Vegetation Effects Analysis

Contents

Vegetation Effects Analysis 1
Introduction 1
Effects Analysis Scale and Applicability 1
Indicators and Measures 2
Assumptions 9
Forest Structure 13
Environmental Consequences 18
Large and Old Trees 21
Affected Environment 21
Environmental Consequences 24
Species Composition 26
Affected Environment 26
Environmental Consequences 28
Disturbance Regimes ..... **Error! Bookmark not defined.**
Vegetation Effects Summary ..... **Error! Bookmark not defined.**
Cumulative Effects Common to all Alternatives ..... **Error! Bookmark not defined.**
References 30
Other Literature Consulted 35

Introduction

One of the primary goals of the Eastside Screens was to conserve and promote old forest including the components of "remnant old and late seral and/or structural live trees". This was originally defined as trees greater than 21 inches in diameter at breast height (dbh). Although the purpose and need of the Eastside Screens has not changed, new science and our evolving understanding of landscape ecology in eastern Oregon and Washington has demonstrated that this original definition is no longer complete or adequate to support landscape restoration and resiliency efforts (Merschel et al. 2019, Johnston et al. 2018, Johnston 2017, Spies et al. 2018, Stine et al. 2014).

The goal of this vegetation analysis is to assess the effects of changing the 21-inch dbh harvest restriction on forest structure, including old trees and large trees, and species composition across the landscape. Describing and measuring the effects on these indicators is done several ways in this analysis, and our analysis methods are described below.

Effects Analysis Scale and Applicability

This is a programmatic rather than site specific analysis so does not authorize any activities on the ground. Project level NEPA analysis will be required to authorize site specific management and evaluate site-specific environmental effects.

This analysis is narrowly focused on Scenario A of the Eastside Screens wildlife standard, i.e. in areas that are considered below and outside of LOS forest as classified during project specific historical range of variability (HRV) analysis. HRV analyses will continue to occur at the forest or project level as part of the Eastside Screens ecosystem standard, which we do not address or propose to change with this analysis.

Indicators and Measures

Indicators and measures were developed based on the scientific literature and early public and internal Forest Service engagement. Indicators used in this analysis include: 1) forest species composition, and 2) forest structure, including large and old trees. These terms are defined for this analysis as:

- **Species Composition** – Species composition is described as the absolute (count) or relative proportions (percentage) of species present in a stand. In this analysis we use Society of American Foresters cover types (Eyre 1980) to represent the species compositions across the landscape as calculated by the Forest Inventory and Monitoring protocols (Arner et al. 2001). Cover types are named after the primary dominant tree species within a forest or stand by abundance. The effect analyses of each alternative also use the relative proportion of fire tolerant species as an indicator. Primary species considered fire tolerant are ponderosa pine, western larch and Douglas-fir.

- **Forest Structure** – Stands have been defined and measured based on a combination of tree size and canopy layers and placed into structural categories including: Late Open, Late Closed, Mid Open, Mid Closed, and Early. Late and Old Structure (LOS) forest as described in the Eastside Screens ecosystem standard and includes both Old Forest Multi-Strata/Late Closed and Old Forest Single Strata/Late Open (O' Hara 1996). This analysis has cross walked the original O'Hara descriptions to the measurable structural classifications used here including open and closed LOS. Our structure indicator includes old trees, large trees, and canopy cover. We assess old trees and large separately as well.

- **Large Trees** – Individual trees that are 21 inches diameter at breast height (dbh) or larger. This is based on the pre-existing criteria within the Eastside Screens wildlife standard.

- **Old Trees** – Old trees exhibit morphological characteristics that develop through age and survival through natural processes and disturbances. These characteristics can include deep fissured bark, lack of visible knots, mature epicormic branches, a significant proportion of heartwood, and/or complex crowns (Franklin et al. 2013, Henjum et al. 1994). For this analysis we use 150 years and older to define old trees (Henjum et al. 1994, Van Pelt 2008, Hessburg et al. 2020). The Eastside Forests Scientific Society Panel (1994) defined late-successional and old-growth forests as more than 150 years old or greater than 21 inches in diameter.

Forest Structure Indicator

Our structure indicator includes measures of tree size and canopy cover relative to site potential and natural disturbance regimes. For this analysis, we assess old and large trees separately. In order to measure forest structure for this analysis, we cross walked the forest structures described by O'Hara (1996) to more measurable vegetation-canopy classes. The rule set applied for defining forest structure (DeMeo et al. 2020) has evolved from the history of Region 6 efforts to define forest structure at the landscape scale for planning purposes, including the Northwest Forest Plan of 1994, the 1996 Interim Old Growth Standards (USDA Forest Service 1996) and the 2004 Regional Vegetation Mapping Standards (USDA Forest Service 2004). The 2004 Regional standard diameter class definitions were heavily influenced by (Johnson and O'Neil 2001). For this analysis the classic "5 Box Model" of FRCC (Barrett et al. 2010) is used. The methodology for creating the structural class layer involves two major steps, beginning with definition of tree size classes associated with different potential vegetation types (PVTs). A lookup table is then used to relate tree size class, canopy cover, and biophysical setting to a final structural class.

More LOS forest is desired under Scenario A of the wildlife standard. More open forest structure is desired both in LOS forest and mid seral forest.

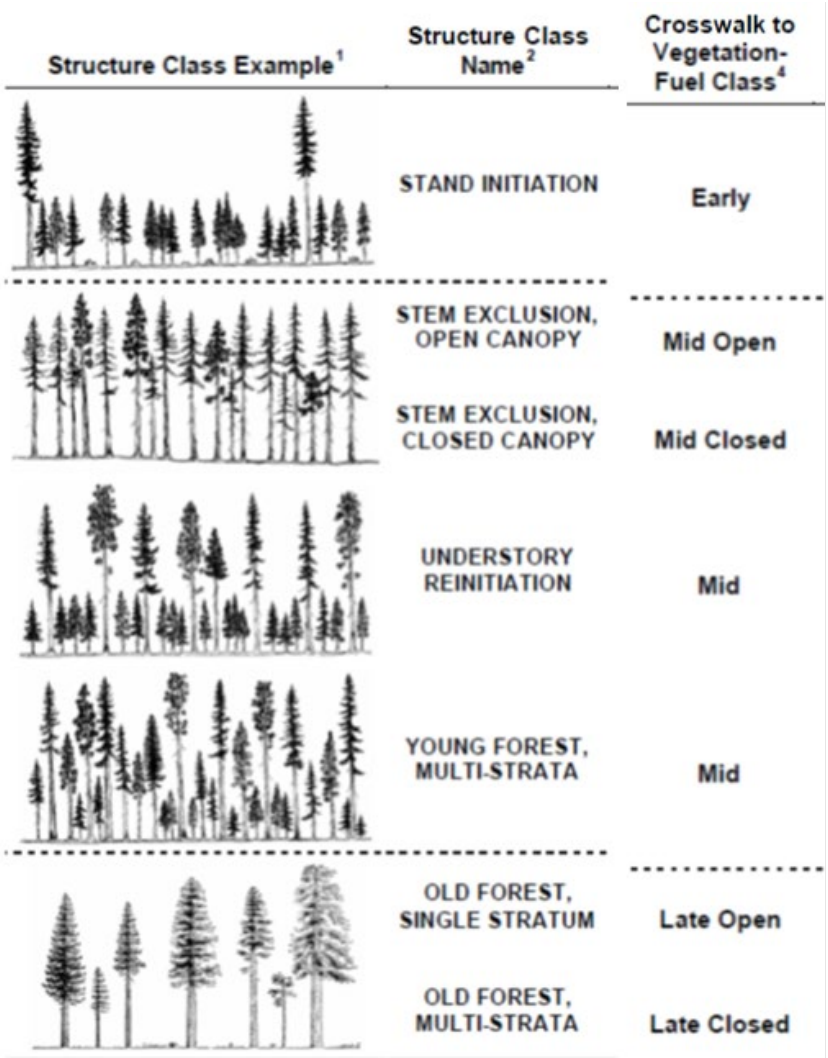

Figure 1. Forest structural class graphic example compared to eastside screen structural class name (O'Hara et al. 1996)and for this work we cross walk this structural classification to the vegetation-fuel classic "five box" model of Fire Regime Condition Class (Barrett et al. 2010) with early, mid-seral closed, mid-seral open, late seral open, and late seral closed seral stages. Old Forest Single Structure (Late Open) and Old Forest Multi Strata (Late Closed) are consider Late and Old Structure forest under the eastside screens ecosystem standard. The ecosystem standard then informs the wildlife standard scenario (A: below HRV and B: within or above HRV) and application of the 21" diameter harvest limit.

Table 1. Forest Structure Measures. More open forest structure is desired both in LOS forest and mid seral forest.

Forest Structure Measure	Desired Trajectory
LOS Structure	Increase
Promotion of more open conditions on dry and moist forest sites within LOS	Increase
Promotion of more open conditions on dry and moist forest sites outside of LOS	Increase

Large and Old Trees Indicators

As defined above, old trees are at least 150 years of age. Age was estimated within Forest Inventory and Analysis (FIA) plots, a systematic sampling effort of forest conditions across the country (see FIA description for more detail). Old trees play a valuable role in forests by maintaining a legacy of species genetics and providing ecosystem value through long-lived structure and demonstrated resistance to disturbance (Franklin and Johnson 2018, Marcot et al. 2018, Hessburg et al. 2016, Agee and Skinner 2005).

Maintaining or increasing the abundance of large trees, particularly where old trees may be lacking, can be an important element of providing ecological function. While some trees may be both old and large, not all old trees are large, and not all large trees are old (Van Pelt 2008, Hagmann et al. 2018, Johnston et al. 2018, Merschel et al. 2019).

The Eastside Forests Scientific Society Panel (Everett et al. 1994) documents the lack of old forest across the landscape and its importance for ecological function and wildlife habitat. While it's been over 25 years since the Panel's report, old trees naturally take a long time to grow. Trees have gotten larger across the landscape, but old trees are still lacking compared to historic levels. Large trees can substitute for some of the ecological function in the short-term. The desired trajectory for large and old trees is an increase in both across the landscape where these elements are currently lacking. FIA data show that large trees are already increasing across the landscape, but old trees are declining.

Table 2. Large and Old Tree Indicators.

Large and Old Tree Indicators	**Desired Trajectory**
Large Trees (≥ 21" dbh)	Increase
Old Trees (≥ 150 years of age)	Increase

Desired trajectory for large and old trees an increase in both across the landscape. Large trees are already increasing across the landscape, but old trees are declining.

Forest Species Composition Indicator

Tree species can be categorized as being tolerant of various disturbances like fire, meaning they are resistant to specific impacts based on individual physiological characteristics. The term

'shade tolerance' is also used to describe how various tree species respond to limitations on sunlight used for growth (Powell 2014a, b, Hessburg et al. 2020). Species that are fire tolerant, like ponderosa pine, are generally not tolerant of light limited growing conditions, so are referred to as shade intolerant. Conversely, species that are intolerant of fire are generally shade tolerant and are capable of growing under the canopy of shade intolerant species and competing with them for water and other resources. We use fire tolerant species (rather than shade intolerant) as our indicator and use this term to refer to species that grow best in open stands.

Across eastern Oregon and southeastern Washington basal area of fire intolerant species, like grand fir and white fir, is increasing (Johnston 2017, Hagmann et al. 2014, Merschel et al. 2014), creating dense forests less resistant to the effects of fire and other disturbances (i.e. more vulnerable to mortality) (Hessburg et al. 2020, Tepley and Hood 2020, Voelker et al. 2019). This analysis also addresses species that are resistant to disturbances other than fire (e.g. insects, disease, drought, changing water tables, etc.), which we refer to as disturbance resistant. The desired trajectory for forest species composition in both dry and moist forest is for increases in biophysically appropriate fire tolerant species.

Table 3. Forest Species Composition Indicator.

Forest Species Composition	**Desired Trajectory**
Dry and moist forest sites with dominance of fire tolerant species	Increase

Desired trajectory for forest species composition in both dry and moist forest is for increases in biophysically appropriate fire tolerant species.

Disturbance Regime Indicator
To better adapt landscapes to disturbances and to better align ecosystem processes on dry and moist biophysical settings, we describe some analysis results that address species compositions that are resistant to disturbances other than fire (e.g. insects, disease, drought, changing water tables, etc), which we refer to as disturbance resistant.

Landscape Stratification
For our analysis, we stratify the analysis area into dry and moist forest based on Potential Natural Vegetation (PNV) zones. Dry forest consists of ponderosa pine, Douglas-fir, and pinyon juniper PNVs. Moist forest includes white fir and grand fir PNVs. Wet/cold/other forest vegetation zones include other PNV zones such as mountain hemlock, lodgepole, hardwood, subalpine fir, and parklands and shrublands.

Table 4. Summary of Vegetation Indicators, landscape stratification and correlated potential vegetation zones.

Landscape Stratification	**Potential Natural Vegetation Zones**
Dry forest	Ponderosa pine

Landscape Stratification	Potential Natural Vegetation Zones
	Douglas-fir Pinyon juniper
Moist forest	Grand fir White fir
Wet/ cold/ other	Shrub Lodgepole Hardwood Red fir Mountain hemlock Subalpine fir Parkland

FIA Data

The Forest Inventory and Analysis (FIA) data that were used in this report are part of a nationally consistent network of forest inventory plots that are located on forested lands of all ownerships (www.fia.fs.fed.us). The FIA plots were located systemically to allow for landscape-scale inference. On federal lands there is approximately 1 plot per 6,000 acres. On Forest Service lands in this analysis area, additional plots are maintained which increases the plot density to approximately 1 plot per 2,000 acres. Any particular plot in the FIA dataset is sampled every 10 years.

The FIA data used for this analysis area are composed of the plots that have been visited twice and represent changes across the past 20 years (2001 – 2017). The data are accessible in the FIADB 8.0 Phase 2 and were summarized with the assistance of the ecologists and biometricians within the Forest Inventory and Analysis group. These data were used to describe the existing conditions as well as trends and change over time. In addition, the plot level data that met a minimum area threshold (0.25 acres) were also used to populate the Forest Service's Forest Vegetation Simulator (see below) in order to estimate stand level and landscape level effects of the alternatives.

FVS Analysis

Forest Vegetation Simulator (FVS) modeling was conducted to complement and support the analysis. The purpose of the FVS simulations is not to mimic all potential alternative treatments, effects of those treatments, or all disturbances and succession dynamics. That type of analysis is deferred to project-level analysis. The purpose of FVS modeling is to describe: 1) the range of different outcomes between the alternatives across the landscape, 2) limitations that may make management more or less constrained in applying the alternatives, and 3) how the alternatives could accomplish the desired objective(s) of promoting old forest characteristics (large trees, old trees, or fire tolerant species compositions) with stand level application of one generalized silviculture prescription. We used a prescription focused primarily on density reduction, which is

a common landscape and stand level objective in eastern Oregon and southeastern Washington restoration projects.

The Forest Vegetation Simulator (FVS) is an individual tree, distance independent, forest growth and yield model (Dixon 2015). FVS is useful for simulating growth and yield with and without simulated prescriptions of forest conditions based on site information. FVS provides a modeling framework to support decision making based on expert knowledge of forest planning and implementation and is consistently used by the Forest Service for vegetation project planning and analysis (Keyser 2019, Keyser and Dixon 2019).

We applied a typical prescription designed to increase growing space for trees that remain on site, decrease competition and ecological stress (limited availability of water or light), and favor fire tolerant species. Because we used thousands of plots across a varied landscape, we did not tailor our prescriptions to individual sites, other than using a relative density residual target (percent maximum Stand Density Index). While tailored prescriptions are important at the project scale, for a programmatic analysis looking at the general direction of change and differences between alternatives it is not needed. The FVS analysis assumed that growing conditions, tree physiology, and silvicultural rules would not change during the 25-year analysis window.

For our analysis, when the stand density index (SDI) exceeded 55% of the maximum SDI, we modeled a forest thinning starting with the smallest size classes and increasing in the size of trees removed until the SDI of the forest remaining reached 30% of maximum. However, in the Adaptive Management Alternative, we thinned across age and size classes with less emphasis on removing the smallest trees in order to more fully mimic the potential application of uneven aged management that would be possible without an age or size standard. In all modeling scenarios, fire tolerant species were preferred for retention, meaning that a fire tolerant species would need to be significantly smaller (5-10") before it would be removed instead of a fire intolerant species.

The FVS modeling was carried out consistent with the following assumptions for all alternatives (except where noted):

- Any stand with 2,000 bd/ft/acre of merchantable volume that exceeds 55% of maximum stand density index (SDI) for the site would be reduced to a condition as close to 30% maximum SDI as possible given constraints unique to each alternative.
- Each simulation had constraints consistent with the alternatives:
    - Current Management: No removal of 21-inch dbh and larger trees.
    - Old and Large Tree Guideline: No removal of trees older than 250 years.
    - Old Tree Standard: No removal of trees older than 150 years.
    - Adaptive Management: No age or size restrictions.
- Any stand could be treated at any (or all) of three possible points in time, 2020, 2030, and 2040.
- Effects were assessed in 2045.

- None of the scenarios simulated understory regeneration or changes in climate. Changes in climate (e.g. longer fire seasons and increased drought stress) were considered in the qualitative effects.
- Tracking the age of individual trees is not possible in FVS so modeling reports effects on trees >150yrs in age at the time of plot sampling (2001 – 2017). It is expected that additional trees that were between 106 – 122 years of age at the beginning of the 25-year analysis window would provide more 'old' trees in 2045.
- Simulations did not incorporate management constraints associated with planning, capacity, operational feasibility, or cost of treatments.

Assumptions

The following assumptions guided our analysis. The assumptions cover: disturbance, forest succession (how forests grow over the next 25 years), and management actions. Current management trends guide assumptions around the methods and extent of future management.

Disturbance Assumptions: All Alternatives

Disturbances in eastern Oregon and southeastern Washington landscapes help maintain ecosystem function and promote small and large-scale change in vegetation and processes. Eastern Oregon and southeastern Washington landscapes have frequent disturbances like wildfire and insect outbreaks which result in dynamic landscape characteristics. Forest structures and species compositions change through time in response to disturbances, but the hallmarks of the ecosystem survive in the form of legacy trees that influence subsequent stand development (Marcot 2018, Hessburg 2016, Belote et al. 2015). The complex interactions of succession and disturbance result in vegetation that shifts in location, quantity, and maturation, a characteristic of frequent-disturbance landscapes necessary for sustainable ecosystem function (Johnston et al. 2016, Peterson 2002, Hemstrom 2001, Spies and Turner 1999).

Climate change will increase the extent of disturbance including fire, insects, disease, and drought. Fires will increase in size, and potentially severity (i.e. mortality) (Kolden et al. 2015b, Hamilton et al. 2016, Westerling 2016, Kerns et al. 2018, Parks et al. 2018). Large-scale insect and disease outbreaks and mortality will likely increase, especially where trees are already stressed for resources (Kerns et al. 2018, Irwin et al. 2018, Pureswaran 2018, Littell et al. 2018, Mote and Salathe 2010). In addition to direct climate impacts such as moisture availability, warmer temperatures and longer fire seasons, the associated interactions between abiotic environmental stressors and biotic processes are expected to have compounding effects into the future (Fettig et al. 2019, vanMantgem et al. 2013, Sturrock et al. 2011, Hankin et al. 2019, Kemp et al. 2019, Korb et al. 2019).

Forest Succession Assumptions: All Alternatives

Species composition will continue to shift toward fire intolerant species like grand fir and white fir. Less fire tolerant trees like white fir and grand fir will be the most abundant young trees as they can flourish in shady understories in the absence of periodic fire. Large fires with

uncharacteristically large patch sizes will favor species with light windborne seeds that are capable of reseeding areas much farther away from reproducing survivors instead of the fire adapted species with heavy seeds (e.g. ponderosa pine) which do not travel far from the reproducing individual (Kemp et al. 2016, Westerling 2016, Owen et al. 2017, Coop et al. 2019, Downing et al. 2019, Hessburg et al. 2019). The increasing representation of these fire intolerant trees in dry and moist forest landscapes creates a feedback loop that perpetuates conditions more conducive to severe large-scale disturbances with increased risk of a future altered or unique vegetation conditions (Walker et al. 2018, Davis et al. 2019).

The current trend toward closed, dense forest structure will continue. Relatively closed, mid-aged (50-150 years) stands are the most abundant forest on the landscape due to a combination of fire history and past harvest (Johnston 2017, Hagmann et al. 2014, Merschel et al. 2014, Quigley and Arbelbide 1997, Haynes et al. 1996, Quigley et al. 1996). Repetitive cycles of fire (and some other disturbances) that would have historically created open forests by reducing density are not occurring at a rate that will substantially alter this trend. Furthermore, rates of mechanical treatment that open forest and reduce density are not occurring and are not projected to occur at rates that outpace current regeneration and succession (Haugo et al. 2015).

Growth of shade tolerant trees will continue to outpace growth of other species. Increasingly, large trees across the landscape will be comprised of less fire tolerant species because of their current abundance (Johnston et al. 2017, Johnson 2017). Large trees of fire tolerant species like ponderosa pine and western larch will experience increasing stress from competition, insects and disease (Voelker et al. 2019, Bottero et al 2017). Shade tolerant trees are also able to grow more quickly than shade intolerant trees when site conditions are equally favorable for both categories (Johnson et al. 2019).

Trees will become increasingly vulnerable to mortality. Tree mortality will be driven by compounding stressors including inter-tree competition, insects and disease, and climate change and past management including fire exclusion and landscape scale alteration of structure (Fettig et al. 2019, McMahon et al. 2019, Anderegg et al. 2015, Battles et al. 2008, Raffa et al. 2008).

Management Assumptions: All Alternatives

Current management trends will continue at a similar rate as observed over the past decade. This includes commercial thinning (Figure 3) and timber harvest levels (Figure 4). Similar silvicultural treatments that have been implemented over the past decade will continue. This has been about 34,000 acres of commercial treatment per year for the past decade in the analysis area. FVS simulations were not limited by management constraints other than forest plan management direction. This allowed us to model an average of 100,000 acres of treatment per year, which is much higher than is assumed from recent management trends. Restoration treatment priorities will continue to emphasize restoring fire adapted landscapes under the framework of shared stewardship and cross boundary collaboration.

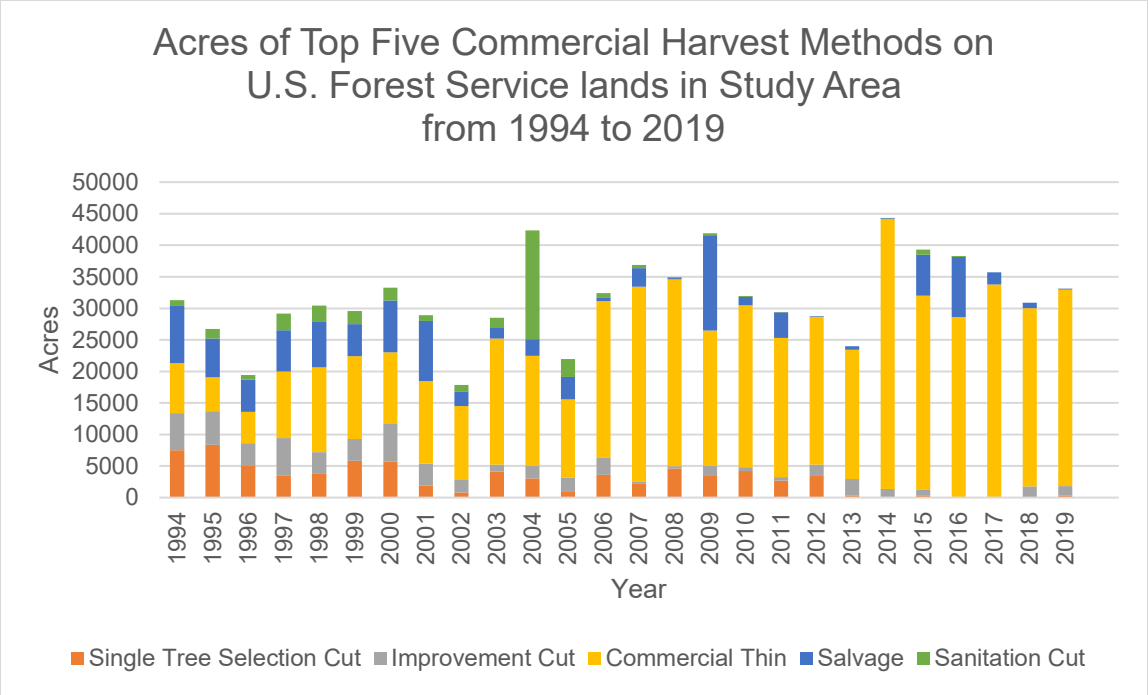

Figure 2. Acres of harvest by type within the analysis area since 1994 to 2019. Commercial thinning dominates harvest methods in eastern Oregon and southeastern Washington.

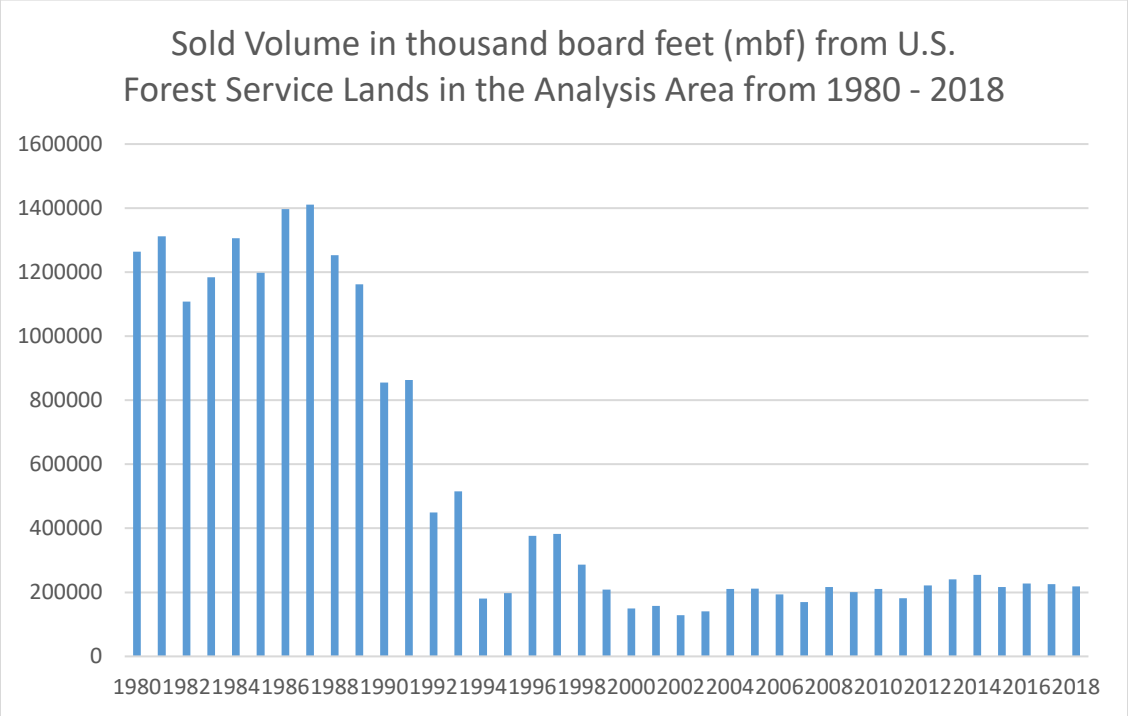

Figure 3. Timber volume sold from Forest Service lands within the analysis area from 1980 to 2018. Average timber harvest levels over the last 10 years are assumed to continue with an approximate average harvest of 200 million board feet per year.

Wildfire will continue to be suppressed at current rates (about 98%). We assume that fire seasons will become longer and extreme weather conditions will become more frequent (Hessburg et al. 2020, Keyser and Westerling 2019, Littell et al. 2009, Westerling et al. 2003). We assume that the vulnerability of eastern Oregon and southeastern Washington forests due to fire exclusion and past use has created homogenous forest conditions consisting of dense forests, less fire tolerant species, and reduced variability in vertical and horizontal canopy structure which creates uncharacteristic potential for fires with higher mortality levels in many areas throughout the landscape (Littell et al. 2018, Mote and Salath 2010). We assume that the successful suppression of fires during moderate fire weather conditions reduces the potential positive benefits of fires on the landscape (Davis et al. 2019), such as a reduction in surface fuels and ladder fuels, which creates landscape heterogeneity, and promotes fire tolerant species composition (Parks et al. 2014, North et al. 2015, North et al. 2012).

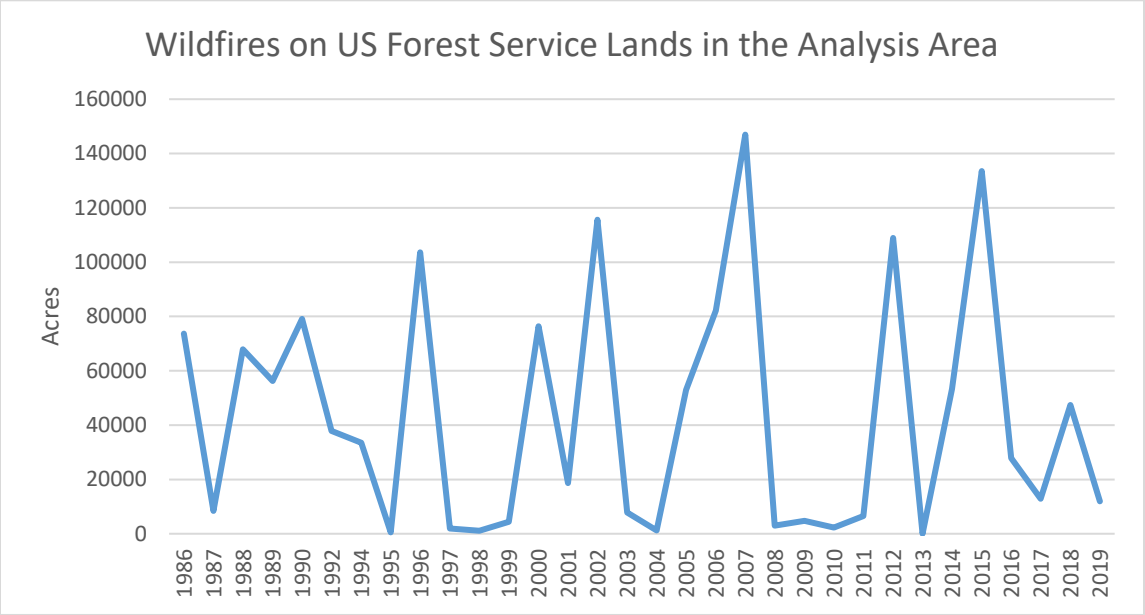

Figure 4. Acres of wildfire within the analysis area since 1986 to 2019. Years are highly variable, but area affected by wildfire is an average of about 60,000 acres per year.

Stand level silvicultural and prescribed fire treatments will be consistent with the Eastside Screens goal of maintaining the abundance and distribution of LOS forest. Management activities will preserve those components of the landscape and aim to cultivate old and large trees in a manner that also creates ecologically appropriate LOS forest and wildlife habitat.

The area affected by timber harvest under all alternatives will remain stable while the prescriptions within treated stands will likely change to some extent. This proposed amendment would not expand the area available for timber harvest because harvest levels are more influenced by factors including road systems, logging systems, capacity, budget and individual forest plan direction.

Additional Management Assumptions

Under the Old Tree Standard Alternative, we assume that some old trees will be cut and some trees younger than 150 will be retained because implementation of the standard relies on visual

characteristics rather than direct measurement of age. The harvest of some old trees and retention of some younger trees would be negligible at both the project and landscape scale.

Under the Current Management Alternative, we assume there will be no change in the common practice of forests applying sub-part 2(a) to subpart 1 of Scenario A of the wildlife standard. This means that when projects are under Scenario A of the wildlife standard, trees equal to or greater than 21 inches dbh would not be harvested.

Under all action alternatives, we assume that subpart 1 of Scenario A is not interpreted as having a 21-inch dbh tree harvest prohibition as long as the intent of the ecosystem standard and Scenario A wildlife standard are met including not net loss of LOS from respective biophysical environments. When LOS (single- or multi-strata) is within or above HRV for a biophysical setting, timber sale activities that accomplish either 1) the maintenance or improvement of LOS conditions or 2) the manipulation of multi-strata LOS to single strata LOS consistent with the historical ranges of variation is acceptable as long as there is no net loss of LOS.

Analysis Methods

We use two methods to evaluate the effects of each alternative. First, we simulate typical timber harvest in the Forest Vegetation Simulator (FVS) using Forest Inventory and Analysis plot data to help establish a baseline understanding of different alternatives' effects within stands. We also use a qualitative assessment based on the disturbance, succession and management assumptions outlined below. Both methods use a 25-year analysis window. Both quantitative and qualitative assessments are based on best available science, field experience, and professional judgement and expertise.

Forest Structure

Affected Environment

For all six national forests, late and old structure (LOS) has increased since 1995. This is an absolute increase, with most of the LOS gain in closed canopy forest. Open canopy forest has also increased since 1995. Closed LOS has increased more than open LOS primarily because of ingrowth (regeneration) and growth of trees into larger size classes over time. This growth has also made forests more dense. Overall the increase in closed canopy forests indicates a departure from historical conditions across much of the analysis area, as documented in other assessments across eastern Oregon and Washington (DeMeo et al. 2018, Haugo et al. 2015, Johnson et al. 1994).

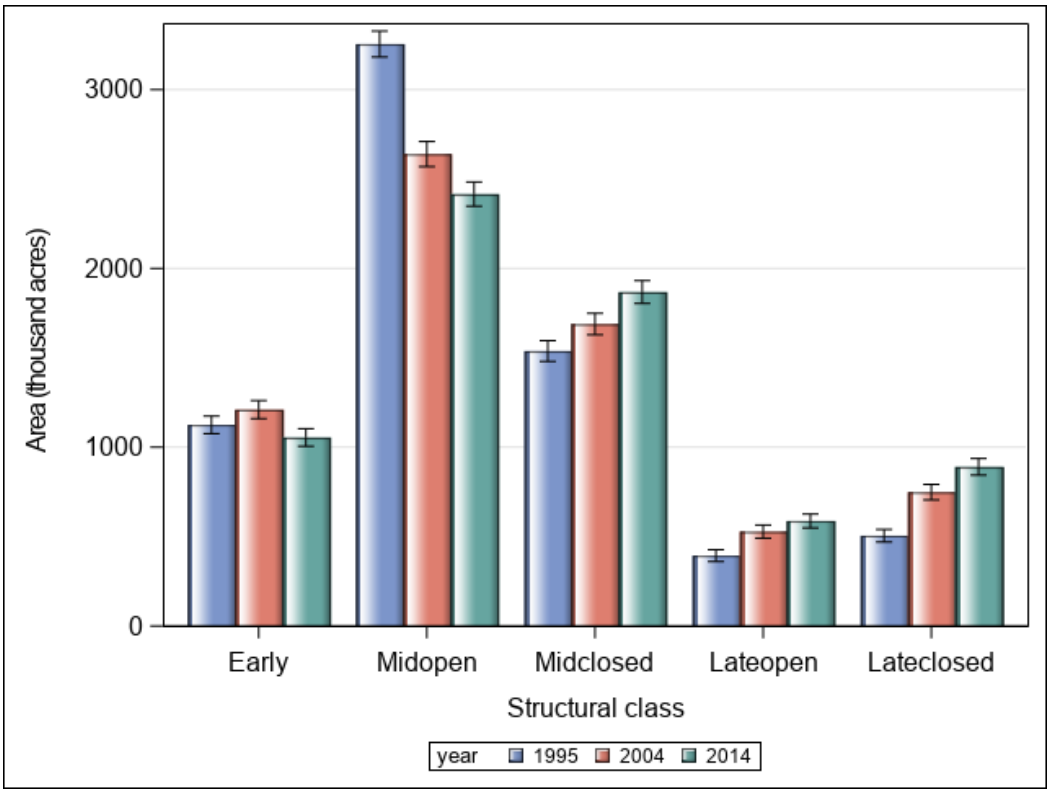

Figure 5. Structural classes across the analysis area in three time periods: 1995, 2004, and 2014 for all forest types within the analysis area. All closed structures (mid and late closed forest) have increased since 1995. Mid open forest has decreased through time while late open has increased. Early seral forest has remained relatively stable or is slightly decreasing. Source: Forest Inventory and Analysis data classified using methods outlined in DeMeo et al. (2020).

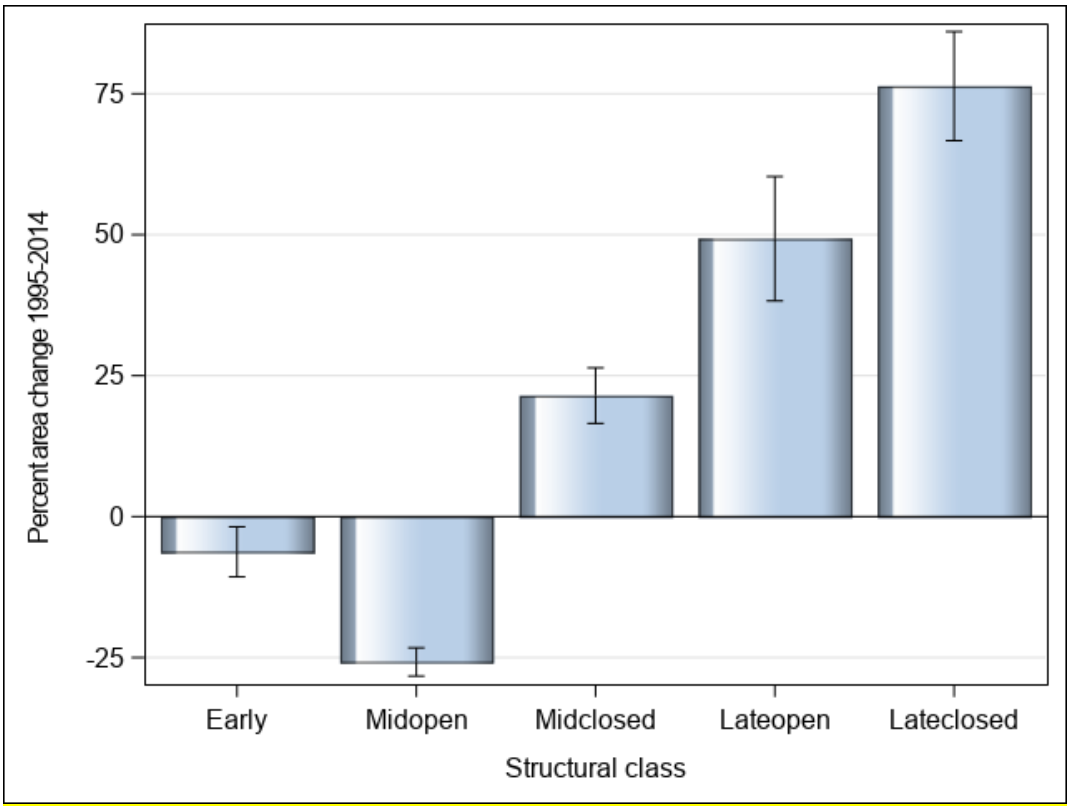

Figure 6. Percent change in structural classes across the analysis area between 1995 and 2014 for all forest types within the analysis area. All closed structures (mid and late closed forest) have increased since 1995. Late open structures increased (about 50%) while mid open structure have decreased (about 25%) through time. Early seral forest has remained stable or slightly decreasing. Source: Forest Inventory and Analysis data classified using methods outlined in DeMeo et al. (2020).

In dry forest the changes in structural class are slightly different than for the landscape as a whole. There is a greater percent increase in dry forest for LOS structure including both late open and late closed forest than compared with moist forest. The biggest difference is that in dry forest late closed forest has increased about 125% whereas in moist forest it has increased just over 50%. One reason for this difference could be that in dry forest, the definition of closed canopy can be lower than in moist sites because the low natural productivity of dry sites.

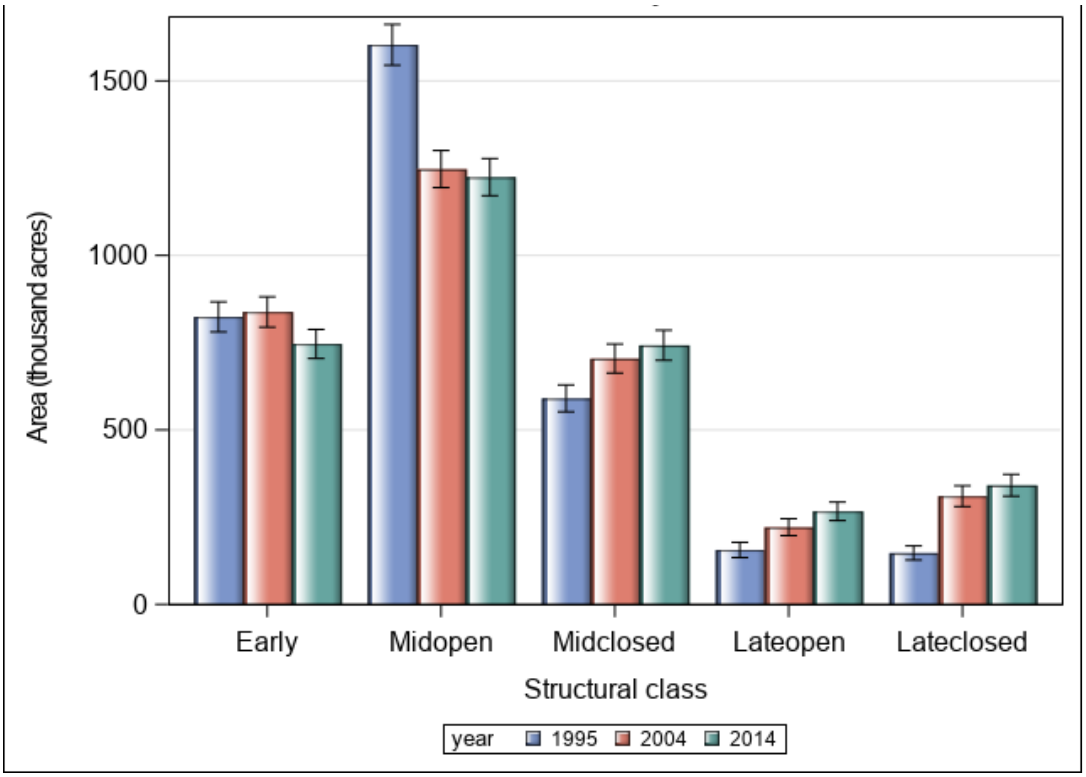

Figure 7. Dry Forest. Trends in structural classes within dry forest between 1995 and 2014 within the analysis area. All closed structures (mid and late closed forest) have increased since 1995. Late open structures increased while mid open structure have decreased through time. Early seral forest has remained stable or slightly decreasing. Source: Forest Inventory and Analysis data classified using methods outlined in DeMeo et al (2020).

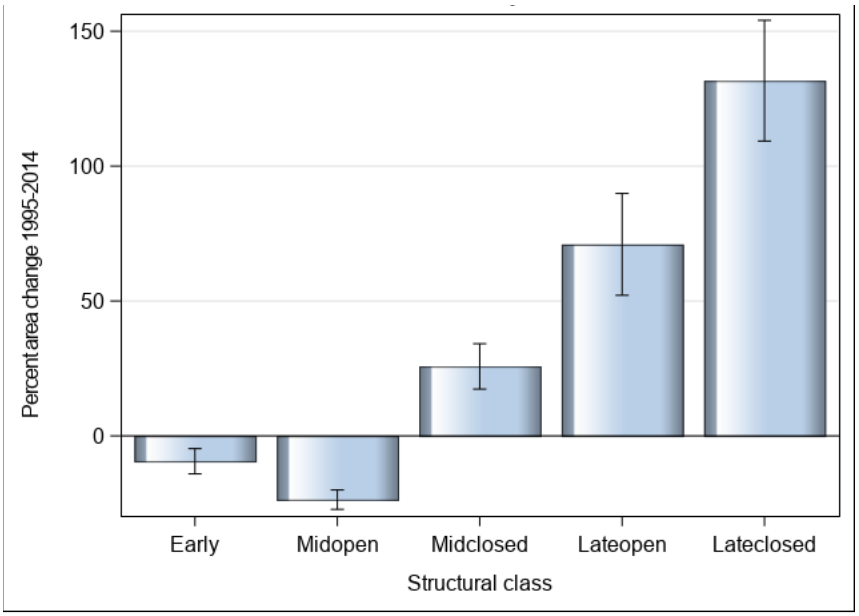

Figure 8. Dry Forest. Percent change in structural classes across the analysis area between 1995 and 2014 dry forest within the analysis area. All closed structures (mid and late closed forest) have increased since 1995 with late closed increasing about 125%. Late open structures increased (about 60%) while mid open structure have decreased slightly. Early seral forest has remained stable or is slightly decreasing. Source: Forest Inventory and Analysis data classified using methods outlined in DeMeo et al (2020).

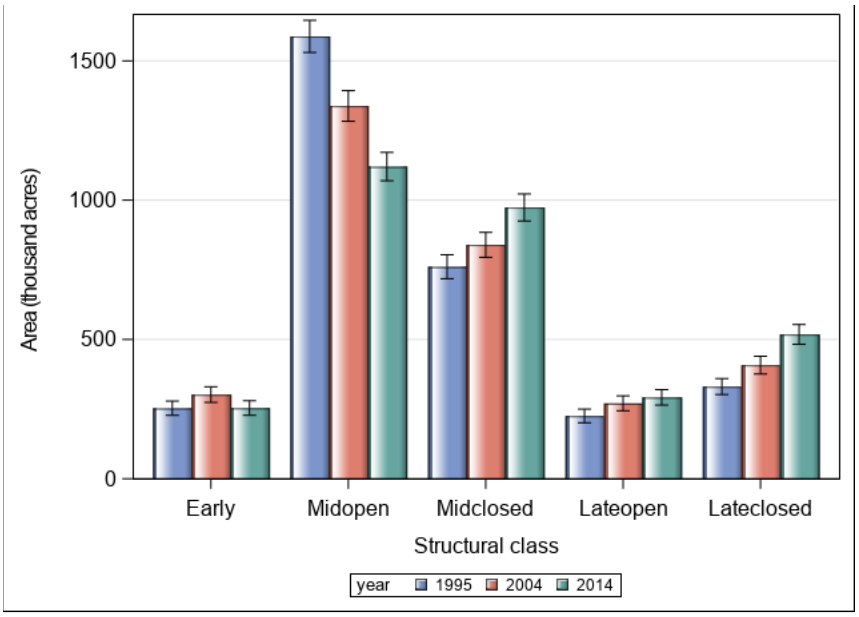

Figure 9. Moist Forest. Trends in structural classes within dry forest between 1995 and 2014 within the analysis area. All closed structures (mid and late closed forest) have increased since 1995. Late open structures increased while mid open structure have decreased through time. Early seral forest has remained stable. Source: Forest Inventory and Analysis data classified using methods outlined in DeMeo et al. (2020).

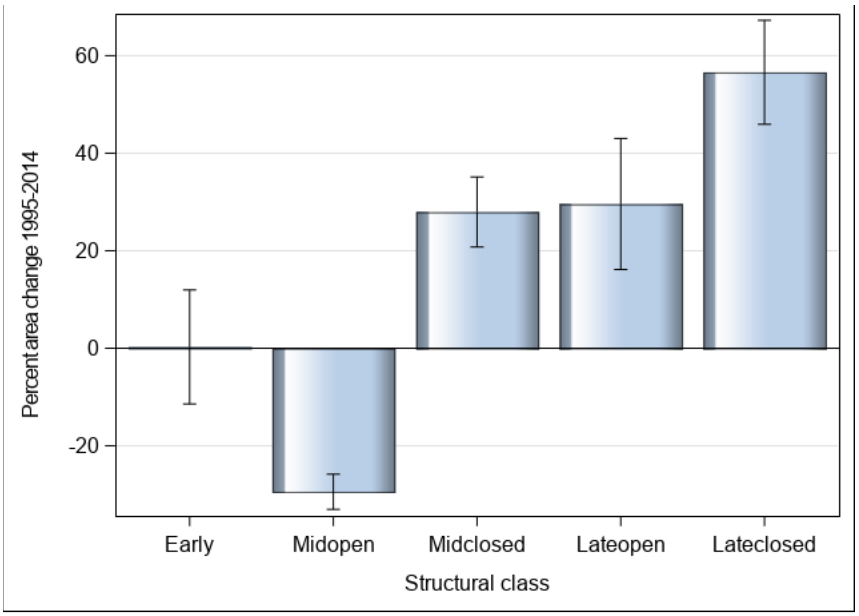

Figure 10. Moist Forest. Percent change in structural classes across the analysis area between 1995 and 2014 in moist forest within the analysis area. All closed structures (mid and late closed forest) have increased since 1995 with late closed increasing just under 60%. Late open structures increased (about 50%) while mid open structure have decreased about 25%. Early seral forest has remained stable. Source: Forest Inventory and Analysis data classified using methods outlined in DeMeo et al. (2020).

Desired Trajectory

The Eastside Screens intended to maintain or increase LOS forest until it was within historical levels and that no net loss of LOS from a particular biophysical environment should occur. For this analysis, if an alternative's effects are to maintain or increase the abundance of ecologically appropriate LOS forest, that alternative would be moving toward eastside screen goals. The increased amount of open LOS forest in both the dry and moist forest groups is an indicator that we are moving toward eastside screen goals. Historically frequent fire kept the canopy of both dry and moist forests open in various sized patches across the landscape. Openings create heterogeneity that can help limit the size and spread of wildfire, reduce competition, and create openings in the forest canopy needed for fire tolerant species to regenerate (Churchill et al. 2013, Larson and Churchill 2012).

Environmental Consequences

Table 5. Forest Structure Indicators, Desired Trajectories and Effects.

Measure	Desired Trajectory	Current Management	Old Tree Standard	Old and Large Tree Guideline	Adaptive Management
LOS Forest	Increase	Increase	Increase	Increase	Increase
Promotion of more open conditions within LOS on dry	Increase	Increase at low rate; limited by tree size	Increase at low to moderate rate	Increase at low to moderate rate	Increase at low to moderate rate

and moist forest sites					
Promotion of more open conditions on dry and moist forest sites outside of LOS	Increase	Decrease high rate	Decrease moderate rate	Decrease moderate rate	Decrease moderate rate

Late and Old Structure Forest

Based on the forest disturbance, succession and management assumptions, the current trend of increasing LOS forest will continue for all alternatives. The increase in LOS would create both more late open and late closed forest. Closed canopies will continue to increase because tree growth and regeneration will outpace thinning effects from both wildfire and management. Future treatments would need to increase the removal of small and mid-sized trees from closed canopy forests in order to change this trajectory, and that activity is outside the scope of this proposed amendment.

Open Conditions within LOS in Dry and Moist Forests

Current Management Alternative

- The extent of late open LOS will continue to increase across the landscape at a **low rate** because creating more open forest conditions is limited to trees less than 21 inches dbh.
- Managers' ability to adapt treatments to site specific conditions in order to maintain and develop disturbance resistant LOS forest will be limited.

Old and Large Tree Guideline Alternative

- A somewhat greater extent of closed LOS could be converted to open LOS compared to the Current Management Alternative because slightly more large trees could be cut. The ability to create open LOS conditions would be constrained by tree age and size.
- Management adaptability to project and site-specific conditions in order to maintain and develop more open LOS would be somewhat greater than the Current Management or the Old Tree Standard Alternative. This is because both old and large trees could be considered for retention or harvest to help move stands and landscapes toward desired conditions.

Old Tree Standard Alternative

- A somewhat greater extent of closed LOS could be converted to open LOS compared to the Current Management Alternative because large, young trees could be cut. The ability to create open LOS conditions would be constrained by tree age.
- Managers would be more able to adapt treatments to site specific conditions in order to maintain and develop LOS compared to current management.

Adaptive Management Alternative

- A greater extent of closed LOS could be converted to open LOS compared to the Current Management Alternative because of the considerable flexibility managers would have to create open conditions. Development of LOS conditions would still be guided by desired conditions.
- Management adaptability to project and site-specific conditions in order to maintain and develop more open LOS will be greater than all other alternatives because tree selection would be based on project and site-specific desired conditions.

Modeling Results

Direction of Change and Magnitude of Difference between Alternatives: FVS indicates an overall increase in open forest conditions within LOS for all alternatives, including current management. Modeling indicates less than 2.8% difference between alternatives in the amount of open LOS forest that will be created over the analysis period. The modeling results are not constrained by planning, access or logging systems considerations. The qualitative analysis below does include consideration of these constraints.

Open Conditions in Dry and Moist Forests Outside of LOS

Current Management Alternative

- Mid seral open forest structures will continue to decrease because of the prohibition on harvesting trees over 21 inches dbh and the large amount of closed non-LOS forest currently on the landscape.

Old and Large Tree Guideline Alternative

- Mid seral open forest structures will decrease at a slightly lower rate compared to the Current Management Alternative because trees over 21 inches dbh and old trees could be removed to help create more open conditions, although the majority of trees that need to be removed to achieve open conditions are less than 21 inches.
- There would be somewhat greater management adaptability to project and site-specific conditions in order to maintain and develop more open conditions than the Current Management Alternative and Old Tree Standard Alternative because both old and large trees could be considered for retention or harvest to help move stands and landscapes toward desired conditions.

Old Tree Standard Alternative

- Mid seral open forest structures will decrease at a slightly lower rate compared to the Current Management Alternative because trees over 21 inches dbh could be removed to help create more open conditions, although the majority of trees that need to be removed to achieve open conditions are less than 21 inches.

- Managers would, to some extent, be more able to adapt treatments for site specific conditions in order to maintain and develop open/single-strata conditions compared to current management.

Adaptive Management Alternative

- Mid seral open forest structures will decrease at a lower rate compared to the Current Management Alternative because managers would have considerable flexibility to create open conditions outside of LOS. More effective reduction of closed mid seral forest could be supported by this alternative, although the bulk of trees needing to be removed would still be trees under 21 inches dbh.
- Management adaptability to project and site-specific conditions in order to maintain and develop more open conditions would increase more than all other alternatives because tree selection would be based on project and site-specific desired conditions.

Modeling Results

Direction of change and magnitude of difference between alternatives: FVS indicates an overall increase in open canopy conditions outside of LOS for all alternatives. Currently, median canopy closure of stands analyzed is 46%. All alternatives decrease canopy cover outside of LOS by about 15%, with difference between alternatives within 0.2%. Results across alternatives are similar because stands outside of LOS have few old or large trees that would be managed differently between alternatives. Instead each alternative achieves the minimum modeled target of 30% maximum SDI. Modeling results are not constrained by planning, access or logging system considerations. For example, current commercial timber harvest over the last ten years had averaged about 34,000 acres. If this rate continues, about 850,000 acres would be managed over the next 25 years as compared to the modeled 1.3-1.5 million acres of non-LOS.

Structural Change in Wet, Cold, or Other Forest

No difference between any alternative is expected.

Large and Old Trees

Affected Environment

Old Trees

Old trees are declining across the eastern Oregon and southeastern Washington landscape. Trees older than 150 years in age have decreased by approximately 8% between 2001 and 2017. Old trees have decreased in the project area by 5% over the last decade alone.

Old trees in all but two cover types2F[1] have decreased by 10 to 100 percent of their original inventoried area since 2001. For example, area of old ponderosa pine has transitioned across nearly 24,000 acres (~11%) to another species combination or to non-forested conditions. This

[1] Cover types describe naturally occurring species combinations and are named after the predominant species that are present on the site (Eyre 1980). Cover types have inherent processes associated with them and changes in cover types imply a change in ecosystem function.

condition may be dominated by herbaceous plants such as grasses or shrubs, or it may be more of a woodland.

Old Douglas-fir and western larch trees have decreased by 14 % and 29%, respectively. On the other hand, old grand/white fir and western juniper trees have increased by 5% and 8%, respectively. Approximately 8,900 acres of old trees dominated by hardwood cover type has also disappeared. Across all age classes, transitions of forested to non-forested conditions represents the biggest proportion of change, representing a 34% increase.

Large Trees

In the past decade fire has contributed more to the loss of large trees and old trees than mechanical treatments. Increased density and observed shifts in species compositions have likely made fire more harmful to the large trees on the landscape through the development of ladder fuels and by creating more competition for resources which makes individuals more susceptible to the primary and secondary effects of fire (Fettig et al. 2019, Stephens et al. 2018, vanMantgem et al. 2013). Of total large tree mortality, 63% was caused by insects and disease, 24% by fire, and the remaining 13% by other disturbances like weather and drought.

There are an estimated 41.7 million trees larger than 20.9 inches in the analysis area, which is an average of about 6 trees per acre within the analysis area. This population of large trees is comprised mostly of ponderosa pine (48%), grand fir/white fir (23%), and Douglas-fir (15%). There are about 43.5 million trees in the next smaller size class (17-20.9") with similar relative proportion of species. The distribution of species within size class distributions would historically be filtered early in stand development by naturally occurring processes like fire. This would free growing resources for the fire tolerant surviving trees allowing them to become established as the dominant individuals that would exert influence on the within stand processes.

The change in large trees in managed forests is different than in forests that only experienced natural disturbance. The number of large trees increased by 13% in forests that have only been mechanically treated, 11% in forests that have had no disturbance, and 10% in forests with insect and disease impacts. Conversely, where fire (wildland or prescribed) alone occurred on the landscape there was a 20% reduction in large trees3F[2]. Where mechanical treatments and fire co-occurred, there was a 17% decrease in large trees.

The rate of large tree development across the landscape varies by species, with some species showing an increase, and others a decrease between 2001 and 2017 (Table 7).

Table 6. Rate of large tree development by species (2001-2017) (FIA data).

Rate of large tree development by species (2001-2017) (FIA data)	
Species	Rate (%)
Subalpine fir	-55

[2] This number differs from the fire caused 24% mortality mentioned above because this number does not include fire-killed trees in areas where fire and cutting co-occurred, or fire damage happened in the past, or fire was highly localized in the stand (e.g., lightning strike).

Rate of large tree development by species (2001-2017) (FIA data)	
Lodgepole pine	-53
Incense cedar	-25
Western white pine	-2
Sugar pine	+53
White fir and grand fir	+20
Western juniper	+17
Douglas-fir	+14
Western Larch	+12
Ponderosa pine	+8
Englemann spruce	+6
Mountain hemlock	+5

In unmanaged forest, the number of large trees has increased by 8.5% in the past decade. In comparison, managed forests have seen an increase of 12.9% in the number of large trees on the landscape. Individual large trees in non-managed forests are competing with more numerous and smaller trees for light and water resources. In these stands, trees of all sizes more easily succumb to the primary mortality effects of insect attacks, disease, drought, and fire. Even when they survive the primary effects of these disturbances they may succumb to secondary effects (or disturbances) because the trees are unable to recover from the initial deficit imposed by inter-tree competition. Importantly, within stands of increasing density and competition, individual trees direct their limited growth resources to develop roots and canopy in attempt to maximize a competitive edge, thus the amount of diameter (or radial) growth is limited and large trees are slower to develop.

The proportional basal area of large trees is 9% in young (less than 50 years old) forest. In mid age and old forest, old trees represent 25% and 48% of basal area, respectively (Table 3). In size classes greater than 15 inches dbh all species have seen an increase in basal area over the past two decades.

Table 7. Large Trees in the Project Area.

Stand Age	Proportion of large trees (>20.9" dbh) in the analysis area*	Percent basal area(ft^2/acre) of large trees
<50 years	3%	9.1%
50-150 years	68%	25.3%
>150 years	29%	47.7%

*There are 41.7 million trees larger than 20.9 inches dbh in the project area

Environmental Consequences

Table 8. Old and Large Tree Indicators, Desired Trajectories and Effects.

Large and Old Trees	Desired Trajectory	Current Management	Old Tree Standard	Old and Large Tree Guideline	Adaptive Management
Large Trees (≥ 21" dbh)	Increasing	Increase	Increase slower rate than CM	Increase slower rate than CM	Increase – wide potential range
Old Trees (≥ 150 years of age)	Increasing	Decline high rate	Decline low to moderate rate	Decline moderate rate	Decline – wide potential range

Indicator: Large Trees

Current Management Alternative
Large trees over 21 inches dbh will **continue to increase**. This helps move the landscape toward desired conditions in structure but not necessarily other desired forest characteristics such as species composition. This will contribute to a landscape increase in large trees, but many of these trees will be less resistant to fire, drought, insect and other disturbances than older fire tolerant species. Failing to remove larger grand fir and Douglas fir likely increases the vulnerability of old ponderosa pine, western larch and other early seral shade intolerant species.

Old and Large Tree Guideline Alternative
Large trees over 21 inches dbh **would continue to increase across the landscape but at a slightly slower rate** than under the Current Management Alternative. There would be a decrease in the number of large grand fir/white fir in order to promote more fire tolerant species composition over time.

Old Tree Standard Alternative
Large trees over 21 inches dbh would continue to **increase across the landscape but at a slower rate** than under the Current Management Alternative. There would be a decrease in the number of large grand fir/white fire since a portion of these trees less than 150 years of age could be harvested. This would help move the landscape toward desired trajectories in other forest attributes like species composition.

Adaptive Management Alternative
As with the other action alternatives, large trees over 21 inches dbh would continue to increase across the landscape but at a slower rate than under the Current Management Alternative. There would be a decrease in the number of large grand fir/white fir in order to promote more disturbance resistant species compositions over time. This alternative retains the fewest large trees per acre though the difference between alternatives is relatively small. Adaptive management would ensure LOS is increasing across the landscape and enable a change in management if needed.

Modeling Results
Direction of change and magnitude of difference between alternatives: Modeling with FVS indicates that continued implementation of the Current Management Alternative will result in an average of 8.8 large trees per acre remaining following thinning over the 25-year analysis period. The Large and Old Tree Guideline will result in an average of 8.5 large trees per acre remaining following thinning over the analysis period (a 3.4% decrease from current management). The Old Tree Standard will result in an average of 8.6 large trees per acre remaining following thinning (a 2.3% decrease from current management), and the Adaptive Management Alternative will result in an average of 7.9 large trees per acre left following thinning (a 10.2% decrease from current management). Because thinning is expected to occur on a relatively small portion of the total landscape, and because thinning, fire, and other disturbance that kills trees is not expected to outpace growth and establishment of trees, FVS modeling indicates that the number of large trees on the landscape will increase over time under all alternatives from the current baseline of 7.6 large trees per acre.

The relatively small difference in large trees remaining following thinning under the Current Management, Large and Old Tree Guideline and Old Tree Standard Alternatives results from application of a the thin from below prescription to all alternatives. The thin-across-age-classes prescription for the Adaptive Management Alternative allows both large (and old) trees to be cut at a higher rate than other action alternatives. The qualitative assessment below describes differences in ecological outcomes that would likely result from the different alternatives.

Indicator: Old Trees

Current Management Alternative
The Current Management Alternative would protect all old trees that are >21 inches, although many old trees would remain vulnerable to competition from large grand fir and other shade tolerant species that cannot be removed under current management. The current management alternative would also allow harvest of old trees that are less than 21 inches dbh. The current high rate of decline of old trees is expected to continue.

Old and Large Tree Guideline Alternative
This alternative would provide flexibility to remove large but young trees from around old trees, while maintaining large tree cover consistent with the objective of conserving old trees. This would reduce competition and support old tree persistence on the landscape. This alternative would provide greater protection for old but small trees.

Old Tree Standard Alternative
This alternative would maximize protection for all old trees within a stand, although there would be somewhat less flexibility than the old and large tree guideline to create desired species composition and density.

Adaptive Management Alternative
The Adaptive Management Alternative allows for the broadest suite of considerations in choosing trees to retain to meet management objectives.

Modeling Results
Direction of change and magnitude of difference between alternatives: Modeling with FVS indicates that continued implementation of the Current Management Alternative will result in an average of 7.0 old trees per acre following thinning. The Old and Large Tree Guideline will result in an average of 7.4 old trees per acre following thinning (a 5.7% increase over current management). The Old Tree Standard Alternative will result in an average of 8.9 old trees per acre following thinning (a 27.1% increase over current management), and the Adaptive Management Alternative will result in an average of 5.7 old trees per acre following thinning (an 18.6 decrease from current management). Because thinning is expected to occur on a relatively small portion of the total landscape, and because fire, insect attack, and other disturbance that kills old tree at a high rate in untreated forests will continue, modeling indicates that the number of old trees will decrease across the landscape over the analysis period.

Modeling of the current management, old and large tree guideline, and old tree guideline applied a thin from below prescription. The Adaptive Management Alternative thinned across age classes and included removal of large and old trees.

Changes in Large and Old Trees in Wet, Cold, or Other Forest
No difference between any alternative is expected.

Species Composition

Affected Environment
Species composition of forests in eastern Oregon and southeastern Washington, including the dynamic interactions between species composition and forest structure, is integral to managing for landscape resilience to disturbance (Hessburg et al. 2013, Hessburg et al. 2016, Johnston

2017, Johnston et al. 2018, Hessburg et al. 2019). In this analysis area, conifer species can generally be divided into two major groups: **fire tolerant**/shade intolerant or **less fire tolerant** /shade tolerant. Trees fall into these groups based on tolerances to environmental factors like disturbance, light, and water limitations. Fire tolerant species are those species that tend to regenerate best under open conditions and have physiological characteristics, such as thick bark, that increase the likelihood the tree will survive low to moderate severity wildfire. In this analysis area ponderosa pine and western larch are considered fire tolerant species. Species that are more shade tolerant than ponderosa pine and western larch can regenerate in the understory of other trees. Grand fir and white fir are more shade tolerant and less resistant to fire in this analysis area. Douglas-fir, although a fire tolerant species, is less fire tolerant than ponderosa pine and western larch (Keane et al. 1990).

FIA data and empirical research show that grand fir/white fir have become more dominant cover types across the landscape, with negative consequences for stand and landscape resilience (Hagmann et al. 2014, Merschel et al. 2014, Johnston 2017, Johnston et al. 2018). Grand fir and white fir cover types are increasing at a faster rate than other cover types across the landscape as a whole. In addition, non-forested conditions (less than 10% tree cover) have increased by 33%, due mostly to fire though these non-forested conditions are often transitory.

Shifting species composition and the exclusion of wildfire has resulted in forests with considerably higher densities and different structure compared with historical forests (Johnston et al. 2018, Hagmann et al. 2014, Merschel et al. 2014, Johnson et al. 1994). In addition, grand fir and white fir often make up the bulk of the youngest trees, setting stands on a trajectory at times maladapted to the biophysical environment.

Shifting species composition affects a wide range of ecosystem functions. The same basal area of grand fir or white fir uses more water than shade intolerant species like ponderosa pine (Johnston et al. 2019, Gersonde and O'Hara 2005). Moreover, ponderosa pine are more drought tolerant than shade tolerant species (Lopushinsky and Klock 1974). Not surprisingly then, the shift in species composition and associated increase in stand basal area over the last century has reduced drought resistance in eastern Oregon and southeastern Washington (Voelker et al. 2019). Drought stress can be compounded by additional disturbances. For example, vanMantgem et al. (2013) found higher mortality rates in drought-stressed trees following wildfire.

Species composition is also critical when considering disturbances such as insects and disease. Species composition, in concert with forest density and structure, is a key driver of forest mortality from insects and disease. Species like Douglas-fir, grand fir and white fir have moved into areas where their densities were historically lower in predominately ponderosa pine systems (Hagmann et al. 2013, Heyerdahl et al. 2019a). FIA data also show that disturbance impacts species differently. For example, the mortality rate of ponderosa pine over the last 10 years was 6%, with 59% of mortality attributed to insects and disease. Grand fir and white fir had a mortality rate of 11%, with 68% of that mortality attributed to insects and disease.

The combined effect of increased density and altered species composition will increasingly push mixed conifer forests across a threshold that makes them less resistant to drought and less resilient to bark beetle outbreaks and wildfire (Millar and Stephenson 2015, Fettig et al. 2007).

Desired Trajectory
Species composition is an important basis for individual tree, stand, and landscape level resistance and resilience of the forest. For dry and moist forests, the desired path is toward forests with a relatively greater proportion of fire tolerant species.

Environmental Consequences

Table 9. Forest Species Composition Indicators, Desired Trajectories and Effects.

Forest Species Composition	Desired Trajectory	Current Management	Old Tree Standard	Old and Large Tree Guideline	Adaptive Management
Dominance of fire tolerant species (e.g. ponderosa pine)	Increasing	Continued decrease	Decrease less than CM	Decrease less than CM	Decrease – wide potential range

Indicator: Dry and Moist Forest with Fire Tolerant Species

Current Management Alternative
- Old ponderosa pine and larch trees will **continue to decrease** in relative abundance to shade tolerant species like white fir/grand fir because shade tolerant species establish at a higher rate and grow faster. Thinning from wildfire and management will continue to lag behind the rate of growth and regeneration. In dry and moist forests, this will lead to forests more vulnerable to uncharacteristic disturbance mortality.

Old and Large Tree Guideline Alternative
- While individual old fire tolerant trees will increase slightly in abundance relative to the Current Management Alternative, succession will continue to promote shade tolerant species like white fir/grand fir while the relative dominance of fire tolerant species continues to decline. Thinning from wildfire and management will continue to lag behind the rate of growth and regeneration, particularly of the large class of middle age forest.
- Management adaptability to site specific and future conditions to develop ecologically appropriate species composition is greater in this alternative than in the Current Management Alternative and Old Tree Standard Alternative because species preference could be implemented more fully.

Old Tree Standard Alternative
- While individual old fire tolerant trees will increase slightly in abundance relative to the Current Management Alternative, succession will continue to promote shade tolerant species like white fir/grand fir while the relative dominance of fire tolerant species continues to decline. Thinning from wildfire and management will continue to lag behind the rate of growth and regeneration, particularly of the large class of middle age forest.
- Managers' ability to adapt treatments for site specific and future conditions in order to maintain and develop disturbance resistant species compositions would be greater

compared to current management but less than under the Old and Large Tree Guideline Alternative.

Adaptive Management Alternative

- While managers will have increased ability to protect individual old fire tolerant trees, succession will continue to promote shade tolerant species like white fir/grand fir because thinning from wildfire and management will continue to lag behind the rate of growth and regeneration, particularly of the large class of middle age forest.
- This alternative confers the greatest flexibility to managers to shift species composition based on site conditions or desired future conditions. Managers would have greatly increased ability to create diverse post-treatment spatial pattern because there would be no constraints on size or age of trees for removal.

FVS Results

Direction of change and magnitude of difference between alternatives: FVS indicates an overall slight increase from present condition in the dominance of fire tolerant species like ponderosa pine, western larch, and Douglas-fir. The Old and Large Tree Guideline and the Old Tree Standard Alternatives would result in about 1.5% increase in fire tolerant species basal area compared to the Current Management Alternative. The Adaptive Management alternative results in about 5% decrease in basal area of fire tolerant species relative to current management. The Adaptive Management Alternative allows for the greatest choice in selecting trees to meet management objectives. This modeling exercise focused on density reduction. Modeling did not constrain acres treated based on planning, access or logging systems. In the qualitative analysis below, we assumed that managers could strategically focus on particular areas and more effectively promote desired species.

Wet, Cold, or Other Forest Types with Dominance of Disturbance Resistant Species

No difference between any alternative is expected.

References

Arner, S. L., S. Woudenberg, S. Waters, J. Vissage, C. MacLean, M. Thompson, and M. Hansen. 2001. National Algorithms for Determining Stocking Class, Stand Size Class, and Forest Type for Forest Inventory and Analysis Plot. USDA Forest Service, Inventory and Analysis, Washington D.C.

Battles, J. J., T. Robards, A. Das, K. Waring, J. K. Gilless, G. Biging, and F. Schurr. 2008. Climate change impacts on forest growth and tree mortality: a data-driven modeling study in the mixed-conifer forest of the Sierra Nevada, California. Climatic Change **87**:193-213.

Boag, A. E., M. J. Ducey, M. W. Palace, and J. Hartter. 2020. Topography and fire legacies drive variable post-fire juvenile conifer regeneration in eastern Oregon, USA. Forest Ecology and Management **474**:118312 (118313 p).

Brohman, R., and L. Bryant. 2004. Existing Vegetation Classification and Mapping Technical Guide., Forest Service, USDA, Washington Office, Ecosystem Management Coordination.

Corlett, R. T. 2015a. The Anthropocene concept in ecology and conservation. Trends in Ecology and Evolution **30**:36-41.

Corlett, R. T. 2015b. The Anthropocene concept in ecology and conservation. Trends in Ecology and Evolution **30(1)**:36-41.

Davis, K. T., S. Z. Dobrowski, P. E. Higuera, Z. A. Holden, T. T. Veblen, M. T. Rother, S. A. Parks, A. Sala, and M. P. Maneta. 2019. Wildfires and climate change push low-elevation forests across a critical climate threshold for tree regeneration. Proceedings of the National Academy of Sciences **116**:6193-6198.

Davis, R. J., D. M. Bell, M. J. Gregory, and Yang. 2020. (in progress; subject to peer review). Northwest Forest
Plan–the first quarter-century:status and trends of late-successional and
old-growth forests. . USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Davis, R. J., J. L. Ohmann, R. E. Kennedy, W. B. Cohen, M. J. Gregory, Z. Yang, H. M. Roberts, A. N. Gray, and T. A. Spies. 2015a. Northwest Forest Plan–the first 20 years (1994-2013): Status and trends of late-successional and old-growth forests. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Davis, R. J., Pacific Northwest Research Station (Portland Or.), and Northwest Forest Plan (U.S.). 2015b. Northwest Forest Plan--the first 20 years (1994-2013) : status and trends of late-successional and old-growth forests. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station,, Portland, OR.

DeMeo, T., R. Haugo, C. Ringo, J. Kertis, S. Acker, M. Simpson, and M. Stern. 2018. Expanding our understanding of forest structural restoration needs in the Pacific Northwest. Northwest Science **92**:18-35.

DeMeo, T., M. Laughlin, C. Ringo, and M. Simpson. 2020. Forest Structural White Paper:
In support of the Screen Team Analysis. USDA Forest Service
Pacific Northwest Region Portland, OR.

Dixon, G. E. 2015. Essential FVS: a user's guide to the Forest Vegetation Simulator. U.S. Department of Agriculture, Forest Service, Forest Management Service Center, Fort Collins, CO.

Donato, D. C., B. J. Harvey, and M. G. Turner. 2016. Regeneration of montane forests 24 years after the 1988 Yellowstone fires: A fire-catalyzed shift in lower treelines? Ecosphere **7**:e01410 (01416 p).

Downing, W. M., M. A. Krawchuk, G. W. Meigs, S. L. Haire, J. D. Coop, R. B. Walker, E. Whitman, G. Chong, and C. Miller. 2019. Influence of fire refugia spatial pattern on post-fire forest recovery in Oregon's Blue Mountains. Landscape Ecology **34**:771-792.

Eyre, F. H. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington, DC.

Franklin, J. F., N. K. Johnson, and D. L. Johnson. 2018. Ecological Forest Management Waveland Press, Inc., Long Grove, IL.

Hagmann, R. K., J. F. Franklin, and K. N. Johnson. 2013. Historical structure and composition of ponderosa pine and mixed-conifer forests in south-central Oregon. Forest Ecology and Management **304**:492-504.

Hagmann, R. K., J. T. Stevens, J. M. Lydersen, B. M. Collins, J. J. Battles, P. F. Hessburg, C. R. Levine, A. G. Merschel, S. L. Stephens, A. H. Taylor, J. F. Franklin, D. L. Johnson, and K. N. Johnson. 2018. Improving the use of early timber inventories in reconstructing historical dry forests and fire in the western United States: Comment. Ecosphere **9**:e02232 (02210 p).

Hamilton, L. C., J. Hartter, B. D. Keim, A. E. Boag, M. W. Palace, F. R. Stevens, and M. J. Ducey. 2016. Wildfire, climate, and perceptions in northeast Oregon. Regional Environmental Change **16**:1819-1832.

Hankin, L. E., P. E. Higuera, K. T. Davis, and S. Z. Dobrowski. 2019. Impacts of growing-season climate on tree growth and post-fire regeneration in ponderosa pine and Douglas-fir forests. Ecosphere **10**:e02679 (02620 p).

Harvey, A. E., J. M. Geist, G. I. McDonald, M. F. Jurgensen, P. H. Cochran, D. Zabowski, and R. T. Meurisse. 1994. Biotic and abiotic processes in eastside ecosystems: the effects of management on soil properties, processes, and productivity. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Harvey, B. J., D. C. Donato, and M. G. Turner. 2016. High and dry: post-fire tree seedling establishment in subalpine forests decreases with post-fire drought and large stand-replacing burn patches. Global Ecology and Biogeography **25**:655-669.

Haugo, R., C. Zanger, T. DeMeo, C. Ringo, A. Shlisky, K. Blankenship, M. Simpson, K. Mellen-McLean, J. Kertis, and M. Stern. 2015. A new approach to evaluate forest structure restoration needs across Oregon and Washington, USA. Forest Ecology and Management **335**:37-50.

Haynes, R. W., R. T. Graham, and T. M. Quigley. 1996. A framework for ecosystem management in the interior Columbia basin and portions of the Klamath and Great basins. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Henjum, M. G., J. R. Karr, B. D. L., D. A. Perry, J. C. Bednarz, S. G. Wright, S. A. Beckwitt, and E. Beckwitt. 1994. Interim protection for late-successional forests, fisheries, and watersheds; national forests east of the Cascade crest, Oregon, and Washington. The Wildlife Society, Bethesda, MD.

Hessburg, P., K. Reynolds, R. Salter, J. Dickinson, W. Gaines, and R. Harrod. 2013. Landscape evaluation for restoration planning on the Okanogan-Wenatchee National Forest, USA. Sustainability **5**:805-840.

Hessburg, P. F., S. Charnley, K. L. Wendel, E. M. White, T. A. Spies, P. H. Singleton, D. W. Peterson, J. E. Halofsky, A. N. Gray, R. L. Flitcroft, and R. White. 2020. The 1994 Eastside Screens - Large Tree Harvest Limit: Synthesis of Science Relevant to Forest Planning 25 years Later. USDA, Forest Service, Portland, OR, USA.

Hessburg, P. F., D. J. Churchill, A. J. Larson, R. D. Haugo, C. Miller, T. A. Spies, M. P. North, N. A. Povak, R. T. Belote, P. H. Singleton, W. L. Gaines, R. E. Keane, G. H. Aplet, S. L. Stephens, P. Morgan, P. A. Bisson, B. E. Rieman, R. B. Salter, and G. H. Reeves. 2015. Restoring fire-prone Inland Pacific landscapes: Seven core principles. Landscape Ecology **30**:1805-1835.

Hessburg, P. F., C. L. Miller, S. A. Parks, N. A. Povak, A. H. Taylor, P. E. Higuera, S. J. Prichard, M. P. North, B. M. Collins, M. D. Hurteau, A. J. Larson, C. D. Allen, S. L. Stephens, H. Rivera-Huerta, C. S. Stevens-Rumann, L. D. Daniels, Z. e. Gedalof, R. W. Gray, V. R. Kane, D. J. Churchill, R. K. Hagmann, T. A. Spies, C. A. Cansler, R. T. Belote, T. T. Veblen, M. A. Battaglia, C. Hoffman, C. N. Skinner, H. D. Safford, and R. B. Salter. 2019. Climate, environment, and disturbance history govern resilience of western North American forests. Frontiers in Ecology and Evolution **7**:239 (227 p).

Hessburg, P. F., T. A. Spies, D. A. Perry, C. N. Skinner, A. H. Taylor, P. M. Brown, S. L. Stephens, A. J. Larson, D. J. Churchill, N. A. Povak, P. H. Singleton, B. McComb, W. J. Zielinski, B. M. Collins, R. B. Salter, J. J. Keane, J. F. Franklin, and G. Riegel. 2016. Tamm Review: Management of mixed-severity fire regime forests in Oregon, Washington, and Northern California. Forest Ecology and Management **366**:221-250.

Heyerdahl, E. K., R. A. Loehman, and D. A. Falk. 2019a. A multi-century history of fire regimes along a transect of mixed-conifer forests in central Oregon, U.S.A. Canadian Journal of Forest Research **49**:76-86.

Heyerdahl, E. K., R. A. Loehman, and D. A. Falk. 2019b. A multi-century history of fire regimes along a transect of mixed-conifer forests in central Oregon, U.S.A. Canadian Journal of Forest Resources **49 (2019)**:76-86.

Jennings, M. D., D. Faber-Langendoen, O. L. Loucks, R. K. Peet, and D. Roberts. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs **79**:173-199.

Johnson, D. H., and T. A. O'Neil, managing directors. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Johnston, J. D., C. J. Dunn, M. J. Vernon, J. D. Bailey, B. A. Morrissette, and K. E. Morici. 2018. Restoring historical forest conditions in a diverse inland Pacific Northwest landscape. Ecosphere **9**:e02400 (02423 p).

Johnstone, J. F., C. D. Allen, J. F. Franklin, B. J. Harvey, and P. E. Higuera. 2016. Changing disturbance regimes, ecological memory, and forest resilience. Frontiers in Ecology and the Environment **14(7)**:369-378.

Kemp, K. B., P. E. Higuera, P. Morgan, and J. T. Abatzoglou. 2019. Climate will increasingly determine post-fire tree regeneration success in low-elevation forests, Northern Rockies, USA. Ecosphere **10**:e02568 (02517 p).

Kerns, B. K., D. C. Powell, S. Mellmann-Brown, G. Carnwath, and J. B. Kim. 2018. Effects of projected climate change on vegetation in the Blue Mountains ecoregion, USA. Climate Services **10**:33-43.

Keyser, C. E. 2019. South Central Oregon and Northeast California (SO) Variant Overview - Forest Vegetation Simulator. U.S. Department of Agriculture, Forest Service, Forest Management Service Center, Fort Collins, CO.

Keyser, C. E., and G. E. Dixon. 2019. Blue Mountains (BM) variant overview – Forest Vegetation Simulator. U.S. Department of Agriculture, Forest Service, Forest Management Service Center, Fort Collins, CO.

Kolden, C. A., J. T. Abatzoglou, J. A. Lutz, C. A. Cansler, J. T. Kane, J. W. Van Wagtendonk, and C. H. Key. 2015a. Climate contributors to forest mosaics; ecological persistence following wildfire. Northwest Science **89**:219-238.

Kolden, C. A., J. T. Abatzoglou, J. A. Lutz, C. A. Cansler, J. T. Kane, J. W. V. Wagtendonk, and C. H. Key. 2015b. Climate contributors to forest mosaics: Ecological persistence following wildfire. Northwest Science **89**:219-238.

Korb, J. E., P. J. Fornwalt, and C. S. Stevens-Rumann. 2019. What drives ponderosa pine regeneration following wildfire in the western United States? Forest Ecology and Management **454**:117663 (117616 p).

McMahon, S. M., G. Arellano, and S. J. Davies. 2019. The importance and challenges of detecting changes in forest mortality rates. Ecosphere **10**:e02615 (02610 p).

Merschel, A., R. S. Vora, and T. Spies. 2019. Conserving dry old-growth forest in central Oregon, USA. Journal of Forestry **117**:128-135.

Merschel, A. G., T. A. Spies, and E. K. Heyerdahl. 2014. Mixed-conifer forests of central Oregon: effects of logging and fire exclusion vary with environment. Ecological Applications **24**:1670-1688.

Millar, C. I., and N. L. Stephenson. 2015. Temperate forest health in an era of emerging megadisturbance. Science **349**:823-826.

Nelson, M. L., C. K. Brewer, and S. J. Solem. 2015. Existing vegetation classification and mapping technical guide, version 2.0. U.S. Department of Agriculture, Forest Service, Ecosystem Management Coordination Staff, Washington, DC.

Palmer, M., G. Christensen, and O. Kuegler. 2018. Oregon's Forest Resources, 2006-2015: Ten Year Forest Inventory and Analysis Report. USDA Forest Service

Pacific Northwest Research Station Portland, OR.

Parks, S. A., S. Z. Dobrowski, J. D. Shaw, and C. Miller. 2019. Living on the edge: trailing edge forests at risk of fire-facilitated conversion to non-forest. Ecosphere **10**:e02651 (02617 p).

Parks, S. A., L. M. Holsinger, M. H. Panunto, W. M. Jolly, S. Z. Dobrowski, and G. K. Dillon. 2018. High-severity fire: evaluating its key drivers and mapping its probability across western US forests. Environmental Research Letters **13**:044037 (044013 p).

Powell, D. C. 2014a. Active management of dry forests in the Blue Mountains: Silvicultural considerations. USDA Forest Service, Pacific Northwest Region, Umatilla National Forest, Pendleton, OR.

Powell, D. C. 2014b. Active management of moist forests in the Blue Mountains: Silvicultural considerations. USDA Forest Service, Pacific Northwest Region, Umatilla National Forest, Pendleton, OR.

Pugnaire, F. I., J. A. Morillo, J. Peñuelas, P. B. Reich, R. D. Bardgett, A. Gaxiola, D. A. Wardle, and W. H. van der Putten. 2019. Climate change effects on plant-soil feedbacks and consequences for biodiversity and functioning of terrestrial ecosystems. Science Advances **5**:eaaz1834 (1812 p).

Quigley, T. M., and S. J. Arbelbide. 1997. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins: volume I. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Quigley, T. M., R. W. Haynes, and R. T. Graham. 1996. Integrated scientific assessment for ecosystem management in the interior Columbia basin and portions of the Klamath and Great basins. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Service, U. S. F., and B. o. L. Management. 1994. Record Of Decision for Amendments to Forest Service and Bureau of Land Management
Planning Documents Within the Range of the Northern Spotted Owl and Standards and Guidelines for Management of Habitat for Late-Successional and Old- Growth Forest Related Species Within the Range of the Northern Spotted Owl. Page 2 volumes in 1 (various pagings) *in* U. F. S. a. U. B. o. L. Management, editor. USDA Forest Service and USDI Bureau of Land Management, Regional Ecosystem Office, Portland, OR.

Sloan, J. P. 1998. Interruption of the natural fire cycle in a grand fir forest of central Idaho: changes in stand structure and composition. Pages 250-257 *in* T. L. Pruden and L. A. Brennan, editors. Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Research Station, Tallahassee, FL.

Steele, R. 1994. The role of succession in forest health. Journal of Sustainable Forestry **2**:183-190.

Steele, R., S. F. Arno, and K. Geier-Hayes. 1986. Wildfire patterns change in central Idaho's ponderosa pine–Douglas-fir forest. Western Journal of Applied Forestry **1**:16-18.

Stockdale, C. A., N. McLoughlin, M. Flannigan, and S. E. Macdonald. 2019. Could restoration of a landscape to a pre-European historical vegetation condition reduce burn probability? Ecosphere **10**:e02584 (02518 p).

Sturrock, R. N., S. J. Frankel, A. V. Brown, P. E. Hennon, J. T. Kliejunas, K. J. Lewis, J. J. Worrall, and A. J. Woods. 2011. Climate change and forest diseases. Plant Pathology **60**:133-149.

Tepley, A. J., F. J. Swanson, and T. A. Spies. 2013. Fire-mediated pathways of stand development in Douglas-fir/western hemlock forests of the Pacific Northwest, USA. Ecology **94(8)**:1729-1743.

USDA Forest Service. 1996. Interim Old-Growth Definitions for the Pacific Northwest Region. Regional direction. Portland, OR

USDA Forest Service. 2004. Standards for mapping of vegetation in the Pacific Northwest Region. Portland, OR: Regional Office direction, report on file, 22 pp. **454**:117667.

Van Pelt, R. 2008. Identifying old trees and forests in eastern Washington. Washington State Department of Natural Resources, Land Management Division, Ecosystem Services Section, Olympia, WA.

Walker, R. B., J. D. Coop, S. A. Parks, and L. Trader. 2018. Fire regimes approaching historic norms reduce wildfire-facilitated conversion from forest to non-forest. Ecosphere **9**:e02182.

Wang, Y., X. Wei, A. D. del Campo, R. Winkler, J. Wu, Q. Li, and W. Liu. 2019. Juvenile thinning can effectively mitigate the effects of drought on tree growth and water consumption in a young *Pinus contorta* stand in the interior of British Columbia, Canada. Forest Ecology and Management **454**:117667.

Welch, K. R., H. D. Safford, and T. P. Young. 2016. Predicting conifer establishment post wildfire in mixed conifer forests of the North American Mediterranean-climate zone. Ecosphere **7**:e01609 (01629 p).

Westerling, A. L. 2016. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. Philosophical Transactions of the Royal Society B: Biological Sciences **371**:20150178 (20150112 p).

Wickman, B. E., R. R. Mason, and H. G. Paul. 1992. Thinning and nitrogen fertilization in a grand fir stand infested with western spruce budworm. Part II: tree growth response. Forest Science **38**:252-264.

Wickman, B. E., R. R. Mason, and T. W. Swetnam. 1994. Searching for long-term patterns of forest insect outbreaks. Pages 251-261 *in* S. R. Leather, K. F. A. Walters, N. J. Mills, and A. D. Watt, editors. Individuals, populations and patterns in ecology. Intercept, Ltd., Andover, Hampshire, UK.

Winthers, E., D. Fallon, J. Haglund, T. DeMeo, G. Nowacki, D. Tart, M. Ferwerda, G. Robertson, A. Gallegos, A. Rorick, D. T. Cleland, and W. Robbie. 2005. Terrestrial ecological unit inventory technical guide: landscape and land unit scales. U.S. Department of Agriculture, Forest Service, Washington Office, Ecosystem Management Coordination Staff, Washington, DC.

Other Literature Consulted

Arner, S. L., S. Woudenberg, S. Waters, J. Vissage, C. MacLean, M. Thompson, and M. Hansen. 2001. National Algorithms for Determining Stocking Class, Stand Size Class, and Forest Type for Forest Inventory and Analysis Plot. USDA Forest Service, Inventory and Analysis, Washington D.C.

Battles, J. J., T. Robards, A. Das, K. Waring, J. K. Gilless, G. Biging, and F. Schurr. 2008. Climate change impacts on forest growth and tree mortality: a data-driven modeling study in the mixed-conifer forest of the Sierra Nevada, California. Climatic Change **87**:193-213.

Boag, A. E., M. J. Ducey, M. W. Palace, and J. Hartter. 2020. Topography and fire legacies drive variable post-fire juvenile conifer regeneration in eastern Oregon, USA. Forest Ecology and Management **474**:118312 (118313 p).

Coop, J. D., T. J. DeLory, W. M. Downing, S. L. Haire, M. A. Krawchuk, C. Miller, M.-A. Parisien, and R. B. Walker. 2019. Contributions of fire refugia to resilient ponderosa pine and dry mixed-conifer forest landscapes. Ecosphere **10**:e02809 (02824 p).

Corlett, R. T. 2015a. The Anthropocene concept in ecology and conservation. Trends in Ecology and Evolution **30**:36-41.

Corlett, R. T. 2015b. The Anthropocene concept in ecology and conservation. Trends in Ecology and Evolution **30(1)**:36-41.

Davis, K. T., S. Z. Dobrowski, P. E. Higuera, Z. A. Holden, T. T. Veblen, M. T. Rother, S. A. Parks, A. Sala, and M. P. Maneta. 2019. Wildfires and climate change push low-elevation forests across a critical climate threshold for tree regeneration. Proceedings of the National Academy of Sciences **116**:6193-6198.

Davis, R. J., D. M. Bell, M. J. Gregory, and Yang. 2020. (in progress; subject to peer review). Northwest Forest
Plan–the first quarter-century:status and trends of late-successional and
old-growth forests. . USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Davis, R. J., Pacific Northwest Research Station (Portland Or.), and Northwest Forest Plan (U.S.). 2015. Northwest Forest Plan--the first 20 years (1994-2013) : status and trends of late-successional and old-growth forests. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station,, Portland, OR.

DeMeo, T., R. Haugo, C. Ringo, J. Kertis, S. Acker, M. Simpson, and M. Stern. 2018. Expanding our understanding of forest structural restoration needs in the Pacific Northwest. Northwest Science **92**:18-35.

DeMeo, T., M. Laughlin, C. Ringo, and M. Simpson. 2020. Forest Structural White Paper:
In support of the Screen Team Analysis. USDA Forest Service
Pacific Northwest Region Portland, OR.

Dixon, G. E. 2015. Essential FVS: a user's guide to the Forest Vegetation Simulator. U.S. Department of Agriculture, Forest Service, Forest Management Service Center, Fort Collins, CO.

Donato, D. C., B. J. Harvey, and M. G. Turner. 2016. Regeneration of montane forests 24 years after the 1988 Yellowstone fires: A fire-catalyzed shift in lower treelines? Ecosphere **7**:e01410 (01416 p).

Downing, W. M., M. A. Krawchuk, G. W. Meigs, S. L. Haire, J. D. Coop, R. B. Walker, E. Whitman, G. Chong, and C. Miller. 2019. Influence of fire refugia spatial pattern on post-fire forest recovery in Oregon’s Blue Mountains. Landscape Ecology **34**:771-792.

Everett, R., P. Hessburg, M. Jensen, and B. Bormann. 1994. Volume I: executive summary. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Everett, R. L. 1994. Volume IV: restoration of stressed sites, and processes. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Eyre, F. H. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington, DC.

Franklin, J. F., N. K. Johnson, and D. L. Johnson. 2018. Ecological Forest Management Waveland Press, Inc., Long Grove, IL.

Hagmann, R. K., J. F. Franklin, and K. N. Johnson. 2013. Historical structure and composition of ponderosa pine and mixed-conifer forests in south-central Oregon. Forest Ecology and Management **304**:492-504.

Hagmann, R. K., J. T. Stevens, J. M. Lydersen, B. M. Collins, J. J. Battles, P. F. Hessburg, C. R. Levine, A. G. Merschel, S. L. Stephens, A. H. Taylor, J. F. Franklin, D. L. Johnson, and K. N. Johnson. 2018. Improving the use of early timber inventories in reconstructing historical dry forests and fire in the western United States: Comment. Ecosphere **9**:e02232 (02210 p).

Hamilton, L. C., J. Hartter, B. D. Keim, A. E. Boag, M. W. Palace, F. R. Stevens, and M. J. Ducey. 2016. Wildfire, climate, and perceptions in northeast Oregon. Regional Environmental Change **16**:1819-1832.

Hankin, L. E., P. E. Higuera, K. T. Davis, and S. Z. Dobrowski. 2019. Impacts of growing-season climate on tree growth and post-fire regeneration in ponderosa pine and Douglas-fir forests. Ecosphere **10**:e02679 (02620 p).

Harvey, A. E., J. M. Geist, G. I. McDonald, M. F. Jurgensen, P. H. Cochran, D. Zabowski, and R. T. Meurisse. 1994. Biotic and abiotic processes in eastside ecosystems: the effects of management on soil properties, processes, and productivity. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Harvey, B. J., D. C. Donato, and M. G. Turner. 2016. High and dry: post-fire tree seedling establishment in subalpine forests decreases with post-fire drought and large stand-replacing burn patches. Global Ecology and Biogeography **25**:655-669.

Haugo, R., C. Zanger, T. DeMeo, C. Ringo, A. Shlisky, K. Blankenship, M. Simpson, K. Mellen-McLean, J. Kertis, and M. Stern. 2015. A new approach to evaluate forest structure restoration needs across Oregon and Washington, USA. Forest Ecology and Management **335**:37-50.

Haynes, R. W., R. T. Graham, and T. M. Quigley. 1996. A framework for ecosystem management in the interior Columbia basin and portions of the Klamath and Great basins. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Henjum, M. G., J. R. Karr, B. D. L., D. A. Perry, J. C. Bednarz, S. G. Wright, S. A. Beckwitt, and E. Beckwitt. 1994. Interim protection for late-successional forests, fisheries, and watersheds; national forests east of the Cascade crest, Oregon, and Washington. The Wildlife Society, Bethesda, MD.

Hessburg, P., K. Reynolds, R. Salter, J. Dickinson, W. Gaines, and R. Harrod. 2013. Landscape evaluation for restoration planning on the Okanogan-Wenatchee National Forest, USA. Sustainability **5**:805-840.

Hessburg, P. F., S. Charnley, K. L. Wendel, E. M. White, T. A. Spies, P. H. Singleton, D. W. Peterson, J. E. Halofsky, A. N. Gray, R. L. Flitcroft, and R. White. 2020. The 1994 Eastside Screens - Large Tree Harvest Limit: Synthesis of Science Relevant to Forest Planning 25 years Later. USDA, Forest Service, Portland, OR, USA.

Hessburg, P. F., D. J. Churchill, A. J. Larson, R. D. Haugo, C. Miller, T. A. Spies, M. P. North, N. A. Povak, R. T. Belote, P. H. Singleton, W. L. Gaines, R. E. Keane, G. H. Aplet, S. L. Stephens, P. Morgan, P. A. Bisson, B. E. Rieman, R. B. Salter, and G. H. Reeves. 2015. Restoring fire-prone Inland Pacific landscapes: Seven core principles. Landscape Ecology **30**:1805-1835.

Hessburg, P. F., C. L. Miller, S. A. Parks, N. A. Povak, A. H. Taylor, P. E. Higuera, S. J. Prichard, M. P. North, B. M. Collins, M. D. Hurteau, A. J. Larson, C. D. Allen, S. L. Stephens, H. Rivera-

Huerta, C. S. Stevens-Rumann, L. D. Daniels, Z. e. Gedalof, R. W. Gray, V. R. Kane, D. J. Churchill, R. K. Hagmann, T. A. Spies, C. A. Cansler, R. T. Belote, T. T. Veblen, M. A. Battaglia, C. Hoffman, C. N. Skinner, H. D. Safford, and R. B. Salter. 2019. Climate, environment, and disturbance history govern resilience of western North American forests. Frontiers in Ecology and Evolution **7**:239 (227 p).

Hessburg, P. F., T. A. Spies, D. A. Perry, C. N. Skinner, A. H. Taylor, P. M. Brown, S. L. Stephens, A. J. Larson, D. J. Churchill, N. A. Povak, P. H. Singleton, B. McComb, W. J. Zielinski, B. M. Collins, R. B. Salter, J. J. Keane, J. F. Franklin, and G. Riegel. 2016. Tamm Review: Management of mixed-severity fire regime forests in Oregon, Washington, and Northern California. Forest Ecology and Management **366**:221-250.

Heyerdahl, E. K., R. A. Loehman, and D. A. Falk. 2019a. A multi-century history of fire regimes along a transect of mixed-conifer forests in central Oregon, U.S.A. Canadian Journal of Forest Resources **49 (2019)**:76-86.

Heyerdahl, E. K., R. A. Loehman, and D. A. Falk. 2019b. A multi-century history of fire regimes along a transect of mixed-conifer forests in central Oregon, U.S.A. Canadian Journal of Forest Research **49**:76-86.

Johnson, D. H., and T. A. O'Neil, managing directors. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Johnston, J. D., C. J. Dunn, M. J. Vernon, J. D. Bailey, B. A. Morrissette, and K. E. Morici. 2018. Restoring historical forest conditions in a diverse inland Pacific Northwest landscape. Ecosphere **9**:e02400 (02423 p).

Johnstone, J. F., C. D. Allen, J. F. Franklin, B. J. Harvey, and P. E. Higuera. 2016. Changing disturbance regimes, ecological memory, and forest resilience. Frontiers in Ecology and the Environment **14(7)**:369-378.

Kemp, K. B., P. E. Higuera, and P. Morgan. 2016. Fire legacies impact conifer regeneration across environmental gradients in the U.S. northern Rockies. Landscape Ecology **31**:619-636.

Kemp, K. B., P. E. Higuera, P. Morgan, and J. T. Abatzoglou. 2019. Climate will increasingly determine post-fire tree regeneration success in low-elevation forests, Northern Rockies, USA. Ecosphere **10**:e02568 (02517 p).

Kerns, B. K., D. C. Powell, S. Mellmann-Brown, G. Carnwath, and J. B. Kim. 2018. Effects of projected climate change on vegetation in the Blue Mountains ecoregion, USA. Climate Services **10**:33-43.

Keyser, C. E. 2019. South Central Oregon and Northeast California (SO) Variant Overview - Forest Vegetation Simulator. U.S. Department of Agriculture, Forest Service, Forest Management Service Center, Fort Collins, CO.

Keyser, C. E., and G. E. Dixon. 2019. Blue Mountains (BM) variant overview – Forest Vegetation Simulator. U.S. Department of Agriculture, Forest Service, Forest Management Service Center, Fort Collins, CO.

Kolden, C. A., J. T. Abatzoglou, J. A. Lutz, C. A. Cansler, J. T. Kane, J. W. Van Wagtendonk, and C. H. Key. 2015a. Climate contributors to forest mosaics; ecological persistence following wildfire. Northwest Science **89**:219-238.

Kolden, C. A., J. T. Abatzoglou, J. A. Lutz, C. A. Cansler, J. T. Kane, J. W. V. Wagtendonk, and C. H. Key. 2015b. Climate contributors to forest mosaics: Ecological persistence following wildfire. Northwest Science **89**:219-238.

Korb, J. E., P. J. Fornwalt, and C. S. Stevens-Rumann. 2019. What drives ponderosa pine regeneration following wildfire in the western United States? Forest Ecology and Management **454**:117663 (117616 p).

McMahon, S. M., G. Arellano, and S. J. Davies. 2019. The importance and challenges of detecting changes in forest mortality rates. Ecosphere **10**:e02615 (02610 p).

Merschel, A., R. S. Vora, and T. Spies. 2019. Conserving dry old-growth forest in central Oregon, USA. Journal of Forestry **117**:128-135.

Merschel, A. G., T. A. Spies, and E. K. Heyerdahl. 2014. Mixed-conifer forests of central Oregon: effects of logging and fire exclusion vary with environment. Ecological Applications **24**:1670-1688.

Millar, C. I., and N. L. Stephenson. 2015. Temperate forest health in an era of emerging megadisturbance. Science **349**:823-826.

Owen, S. M., C. H. Sieg, A. J. Sánchez Meador, P. Z. Fulé, J. M. Iniguez, L. S. Baggett, P. J. Fornwalt, and M. A. Battaglia. 2017. Spatial patterns of ponderosa pine regeneration in high-severity burn patches. Forest Ecology and Management **405**:134-149.

Palmer, M., G. Christensen, and O. Kuegler. 2018. Oregon's Forest Resources, 2006-2015: Ten Year Forest Inventory and Analysis Report. USDA Forest Service

Pacific Northwest Research Station Portland, OR.

Parks, S. A., S. Z. Dobrowski, J. D. Shaw, and C. Miller. 2019. Living on the edge: trailing edge forests at risk of fire-facilitated conversion to non-forest. Ecosphere **10**:e02651 (02617 p).

Parks, S. A., L. M. Holsinger, M. H. Panunto, W. M. Jolly, S. Z. Dobrowski, and G. K. Dillon. 2018. High-severity fire: evaluating its key drivers and mapping its probability across western US forests. Environmental Research Letters **13**:044037 (044013 p).

Powell, D. C. 2014a. Active management of dry forests in the Blue Mountains: Silvicultural considerations. USDA Forest Service, Pacific Northwest Region, Umatilla National Forest, Pendleton, OR.

Powell, D. C. 2014b. Active management of moist forests in the Blue Mountains: Silvicultural considerations. USDA Forest Service, Pacific Northwest Region, Umatilla National Forest, Pendleton, OR.

Pugnaire, F. I., J. A. Morillo, J. Peñuelas, P. B. Reich, R. D. Bardgett, A. Gaxiola, D. A. Wardle, and W. H. van der Putten. 2019. Climate change effects on plant-soil feedbacks and consequences for biodiversity and functioning of terrestrial ecosystems. Science Advances **5**:eaaz1834 (1812 p).

Quigley, T. M., and S. J. Arbelbide. 1997. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins: volume I. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Quigley, T. M., R. W. Haynes, and R. T. Graham. 1996. Integrated scientific assessment for ecosystem management in the interior Columbia basin and portions of the Klamath and

Great basins. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Sloan, J. P. 1998. Interruption of the natural fire cycle in a grand fir forest of central Idaho: changes in stand structure and composition. Pages 250-257 *in* T. L. Pruden and L. A. Brennan, editors. Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Research Station, Tallahassee, FL.

Steele, R. 1994. The role of succession in forest health. Journal of Sustainable Forestry **2**:183-190.

Steele, R., S. F. Arno, and K. Geier-Hayes. 1986. Wildfire patterns change in central Idaho's ponderosa pine–Douglas-fir forest. Western Journal of Applied Forestry **1**:16-18.

Stockdale, C. A., N. McLoughlin, M. Flannigan, and S. E. Macdonald. 2019. Could restoration of a landscape to a pre-European historical vegetation condition reduce burn probability? Ecosphere **10**:e02584 (02518 p).

Sturrock, R. N., S. J. Frankel, A. V. Brown, P. E. Hennon, J. T. Kliejunas, K. J. Lewis, J. J. Worrall, and A. J. Woods. 2011. Climate change and forest diseases. Plant Pathology **60**:133-149.

Tepley, A. J., F. J. Swanson, and T. A. Spies. 2013. Fire-mediated pathways of stand development in Douglas-fir/western hemlock forests of the Pacific Northwest, USA. Ecology **94(8)**:1729-1743.

Van Pelt, R. 2008. Identifying old trees and forests in eastern Washington. Washington State Department of Natural Resources, Land Management Division, Ecosystem Services Section, Olympia, WA.

Walker, R. B., J. D. Coop, S. A. Parks, and L. Trader. 2018. Fire regimes approaching historic norms reduce wildfire-facilitated conversion from forest to non-forest. Ecosphere **9**:e02182.

Welch, K. R., H. D. Safford, and T. P. Young. 2016. Predicting conifer establishment post wildfire in mixed conifer forests of the North American Mediterranean-climate zone. Ecosphere **7**:e01609 (01629 p).

Westerling, A. L. 2016. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. Philosophical Transactions of the Royal Society B: Biological Sciences **371**:20150178 (20150112 p).

Wickman, B. E., R. R. Mason, and H. G. Paul. 1992. Thinning and nitrogen fertilization in a grand fir stand infested with western spruce budworm. Part II: tree growth response. Forest Science **38**:252-264.

Wickman, B. E., R. R. Mason, and T. W. Swetnam. 1994. Searching for long-term patterns of forest insect outbreaks. Pages 251-261 *in* S. R. Leather, K. F. A. Walters, N. J. Mills, and A. D. Watt, editors. Individuals, populations and patterns in ecology. Intercept, Ltd., Andover, Hampshire, UK.