f.s., pers. comm., 2025*). Often, improvement cuts result in similar structure to selection harvests and will likely trigger regeneration, which demonstrates the tendency for improvement cuts to blur the lines between regeneration harvest and tending while reducing pressure to secure a new cohort (*personal observation*). The Individuals, Clumps, and Openings (ICO) (Churchill et al. 2013) framework is often used to restore clumpy-gappy forest structure in this forest type. Some pruning is done in this type to reduce ladder fuels.

To diminish surface fuels and improve regeneration composition, prescribed fire is used with the intent to be repeated on regular intervals, emulating the historical and natural high-frequency and low-severity fire regime (Larson and Churchill 2023). Unlike past applications of fire coupled with silvicultural treatments, the primary emphasis is not on clearing harvest debris for site preparation, but rather on managing fuel loading and emulating natural disturbances (Churchill 2020). While there is substantive evidence for the efficacy of mechanical treatments coupled with prescribed fire to reduce catastrophic wildfire risk, support ecological functioning, and enhance stand resiliency (Clark et al. 2024), there are substantial implementation challenges due to a lack of public acceptance of smoke, risk of escaped fire, and reduced burn windows (Ryan et al. 2013).

Spruce-Fir Type

Spruce-fir forests in the Northern Rocky Mountains occur in areas of cold climate. Current trends show that subalpine fir mortality is exceeding growth, while Engelmann spruce mortality nearly equals growth (Fig. 3). Subalpine fir's decline is occurring primarily at lower and mid elevations of its range due to wildfire, disease, insects, and drought stress (Perret et al. 2023). The forest type has expanded in some subalpine forests historically dominated by other species due to fire suppression (Keane et al. 1994). Spruce-fir forests are prime habitat for Canada lynx (Squires et al. 2010), which was listed as threatened under the US Endangered Species Act in 2000 and much of the management since then has focused on maintaining habitat.

Canada lynx in the Northern Rocky Mountains have the greatest chance of producing litters when there is a landscape mosaic dominated by mature, multistoried forests that provide habitat for snowshoe hare (*Lepus americanus*) (Holbrook et al. 2019; Kosterman et al. 2018). This complex structure is common in this forest type, where clumps of shade-tolerant subalpine fir and Englemann spruce regenerate in openings following gap-based overstory mortality.

Spruce-fir forests have been affected by a variety of biotic disturbances in recent years that have influenced forest structure and composition, and the ability to meet management objectives. Balsam woolly adelgid (*Adelges picea*; BWA) was introduced from Europe and damages true firs in North America. The species was first identified in the interior west region in Idaho in 1983 and surveys since 2006 have positively identified damage across Idaho and western Montana (Davis et al. 2020a). Infestation and mortality from BWA increased in Idaho between 2008 and 2018 across all size classes from seedlings to mature trees (Davis et al. 2022), a period associated with average warmer and wetter climate (Hicke et al. 2023). Additional native insects also damaged subalpine fir in recent years including western spruce budworm (*Choristoneura freemani*) and fir engraver beetle (*Scolytus ventralis*) (The Montana DNRC 2025; Forest Service 2025c).

Subalpine fir decline was recently identified as a major problem across the range of subalpine fir in the interior West (Lalande et al. 2020; Tutland et al. 2025). The decline is due to a combination of factors including fungal pathogens (*Armillaria* spp. and *Heterobasidium* spp), western balsam bark beetle (*Dryocoetes confuses*), and drought. Although the decline has been most studied in Colorado (Lalande et al. 2020; Tutland et al. 2025), the Forest Service, Forest Health Protection monitoring program has found subalpine fir decline in the Northern Rocky Mountains in recent years (The Montana DNRC 2023).

The increased damage from biotic agents and abiotic stress affecting spruce-fir forests along with Canada lynx habitat concerns has resulted in minimal management of these forests and general decline in forest health. Wildfires have been more common in this type in recent years (Zhao et al. 2015). When these forests burn, there are often large, contiguous patches of canopy loss due to dense live and dead fuels and low canopy architectures that act as ladder fuel (Menick et al. 2024). Increasing wildfires in this type are concerning from the perspective of Canada lynx, as Canada lynx avoid high severity burn areas but traverse these areas to access unburned islands of intact forest (Squires et al. 2026). If fires are natural starts, they are often managed under supervision, except in WUI areas where active suppression is common. In areas that have been disturbed, management focuses on moving stand composition towards desired species such as western larch, Douglas-fir, and lodgepole pine for improved fire resilience. These desired species are also favored by regenerating in gaps that are intermixed with open and closed canopy overstories. Minimal thinning occurs due to management guidelines for Canada lynx.

Western Larch Type

While state and private landowners have harvested slightly more western larch than their gross growth, most of the reduction in this type on federal lands has been due to

natural mortality (Fig. 3). Many western larch forests on federal lands were clearcut in the early and mid-twentieth century, and these even-aged stands are advancing in age toward commercial maturity (Menlove et al. 2012). In stands with older trees, there has been a loss of the largest relic cohort from combinations of drought stress, high-severity wildfire, and insect-caused mortality (*Personal observation*), similar to patterns seen in the Blue Mountains of eastern Oregon and Washington (Lintz et al. 2016). Species envelope modeling has suggested western larch may no longer suitably regenerate in the warmer and drier parts of its range (Rehfeldt and Jaquish 2010). However, recent research indicates a more positive outlook for the species as disturbance (i.e., fire and harvesting) creates new early seral growing conditions that outweigh negative climate pressure (Steed and Goeking 2020; Vieira et al. 2024).

Native foliar pathogens (e.g., *Hypodermella laricis* and *Meria laricis*) have repeatedly damaged western larch trees in Idaho in recent years (Forest Service 2025c). Although these pathogens rarely kill trees, they have the potential to reduce growth if trees do not rapidly produce new foliage after infection (Miller 2023). In addition, sapling-sized western larch trees have recently shown significant top die-back believed to be caused by a wood-boring *Cydia* spp. moth (Eidson et al. 2019). Although the moth may be native, little is known about the species and the reports of damage since 2018 are the first to document tree death.

In recent decades there has been an increase in preference for western larch forests, which span Douglas-fir and subalpine fir climax series as a fire-dependent seral phase and thrive in mesic topographic positions. The species is favored because of its rapid growth, fire tolerance, disease resistance, and timber value (Schmidt and Shearer 1995), but fire and management exclusion have shifted composition toward more shade-tolerant, fire-susceptible, and disease-prone species (Arno et al. 2000, 1997; Jain and Graham 2015). Recognition of the importance of fire and posture toward resilience to future disturbances has caused managers to shift landscape composition back toward western larch, particularly on National Forests whose land management plans dictate increasing the species (e.g., Forest Service 2015a, 2015b, 2018, 2025d). Managers frequently retain and enhance western larch and particularly large-diameter individuals because of an emphasis on conservation, recognizing the importance of long-lived, early seral species for non-timber values such as wildlife and structural heterogeneity (Hopkins et al. 2014). As reflected in the western larch Adaptive Silviculture for Climate Change study, management intent is often to perpetuate this more mesic forest type because of its local importance and resistance to disturbances (Crotteau et al. 2019), though managers are willing to interplant western larch with more drought-tolerant species in drier conditions (Scott et al. 2013).

Seed tree and shelterwood systems are still used by all landownership groups, where the overwood is typically retained on federal ownerships to improve wildlife habitat and resilience to disturbances (Forest Service 2022, 2025b). Some stands, particularly on federal lands, have been managed with multi-aged management as a means of retaining structural diversity while still providing adequate space for regeneration (Forest Service 2025b).

Between harvests and wildfire recovery, reforestation has been a major part of western larch forest management. On the moistest sites, natural forest regeneration

has largely been adequate, but moderate and drier sites have required planting to supplement natural stock (per Holden et al. 2025). When planting, federal managers have shifted to a larger stock type than in the past and have begun planting at lower density (220–300 TPA) to improve resistance to drought and in anticipation that there may not be funding for pre-commercial thinning (*f.s., pers. comm., 2025*). Managers have begun using assisted population expansion (i.e., supplementing from lower elevation seed zones; Bower et al. 2024) and enriching with ponderosa pine on drier aspects and habitat types in anticipation of hotter and more droughty conditions (e.g., as in Crotteau et al. 2019).

Short rotation western larch plantations are mostly concentrated on state and private lands, while most stands on federal lands are 40–80 years old and have not reached the culmination of mean annual increment. These short rotation plantations are established using wild-collected seeds but planting of improved western larch seedlings selected for increased volume growth through the IETIC (Jaquish et al. 1995) has also increased. Seed is readily available to landowners through private and IETIC-managed seed orchards (*personal observation*).

Tending is an important activity in western larch forests, though it often does not occur in prime grizzly bear (*Ursus arctos horribilis*) and Canada lynx habitat (Forest Service 2007). Pre-commercial thinning and weeding are perceived as the most important tending technique in this type to reduce competition from shade-tolerant trees and provide a competitive advantage for the light-demanding western larch (Schaedel et al. 2017). In addition, early thinning can help western larch trees resist reduction in growth caused by drought and spring frosts (Beisel et al. 2026). Though larch grows taller faster than most of its competition, it is sensitive to crown abrasion and shading, and requires more growing space to develop large diameters (Schmidt et al. 1976). Thinning from below is a common prescription for commercial thinning, as is fuel reduction along roadsides and in the WUI. In restoration treatments, managers frequently opt for daylight thinning around focal legacy trees to reduce local competition and fire hazards (*f.s., pers. comm., 2025*).

Whitebark Pine Type

The whitebark pine type occurs almost exclusively at high elevations up to the upper timberline. It is considered a keystone and foundational species that promotes ecosystem diversity and stability (Tomback et al. 2001). More specifically, whitebark pine has a mutualistic relationship with Clark's Nutcracker (*Nucifraga columbiana*), which breaks open cones and disperses the seeds. Many other wildlife species rely on whitebark pine seed as a food source, including grizzly bears. A more in-depth description of whitebark pine's autecology and community ecology of subalpine ecosystems can be found in Keane et al. (2012).

Whitebark pine has been declining for many years due to white pine blister rust, MPB, and wildfires that have burned at greater severity because of subalpine fir ingrowth and ladder fuel development (Keane et al. 2017; Shanahan et al. 2016; United States Fish and Wildlife Service 2018). Currently, more volume of whitebark pine is lost to mortality than is added through growth each year (Fig. 3). A recent analysis using FIA data found that 51% of all whitebark pine trees are dead across

its range (Goeking and Izlar 2018). The various threats and the associated decline led to the listing of the species in the United States as Threatened under the Endangered Species Act starting in 2023 (United States Fish and Wildlife Service 2022a). This followed the listing of whitebark pine as endangered in Canada under the Species at Risk Act.

Historically, these forests remained unmanaged due to their inaccessibility and low productivity, but there is a recent interest in management to conserve whitebark pine. Ongoing and proposed future management efforts for recovery focus on enhancing resistance and resilience of whitebark pine to these various interacting disturbing factors (e.g., Forest Service 2025a). Although the US Fish and Wildlife Service recovery plan is under development, the available recovery outline presents a general strategy for whitebark pine (United States Fish and Wildlife Service 2022b). Ten focused management actions have been proposed to assist with recovery including, among others, condition assessment, seed collection, seedling planting, silvicultural treatments of existing stands, and monitoring (Tomback et al. 2022). These management actions cover a wide range of initial conditions and provide flexibility to adjust silvicultural activities to local conditions and administrative constraints using the best available research.

Various governmental agencies, non-governmental organizations, and collaborative working groups are actively involved in science, policy, monitoring, and developing conservation actions to conserve whitebark pine (United States Fish and Wildlife Service 2022b). For example, the Whitebark Pine Ecosystem Foundation (WPEF) and American Forests are working on a National Whitebark Pine Restoration Plan (WPEF 2026). The plan actively engages federal agencies and Tribes on an inter-agency strategic plan that proposes targeted regions for conservation efforts. The WPEF has also developed a monitoring protocol for blister rust infection and damage that is currently being tested in whitebark pine ecosystems in the Northern Rocky Mountains.

Relying solely on natural regeneration of whitebark pine is unlikely to help conserve the species into the future due to the low level of natural resistance to white pine blister rust. Therefore, a considerable effort is underway to screen whitebark pine for blister rust resistance. High levels of quantitative resistance have been found in some families in Oregon and Washington populations providing promise for restoration programs focused on species recovery in that region (Sniezko et al. 2024). Rust resistance has been found in numerous whitebark pine families in the Northern Rocky Mountains during controlled rust resistance screening trials, where rust resistance increased from the southeast to the northwest within the region (Mahalovich et al. 2006). Other studies that include progeny site installations across a large portion of the species' range are still in their early stages but are showing promising results for selecting blister-rust resistant genetic material for reforestation (Cartwright et al. 2022).

Thinning in whitebark pine stands may also help with ecosystem conservation. Thinning, although not widely practiced due to the inaccessibility of many sites, primarily focuses on reducing densities of non-whitebark pine species such as sub-alpine fir. Most of the thinning is daylight thinning, which results in variable densities of residual whitebark pine trees (Keane et al. 2012). Thinning around whitebark

pine trees has been found most effective in increasing residual tree diameter growth on transitional sites when subalpine fir competition is removed and less effective in stimulating growth in more open canopy stands (Maher et al. 2018). Thinning and prescribed fire have shown to increase growth of younger, smaller whitebark pine trees compared to larger trees (Retzlaff et al. 2018). In addition to increasing diameter, thinning can increase resin duct numbers and resin duct sizes across a range of tree sizes, with minimal impact on whitebark pine mortality (Kichas et al. 2024). The increase in resin duct number and size could help with tree defenses against MPB.

Advances in Tools Supporting Silviculture

The Northern Rocky Mountains are seeing an increased interest in the use of emerging technologies to assist with management decisions. Examples include high resolution imagery and LiDAR, which are frequently used to remotely determine forest inventory, structure, and productivity metrics across vast landscapes. The FIA program has nearly completed two cycles of annual measurements across the region making it possible to examine trends in ground-truthed forest conditions and disturbance regimes over the last 25 years. Our modeling capacity has expanded and is used regularly to support silviculture and forest management. Growth is frequently predicted with tools like the Forest Vegetation Simulator (FVS; Dixon 2002) and Forest Projection System (Forest Biometrics Research Institute 2026); prescribed fire behaviors and effects are predicted with BehavePlus (Andrews 2014) or the Fire and Fuels Extension to FVS (Rebain 2010 (revised October 23, 2025)); and favorable reforestation species and planting locations are selected with RegenMapper (Holden et al. 2025). Forest landscape simulation models like LANDIS-II have also provided opportunities to better understand how silvicultural treatments, climate change, and disturbance operate at large spatial scales (Scheller et al. 2007). The Seedlot Selection Tool was also recently developed, which incorporates past and future climate projections to assist in selecting seed sources adapted to future site conditions (St.Clair et al. 2022). A stand carrying capacity model was recently developed for the Northern Rocky Mountains to help develop silvicultural prescriptions to meet a variety of objectives associated with forest health and productivity (Kimsey et al. 2019). Tools such as GIS-enabled tablets enable greater spatial precision for implementing detailed and site-specific silvicultural prescriptions (e.g., mapping out reserves, or real-time ICO) (Maher et al. 2019). Additionally, some collaboratives have adopted integrated landscape decision-support tools from private consulting groups to optimize treatments in time and space given complex interacting objectives.

What May Happen in the Future

There are many uncertainties as we think about the future of forest management in the Northern Rocky Mountains. In the public sphere, managers are still learning the applications of developments like new Categorical Exclusions, new authorities

such as the Good Neighbor Authority, and new approaches like condition-based management; much of their success will be mediated by translatable silviculture, human relationships, and land ethic. Many public timber sales get held up in court for NEPA or Endangered Species Act compliance, thus judicial rulings can either advance management or forestall it. It is unclear how the profession and industry are going to rebound from reductions in workforce occurring within federal agencies. Mergers are also occurring on private timberland. For example, in January 2026 PotlatchDeltic Corporation, Idaho's largest private landowner, merged with Rayonier Inc., forming the second largest publicly traded timber and wood products company in the USA (Rayonier 2026).

However, a few things are clear about the future of forest management in the Northern Rocky Mountains. National and regional teams have identified priority landscapes and fireheds within the region that have developed all-lands collaboratives that are having real impact executing active management across large landscapes (e.g., Southwestern Crown Collaborative in Montana; Southwest Idaho Landscape All Lands Partnership). Multiple resource management on federal lands is as important as ever. States are working to implement more forest activities with Good Neighbor Authority. The 2020 Montana Forest Action Plan assesses cross-ownership needs and outlines a strategy to accomplish priority state and landscape-level forest health goals (Montana DNRC 2020). Idaho recently signed a statewide Shared Stewardship agreement with the Forest Service to assist in forest management activities over a long period of time and increase annual timber sale volumes, accelerate restoration, and increase fuel reduction treatments on National Forests in Idaho (State of Idaho and Forest Service 2025).

While we cannot foresee the various flavors silviculture will take due to shifting objectives, decisions, priorities, markets, etc., one thing is still certain: people care about forests and are dependent on the ecosystem services they provide. Active engagement with these forests through management and practices is a necessary part of our thriving future. Silviculture is the sustainable and thought-out means by which we accomplish that goal.

Acknowledgements We thank Shelagh Fox for reviewing an earlier version of the manuscript. We also thank federal silviculturists across the Northern Rocky Mountains who provided input on common management objectives and actions for each forest type on federal lands that are discussed in the manuscript. This included Wayne Beck, Andrew Reed, Elliott Meyer, James Pass, Michael Reichenberg, John Rilling, Megan Strom, and Jodi Wetzstein; we refer to these in the text as “federal silviculturists, *personal communication*.” Adrian Leighton provided input on developments in tribal forest management. We also thank Marc Rust with the Inland Empire Tree Improvement Cooperative who provided input on advances in tree improvement in the region as well as Chance Brumley with Rayonier Inc. who provided input on private corporate plantation management.

Author Contributions ASN: Conceptualization, Formal analysis, visualization, writing – original draft, reviewing & editing. A.H. Conceptualization, writing – original draft, reviewing & editing. J.S.C. Conceptualization, writing – original draft, reviewing & editing. S.S. writing – original draft, reviewing & editing.

Funding A.S.N. supported by the Tom A. Alberg and Judith Beck Endowed Chair of Native Plant Regeneration at the University of Idaho. A.H. supported by US Department of Agriculture National Institute of Food and Agriculture, McIntire Stennis Accession #7006764. J.S.C. was supported by the U.S. Department of Agriculture, Forest Service. S.S. supported by U.S. Department of Agriculture, Forest Service,

Rocky Mountain Research Station, Forest Inventory and Analysis, Agreement #25-JV-11221638–071 as part of ongoing Timber Products Output reporting for National Resource Use Monitoring.

Data Availability No original data was used for this manuscript. Only publicly available data, which is cited appropriately.

Declarations

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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