Climate Adaptations to the Northwest Forest Plan: Science Summary and Adaptation Framework to Address Key Issues

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Introduction

Decades of controversy over the management of old growth forests in the Pacific Northwest led to the creation of the Northwest Forest Plan. The rapid rate at which old growth forests were being harvested and calls for the protection of the remaining old forests eventually led to the listing on the northern spotted owl (*Strix occidentalis*) in 1990 (USFWS 1990). Concerns for the viability of a wide-variety of other mature and old growth associated species (Thomas et al. 1990) also resulted in numerous lawsuits and interventions from the highest levels of government. In 1994, the Record of Decision for the Northwest Forest Plan (NWFP) catalyzed a rapid change in forest management emphasis and direction in the Pacific Northwest, bringing in an era focused on ecosystem management (Thomas et al. 2006). The NWFP has been successful in protecting mature and old growth forests from timber harvesting on federal lands within the NWFP area (Spies et al. 2018). However now, after nearly 30 years of implementation, rapid climate change has created another moment where transformational adaptation is warranted (Kates et al. 2012, Gaines et al. 2022).

This synthesis paper is intended to provide a foundation for adaptive management of National Forest Plans within the NWFP area to better address climate change issues related to the sustainability of old forests and wildlife species dependent upon late successional forest habitat. The primary goal is to provide a science basis that National Forest planners can use to develop plan alternatives that allow managers can use to develop climate adaptation strategies and proactively move forested landscapes towards more resilient structure and composition.

As such, our task is to address three interrelated issues: (1) protection of mature and old growth forests, (2) the role of reserves, and (3) the increasing frequency and intensity of forest disturbances associated with warming temperatures and increasingly severe wildfire seasons. These issues are interrelated and influence a host of other important planning issues such as habitat for listed species, social and economic issues, and a variety of other ecosystem services. However, these three issues are of primary concern in terms of the ongoing and immediate impacts of climate change. Thus, we provide a summary of the background and science understanding for each issue area and how they are interrelated.

Our final objective is to provide a framework for the development of alternatives or adaptations to existing NWFP direction, based both on our science summary and on the 2012 planning rule, including amendments. The intent is that the framework could be used to develop NWFP alternatives to be evaluated in the plan amendment planning process. To develop this framework, we held a series of structured interviews with scientists and managers (Appendix A). The goal of these workshops was to capture and synthesize relevant science understanding, document adaptive management options, and identify areas of considerable agreement and areas of divergence.

Topic 1: Relevant Components of the 2012 Planning Rule

National Forests and Grasslands are governed by land and resource management (Forest) plans that are intended to be updated every 15 years to reflect changing social, economic, and environmental conditions and to address new priorities (Ryan et al. 2018). A Forest planning rule finalized in 2012 introduced a new planning approach and requirements (Nie 2018, Ryan et al. 2018). The key purpose and need statement for the new planning rule was to "*emphasize restoration of natural resources to make National Forest System (NFS) lands more resilient to climate change, protect water resources, and improve forest health*" (FR 2012). We describe some components of the 2012 plan rule that are most relevant to climate adaptations for the NWFP. We fully recognize there are many other components (e.g., public involvement and collaboration) that are relevant to any effort to amend the NWFP. Here we focus on *ecological integrity, ecosystem resilience, ecological connectivity*, and *adaptive management*, as they are central to any efforts to address amendments to the management of mature and old growth forests, reserves, and disturbances.

Ecological integrity, which is a key emphasis of the planning rule, is defined in the rule as "*the quality or condition of an ecosystem when its dominant ecological characteristics (composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation*." The natural range of variation is used as an "ecological reference model" to assess whether an ecosystem has "integrity" (FSH 1909.12). Historical ranges of variation can provide informative reference metrics for forest composition, structure and function under past climate (Keane et al. 2009, 2011). However, climate change has already altered site conditions and disturbance regimes so much that updated metrics of are required. One approach is to reference contemporary landscapes that function under warmer and drier conditions to establish future ranges of variability to inform more realistic ecological reference conditions (Duncan et al. 2010, Hessburg et al. 2019).

Another important emphasis of the 2012 planning rule is the desire to "*make NFS lands more resilient to climate change*" (FR 2012, Bone et al. 2016). ***Ecosystem resilience*** refers to the ability of a system (e.g., vegetation community) to recover following disturbance (Hessburg et al. 2019, Falk et al. 2022). As described by Falk et al. (2022), ecological resilience includes three components that operate at different biological levels (e.g., organism, population, community): persistence, recovery, and reorganization. Persistence, the ability to withstand environmental stressors or disturbance, is at the scale of individual organisms. If limits of persistence are exceeded, recovery depends on the ability of organisms to reestablish through existing seed sources or dispersal. Where recovery is not possible, type conversions can occur with multiple trajectories of ecosystem reorganization. Historically, wNA forests were dynamically maintained through Indigenous stewardship, active fire regimes and other agents of change including native insects, pathogens, wind, and drought (Hessburg et al. 2019). Following Euro American colonization of wNA, forested landscapes have undergone profound changes and stressors through loss of cultural burning and other forms of Indigenous stewardship, active wildfire suppression, forest harvesting, and land development (Hessburg et al. 2005, Hagmann et al. 2021). Climate change adds a compounding threat to wNA forests through the increasing incidence of episodic drought, extreme heat, insect and disease outbreaks, and longer and more severe wildfire seasons (Coop et al. 2022). Threats to old forests and associate habitat are of particular concern due to widespread harvesting of the past and the increased size, severity and occurrence of fire and other disturbances (Hessburg et al. 2019, Falk et al. 2022). A central challenge for amending the NWFP will be how plan components can be designed to restore the ability of systems to persist and recover under a changing climate and promote ecological integrity into the future. Climate change will also inevitably lead to major reorganizations of forest ecosystems, and adaptive strategies to anticipate type changes and the emergence of novel ecosystems.

The 2012 Planning Rule includes the first requirements in US public land management history for National Forests to evaluate, protect and/or restore ***ecological connectivity*** as land management plans are revised. As such, ecological connectivity refers to the degree to which a landscape facilitates or impedes movement among patches (Williamson et al. 2019). Maintaining and restoring connectivity is a priority in many wildlife conservation strategies and is the most frequently proposed climate adaptation strategy for biodiversity conservation (Krosby et al. 2015). Thus, an amendment to the NWFP management direction will need to include a process to evaluate and provide for ecological connectivity.

Adaptive management is described in the USFS planning handbook (FSH 1909.12 Zero Code) as a "*structured, cyclical process for planning and decision-making in the face of uncertainty and changing conditions with feedback from monitoring, which includes using the planning process to actively test assumptions, track relevant conditions over time and measure management effectiveness*." The NWFP attempted to institutionalize monitoring and adaptive management. In practice, social license and funding to implement adaptive management never materialized, and adaptive management has fallen short of expectations (Stankey et al. 2003, Bormann et al. 2007, Spies et al. 2018a, b). However, a robust monitoring program has been ongoing and provides information upon which to adapt management through an amendment to the NWFP (e.g., Davis et al. 2016).

Topic 2: Overview of Key Issues

Mature and Old Growth Forests and Habitats

The NWFP was successful in protecting much of the remaining mature and old growth forests from timber harvest on federal lands (Davis et al. 2015, Spies et al. 2018). This was largely accomplished through a system of reserves that extended over about 80% of the federal USFS and BLM land base (Spies et al. 2018). In addition, the land allocation known as matrix lands, where timber harvest was to be focused, included management objectives to retain some mature and old growth forest components. The NWFP provided different management guidance for areas referred to as Dry Forest and Moist Forest (**Figure 1**).

As described in Johnson and Franklin (2009), old forests are defined differently in *moist forests* and *dry forests* through identification of key age and structural elements. Across moist and dry forest zones, large and old trees are recognized as a key structural element of old growth forests (Franklin et al. 2002, Lindenmayer et al. 2013). Throughout wNA and across the NWFP area, past forest management practices have resulted in large and old tree abundance being below historical abundances, and these important structures take several decades to centuries to develop (Hessburg et al. 1995, Hessburg et al. 2020). Large and old trees provide a diversity of ecosystem functions including carbon storage, wildlife habitat, and structural diversity in forest stands (Lindenmayer et al. 2013, Lutz et al. 2013). They also have considerable cultural and social value (Blicharska and Mikusiniski 2014).

In moist forest zones, Johnson and Franklin (2009) define three age thresholds to define conservation goals for mature and old forests: forests greater than 80 years, which captures essentially all mature and old growth forests within the NWFP, 120 years, which includes most of the mature and old growth forests, and 160 years, which includes the most structurally advanced mature and all of the old growth forest. Within moist forests, Johnson and Franklin (2009) recommend that all forests within these age brackets be protected from timber harvest.

In dry forest zones, Johnson and Franklin (2009) emphasize the importance of individual old trees due to their harvest history and disturbance regime. They define an old tree based on structural characteristics as being at least 150 years old (Van Pelt 2008) and recommend they be protected from timber harvest. Although late successional reserves were established in dry zone forests of the NWFP, they were identified as areas that were vulnerable to high severity fire and as such, may require active management including forest thinning and prescribed burning.

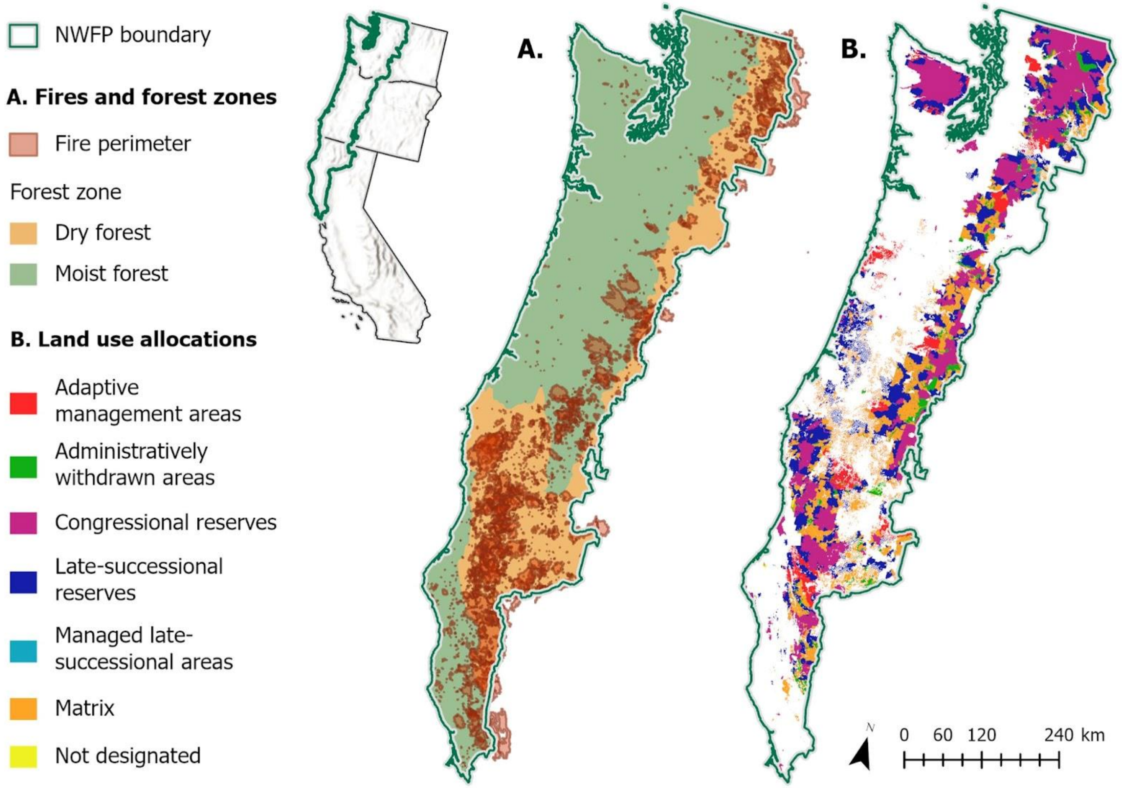

Figure 1. Northwest Forest Plan Area, including dry and moist forest zones, fire perimeters from 1985-2022, and major land use allocations (from Cova 2024).

To assess the effectiveness of the NWFP in protecting and promoting the development of mature and old growth forests over time, the NWFP monitoring program uses the Old Growth Structure Index (OGSI, Davis et al. 2015). OGSI is calculated using one to four measurable old growth structure elements including (1) density of large live trees, (2) diversity of live-tree classes, (3) density of large snags, and (4) percentage cover on down woody material (Davis et al. 2015). A network of forest inventory plots is used to examine age-class distributions for different diameter classes in different forest types to determine relevant forest structural metrics. Two age-related thresholds are then applied to estimate when structural conditions developed for mature forests. The first threshold is broadly referred to as OGSI80 and applies a threshold of 80 years for all forest vegetation zones to represent the general time scale at which young forests in the region generally begin to mature. An exception to this rule is applied to ponderosa pine forests, which are located in warmer, drier sites and generally take over 120 years to begin to mature. The second threshold is the OGSI200 based on stand age of 200-years, which corresponds to the range of ages used to define an old growth forest condition. NWFP monitoring has documented considerable declines in the amount of mature and old growth forest on federal lands, primarily owing to the increase in the size and severity of wildfires (**Figure 2**).

In addition to monitoring mature and old growth forest structure, the NWFP monitoring program also tracks changes to northern spotted owl habitat and population across the plan area. The northern spotted owl was used as a focal species to design the size and spatial distribution of forest reserves (Thomas et al. 1990), and the NWFP served as the primary conservation strategy until a recovery plan completed (USFWS 2011) and critical habitat designated (USFWS 2012). Monitoring data over the past two decades show considerable reductions in the amount of habitat, especially in the fire-prone Dry Forests (**Figure 3**). These large fires, referred to as megafires, can result in site abandonment and prolonged lack of recolonization by spotted owls (Clark et al. 2013, Jones et al. 2021a). The cumulative impacts of habitat loss from large, high severity wildfires and competition from barred owls is challenging the recovery efforts of the northern spotted owl, especially in the northern most portions of its range (USFWS 2011, 2012).

While the safeguards imposed by the NWFP protected most of the remaining mature and old growth forests on federal lands from timber harvest, the increasing incidence and area burned by high severity fires are dramatically impacting mature and old growth forests throughout the NWFP area (Phalan et al. 2019, Davis et al. 2022, Cova et al. in prep). A warming climate, coupled and forest densification after a century of fire exclusion, are leading to drought-induced mortality of old growth forests (van Mantgem et al. 2009) and increased vulnerability to wildfires that burn at high severity (Reilly et al. 2017). Recent studies have documented the negative effects of these so-called "megafires" on old-forest associated species (Jones et al. 2016, 2021a,b). In addition, long-term drought in dry forests has dramatically increased the mortality of large trees (Stephens et al. 2018).

Many researchers have compared the current condition of Pacific Northwest forest ecosystems, including mature and old growth forests, to ecological reference conditions (e.g., Hessburg et al. 2005, Haugo et al. 2015, 2019; DeMeo et al. 2018, Donato et al. 2019) and found that past management practices, including timber harvest, grazing, and fire suppression have altered their composition, structure, function, and connectivity. The impacts of climate change, in particular large high severity fires, now exacerbate these conditions and make it particularly challenging to protect or restore the ecological integrity of these important ecosystems.

The Role of Reserves

The network of reserves designated in the NWFP (**Figure 4**) was foundational to protecting mature and old growth forests and conserving biodiversity. Designations of Late Successional Reserves (LSRs) were largely driven by where the remaining mature and old growth forests still existed. The original size and distribution of the reserves was based on the Interagency Scientific Committee's northern spotted owl conservation strategy (Thomas et al. 1990). At the time, the LSRs that were designated in the NWFP served as the conservation strategy for the northern spotted owl until a recovery plan was completed (USFWS 2011) and critical habitat designated (USFWS 2012).

The NWFP reserves were designed to protect mature and old growth forests, to conserve the many species associated with mature and old growth forests, and to contribute to the recovery of the northern spotted owls and native salmonid populations (Thomas et al. 2006). However, the NWFP did not explicitly address climate change (Spies et al. 2010, 2018). Spies et al. (2010) highlighted that while NWFP guidance provided a solid initial foundation for conservation, it was grounded in stable climate assumptions and management restrictions that inherently limited adaptation. Based on multiple climate- and disturbance-related threats to NWFP reserves, Spies et al. (2010) offered the following adaptive actions for all NWFP forests: (1) increase landscape area devoted to critical NSO habitats and resilient ecosystem types; (2) maintain existing older forests; (3) use regional planning to coordinate changes across management units and jurisdictions; (4) revise land management goals and objectives to be consistent with dynamic processes and rapid warming under climate change; and, (5) incorporate uncertainty into planning and make adapting to climate change a long-term, iterative process. Similarly, Carroll et al. (2010) evaluated the effectiveness of NWFP reserve networks under contemporary and predicted climate change. They recommended that planners consider potential species' range shifts when evaluating alternative network designs, and that a broader range of focal and local species and associated habitat conditions be used to design habitat networks.

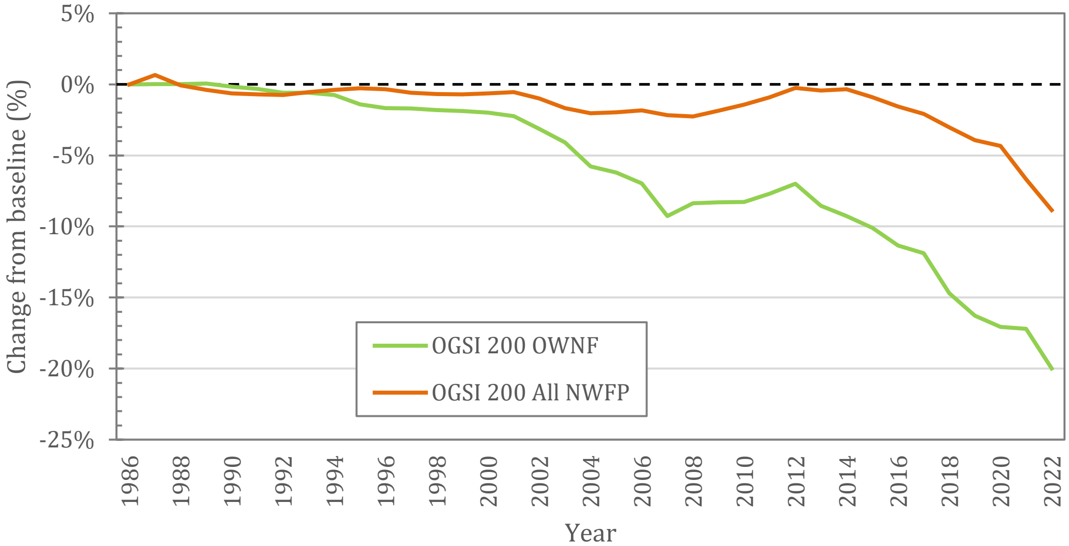

Figure 2. Change in OGSI forest area across the Northwest Forest Plan (NWFP) area and the Okanogan-Wenatchee National Forest (OWNF), one of the fire-prone forests that occur in the Dry Zone.

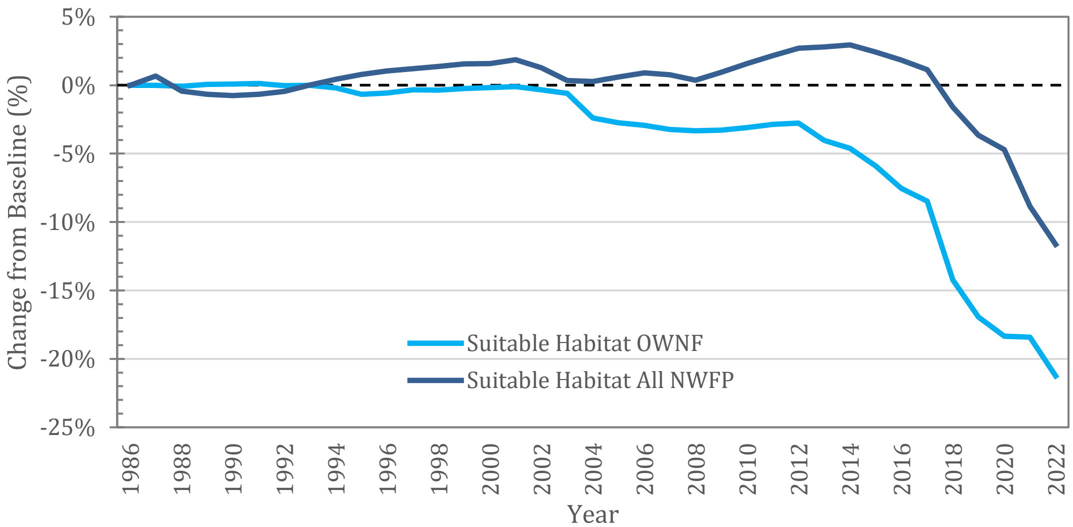

Figure 3. Suitable habitat for the northern spotted owl for all of the Northwest Forest Plan (NWFP) area and for the Okanogan-Wenatchee National Forest (OWNF), one of the fire-prone forests that occur in the Dry Zone.

Late successional reserves were designed to withstand large wildfire events over 50 years, such that unburned portions could maintain a well-connected network of spotted owl nesting, roosting and dispersal habitat. However, the projected amount of wildfire was based on the area burned in decades that preceded the plan; large wildfires since then have far exceeded the area burned in the decades leading up to the Plan (Davis et al. 2011, 2016, Westerling et al. 2006, Westerling 2016). Presently, this increased area burned is overwhelming the NWFP accounting for habitat loss to fires, especially in those provinces with large amounts of dry forest.

Revisiting the design of current reserves is important to help assure that they protect climate refugia, promote habitat connectivity for endemic species sensitive to location conditions (Carroll et al. 2010), and buffer against habitat losses from fire (Reilly et al. 2018, Spies et al. 2019). Alteration to the design and management of reserves may be needed to meet new policy goals that focus on ecological integrity and resilience, and to reduce threats to biodiversity (Spies et al. 2019).

Forest Disturbances

Wildfires

Although reserve-based management was successful in protecting remaining old and mature forest habitat within the NWFP from timber harvest, climate change is contributing to multiple stressors to forests, particularly within drier, fire-prone forest ecosystems. Summer wildfire seasons are lengthening and increasingly associated with episodic drought, atmospheric instability and severe fire events (Westerling 2016, Parks and Abatzoglou 2020). Recent research has shown that with warmer longer and drier summers, the incidence of synchronous large wildfires across regions is increasing and will pose even greater challenges to suppression operations and resources (Abatzoglou et al. 2016, 2021, Cullen et al. 2023).

Large wildfires have variable effects with portions of fire area left in unburned patches and portions burned in low, moderate and high severity events (Churchill et al. 2022, Cova et al. 2023). However, because large wildfire growth is associated with antecedent drought and extreme day-of-burn fire weather including strong winds, patches of high severity are becoming increasingly prevalent (Parks and Abatzoglou 2020, Cova et al. 2023, Cova 2024). The increase size and severity of wildfires is of particular concern for old and mature forests, which are being eroded by recent high severity wildfires (Reilly et al. 2017, Steel et al. 2018), particularly within the dry forest zone of the NWFP (**Figures 4, 5**). Forest fires in the driest ponderosa pine forests within the east Cascades are already leading to instances of long-term or permanent conversion to nonforest vegetation including grasslands, shrublands and sparse woodlands (Meigs et al. 2022). Assessments of the relative impacts and restoration benefits of recent wildfires are increasingly relevant for informing climate adaptation strategies for dry, fire-prone forests (Cansler et al. 2022, Larson et al. 2022, Jeronimo et al. 2022).

In semi-arid forests across the western US and Canada, forest health assessments have documented how prolonged fire exclusion has contributed to a decline in forest resilience, particularly under climate change (Hessburg et al. 1999, 2005, Spies et al. 2018, Hagmann et al. 2021). Conifer encroachment has led to steep declines in open pine-dominated forests and woodlands, oak woodlands, grassland, and shrublands and to greater susceptibility to high-severity wildfires (Agee and Hessburg 2005, Hessburg et al. 2019). Within NWFP reserves located in dry forest types of the east Cascades, southwestern Oregon and northern California, patch and landscape contagion to wildfires has also increased and poses a severe threat to old and mature forests (Spies et al. 2018, Gaines et al. 2022, Larson et al. 2022).

In wildland fire behavior modeling, the live and dead biomass of forests are referred to as wildland fuels (Keane 2015). At their most basic expression, wildland fuels are potential energy. How readily that potential energy can be released by fire depends on the availability, amount and configuration of fuels. Fire requires consumable biomass and oxygen – optimal configurations of fuels are within close enough contact for efficient energy transfer but with sufficient oxygen to sustain combustion (Finney et al. 2021). At the low end of combustion efficiency are dense organic soils and coarse wood; these fuel types generally lack the porous structure to sustain flaming combustion and instead burn within longer-term smoldering combustion due to low oxygen availability. At the high end of combustion efficiency are optimally packed fuels with high surface area and porosity to supply oxygen for combustion but with close enough packing for heat transfer among particles. With high amounts of live and dead vegetation and with dense, multi-layered forest canopies, many of the forests within Late Successional Reserves of the PNW have optimal structure for contagious fire spread and energy release. To preserve old and mature trees within dry, fire-prone forests, fuel reduction and maintenance burning through revitalization of intentional fire use is increasingly recognized as critical components of adaptive management (Churchill et al. 2013, Kalies and Kent 2016, Prichard et al. 2021).

In addition to the structure of wildland fuels, fuel moisture is a critical variable that determines when forest fuels are available for burning (Estes et al. 2012, Argañaraz et al. 2018). In moist mixed conifer forests, fuels are often not available to burn due to high water content. Thresholds to burning exist for short periods of time during the driest weeks of summer – thus, the probability of large forest fire growth is still relatively low within moist forests of the western Cascades. However, in dry mixed conifer forests, thresholds to burning exist for longer periods throughout the wildfire season.

As climate warms, the period of time when dry, fire-prone forests are primed for contagious fire growth is not only growing longer, but long-term water deficits are increasing the availability of fuels for burning in moist forests as well (Littell et al. 2018, Halofsky et al. 2018). Climate change adaptation for dry forests within the NWFP will require assessment not only of current forest structure and composition but also the biophysical environment to identify forests at high risk of wildfire due to expanding areas with site water deficits. Place-based management of forests will be required to assess where old and mature forests are fire prone and climate-smart forestry strategies for enhancing their resilience to future drought, wildfire events, and insect and disease agents.

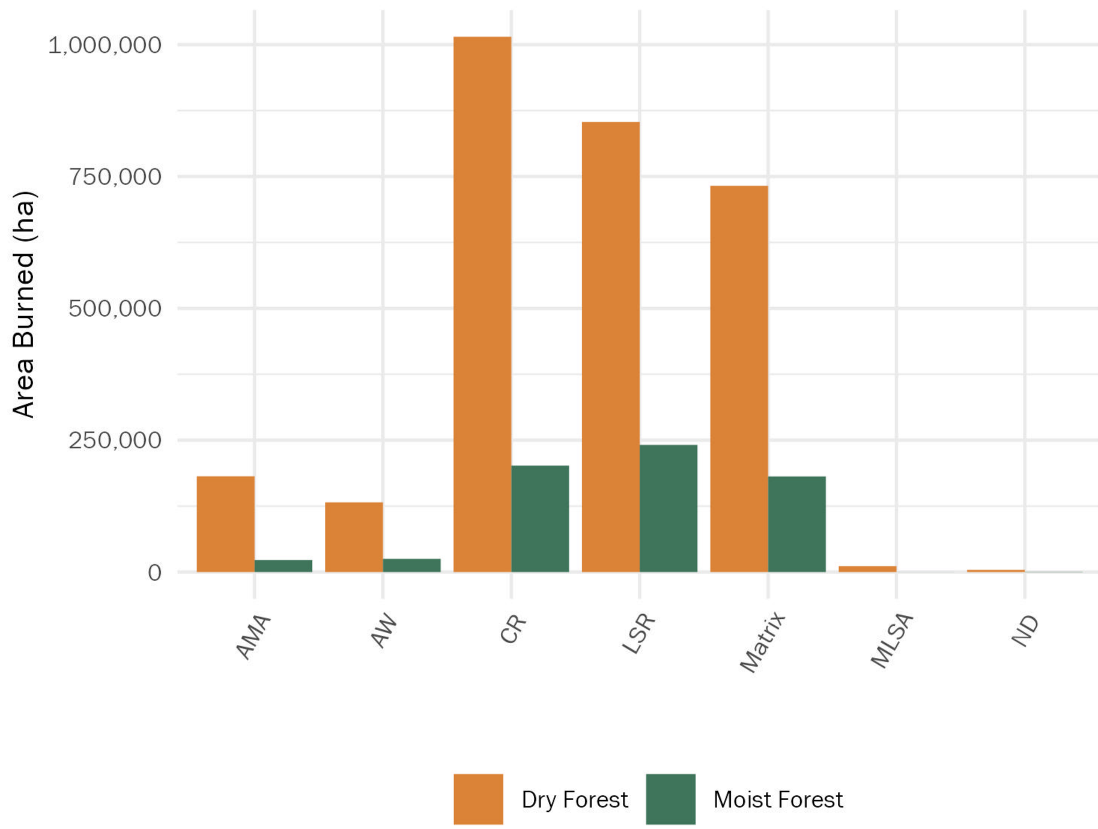

Figure 4: Total area burned in dry and moist forest zones from 1985 to 2023 across land allocations within the NWFP including adaptive management areas (AMA), administratively withdrawn areas (AW), congressional reserves (CW), late successional reserves (LSR), matrix lands (Matrix), managed late successional area (MLSA), and no designation (ND). Adapted from Cova (2024).

Box: Trends in Burned Area and Severity across the NWFP (1985 to 2022)

In a study of trends in burned area and severity across the NWFP area, Cova (2024) examined wildfire area burned across all NWFP federal forests and the major land allocations within the NWFP (**Table 1**). To date, area burned in dry forests is over four times that of moist forests with 55% of the total area in NWFP east zone forests burned since 1985. Within dry forest zones, 59% of the total area in designated late successional reserves and 67% of congressional reserves have burned in recent wildfires. Of the burned area in late successional reserves and congressional reserves, over 60% of the area burned is classified as moderate and high severity in approximately equal proportions. Dry forest matrix lands fared somewhat better than late successional and congressional reserves with 47% of the total area burned but with a similar proportion of moderate and high severity area.

In contrast, a relatively small percentage (14.3%) of NWFP moist zone forests have burned, with 32% of burned area classified as high severity and 25% as moderate severity. Percentage of total burned area and proportions burned by low, moderate and high severity fire are similar across late successional reserves, congressional reserves and matrix lands.

Burned area has increased significantly across dry and moist forest zones with steep increases in congressional reserves, late successional reserves, matrix lands, which together represent the majority of lands within the NWFP (Cova 2024). As summarized in Table 1, overall area burned is much greater than dry forests, with an initial large fire year in 1986 followed major fire activity since 2000. In contrast, large fire years in moist forests were relatively rare until 2017. As depicted in **Figure 5**, moderate and high severity fires dwarf that of unburned/low and low severity fires. Within dry forest zones, these continued trends represent a major departure in severity compared to historical fire regimes (Hagmann et al. 2021).

Based on this current dataset, the majority of area burned within the NWFP has been in dry mixed conifer and mixed evergreen forests of the eastern Cascades and northwestern California. Cold forests have also substantially contributed to area burned. Moist mixed conifer forests and coastal rainforests have recently burned in large wildfire events in western Oregon, which has contributed to the majority of area burned in NWFP moist zone forests (**Figure 6**).

Table 1: Total area burned by fire severity, dry/moist forest zone, summarized by a) all NWFP federal forests, b) late successional reserves, c) congressional reserves, and d) matrix lands.

All NWFP Federal Forests						
	Dry Forests (ha)		Moist Forests (ha)		All NWFP (ha)	
Total Area Burned	2,929,946	55.0%	672,946	14.3%	3,602,892	35.9%
Unburned/Very Low	225,689	4.2%	101,941	2.2%	327,630	3.3%
Low	777,222	14.6%	181,912	3.9%	959,134	9.5%
Moderate	952,876	17.9%	172,014	3.6%	1,124,891	11.2%
High	974,159	18.3%	217,079	4.6%	1,191,238	11.9%
Total NWFP Area	**5,328,275**		**4,720,124**		**10,048,399**	
Late Successional Reserves						
	Dry Forests (ha)		Moist Forests (ha)		All LSRs (ha)	
Total Area Burned	853,469	59.4%	241,083	16.9%	1,094,552	38.2%
Unburned/Very Low	64,179	4.5%	40,317	2.8%	104,496	3.6%
Low	240,742	16.7%	80,670	5.6%	321,412	11.2%
Moderate	274,732	19.1%	64,508	4.5%	339,240	11.8%
High	273,816	19.0%	55,589	3.9%	329,405	11.5%
Total LSR Area	**1,437,790**		**1,430,048**		**2,867,838**	
Congressional Reserves						
	Dry Forests (ha)		Moist Forests (ha)		All CRs (ha)	
Total Area Burned	1,015,009	67.5%	201,839	11.9%	1,216,848	38.1%
Unburned/Very Low	89,369	5.9%	23,696	1.4%	113,065	3.5%
Low	278,636	18.5%	46,771	2.8%	325,407	10.2%
Moderate	316,154	21.0%	52,467	3.1%	368,621	11.5%
High	330,850	22.0%	78,906	4.7%	409,756	12.8%
Total CR Area	**1,503,937**		**1,689,768**		**3,193,705**	
Matrix Lands						
	Dry Forests (ha)		Moist Forests (ha)		All Matrix Lands (ha)	
Total Area Burned	732,401	47.4%	181,325	16.3%	913,726	34.4%
Unburned/Very Low	47,140	3.0%	31,836	2.9%	78,977	3.0%
Low	169,894	11.0%	45,520	4.1%	215,415	8.1%
Moderate	248,895	16.1%	43,771	3.9%	292,666	11.0%
High	266,472	17.2%	60,197	5.4%	326,668	12.3%
Total Matrix Area	**1,545,594**		**1,110,071**		**2,655,665**	

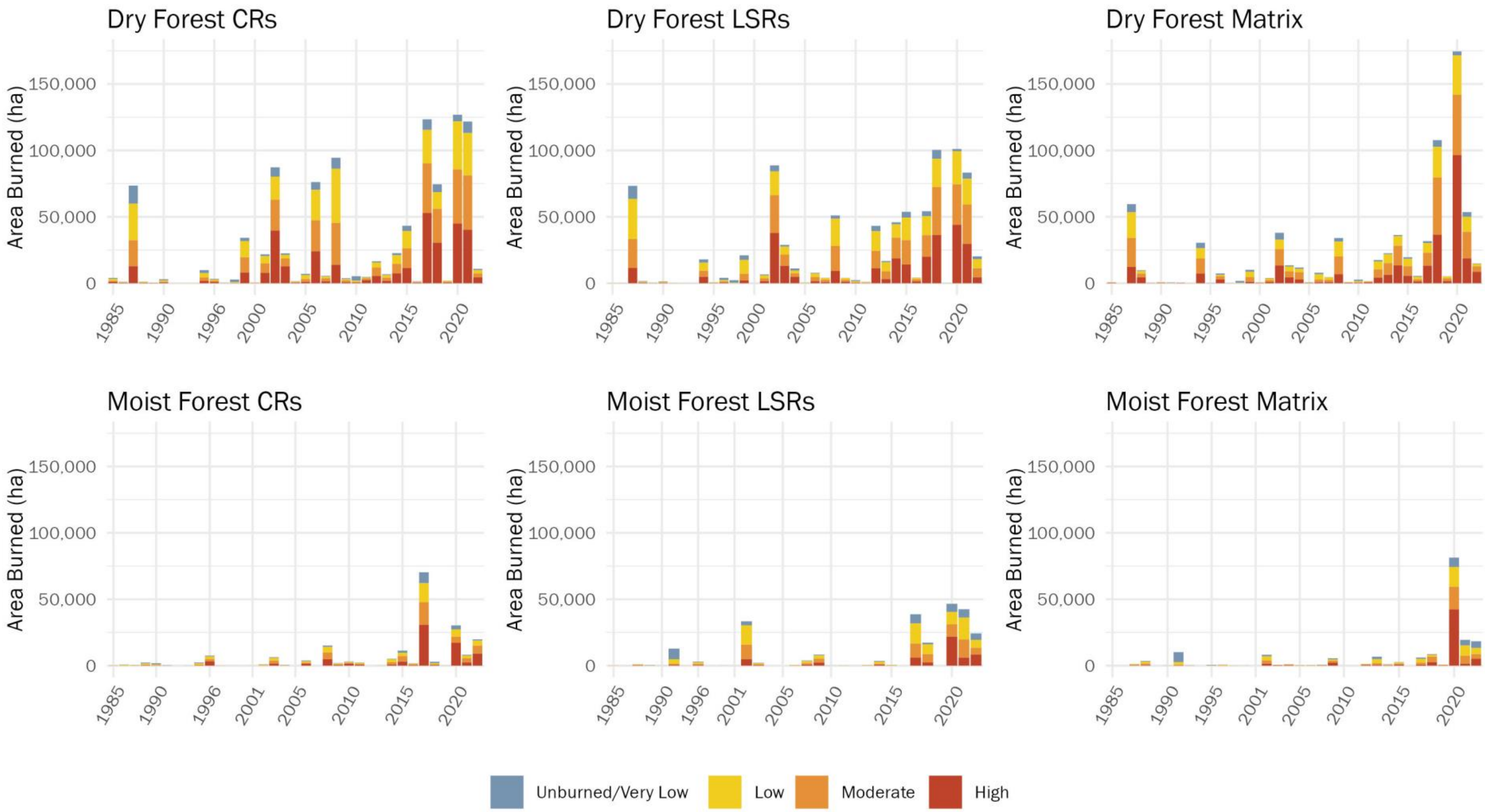

Figure 5: Trends in area burned and burn severity across dry and moist forest zones by major land allocations in the NWFP, including congressional reserves (CRs), late successional reserves (LSRs), and matrix lands (Matrix).

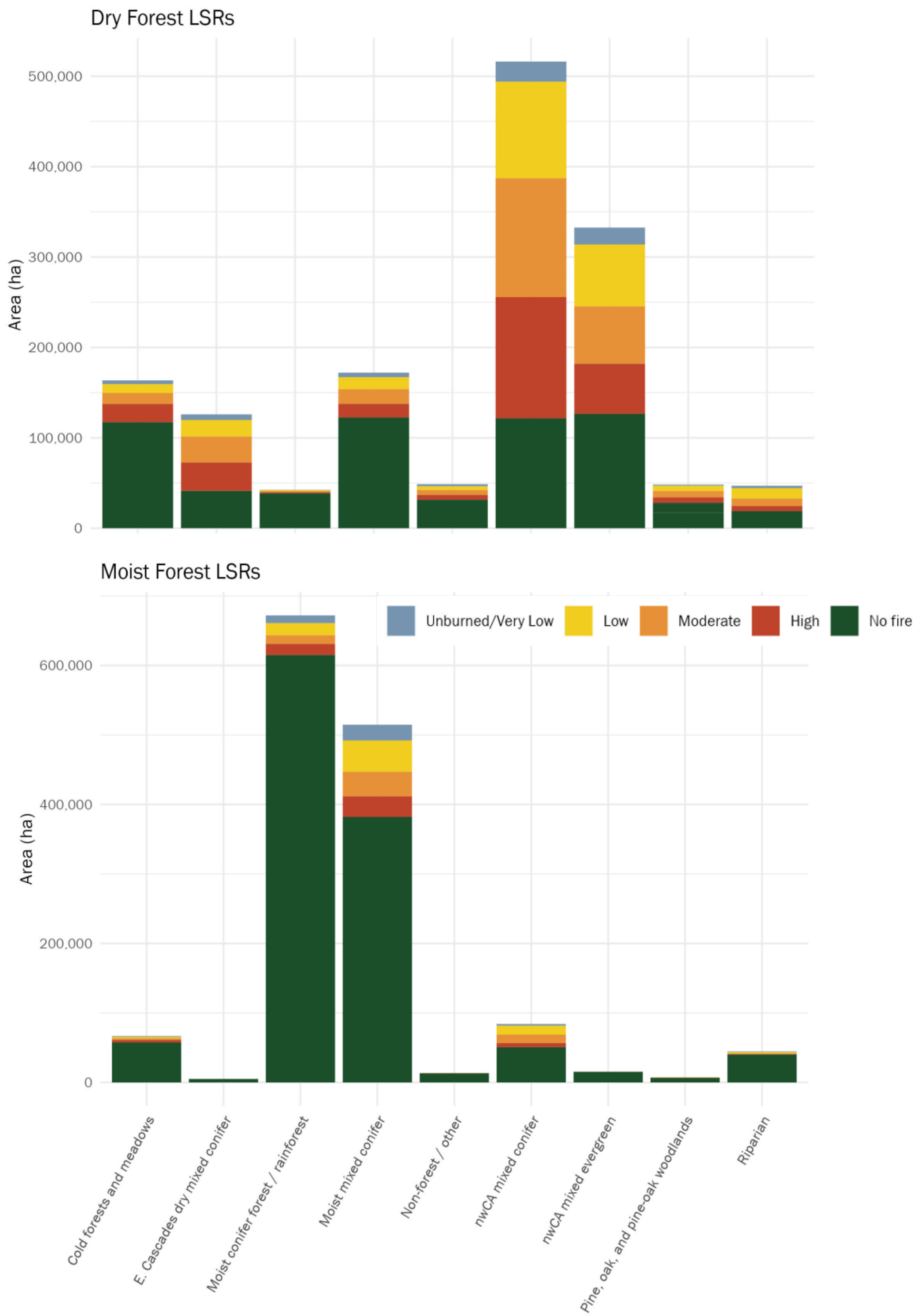

Figure 6: Area burned by major forest type within dry forest and moist forest late successional reserves.

Forest insects and pathogens

As with fire events, outbreak events of native bark beetles, such as mountain pine beetle (*Dendroctonus ponderosae*), western pine beetle (*D. brevicomis*), Douglas-fir beetle (*D. pseudotsugae*), and defoliators, including western spruce budworm *Choristoneura freeman* and Douglas-fir tussock moth (*Orgyia pseudotsugata*), are associated with how contagiously they can spread through forested landscapes of the Pacific Northwest (Pettinger and Goheen 1972, Hessburg et al. 2013). Prolonged drought and fire exclusion both play roles in increasing the landscape contagion of forests to insect outbreaks (Raffa et al. 2008,) and forest diseases including root rot and dwarf mistletoe (Shaw and Agne 2017). As climate change contributes to warmer and often drier conditions in the Pacific Northwest, episodic and chronic drought stress in forests can lead to greater incidence of tree mortality related to insect and disease agents (Agne et al. 2018). For example, mountain pine beetle preferentially attacks mature lodgepole pine and other pine species. If available host trees are drought stressed, they are especially susceptible to attack and if these host trees are numerous across broad areas, outbreaks can be extensive (Safranyik and Wilson 2006, Lundquist and Reich 2014). Similarly, defoliators such as western spruce budworm and Douglas-fir tussock moth are far more likely to attain outbreak levels if there are broadly available, dense and multi-layered forests which are common in fire-excluded late-successional reserves. Drought stress further weakens potential host trees and makes them even more susceptible to defoliation.

In dry pine and mixed conifer forests, climate adaptation strategies including forest thinning that selectively removes small to medium trees can increase the resilience of large pine, Douglas-fir and other species to drought, forest insects, and disease agents. Fuel reduction of logging slash is important not only for wildfire risk reduction but also to reduce the potential for insect outbreaks such as Douglas-fir beetle that can build within logging residues (Sturdevant et al. 2022). In montane and subalpine systems, restoring landscape patch mosaics of different vegetation types (forests, grasslands, shrublands) and forest age classes can reduce landscape contagion to forest insect and disease outbreaks.

Mechanical treatments

Mechanical thinning and prescribed burning can be used to reduce both the amount and continuity of fuels for fire, thereby reducing potential fire intensity. Some recent literature has questioned whether thinning forests might contribute to the drying of understory fuels and the overall susceptibility of forests to fire (e.g., Schoennagel et al. 2017). However, with warmer and often much drier summers, many forests are already fire prone and susceptible to high severity fire events. Climate change adaptation strategies will therefore need to be place-based to determine where sites have tipped to having a pronounced water deficit and available fuel to support a high likelihood of ignition and fire spread. Within these fire-prone sites, fuel treatments that thin forests from below and effectively reduce surface fuels will reduce fire intensity and mitigate the severity of fire impacts to forests and contribute to greater resilience to native forest insects and diseases (Kalies and Kent 2016, Prichard et al. 2021).

Topic 3: Nature-based climate solutions and climate-smart forestry

As a potential nature-based climate solution, forests are highly valued for their capacity to sequester and store vast amounts of carbon (Seidl et al. 2012, Domke et al. 2020, Kaarakka et al. 2021). Because of their unusually high biomass and carbon sequestration potential, mature and old forests along the Pacific Coast are of particular interest for conservation. The NWFP represents one of the largest investment by the US National Forest system to conserve and maintain old forests, and will continue to be seen as a model for forest conservation (Johnson et al. 2023). Within discussions of protecting 30% of Earth's terrestrial and ocean ecosystems, large conservation areas such as the NWFP are receiving even more attention (Dinerstein et al. 2019).

In the recent Executive Order (14072: Strengthening the Nation's Forests, Communities, and Local Economies), old and mature forests are recognized for their importance for their community and ecological values: "*Globally, forests represent some of the most biodiverse parts of our planet and play an irreplaceable role in reaching net-zero greenhouse gas emissions. Terrestrial carbon sinks absorb around 30 percent of the carbon dioxide emitted by human activities each year. Here at home, America's forests absorb more than 10 percent of annual United States economy-wide greenhouse gas emissions. Conserving old-growth and mature forests on Federal lands while supporting and advancing climate-smart forestry and sustainable forest products is critical to protecting these and other ecosystem services provided by those forests*." ***Climate-smart forestry***, which is specifically mentioned in EO 14072, is an adaptive forest management and governance to protect and enhance the potential of forests to both adapt to and mitigate climate change (Bowditch et al. 2020, Mathys et al. 2021, Cooper and MacFarlane 2023). It is composed of three main objectives: (1) increasing the mitigation potential via carbon sequestration of forests, (2) adapting forests to climate change, and (3) ensuring the sustainable provision of ecosystem services. Under this model, mitigation of anthropogenic climate change is partly achieved through enhancement in forest carbon sequestration in tree biomass and forest soils. Adaptive capacity to climate change and disturbance regimes is enhanced by promoting genetic, compositional, structural, and functional diversity of forests and woodlands at both stand (patch) and landscape scales. The overall goal of climate-smart forests is to provide continuous delivery of ecosystem services by sustaining ecosystem integrity and functions while enhancing the carbon storage potential of forests. Adaptation strategies thus aim to maintain or improve the ability of forests to grow under current and projected climatic conditions and increase their resistance and resilience.

Given recent trends in old tree mortality, wildfires, and a steep rise in forest insects and pathogens, questions remain on the viability of nature-based climate solutions and where forests will remain viable carbon sinks or in fact become net sources of GHG emissions (von Buttlar et al. 2018). In dry, fire-prone sites, forests may have exceeded their sustainable carbon carrying capacity. Fire hazard reduction treatments that involved mechanical thinning to reduce tree density and crown fire potential may reduce overall total aboveground carbon stores. However, fuel reduction treatments that emphasize retention of larger, fire-resistant trees and forest structure may be effective at stabilizing forest carbon stores and sequestration potential (Hurteau et al. 2019). Specifically, the application of restoration treatments may limit the extent and severity of future fires thus reducing carbon emissions and also shift carbon sequestration to leave trees with greater overall vigor and productivity. However, some short-term emissions will occur as a result of mechanical thinning and prescribed fire treatments (Hunter and Robles 2020).

In the moist forest zone of the NWFP, forest biomass and related carbon stocks have been considerably depleted during the past 150 years of EuroAmerican colonization, land development, and timber harvest. Thus, conservation of existing mature and old forests and the application of silviculture to accelerate the development of large tree structure in younger forests can contribute to climate change mitigation (Seidl et al. 2012). Additionally, Betts et al. (2018) found that old-growth forests may buffer the negative effects of climate change for those species that are most sensitive to temperature increases. The results of their study highlighted a mechanism whereby management strategies to curb degradation and loss of old-growth forests— in addition to protecting habitat— could enhance biodiversity persistence in the face of climate warming.

Conclusions: A Framework for Management Adaptations

Adaptations to the NWFP are critically needed to address the effects of climate change on forests and habitats across the plan area. As more forests become drought and fire-prone, increasing forest resilience is top priority. This will require reconsidering where multi-layered, late-successional forests can be sustained under the changing climate and how to protect old and mature trees and their associated habitats where water deficits are contributing to multiple stressors, including risk of wildfires, insects and diseases. In this final section, we offer the following framework and recommendations for adaptive management within the NWFP area, which are summarized in **Table 2**.

With its emphasis on *ecological integrity,* the 2012 Planning Rule allows federal land managers to promote ecosystems that occur within their natural range of variation to withstand and recover from disturbances including wildfires, insect and disease outbreaks, and periodic drought. Science-based strategies for adaptive, climate-informed practices in fire-prone forests emphasize proactive management to restore more resilient forest structure and composition so that at the scale of patches to landscapes, forests can more readily survive future wildfires, drought and insect/pathogen outbreaks. Indigenous fire use and land stewardship prioritize cultural burning in fire-prone forests and are recognized as integral to many western North American native fire regimes (Lake et al. 2017, Copes-Gerbitz 2023, Eisenberg et al. 2024). Through decades of scientific research and millennia of Indigenous knowledge and practice, adaptive land stewardship is strongly supported in the literature with a restoration of proactive fire use, including support for revitalizing cultural burning practices, as a key restoration goal in dry, fire-prone forests (see Kalies and Kent 2016, Stephens et al. 2020, and Prichard et al. 2021 for reviews).

In order to provide a framework for how the management direction in the NWFP can be adapted to better address climate related impacts, we identified key components of the NWFP (after Gaines et al. 2022). We then used the components to structure peer discussion (Appendix A) of how these components can be adapted to better address climate-related impacts and to increase the likelihood of achieving the original conservation goals of the NWFP and the ecosystem integrity and resiliency goals of the 2012 planning rule. The adaptation topics included: (1) forest zones and the role of reserves for the protection of mature and old forest, (2) mid-scale evaluations, (3) post-fire forest adaptation, (4) protection of old trees and restoration of spatial patterning, and (5) making adaptive management work.

(1) Forest Zones and the Role of Reserves

The NWFP recognized differences in management history and disturbance ecology of Dry and Moist Zone forests. Moist Zone Forests are common within the west Cascades while Dry Zone Forests are typical of the eastern Cascades and southwestern Oregon. An additional potential Forest Zone is the cold high elevation forests of the Olympic and Cascade ranges. In addition, Dry forests also exist within the Puget Lowlands, Willamette Valley, and eastern Olympics, and are expected to expand in western Oregon and Washington as climate changes. Other options to zoning beyond dry and moist may be ecologically warranted (Gaines et al. 2022) but will need to consider how it is applied in land management planning.

<u>Moist forests</u>

Management options that have been recommended in Moist Zone Forests include continuing with the reserve network and protection the remaining mature and old forests that occur in critical habitat. Where plantations exist, strategies can include accelerating tree growth and the development of complexity in young forests. Under rapid climate change, adaptation strategies will require evaluations of sites to determine which moist forests are transitioning to dry with different management needs, including those located in western Oregon and Washington, which may require adjustments to the reserve network.

As the effects of climate change intensify, greater understanding of the biophysical setting of reserve areas is critically needed to anticipate where moist forests are transitioning into drier, more fire-prone sites (Hessburg et al. 2015, 2016). Even with unprecedented investments in fire suppression, static reserves cannot fence out high-severity wildfires and other agents of change.

Dry forests

Dry Zone forests are under combined threats of drought, insect/disease agents and wildfires. Within these ecosystems in particular, continued fire exclusion, including loss of cultural burning, imperils these forests under climate change. Within NWFP reserves located in the east Cascades of Oregon and Washington, the amount of mature and old forest cover has been dramatically reduced by high severity fire. On the driest sites, type conversions of dry ponderosa pine and mixed conifer forests to persistent shrublands or grasslands are already occurring. Proactive forest thinning and intentional, beneficial fire can create more resilient structures that conserve old and mature forests. A continued strategy of active fire suppression coupled with static reserve management in dry, fire-prone forests has profound consequences to forest structure, composition and susceptibility to the effects of climate change and wildfires (Stephens et al. 2020, Prichard et al. 2021).

Through our interviews, we received some recommendations to retaining reserves or emphasis areas but revise standards and guidelines to promote and focus landscape-scale restoration. Others suggested broad-scale adaptation strategies for dry forests that focus on entire landscapes and emphasize the conservation and recruitment of old trees. In this approach, the amount and spatial arrangement of mature and old forest habitats and other forest structure types is evaluated across large landscapes, independent of land allocation. In direct contrast to the more passive approach that has been taken in most dry forest LSRs, this strategy includes proactive treatments to promote persistence of fire-and drought-resilient trees and recovery of old forest and savanna structures that can withstand future wildfire events.

Cold forests

Cold forests are located in mountainous terrain within the NWFP area, many of them within congressionally (wilderness areas) or administratively (roadless areas) withdrawn areas. Generally, thinning and prescribed burning are not appropriate treatments because higher elevation tree species (e.g., true fir, mountain hemlock, lodgepole pine) do not have thick bark or other adaptations to frequent, low-severity fires (Prichard et al. 2021). In cold forests, a strategy of increased heterogeneity of forest patch sizes, age classes and nonforests can be implemented to enhance landscape resilience to fire, insects and disease agents and climate change (Hessburg et al. 2019). Where aspen and birch historically were important in semi-arid cold forest landscapes, restoring hardwood forests can further contribute to landscape heterogeneity and resilience (REF). A primary tool that could be applied to achieve these objectives is managed wildfire with the recognition that continued fire exclusion predisposes cold forests to burning in the most severe portions of wildfire seasons (Povak et al. 2023, Kreider et al. 2024).

(2) Mid-Scale Evaluations

A component of the NWFP included completion of watershed analyses (NWFP ROD, B20-B21). This mid-scale analysis was deemed necessary "*for making sound management decisions*." Watershed analyses "*may include a description of resource needs, capabilities, opportunities, the range of natural variability, and spatially explicit information that facilitates environmental and cumulative effects analyses*." Mid-scale watershed evaluations can be used to identify restoration needs and priorities, and to identify implementation actions and monitoring strategies and objectives. On many national forests, watershed analyses were completed in the first few years following the implementation of the NWFP. Funding to revise and update these analyses has not been adequate to keep them updated and many are now antiquated.

However, other tools also have been applied for mid-scale evaluation on Forest Service lands. For example, under the east-side screens, watersheds are evaluated to assess departure of different forest types and structures and to assess habitat connectivity. On the Okanogan-Wenatchee National Forest, a research-management collaboration resulted in process referred to as an all-lands landscape evaluation that is being used to assess watershed conditions, habitat sustainability, fire risk, and vegetation departures, including climate change analogs (Hessburg et al. 2013, 2015, Cannon et al. 2018, OWNF 2024). This process has been adopted and adapted by the Washington Department of Natural Resources and used as a component 20-year forest health strategy and is being applied to national forest and state lands across eastern Washington (WADNR 2017). These mid-scale evaluations provide valuable tools to step-down broad-scale plan direction, assess ecological integrity and resilience, identify restoration needs and priorities, and can be used as a component of monitoring (Hessburg et al. 2013, Gaines et al. 2022).

(3) Post-fire Adaptation

With so many post-burn landscapes now within the NWFP, post-fire adaptation strategies are being considered to restore forest structure and resilience to future disturbance events. Although a range of adaptation strategies apply to this work, post-fire harvest (salvage) was the only strategy covered in the original NWFP and was limited to situations where it would have a positive effect on late-successional habitats or would not diminish habitat suitability now or in the future. The NWFP guidance did recognize that some salvage harvest may be used to "reduce the risk of fire or insect damage to late-successional forest", a condition most likely to occur in the eastern Oregon or eastern Washington Cascades.

Recent science reviews on the ecological effects of post-fire harvest have shown that there is little ecological justification for the removal of large to very large trees (Peterson et al. 2009, Leverkus et al. 2021). Adaptations to the NWFP that target recently burned areas could include: 1) protect old dead or dying trees from post-fire harvest but encourage removal of small to medium-sized shade-tolerant and fire-intolerant trees where good evidence of highly increase density over the period of fire-exclusion and where the effects of timber harvest can be appreciably mitigated (Leverkus et al. 2021, Gaines et al. 2022); 2) use recent wildfires as opportunities to expand the use of beneficial fire by serving as temporary barriers or defensible space; 3) in areas of high fire risk, consider fuel reduction in and around unburned forests to mitigate future fire severity; and 4) in frequent fire systems, invest in ongoing treatments and maintenance.

(4) Old Trees and Spatial Patterning

Old trees provide important habitats and forest structure and their abundance has been considerably reduced as a result of past management (Hessburg et al. 2020). Large and/or old trees were not explicitly protected in the NWFP. Recommendations have called for the retention all existing old trees (>150 years old) and the identification of old trees based on visual characteristics (e.g., Van Pelt 2008). In addition, it is important to restore the resilience to forest stands where treatments occur. Thus, plan components could be developed to standardize the application of ICO (individual trees, tree clumps, openings) in order to restore spatial patterning in areas where treatments occur (Churchill et al. 2013).

(5) Making Adaptive Management Work

While the 2012 planning rule makes clear an emphasis on adaptive planning and management, the reality is that it has been difficult to implement in practice (Stankey et al. 2003, Bormann et al. 2007, Spies et al. 2018). In the NWFP area, this has been the case despite one of the most rigorous monitoring programs ever implemented. Because of the uncertainties surrounding our ability to predict the effects of climate change and the effectiveness of climate adaptations, monitoring and adaptive management will be vital (Spies et al. 2018, Gaines et al. 2021).

Table 1: Northwest Forest Plan components, descriptions, and proposed climate adaptation strategies.

Plan Component	Description	Proposed adaptation
Plan emphasis	Emphasize restoration of landscape resiliency.	Review and revise purpose and need, proposed actions.
Wildland fire management	Provide managers flexibility to manage wildfires under fire weather conditions that achieve restoration and resiliency objectives.	Establish desired conditions for resilient landscapes and sustainable habitats giving managers the ability to manage wildfires to achieve these objectives.
Forest zones	Zones delineated to address the diversity of fire regimes.	Revise planning zones to guide development of plan components.
Reserves	Account for changing disturbance regimes and landscape dynamics.	Realign reserve land allocations in Moist Forest Zone and use an Emphasis Area approach to land allocations for old forest habitats in Dry Forest Zone.
Mid-scale evaluations	Use landscape evaluation tools.	Require mid-scale landscape evaluations as part of the plan decision and updated and used to inform landscape restoration project planning.
Post-fire management	Evaluate the work of wildfires in guiding future restoration of late successional forests. Emphasize use of post-fire fuel reduction and maintenance burning to reduce fuels where past fire suppression has increased fuels pre-fire.	Use landscape evaluation to inform where treatments may be needed and require post-harvest treatments be addressed (see also below).

Plan Component	Description	Proposed adaptation
Old trees, large snags and spatial patterning	Protect and restore large and old trees and large snags, particularly the most resilient tree species.	Establish standards that requires that old trees and large snags be retained unless a safety hazard; Create specific guidelines to promote the development of large trees to historical levels.
Within-stand spatial variability	Emphasize mimicking historical spatial variability within treated stands to restore key functions.	Establish standards that requires the application of stand-scale spatial variability informed by historical stand reconstructions.
Adaptive management	Essential that adaptive management be effective to address uncertainty.	Integrate adaptive management triggers into decision and monitor to inform triggers. Establish a standard that requires plan amendment if not meeting plan objectives or if new science indicates plan assumptions need revision.

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Appendix A: Outline of topics covered in structured discussions with land managers and scientists.

<u>Key Discussion Topics/Questions</u>

1. Should the NWFP Area be Zoned? If so how? Remap areas that are becoming Dry?
   e.g., Dry vs Moist (see figure)

2. What is the role of Late-Successional Reserves (see figure)?
Should the roles differ by Zone?
Should there be some Zones with no Late-Successional Reserves?
Options:

- Dry Forest
  - Ecosystem restoration focus in Dry Forest Zone with no reserves
  - Reserves with focus on restoration
- Moist Forest
  - Retain existing reserves and protect all remain mature and old forest in critical habitat
  - Assess the resiliency of mature and old forest and redesign reserve network accordingly

3. Are mid-scale evaluations needed? If so what should they include?
Examples:

  - Watershed assessments in the original NWFP
  - Landscape evaluations (Hessburg et al. 2013)

4. What role, if any, should post-fire timber harvest or forest thinning play?

5. How should "old" trees be defined and managed?

- Dry Forest Zone
  - Retain all old trees
    - Use visual characters such as Van Pelt (2008)
    - Make ICO a Standard
- Does this matter in the Moist Forest Zone?

6. How to make sure monitoring and adaptive management actually happen?

7. Open discussion of other topics/issues