Blue Mountains Forest Partners

Upland Forest Restoration Zones of Agreement

Version 2.0
April 2017

Blue Mountains Forest Partners

Table of Contents

Executive summary

These upland forest restoration zones of agreement were developed by the Blue Mountains Forest Partners to help guide planning and implementation of restoration actions across a broad range of upland forest types found within the Malheur National Forest. The zones draw on an intensive collaborative process that included dozens of meetings and field trips with scientists, managers, local residents, and representatives from the timber industry and conservation groups. These upland forest restoration zones of agreement incorporate lessons learned from restoration projects that implemented guidance found in a previous zones of agreement document. The current zones document describes threats to forest resiliency and the findings of recent scientific studies about historical successional and disturbance dynamics. This information helps inform decisions about how to create forest stands that are resilient in the face of future change.

This document describes four different forest types found within the Malheur National Forest: xeric ponderosa pine, dry ponderosa pine, dry mixed conifer, and moist mixed conifer. For all forest types, the zones recommend significantly reducing forest density and shifting species composition from shade tolerant and disturbance intolerant species (e.g., grand fir) to shade intolerant and fire tolerant species (e.g., ponderosa pine and western larch). Ponderosa pine should dominate xeric pine and dry ponderosa pine stands following treatment. Ponderosa pine should dominate dry mixed conifer forests after treatment, although older larch, Douglas-fir, and grand fir should be retained. Larch or ponderosa pine and larch should dominate moist mixed conifer stands after treatment, although there should also be significant older Douglas-fir and grand fir retained.

The zones describe implementation of three different kinds of restoration treatments at different spatial and temporal scales: variable density thinning, openings, and untreated areas. These treatments should not be designed to achieve particular point-in-time forest conditions, but to facilitate desired vegetation response to future climate and disturbance. The zones encourage implementation of a variety of measures in the course of restoration treatments, including:

- Protection and enhancement of old growth trees by removing ladder fuels from around older ponderosa pine and western larch.
- Creation of age-based rather than size based tree retention strategies.
- Removal of conifers that have encroached into previously open areas.
- Creation of diverse post-treatment spatial patterns.
- Reintroduction of fire.

These zones are intended to be the cornerstone of an adaptive management strategy. Ongoing monitoring and research programs will investigate a variety of questions related to forest response to restoration treatments. Results of monitoring and research will be shared with the Blue Mountains Forest Partners and the Malheur National Forest on an annual basis and these zones of agreement will be updated regularly to reflect lessons learned.

I. About the Blue Mountains Forest Partners and the Malheur National Forest

The Blue Mountains Forest Partners (BMFP), established in 2006, is a diverse group of stakeholders who work together to create and implement a shared vision to improve the resilience and well-being of forests and communities in the Blue Mountains. The work of the BMFP takes place on the 1.7 million acre Malheur National Forest (MNF) located in Grant, Harney, and Baker counties in eastern Oregon. The MNF is one of 23 priority landscapes that receive funding under the Collaborative Forest Landscape Restoration Program (CFLRP, Public Law 111-11) to accomplish accelerated restoration to restore forest resiliency (Schultz et al. 2012). The CFLRP explicitly encourages collaborative, science-based restoration and the MNF currently has the most ambitious forest restoration targets of any national forest in the Pacific Northwest Region.

II. Process for developing the zones of agreement and scope of the zones of agreement

These upland forest restoration zones of agreement result from a year long process involving a diverse set of stakeholders, including representatives of the timber industry, conservation groups, local elected officials, community members, scientists, and Forest Service managers. These zones of agreement update and replace an earlier zones of agreement document adopted by the BMFP in 2013. The previous zones of agreement applied primarily to restoration activities in dry ponderosa pine dominated forests. The current zones of agreement are informed by a number of recent scientific studies completed in the last four years within national forests of eastern Oregon (e.g., Hagmann et al. 2017, Hagmann et al. 2014, Merschel et al. 2014, Hagmann et al. 2013).

The BMFP has also participated as a collaborator in a number of recently completed studies designed to inform managers about historical and contemporary forest dynamics in a wide range of forest types on the Malheur National Forest (Johnston et al. in press, Johnston 2017, Johnston et al. 2016). In the last four years, the BMFP has sponsored more than a dozen field trips and forums with scientists designed to synthesize new information, especially new information about appropriate management in moister forest types.

The 2013 zones of agreement relied heavily on published guidelines for dry forest restoration (Franklin and Johnson 2012). The current upland forest restoration zones of agreement document incorporate a number of lessons learned from restoration projects that implemented Franklin and Johnson's direction. These lessons include but are not limited to:

- The need to dramatically reduce forest density throughout a range of forest types, including moister, mixed conifer stands.
- The need to significantly shift species composition from late seral fire intolerant to early seral fire tolerant species across a broad range of forest types.
- The success of efforts to achieve diverse, resilient stands through conservation of fire tolerant old growth trees.

The current upland forest restoration zones of agreement are responsive to the BMFP's strategic plan. This document incorporates by reference a number of supporting documents including notes from field trips, the BMFP forest vegetation and fuels monitoring plan, and four technical papers that summarize the state of relevant scientific knowledge:

- "A literature review of science relevant to management of moist mixed conifer forests."

- "Biophysical context of the Malheur National Forest."
- "Characterizing variation in forest structure, composition, and disturbance over time on the Malheur National Forest."
- "Evaluating competing scientific claims about forest successional and disturbance dynamics in the southern Blue Mountains."

These and other documents can be downloaded from the BMFP's web page: www.bluemountainsforestpartners.org

This document does not provide detailed guidance for management of riparian areas, hardwood stands (e.g., aspen, willow, alder, cottonwood, and mountain mahogany), or special habitats (wetlands, sensitive species habitat, etc.). These features are intermixed with upland forests and many elements of the upland forest restoration zones of agreement will be applicable to riparian areas, hardwood stands, and special habitats, just as zones of agreement developed for those areas will have applicability to upland forests.

Figure 1. Example photographs of different forest types on the Malheur National Forest. Clockwise from top left: Moist mixed conifer, dry mixed conifer, dry pine, xeric pine. Example photographs show open stands that have not previously been logged in order to illustrate differences in species composition. Most contemporary stands are denser and have fewer old trees.

These upland forest restoration zones of agreement apply to ponderosa pine and mixed conifer forests on the Malheur National Forest, and not to low elevation sage-steppe lands or high elevation subalpine forests. Upland forest zones of agreement may have some applicability to some subalpine forest types. For instance, high elevation white-barked pine stands that are found adjacent to spruce-fir forests historically experienced relatively frequent fire and thinning to remove competing late-seral conifers can enhance the persistence of white-barked pine. This document may have applicability to restoration of rangelands and woodlands where juniper has encroached into sage-steppe lands.

Other national forest in eastern Oregon contain similar forest types as the Malheur National Forest, and these zones incorporate lessons learned from scientific research on other forests. But this document is not intended to be used to guide management outside of the Malheur National Forest absent additional site specific information gathering.

A variety of laws and policies constrain Forest Service management, and the BMFP does not contemplate use of any of the restoration practices addressed within these zones of agreement in areas where such practices are prohibited by law or policy.

These zones of agreement represent non-binding suggestions from the BMFP to the Forest Service. This guidance is meant to be flexible and subject to modification by the Forest Service in response to site specific conditions, new information, or emerging management challenges and opportunities.

III. Forest variation on the MNF

Common conifer tree species in upland forests on the MNF include ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), lodgepole pine (*Pinus contorta*), and western juniper (*Juniperus occidentalis*). A key distinction is between 1) early seral, shade intolerant, and disturbance tolerant species; and, 2) late or mid seral, more shade tolerant, and generally less disturbance tolerant species.

Table 1 refers to characteristics of different common tree species. These distinctions are relative, not absolute. For instance, all tree species on the MNF can, to a certain degree, resist disturbance and grow under a wide variety of light conditions. But some species, especially ponderosa pine and western larch, are found less frequently in low light environments, and are exceptionally well adapted to a wide variety of disturbances, especially wildfire. Some species are not easily characterized. For instance, lodgepole pine is an early seral species in cooler environmental settings but late seral in warmer upland mixed conifer stands. Restoration activities must always consider the response of different species to site conditions.

Species	Seral stage	Fire	Insects	Disease	Drought	Shade
Western larch	Early	High	High	High	Moderate	Low
Ponderosa pine	Early	High	High	High	High	Low
Douglas-fir	Mid or late	High	Moderate	Moderate	Moderate	Moderate
Grand fir	Late	Moderate	Low	Low	Moderate	High
Lodgepole pine	Early or late	Low	Low	Moderate	Low	Low
Western juniper	Late	Low	High	High	High	Low

Table 1. Tolerance of major tree species found on the MNF to different environmental characteristics and disturbance processes.

Upland forests found between sage steppe and subalpine forests can be divided into forests that are currently dominated by ponderosa pine and forests that are currently dominated by grand fir and other species (mixed conifer forests). Ponderosa pine and mixed conifer forests can be further subdivided into xeric ponderosa pine, dry ponderosa pine, dry mixed conifer, and moist mixed conifer (see Figure 1). Table 2 describes key differences between these forest types. The key science findings section below summarizes differences between these forest types and describes how they have changed over time.

Forest type	**Current overstory composition**	**Current understory regeneration**	**Plant association group**
Xeric ponderosa pine	Ponderosa pine	Ponderosa pine, juniper, or Douglas-fir	Hot-dry
Dry ponderosa pine	Ponderosa pine	Ponderosa pine, Douglas-fir, and occasionally grand fir	Warm-dry
Dry mixed conifer	Major species: Ponderosa pine, grand fir, Douglas-fir. Minor species: Larch and lodgepole pine	Mostly grand fir with some Douglas-fir and occasionally lodgepole pine.	Warm-dry
Moist mixed conifer	A mix of ponderosa pine, larch, grand fir, and Douglas-fir	Mostly grand fir with some lodgepole and larch.	Cool-moist

Table 2. Characteristics of common upland forest types on the Malheur National Forest

IV. Key science findings that inform the ZoA

The forest restoration methods described by these zones of agreement are informed by scientific findings about forest response to historical and contemporary climatic and disturbance variability.

Hessburg et al. (2005) and other authors summarize four significant changes that have occurred over the last 150 years since Euro-Americans settled in the area. First, fires are routinely suppressed, especially in the period following the establishment of the MNF in 1905 to the present day. Second, many large and old ponderosa pine trees that had survived hundreds of years of drought, fire, and insect disturbance were removed by logging, especially between 1920 and 1990. Third, over-grazing, particularly in the period 1880-1935, removed extensive herbaceous cover that carried surface fires over large areas. Finally, climate has been cooler and

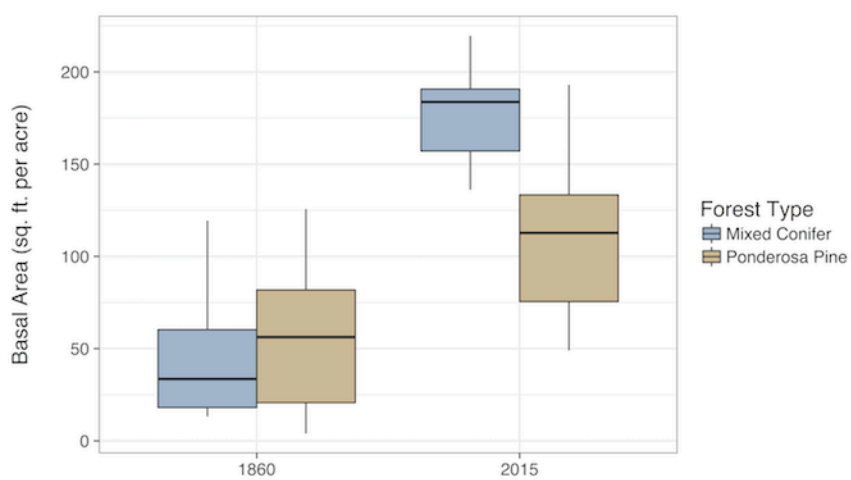

Figure 2. Reconstructed basal area in mixed conifer and ponderosa pine stands in 1860 compared to 2015. The horizontal black line within each box is the mean reconstructed basal area and the box and vertical lines represent the spread of values around the mean. Note that ponderosa pine and mixed conifer stands had similar basal area in the late 1800s but today's grand fir stands have significantly more basal area than ponderosa pine stands. Source: Johnston 2017.

moister since the 1850s than in previous centuries, particularly from 1870-1925 and from 1940 to 1985.

Historical successional and disturbance dynamics

Dendroecological reconstructions indicate that xeric pine, dry pine, dry mixed conifer, and moist mixed conifer forest ecosystems on the MNFs all experienced relatively frequent (every 8-25 years) fire until fire was excluded from the landscape in the late 1800s (Johnston et al. in press, Johnston et al. 2016, Heyerdahl et al. 2001). The tempo and intensity of this fire disturbance, as well as endemic insect disturbance, resulted in fine-scaled successional dynamics—trees died and new trees established within relatively small areas on a regular basis.

The MNF regularly experiences drought. Drought in combination with frequent disturbance favored tree species like ponderosa pine that survive arid conditions and devote significant plant resources to defense against fire and insects.

Frequent disturbance and periodic drought historically resulted in relatively low forest densities, generally 10-25 trees per acre, across a broad range of forest productivity ranging from xeric pine to moist mixed conifer forests (Hagmann et al. 2017, Johnston 2017, Johnston et al. 2016, Hagmann et al. 2014, Hagmann et al. 2013). Contemporary forests are generally two to ten times denser and have a far higher proportion of grand fir, Douglas-fir, and lodgepole pine. Historically there was a far greater proportion of western larch in moister sites, and more ponderosa pine in drier sites (Figure 2 and Table 2).

Much of the old growth ponderosa pine structure in xeric and dry ponderosa pine stands on the Malheur National Forest has been removed by logging. Contemporary xeric ponderosa pine stands are often dominated by young ponderosa pine, Douglas-fir, and western juniper. Contemporary dry ponderosa pine stands are often dominated by young ponderosa pine, Douglas-fir, and sometimes grand fir. Contemporary dry mixed conifer stands have also experienced extensive logging and are usually dominated by grand fir or grand fir and Douglas-fir. Although ponderosa pine was historically a dominant or codominant species in dry mixed conifer stands, the majority of recent regeneration in this forest type is grand fir. Moist mixed conifer stands are today invariably dominated by grand fir or grand fir, lodgepole pine and Douglas-fir. Western larch and ponderosa pine have declined dramatically in moist mixed conifer stands (Johnston 2017).

Species	1860 basal area	2015 basal area	% change
Western larch	5.55	2.38	-57%
Ponderosa pine	41.46	63.97	54%
Douglas-fir	1.45	14.87	925%
Grand fir	2.35	57.50	2,346%

Table 2. Average reconstructed basal area (square feet per acre) of different species in unmanaged stands on the MNF in 1860 and in 2015. Source: Johnston 2017.

Resiliency of contemporary stands

Changes to upland forests that have occurred over the past 150 years have important consequences for the stability of forest ecosystems. When disturbances do occur, they spread through younger and denser forests composed of species that are relatively less resistant to disturbance, leading to extensive mortality. Arid conditions and increased competition in forests stress trees over a wide area and make them more vulnerable to mountain pine beetle, western pine beetle, spruce budworm, and other insects (Millar and Stephenson 2015, Williams et al. 2013).

Although both data and anecdotal evidence suggest that mortality from drought and insects are increasing on the MNF, it is highly likely that mortality will be many orders of magnitude greater in the future. Many forests in the American West that have or are experiencing severe drought provide a preview of the mortality dynamics that are likely on the MNF in the future. In the 1990s and early 2000s, drought in dense fire-excluded forests was implicated in massive die-offs of spruce and fir trees in national forests of Colorado (Bigler et al. 2007). Mountain pine beetle killed between 70-90% of lodgepole, limber, and ponderosa pine across 4 million acres in northern Colorado and southern Wyoming in the 2000s (Clow et al. 2011, Raffa et al. 2008). There has been extensive mortality of spruce over more than 2.5 million acres in coastal Alaska national forests, and close to 100% mortality of lodgepole pine on more than 25 million acres in British Columbia (Kurz et al., 2008, Berg et al. 2006). In national forest of Arizona and New Mexico, drought and insects have killed most of the piñon pine on more than 2 million acres (Breshears et al. 2011, Williams et al. 2010, Breshears et al. 2005). The synergistic effects of drought and competition in dense forests has resulted in extensive mortality in mixed conifer forests of the Sierra Nevada in California. Millions of trees in California have died from prolonged drought stress and insect attack (Young et al. 2017, Collins et al. 2011, Das et al. 2011).

Drier and warmer conditions on the MNF are a certainty for two reasons. First, paleo-ecological reconstructions demonstrate that natural climate variability caused much more serious droughts in the 200-500 years prior to extensive Euro-American settlement than have been experienced in the last 150 years (Johnston unpublished data, Youngblood et al. 2004, Garfin and Hughes 1996). Second, anthropogenic carbon emissions will continue to cause significant warming. Most climate change modeling projects temperature increases between 2.5 to 3.5˚ C in the inland Pacific Northwest over the next 50 years. Future precipitation projections are far less certain, with estimated changes ranging from -10 to +20% over the next 50 years. Many models predict higher precipitation in the winter and decreased precipitation in the summer months when water availability limits plant growth and establishment (Mote and Salathe 2010). Scientists agree that warmer temperatures and more variable precipitation will lead to significant tree mortality (Young et al. 2017, Wimberly and Liu 2014, Williams et al. 2013, Coops and Waring 2011, Littell et al. 2010, Waring et al. 2009, van Mantgem and Stephenson 2007).

Common forest restoration practices provide an opportunity for MNF managers to avoid the worst impacts that have occurred in other parts of the West by reducing forest density and shifting species composition to more drought and disturbance tolerant species. The use of restoration silviculture techniques involves inherent uncertainties about effects to wildlife, water quality, vegetation dynamics, and future disturbance processes. However, restoration treatments are appropriate on the MNF for three reasons: First, inaction often poses greater risks to natural resources than action. Second, inaction often involves more uncertainty about impacts to natural resources than action. Finally, scientists have a good general understanding of the relationship between forest density, species composition, and disturbance processes, and risks and uncertainties can be managed within an adaptive management framework (see section VII).

There is an extensive body of scientific literature that demonstrates that mechanical thinning and/or the reintroduction of fire is effective in reducing extensive mortality from drought, insects, and fire in similar forest types as those found on the MNF (Ziegler et al. 2017, Kalies and Kent 2016, Sollmann et al. 2016, van Mantgem et al. 2016, Thomas and Waring 2015, Vaillant et al. 2015, Busse et al. 2014, Jenkins et al. 2014, Kennedy and Johnson 2014, Stevens et al. 2014, D'Amato et al. 2013, Martinson et al. 2013, Fulé et al. 2012, Lyons-Tinsley and Peterson 2012, Stephens et al 2012, Prichard et al. 2010, Ritchie et al. 2008, Stephens et al. 2008, Youngblood et al. 2008, Ager et al. 2007, Youngblood et al. 2006, Peterson et al. 2005, Raymond and Peterson 2005, McDowell et al. 2003). These zones of agreement incorporate lessons learned from this literature and tailor these lessons to the specific forest types and management challenges present on the MNF.

Research indicates that restoration treatments must take place at a landscape scale and treat a large portion of the landscape. Treating between a quarter and half of the Malheur National Forest is necessary to substantially alter landscape scale fire behavior (Collins et al. 2010, Ager et al. 2007, Finney 2007, Finney et al. 2007). Treating an even larger area may be necessary to avoid impacts from drought and insects, which are more spatially extensive disturbance processes than fire (Hicke et al. 2012, Raffa et al. 2008, Williams and Birdsey 2003, Dale et al. 2001).

A handful of scientists offer a different perspective on the need for forest restoration, but overall, the weight of evidence supports use of restoration silviculture to promote ecological resilience. A further discussion of alternative views of historical and contemporary successional and disturbance dynamics is found in the BMFP technical paper: "Evaluating competing scientific claims about forest successional and disturbance dynamics in the southern Blue Mountains."

Although restoration activities sometimes involve tradeoffs with wildlife habitat at different spatial and temporal scales, in general, restoring many of the characteristics of historical forests is expected to create optimal conditions for a wide range of sensitive fish and wildlife species over the long term (Margolis and Malevich 2016, Tempel et al. 2015, Roberts et al. 2011). Active management to restore many aspects of historical forests is an important component of climate change adaptation and will help preserve a range of options for managers in the face of future change (Jackson and Hobbs 2009, Fulé 2008).

V. Goals, objectives, and strategies for upland forest restoration

The overall goals of upland forest restoration are to:

Create ecological resiliency at multiple spatial and temporal scales:

1. Facilitate a range of future fire effects, with an emphasis on low severity surface fire.
2. Prevent spatially extensive mortality of older forest structure from drought, insects, and fire.
3. Facilitate a range of fish and wildlife habitat.

Promote social and economic resilience of local communities:

1. Reintroduce low severity fire to reduce risk to human lives and property from high severity fire.
2. Provide a consistent and reliable supply of wood products to support jobs and a local manufacturing base.
3. Create a diverse range of forest restoration jobs, including but not limited to jobs involving reintroducing and managing fire, pre-commercial thinning, and habitat restoration.
4. Ensure a range of other commercial and non-commercial opportunities including but not limited to recreation, wood cutting, and small diameter wood and special forest products utilization.
5. Manage smoke impacts through the use of prescribed fire and managed wildland fire that helps avoid significant smoke incursions from large out-of-control fire events.

Specific objectives that will help measure achievement of these goals include:

1. Complete planning for an average of two planning areas per year over a ten-year period.
2. Mechanically treat an average of at least 25-50,000 acres per year over a ten-year period to reduce forest density and shift species composition.
3. Reintroduce fire, including prescribed fire and wildland fire that significantly reduces surface fuel on an average of 25,000-50,000 acres per year.
4. Achieve an overall increase in the number of old trees on the landscape.
5. Maintain or expand the geographic extent of rare species, e.g., whitebark pine and western white pine.
6. Provide habitat for native and desirable non-native species consistent with ecological resiliency objectives and legal obligations.
7. Produce timber sufficient to maintain full employment in existing manufacturing infrastructure and expand other industries that process small or other wood products.
8. Increase local employment in the forest restoration industry.

Specific silviculture techniques that will help meet objectives include:

1. Mechanical thinning
2. Fire, including both prescribed fire and wildland fire
3. Other treatments that are consistent with achieving resilience goals, including but not limited to road management, treatment of invasive species, etc.

Process-based forest restoration prescriptions below describe the application of these strategies.

VI. Process based forest restoration prescriptions

The goal of forest restoration is not to create particular point in time forest conditions, but to facilitate a range of desirable future forest responses to climate and disturbance processes. Restoration prescriptions should anticipate significant drought, fire activity, and insect activity on the MNF. Restoration treatments should be designed so that forests will interact with these processes in such a way as to maintain key forest structure and continue to provide desired wildlife habitat, water quality, recreation, and other human uses.

Basic principles

Principles for dry forest restoration presented by Franklin and Johnson (2012) serve as the basis for these process-based forest restoration prescriptions. Franklin and Johnson principles have been implemented during several restoration projects on the Malheur and reflect other scientific recommendations (e.g., Hessburg et al. 2016, Stine et al. 2014, Agee and Skinner 2005, Brown et al. 2004).

Key Franklin and Johnson principles adapted to respond to the needs of MNF upland forests are:

- Retain and improve survivability of older conifers by removing ladder fuels and competing trees.
- Thin forests to reduce forest density and shift composition from late seral shade tolerant species to early seral shade intolerant species.
- Reduce surface fuels by reintroducing fire to stands following treatment.

- Increase forest diversity at both the stand and landscape scales by varying treatment intensity, creating openings and leaving untreated areas, and by implementing restoration activities in special habitats like hardwood stands, riparian areas, and meadows.

Spatial and temporal pattern of treatments

Mechanical operations will create three different types of restoration treatments:

1. Variable density thinning
2. Openings
3. Untreated areas

Achieving restoration goals and objectives is a matter of tailoring the spatial and temporal pattern of these different types of treatments to different stands and landscapes. Use of variable density thinning, openings, and untreated areas should all have specific ecological rationale tailored to site specific conditions.

At a stand scale, treatments may result in a fine-grained spatial pattern when small-sized (0.1 to 0.5 acre) openings and untreated areas are scattered throughout a matrix of variable density thinning. Treatments may result in a moderately coarse-grained pattern when medium-sized (0.5 to 2 acre) openings and untreated areas are located within a matrix of variable density thinning. In some cases, a coarse-grained pattern may be appropriate in which large (2 acres and greater) areas are left untreated or where all or most trees are removed from a larger area (for instance to restore meadow habitat or create conditions for regenerating early seral species).

Treatments may result in a relatively regular pattern where variable density thinning dominates a stand and there are few if any untreated areas or openings, or when there is relatively even spacing between openings and untreated areas. Treatments may result in irregular patterns when openings or untreated areas are concentrated in one part of a stand or distributed unevenly across the stand. Even in stands with relatively regular patterns, variable density thinning should still result in considerable spatial diversity in residual tree structure, including variably spaced individual trees and small clumps or aggregations of trees.

At a landscape scale, patterns may be relatively regular, as when variable density thinning occurs within 75-90% of a watershed. Landscape scale patterns may be irregular as when variable density thinning occurs in a mosaic of patches among past clearcuts, meadows, and large untreated areas, or when these different features are aggregated within one part of a landscape.

The most desirable spatial pattern for both stands and landscapes is determined by considering how stands and landscapes will change over time as successional and disturbances processes interact with residual forest structure. As an example, untreated areas may persist as denser, multi-layered stands for many decades if they occupy landscape positions with sufficient water resources and/or if they are relatively insulated from insects and fire within a heavily treated landscape. In other cases, an untreated area may experience stand replacing disturbance within a relatively short period of time and begin functioning as an early seral opening. Openings may persist indefinitely if recurrent disturbance removes trees, or they may quickly regenerate and function as dense forest habitat.

All restoration prescriptions should explicitly address how treatments will interact with future vegetation succession, fire, insect activity, climate variability, and management activities.

Restoration prescriptions should be explicitly tied to plans to implement prescribed fire and managed wildfire.

Although the precautionary principle is often interpreted to suggest that managers maintain existing forest structural and compositional elements, a conservative approach to restoration often involves significantly more risk than aggressive restoration actions. Most stands on the MNF have much more forest cover than can be sustained over time. There has been significant conifer infill into meadows that were previously treeless, and into hardwood and riparian areas. Current federal policy tends to ensure that significant portions of planning areas will not be treated. Although there is a role for untreated areas, in most treatment units an emphasis on openings and variable density thinning with small leave patches and clumps of trees has the highest probability to achieve landscape scale resiliency on the MNF.

Operational considerations

The following operational considerations expand on the principles adopted from Franklin and Johnson (2012) and should inform the pattern of variable density thinning, openings, and untreated areas.

Treat as large of an area as practical: Spatially extensive treatments are necessary to promote landscape scale resiliency. Restoration treatments should be implemented over as large a scale as possible consistent with economic and planning efficiencies, legal mandates, and other resource management objectives.

Create cost-effective restoration treatments: Many needed restoration treatments will involve significant investments and will generate few or no receipts. But where possible and consistent with ecological resilience objectives, restoration treatments should be designed to minimize costs while maximizing ecological and economic returns. Environmental analysis should be concise as possible consistent with informing stakeholders and ensuring rigorous compliance with legal obligations.

Use innovative and efficient contracting and implementation authorities: All restoration prescriptions should be flexible and tailored to the needs of particular sites. Using stewardship authorities, integrated resource contracts, designation by prescription, and other innovative contracting and implementation mechanisms can help achieve these goals.

Create integrated restoration projects: Upland forest restoration treatments should be integrated with a range of ecological restoration actions including but not limited to:

1. Management of the road system consistent with ecological resilience objectives, legal obligations, and stakeholder expectations.
2. Treatment of invasive species
3. Instream habitat restoration
4. Improving fish passage
5. Range improvements
6. Creation, protection, and enhancement of special habitats and habitat structures.

Protect old trees and enhance the survivability of old trees by reducing ladder fuels: A primary objective of restoration is to create conditions where old growth trees can persist in the face of future disturbance and climate variability. In many cases this will involve heavy thinning or complete tree removal in an area equivalent to twice the dripline around trees that exhibit old growth characteristics. Other old growth trees within and around the canopy of old growth trees should be retained. In some cases, it will be desirable to maintain younger trees within and around the canopy of old growth trees to provide old growth replacements over time or to maintain under-represented forest structure.

Utilize age-based tree conservation strategies: An important desired future condition for many forest stands involves widely spaced older early seral species. Age-based rather than size-based cutting limits better achieve resilience objectives. Absent a site-specific analysis that indicates logging older trees is necessary to achieve resilience objectives, trees that were well established prior to extensive Euro-American interventions on the landscape beginning in the 1860s should be protected. Adopting a younger age threshold may be necessary to ensure recruitment of old growth trees when there are few or no older trees present in stands. Leaving sufficient younger trees to perpetuate desired structure and species composition is usually necessary. Protecting trees that exhibit morphological characteristics indicative of old age using existing field guides or new guides under development will help determine which trees to retain in the course of restoration activities (Van Pelt 2008).

Select trees for retention with high wildlife value: Traditional forestry practices emphasize leaving healthy and vigorous trees. Younger, vigorous grand fir and Douglas-fir are often the biggest threats to stand resiliency because they compete with older larch and ponderosa pine. The Forest Service should consider retaining late seral species with significant defects which better provide habitat for cavity excavators and other wildlife where appropriate. Older, defective, grand fir in dry and moist mixed conifer sites are excellent wildlife trees.

Figure 3. Variation in forest structure and composition at fine spatial scales. Top photo: Highly variable density within a dry mixed conifer stand. Bottom photo: Transition from forest to opening.

Reduce density across a broad range of forest types: Restoration treatments should significantly reduce forest density. At small spatial scales (areas smaller than individual treatment units), there may be wide variation in post-treatment forest density, including openings where all trees are removed or patches of leave trees where no trees are removed. At larger spatial scales (the size of one or more individual treatment units), residual basal area of between 25 and 75 square feet per acre is generally appropriate to achieve resiliency objectives within upland forest types. Appropriate post-treatment forest density should be determined by considering characteristics of individual sites. Post-treatment forest density targets should be reached by considering post-treatment density following a full range of stand treatments including mechanical thinning, post-treatment fire, as well as natural mortality.

- On xeric and dry ponderosa pine sites: Younger trees that will become old growth trees over time should be retained both as scattered individuals and patches or clumps. But the majority of residual basal area should be concentrated in the oldest age classes of ponderosa pine present on the site. Operations in ponderosa pine sites should usually result in a significant increase in mean stand diameter.
- On dry and mixed conifer sites: It is often appropriate to spread residual basal area through a range of size classes in mixed conifer sites. This may result in a smaller increase in mean stand diameter.

Significantly shift species composition from shade tolerant and relatively disturbance intolerant to shade intolerant and disturbance tolerant species: All restoration treatments should significantly shift species composition from tree species that are less resistant to future climate and disturbance variability to species that more closely resemble historical conditions and are more likely to persist in the face of future change.

- On xeric ponderosa pine sites: The primary opportunity is to restore stands that are dominated by ponderosa pine, and all or almost all residual basal area should be ponderosa pine. Leaving older Douglas-fir or western juniper if these species were historically present is usually desirable.
- On dry ponderosa pine sites: The primary opportunity is to restore stands that are dominated by ponderosa pine, and all or almost all residual basal area should be ponderosa pine. Old-growth western larch, grand fir, and Douglas-fir are sparsely distributed in ponderosa sites but should be retained if they were historically present.
- On dry mixed conifer sites: In most cases, the largest proportion of residual basal area should be ponderosa pine. Western larch should also be retained if present, and it is usually appropriate to leave old-growth grand fir and/or Douglas-fir.
- On moist mixed conifer sites: It is usually appropriate to create conditions where larch and/or ponderosa pine will be dominant or co-dominant in the overstory. A mix of the major conifer species present, including grand fir and Douglas-fir, should also be retained.

Vary treatments at fine spatial scales where appropriate: Structure and composition of upland forests can vary at fine spatial scales on the MNF. In many treatment units, several if not all of the forest types described by these zones of agreement may be present, along with meadows, hardwood stands, and other special habitats. Treatments should explicitly account for the influence of edaphic and microclimatic controls on vegetation dynamics and vary treatments accordingly at very small spatial scales if necessary (Figure 3). In general, restoration prescriptions should be flexible and adapted to site conditions based on the professional expertise of managers. The Forest Service should be conscious of the skills and experience of operators and work closely with operators to achieve desired results.

Address conifer encroachment into formerly treeless areas where appropriate: Openings play an important role in mediating the behavior of fire and insect disturbance and can be an important source of vegetative diversity. Removing conifers that have encroached into areas that historically had little or no tree cover will often make an important contribution to landscape scale diversity and resilience. Restoring historical openings may involve removing most or all extant forest cover. Extensive conifer removal should not be undertaken without a rigorous methodology for identifying areas that were historically open. This may involve analysis of physical evidence, soil characteristics, or historical records. Restoring meadow habitat will usually involve restoring the edaphic, hydrologic, and/or disturbance processes that maintained open conditions.

Create diverse spatial pattern: Past management regimes have left relatively dense forests throughout the MNF. Restoration efforts should generally seek to break up continuity of forest cover in the course of reducing overall stand density. Distances between residual trees and the aggregation of residual forest structure should vary as appropriate given site conditions and objectives. Leaving clumps of trees where older trees or stumps are found in clumps, removing trees from around the canopies of old trees, and removing trees from historically treeless areas will all tend to create diverse spatial pattern.

- On xeric and dry ponderosa pine sites: The primary opportunity is to leave both isolated older and mature trees and clumps of mature and old trees, as well as small patches of younger regeneration.
- On dry and mixed conifer sites: Sites that historically supported older grand fir and/or Douglas-fir may have had more variable spatial pattern over time than ponderosa pine sites. It may be appropriate to experiment with a variety of post-treatment spatial patterns that are compatible with reintroducing surface fire.

Reintroduce fire to stands to the maximum extent practical: Reducing surface fuel is critical to stand resilience to fire and restoration prescriptions should include explicit plans for reintroducing fire to stands. Fire that eliminates regeneration is usually desirable to suppress the development of future latter fuels. A mix of future fire effects is inevitable and desirable, however, the most under-represented disturbance pattern on the MNF is large-scale surface fire, and restoration treatments should generally be designed to facilitate surface fire. Tree mortality is inevitable when reintroducing fire to stands where fire has been excluded for more than a century, and significant tree mortality should not deter managers from reintroducing fire.

- On xeric ponderosa pine, dry ponderosa pine, and dry mixed conifer sites: Restoration prescriptions should be designed primarily to facilitate low-intensity surface fire that kills young trees, isolated older and mature trees, and small groups (less than 0.5 acres) of older and mature trees.
- On moist mixed conifer sites: Restoration prescriptions should also be designed to facilitate low-intensity surface fire, but moderate or mixed intensity fire effects that kill larger patches (.5 acres and greater) of mature and older trees will also serve to create desirable landscape scale diversity. Western larch will often survive relatively intense fire, and facilitating the growth and establishment of western larch will permit reintroduction of a wide range of fire intensities in moist mixed conifer stands.

Forest type	**Residual species composition**	**Post-treatment spatial pattern**	**Post treatment fire effects**
Xeric ponderosa pine	Ponderosa pine, with some scattered older Douglas-fir or juniper, if these species were historically present.	Leave individual old trees and small clumps of mature and older trees. Consider retaining patches of ponderosa pine regeneration.	Low intensity surface fire effects.
Dry ponderosa pine	Ponderosa pine, with some scattered older Douglas-fir, larch, and/or grand fir, if these species were historically present.	Leave individual old trees and small clumps of mature and older trees. Consider retaining patches of ponderosa pine regeneration.	Low intensity surface fire effects.

Dry mixed conifer	Dominant overstory species should be ponderosa pine, along with some older larch, Douglas-fir, and grand fir.	Leave individual old trees and small to medium sized patches of mature and older trees. Experiment with a range of different post-treatment spatial patterns.	Low to moderate intensity surface fire effects.
Moist mixed conifer	A mix of species in the overstory, especially larch and ponderosa pine.	Leave individual old trees and small to medium sized patches of mature and older trees. Experiment with a range of different post-treatment spatial patterns.	Low, moderate, and high intensity fire effects

Table 3. Summary of desired restoration outcomes for different forest types.

VII. An adaptive management framework for upland forest restoration

The key to implementing process-based forest restoration is regularly integrating new information about how forests respond to treatment and climate and disturbance variability within different landscape settings. Integrating information into management involves developing new scientific research, monitoring at a stand and landscape scale, and creating specific planning mechanisms by which new information is operationalized in restoration treatments.

The BMPF, MNF, and Oregon State University have partnered to create a forest vegetation and fuels monitoring program that is currently monitoring changes to forest structure and composition, surface fuels, and understory vegetation in approximately 500 systematically located plots in 72 random located units of 12 MNF planning areas. Plot based monitoring will allow managers and stakeholders to answer a variety of questions about the effects of treatment, including but not limited to:

1. How does treatment affect fine surface fuel accumulation over time?
2. How does treatment affect future fire, drought, and insect disturbance patterns?
3. What natural regeneration results from different treatment intensities in different landscape settings?
4. What density of trees and what tree species can persist over time in different landscape settings under different climate and disturbance regimes?
5. How do leave patches and openings respond over time following treatment?

Answers to these and other questions should inform changes to the upland forest restoration zones of agreement. For instance, future zones may suggest:

1. Post-harvest fuel treatments leave more or less surface fuels, and the desired extent, tempo, and intensity of prescribed and wildland fire may be adjusted upward or downward.
2. More or less post-treatment pre-commercial thinning or fire to either reduce or augment natural regeneration.
3. Restoration leave a higher or lower density of trees and a higher or lower proportion of shade intolerant late seral tree species.
4. The size of leave patches and openings decrease or increase.
5. A different intensity or spatial pattern of treatments to account for the effects of insects, pathogens (e.g., mistletoe) and/or drought.

Research should track indicators of landscape scale resilience, including:

1. Trends in the spatial extent of high severity fire over time relative to trends in acreage treated by mechanical thinning, and low and moderate severity wildfire and prescribed fire.
2. Trends in the spatial extent and intensity of insect mortality.

Information from monitoring and new scientific research will be presented on an annual basis to the BMFP and the MNF. Oral and written reports will explicitly address the success of restoration in meeting goals and objectives and recommend changes to management practice to better meet goals and objectives. These reports will be used to revise these zones of agreement at least once every three years.

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