Literature Review: Management of Moist Mixed Conifer Forests

Introduction

The purpose of this literature review is to provide members of the Blue Mountains Forest Partners (BMFP) with an overview of the state of scientific knowledge about management of moist mixed conifer forests (MMC) on the Malheur National Forest (MNF). The BMFP is working to develop strategies to restore forest resilience to a wide range of forest types found on the MNF. Resilience refers to the capacity of an ecosystem to return to the original state following a perturbation, maintaining its essential characteristic taxonomic composition, structures, ecosystem functions, and process rates (Holling 1973).

The BMFP is interested in understanding historical successional and disturbance dynamics in moist mixed conifer forests because historical forests are assumed to have provided for a wide range of desired ecosystem services. Restoring historical conditions is assumed to restore resilience, although future climate and disturbance regimes as well as social, economic, and legal considerations may necessitate management of different forest types outside the historical range of variability.

There is no consistent definition of moist mixed conifer forests in the scientific literature. A "mixed conifer" forest in the inland Pacific Northwest is a stand with more than one conifer species common in the overstory. Moist mixed conifer forests are presumably the moister and more productive mixed conifer forests in our region. There has been very little empirical research that describes historical successional and disturbance dynamics in mixed conifer forests in the inland Pacific Northwest (Stine et al. 2014).

This review begins by describing how managers and scientists categorize different forests. Then it evaluates three different types of scientific literature relevant to management of moist mixed conifer forests on the MNF. The third section summarizes in narrative form a range of empirical research conducted in mixed conifer forests throughout the western United States that may be relevant for understanding moist mixed conifer dynamics in the MNF. The fourth section summarizes three papers that attempt to synthesize knowledge about mixed conifer and moist mixed conifer forests. The fifth section evaluates empirical research into mixed conifer dynamics that has taken place in eastern Oregon and which is most relevant to management of moist mixed conifer forests on the MNF. A conclusions section is designed to summarize findings and evaluate information gaps.

Forest typologies

Forests are typically described by managers and scientists within a vegetation hierarchy that describes variation in forests at progressively coarser scales. At the finest scale, "plant associations" describe characteristic assemblages of overstory trees and understory plants that would dominate a site in the absence of disturbance. Disturbance like fire and insects are inevitable in the southern Blues and "climax" communities that would develop in the absence of disturbance are very rare. Typing stands to the plant communities that would exist if disturbance did not interrupt succession allows plant communities to serve as indicators of inherent site productivity.

Plant associations are aggregated into “plant association groups (PAGs)” that serve as surrogates for the temperature and moisture regimes that are responsible for inherent site productivity. PAGs are labeled by overstory tree type (e.g., “mixed conifer dry”) or the temperature-moisture regime represented (e.g., “warm-dry”).

The coarsest scale of the vegetation hierarchy is the “potential vegetation type (PVT)” or “series.” PVTs usually describe the overstory tree species that would dominate stands in the absence of disturbance. Figure 1 depicts this vegetation hierarchy using example plant associations common on the Malheur National Forest.

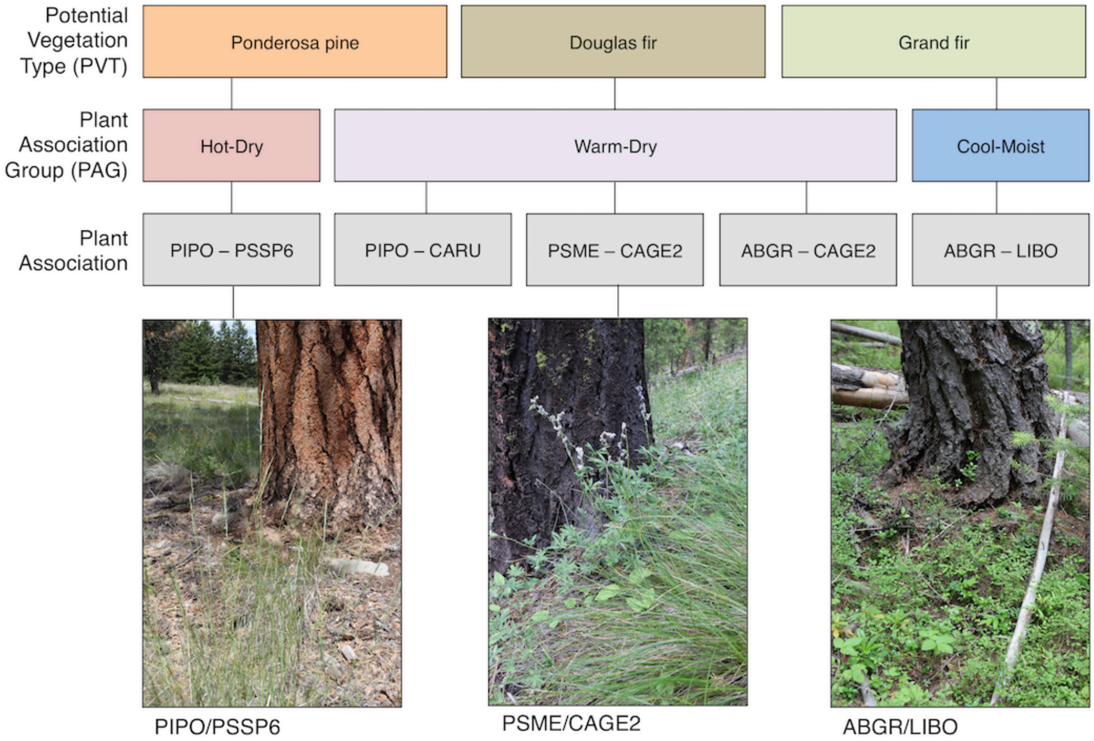

Figure 1. Forest typologies in use on the Malheur National Forest. PIPO = ponderosa pine; PSME = Douglas-fir; ABGR = grand fir; PSSP6 = bluebunch wheatgrass; CAGE2 = elk sedge; LIBO = twinflower.

Large areas of the MNF below 7,000 feet, especially on the south end of the forest, are dominated by the ponderosa pine (*Pinus ponderosa*) and are typed as ponderosa pine or Douglas-fir PVTs. In other areas ponderosa pine is today either a minor species, or, more commonly, codominant with other long lived-conifers including Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), and grand fir (*Abies grandis*) (Powell 2007, Johnson and Clausnitzer 1992, Franklin and Dyrness 1988). These communities are typed to the grand fir PVT.

Franklin and Johnson (2012), following Agee (1994), divide the grand fir PVT into moist and dry mixed conifer forest types. They suggest that grand fir is primarily a late seral species in dry mixed conifer sites, although it may be codominant with ponderosa pine in some areas. Grand fir is either dominant or codominant in moist mixed conifer sites. Simpson (2007) and the Integrated Landscape Assessment Project (ILAP; Hemstrom et al. 2012;

http://ecoshare.info/ilap/) divide the grand fir PVT along similar lines and partition the ponderosa pine PVT into dry ponderosa pine and xeric ponderosa pine. Figure 2 shows ILAP PVTs mapped for the MNF.

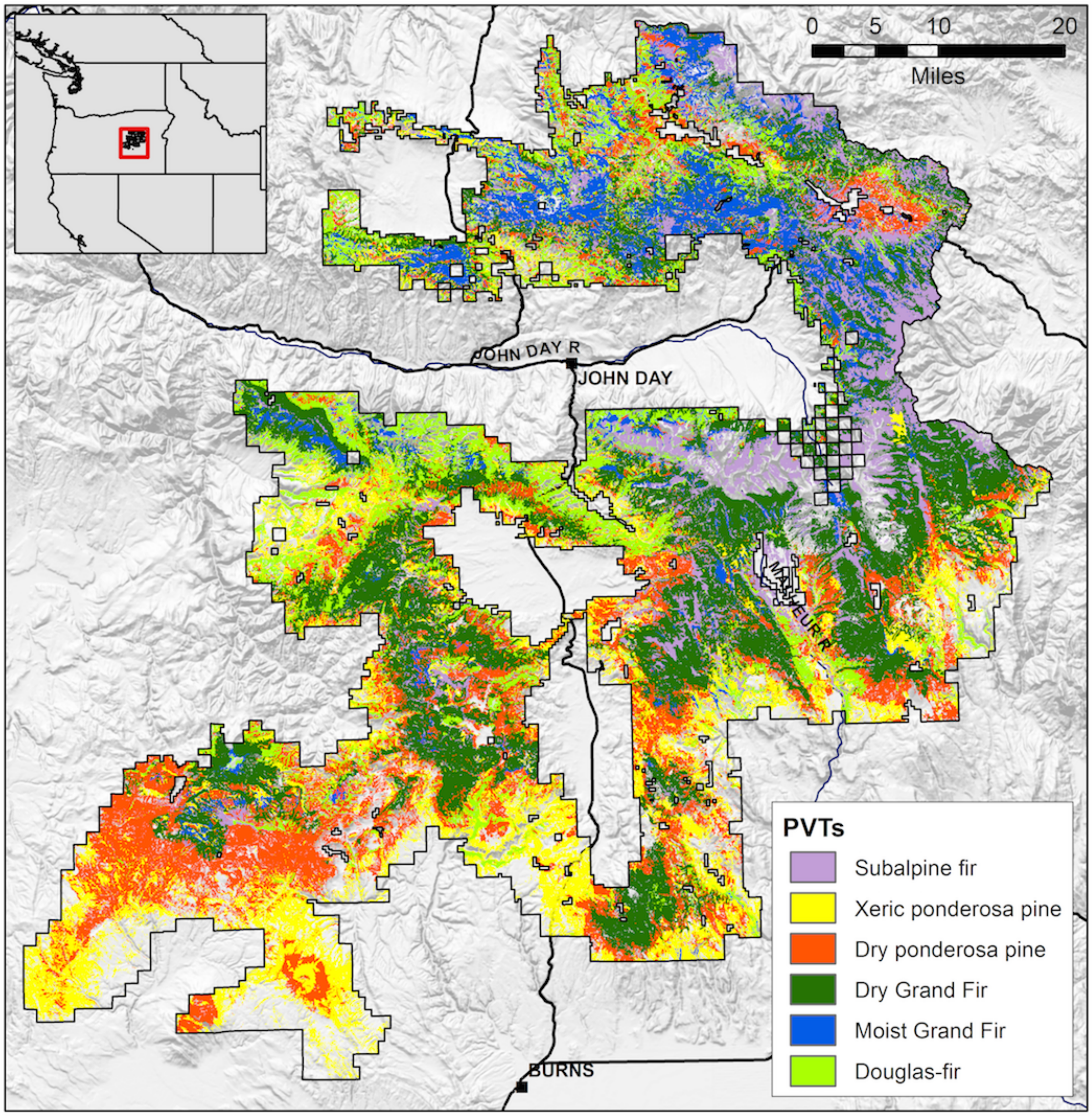

Figure 2. ILAP PVTs mapped for the Malheur National Forest.

A few other species that are not as widely distributed as ponderosa pine, Douglas-fir, and grand fir should be briefly described. Western larch is found in cooler, moister sites associated with ponderosa pine, Douglas-fir, and grand fir (Touzel 2013, McCune 2006). Subalpine fir plant associations dominated by subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) are found at high elevations and at the bottom of ravines in the Blue Mountains. These plant associations are rarely if ever priorities for silvicultural treatments and are not considered further in this review. Lodgepole pine (*Pinus contorta*) is often found in mixed conifer stands, or in cold air drainages within dry pine sites. Quaking aspen (*Populus tremuloides*) is associated with wet areas throughout eastern Oregon. Western juniper (*Juniperus occidentalis*) and mountain mahogany (*Cercocarpus ledifolius*) are found in the more open, dry margins of ponderosa pine sites or in open woodlands that form the transition from montane to arid shrubland environments (Dealy 1978, Dealy 1974).

Empirical research about mixed conifer forests

Ponderosa pine vs. mixed conifer forests

There is a large body of scientific literature that draws a sharp contrast between historical and contemporary ponderosa pine forests. Prior to extensive logging, grazing, and fire suppression activities, ponderosa pine forests are assumed to have been characterized by widely spaced older trees that allowed light to the forest floor sufficient to develop extensive herbaceous cover, which in turn provided a quick regenerating surface fuel type that supported frequent low intensity fire (Hessburg and Agee 2003, Covington and Moore 1994). Following Euro-American interventions on the landscape, ponderosa pine forests are assumed to have experienced a significant increase in forest density, a shift in composition from fire tolerant to fire intolerant species, and a build up of surface and ladder fuels that promotes high intensity fire and uncharacteristic insect attacks (Haugo et al. 2010, Spies et al. 2006, Hessburg et al. 2005a, Perry and Jing 2004, Youngblood and Coe 2004, Hemstrom 2001, Hessburg et al. 1999).

This view of frequent fire in open ponderosa pine stands has been criticized by some researchers, who believe that the importance of frequent fire in dry forests is overstated (Baker 2012, Williams and Baker 2012, Hessburg et al. 2007, Hessburg et al. 2005b, Schoennagel et al. 2004, Baker and Ehle 2001). Much recent scientific literature focuses on the mixed conifer forests that are common in mountain regions throughout western North America and describes "mixed" severity fire as the key driver of the highly variable structure observed in this forest type (Tepley and Veblen 2015, Heyerdahl et al. 2012, Bekker and Taylor 2010, Taylor 2009, Beaty and 2008, Sherriff and Veblen 2008, Beaty and Taylor 2007, Sherriff and Veblen 2007, Scholl and Taylor 2006, Taylor and Skinner 2003, Beaty and Taylor 2001, Taylor 2000, Taylor and Skinner 1998).

Mixed conifer forests are associated with mixed severity fire regimes

A low severity fire regime is defined as a fire regime in which surface fire dominates fire behavior and fire typically kills less than 20% of trees within a given area. A high severity fire regime is often characterized by crown fire and kills more than 70% of the trees in a given area. Mixed severity fire regimes are characterized by the full range of fire behavior and kill between 20-70% of trees within a given area (Agee 1993).

Mixed conifer forests are associated with mixed severity fire regimes in part because multiple species that have different responses to disturbance and potentially play different roles in post disturbance successional pathways are found in mixed conifer forests (Tepley et al. 2013, Gray et al. 2005).

Mixed conifer and mixed severity fire forests are associated with complex topography

Complex topography sharply partitions solar radiation and water availability compared to more uniform topography. More variable water availability and solar radiation results in different transpiration rates, fuel production rates, and fuel moistures which tends to result in greater species diversity and more variable disturbance effects (Tepley et al. 2014, Noss et al.

2006, Beaty and Taylor 2001, Taylor and Skinner 1998).

Complex topography also contains a higher density of features that can impede disturbance spread, including streams (Taylor 2009, Jordan et al. 2008), aspect changes (Heyerdahl 2007), and ridgelines (Hessburg 2005b). Differences in fire frequency and severity are also often found along elevational gradients (Perry et al. 2011, Heyerdahl et al. 2001, Caprio and Swetnam 1995). There is evidence that topographic control of fire behavior is not fixed, that rather than being "barriers," topographic features serve as "filters" through which fire spreads under certain climate conditions, but not others (Taylor and Skinner 2003). Topographically complex landscapes may support microclimates that are buffered from the effects of broad scale climate shifts (Moritz et al. 2011, Camp et al. 1997). Studies suggest that there may be specific thresholds at which topographical complexity no longer strongly influences the spatial pattern of fire (Falk et al. 2011, Kellogg et al. 2008, Heyerdahl et al. 2001).

Key distinguishing features of mixed conifer forests

It is unknown to what degree topographic complexity thresholds may vary by region or climate regime and robust conceptual frameworks for describing controls on structural and compositional variability in mixed conifer forests remain elusive (Halofsky et al. 2011, Perry et al. 2011, Agee 2005, Agee 1996). Hessburg (2007) describes open ponderosa pine forests as equilibrium systems in which structural and compositional features are perpetually regenerated at very fine spatial scales by frequent fire. Mixed conifer forests, in contrast, are non-equilibrium systems in which low, mixed, and high severity fire result in fine and coarse grained vegetation patches.

Beaty and Taylor (2001) suggest that mixed conifer/mixed severity forests are "self-organizing," meaning that a wide range of forest structure is maintained because previously burned patches limit the extent of fire. Climate events like drought can periodically over-ride these self-organizing traits.

It is unclear if these conceptual frameworks imply a continuum between dry pine forests to dry mixed conifer forests to moist mixed conifer forests, or whether each of these forest types is ecologically meaningful and distinct. Agee (2005) insists that mixed severity fire regimes are a discrete biophysical category distinguishable in that the heterogeneity of mixed severity fire is pronounced enough that no particular severity class consistently dominates fire perimeters. It is unknown to what degree this characterization is sensitive to how severity classes are partitioned or whether this pattern is consistent over multiple fire events in the same location.

The "mixed severity fire" concept is probably not particularly useful unless it explicitly references geographic scale. As Perry et al. (2011) write:

> What exactly is a mixed severity disturbance? At a broad regional scale all wildfire is mixed severity, a fact that limits the usefulness of such scales for ecological interpretation. Moreover, all disturbance processes exhibit heterogeneity at one spatial scale or another, which may manifest within stands, across landscapes, or in some combination of the two. Within the spectrum of possible patterns mixed severity regimes grade into low and high severity regimes without distinct thresholds or patterns. To better understand the nature of mixed-severity regimes, we must look to the ecology, the spatial geography, and the variability of fires and their effects.

Recent syntheses of scientific knowledge about mixed conifer and moist mixed conifer forests

Three existing synthesis papers—Perry et al. 2011, Hessburg et al 2016, and Stine et al. 2014—characterize successional and disturbance dynamics and suggest management implications of this knowledge.

Perry et al. 2011, "The ecology of mixed severity fire regimes in Washington, Oregon, and northern California" (Forest Ecology and Management)

Perry et al. (2011) summarize research showing significant change in mixed conifer forests throughout the dry interior west. Of particular concern is an increased density of young conifers, a shift in species composition from fire tolerant to fire intolerant trees, and, especially, a dramatic decline in large and old trees associated with past logging practices.

Perry et al. conceptualize fire in mixed conifer forests as influenced both by "bottom-up" controls, which include soils, topography, vegetation structure, and past disturbance history, as well as by "top-down" climate controls. The strength and importance of these controls vary in space and time. The authors write:

> In the more mesic northerly parts of the region, cool, moist northerly aspects may burn with mixed severity while adjoining southerly aspects burn with low severity, or both may burn with mixed severity with stand replacement fire dominating on the northerly aspects and surface fire dominating on southerly. In the more arid Klamath Mountains the opposite is seen, patchy fires dominating on south and west facing aspects and low severity fires dominating on north and east facing aspects (Taylor and Skinner, 1998). Severe weather conditions can override topographic effects to at least some degree. For example, aspect effects were weak in the Biscuit fire, perhaps because the hot, dry winds that drove the fire during its blow-up period came from the NE and drove the fire against aspects that are often considered refugia (Thompson and Spies, 2010). However, in the Megram fire (Northern California, 1999) under similar severe conditions, topography was significantly associated with fire severity patterns (Jimerson and Jones, 2003).

Perry et al. suggest that fire effects can be a function of vegetation, topography, or fire history, e.g., time since fire. The distribution of patches following fire may strongly influence fire behavior. They believe that a "shifting mosaic of patches" creates a self-reinforcing community structure.

Hessburg et al. 2016, "Management of mixed-severity fire regime forests in Oregon, Washington, and Northern California" (Forest Ecology and Management)

Hessburg et al. (2016) provide an extensive review of mixed severity fire research. Their paper proposes nine strategies for managing mixed severity fire forests. The authors emphasize the variety of forest structure and composition that results from mixed severity fire disturbance, and suggest that "pyrodiversity" is characteristic of mixed severity fire regimes. They believe past management practices have simplified forest structure and composition and that restoring diverse fire effects is the key to restoring appropriate landscape-scale forest function. They encourage variable density mechanical thinning and fire that creates a heterogeneous landscape of different sized patches of both young early successional forests, middle-aged forests, and older closed canopy forests. They believe that topography was a key influence on fire effects and should serve as a template for restoration efforts. They write:

> South-facing aspects and ridgetops and lower montane settings were home to open canopy forests, and fairly large areas of open woodlands, shrublands, and grasslands (Fig. 3). These were primarily maintained by

> frequent fires – low to mixed-severity in the forests and woodlands, and high-severity in the shrub- and grasslands. North-facing slopes and valley bottoms and upper montane settings were home to closed-canopy, multi-layered forests, but also shrublands and meadows, and these were primarily maintained by moderately frequent to infrequent mixed- and high severity fires (Fig. 4). Mid-montane settings were a complex mixture of the two preceding examples and both open and closed canopy forests were present.

The nine strategies recommended by the authors are:

Strategy #1: Landscape-level approaches to restoring pyrodiversity. Managers should increase pyrodiversity with strategically placed fuel reduction actions. In most cases, multiple entries will be required to support desired future fire effects.

Strategy #2: Protecting and restoring large and old, early successional tree abundance. Protecting and restoring old trees is important because these trees tend to be highly resistant to fire. As importantly, large old trees shade stands and limit understory regeneration. Protection and restoration of old trees, at a minimum, involves removal of young trees in their immediate vicinity. Landscape assessments to identify opportunities for protection and enhancement of old tree structure is recommended.

Strategy #3: Expanding use of prescribed and wildfires to restructure forests. It is unlikely that prescribed fire will be implemented at scales necessary to restore forests. They authors believe that managed wildfire is a logical choice for reducing surface fuels to levels consistent with restoration objectives.

Strategy #4: Using topography to tailor restorative treatments to the landscape. The authors believe that topography is the key to understanding variation in forest structure, composition, and characteristic disturbance patterns and recommend tailoring restoration prescriptions to specific topographic features. They write:

> A key consideration in development of restoration prescriptions is the topography of the landscapes in question. Topography strongly influences plant communities, site productivity, fire behavior, and fire severity patterns over large landscapes (Weatherspoon and Skinner, 1995; Jimerson and Jones, 2003; Lydersen and North, 2012; Hessburg et al., 2015). For example, a typical current pattern in California is for more severe fire effects to be manifested in mid- to upper-slope positions on south and west facing slopes, and less severe effects in lower slope positions, and on north- and east-facing slopes (Weatherspoon and Skinner, 1995; Taylor and Skinner, 1998; Skinner et al., 2006; Holden et al., 2009; North et al., 2009; Lydersen and North, 2012; Harris and Taylor, 2015). However, the strength of topographic effects varies by ecoregion, because of unique influences and interactions among geology, geomorphology, and prevailing wind and weather patterns (Habeck, 1976; Neilson, 1986, 1995; Pearson and Dawson, 2003; Collins and Skinner, 2014). Nonetheless, the effects of topography on severity patterns generally appear to be manifest in a gradient: the strongest effects are in steep, complex, rugged landscapes, and effects lessen as relief becomes gentler (Collins and Skinner, 2014).

Strategy #5: Rehabilitating plantations. North aspects and valley bottoms historically supported closed canopy forests and south aspects and ridgetops supported more open forests. Tree plantations have decoupled forest structure from these topographic influences. The authors recommend variable density thinning to accelerate the development of larger fire-resistant trees. Treating the surface fuels that result from thinning will be essential to restoring plantations.

Strategy #6: Creating and maintaining successional heterogeneity. Most mixed severity fire forests historically had tree densities well below site carrying capacity. Forest resilience in mixed severity fire forests is conferred in part by open areas and diverse patch structure. Open areas support life forms (e.g., graminoids) with low flame lengths and energy release during fire events. Restoration involves creating heterogeneity of patch structure including "uneven-aged and irregularly patchy mosaics of individual trees, tree clumps ranging from 2 to 20 or more trees, comparably sized tree gaps, and even larger openings."

Strategy #7: Integrating restoration with late-successional forest habitat needs. This section deals largely with balancing forest resiliency goals with maintaining habitat for the northern spotted owl. But the authors also describe research in the Sierra Nevadas that indicates that fuel reduction treatments are consistent with maintaining habitat for Pacific fisher.

Strategy #8: Mitigating threats from climate change, forest insects, and pathogens. The authors state that stand measures such as basal area and mean DBH are often adequate for measuring resilience goals in even-aged stands, but are inappropriate for multi-aged stands. The authors urge relative measures of stand density like stand density index (SDI), but caution that additional research is needed to develop SDI targets for different forest types under both current and future climate regimes. The difference between potential evapotranspiration in stands and actual evapotranspiration is a good predictor of appropriate forest structure and potential fire effects. Spatial pattern is important to adapting to climate change and existing methodologies like the individuals, clumps, and openings (ICO) procedure (Churchill et al. 2013) can be used to create resilient forest spatial pattern.

Strategy #9: Creating and maintaining early-successional forests. Mixed severity forests are a patchy mosaic of different successional stages. Open areas with light-demanding native shrubs, forbs, and grasses are an important component of landscape scale diversity. Early successional patches following high severity fire that frequently reburn can be expected.

Throughout their paper, the authors urge managers to avoid one sized fits all management strategies. They write:

> The mixed-severity fire bin is quite large, ecologically diverse, and not very useful as a category to guide management and policy. Management for a given set of ecological objectives should reflect the uniqueness of place, including what is known about historical patterns, what is predicted for future climates, and the stressors that exist or can be expected in the future.

Stine et al. 2014, "The Ecology and Management of Moist Mixed-Conifer Forests in Eastern Oregon and Washington: a Synthesis of the Relevant Biophysical Science and Implications for Future Land Management" (Forest Service General Technical Report)

The topic of Stine et al. 2014 is directly inline with the BMFP's interest in management of moist mixed conifer forests. This paper provides a thorough background in ecological theory relevant to moist mixed conifer dynamics, but provides only general advice about management. The authors simultaneously suggest that moist mixed conifer forests are very diverse but that they were structurally and compositionally similar to dry mixed conifer forests. They write:

> The MMC forest landscape included a wide range of cover type and structural class combinations that would derive from a mixture of low- to mixed severity fires with lesser amounts of high-severity fire in the mix (e.g., see app. 3, Hessburg et al. 2007, Perry et al. 2011). Recent studies in MMC forest in central Oregon suggest that the amount of low- and mixed-severity fire and forest structure (e.g., density) and tree layer composition in pre-Euro-American times may not have differed much from nearby dry mixed-conifer PVT (Hagmann et al. 2013, Merschel 2012).

The authors caution that much more empirical research is needed to understand variability in fire effects and the relationship between fire effects and topography in this forest type. They suggest that most fires in moist mixed conifer forests of the inland Pacific Northwest were small or medium sized (2 to 12,000 acres). They state that the prevalence of small and medium sized fires in moist mixed conifer forests resulted in a rich mosaic of successional classes, including areas that were isolated from fire. Although they believe that the severity of fires differed,

> Low-severity fires within MMC forest may have been more common in drier warmer ecoregions with less topographic relief. High-severity fires within MMC forests appear to be more common in cooler and wetter ecoregions and areas with stronger topographic relief. Low-severity fires occurred commonly in moist forests where they were intermixed with dry forests; high-severity fires in moist forests may have been more common where moist forests were intermixed with wet and subalpine forests.

Because moist mixed conifer forests experience diverse fire effects, they also experience diverse successional pathways following fire: "Some old forests were the result of repeated low-intensity fire that maintained multicohort single-stratum condition of fire-tolerant species, while others developed to complex, multiple-strata structures that occasionally experienced mixed- or high-severity disturbances."

Diversity in response to fire means that managers have many options and trying to recreate a particular developmental stage in all cases is not appropriate. Nevertheless, the authors stress the need to protect and enhance the survivability of older trees in all moist mixed conifer stands.

The author's recommend creating spatial variability both by creating landscape scale variation in patch sizes and variable tree clump and gap size distribution within and among patches. Like Hessburg (who is a co-author), they believe that topography offers a template to plan treatments around. They do not believe that dense, multi-layered forests can persist except in topographic positions where they escape disturbance. They believe that riparian areas likely experienced similar disturbance dynamics as surrounding upland areas. Finally, they recommend against diameter limits because they do not give managers flexibility accomplish ecological objectives.

Empirical research about mixed conifer forests in eastern Oregon

There is a sparse but growing body of research that describes variation in historical structure and composition among diverse forest types of eastern Oregon. Perry et al. (2004) used dendroecological methods to demonstrate that forests within the ponderosa pine and dry mixed conifer zones within a study area on the east slope of the Cascades in the Deschutes National Forest had experienced a significant increase in density and species composition shifts over time. 86% of systematically sampled trees were less than 101 years old. 72% of trees older than 150 years were ponderosa pine, while 83% of trees younger than 101 years were grand fir or lodgepole pine.

Merschel et al.'s (2014) work extends dendroecological investigations into a broad range of forest types throughout the Deschutes and Ochoco National Forest. They distinguish four forest types: The Ponderosa Pine group historically consisted entirely or almost entirely of ponderosa pine trees. The Recent Douglas-fir group was historically dominated by ponderosa pine but today includes a number of young and occasionally old Douglas-fir trees. The Recent Grand Fir group is dominated by ponderosa pine but has extensive younger grand fir cohorts. The Persistent Shade Tolerant type is also dominated by ponderosa pine along with varying degrees of codominant grand fir, Douglas-fir, and western larch.

Reconstructions of late 19th century structure and composition using tree cores from live trees and estimates of the age of stumps and dead trees demonstrated that all four forest groups experienced an increase in density between 1890 and 2012. The degree of forest change was strongly correlated to temperature and precipitation gradients, with a higher degree of compositional change noted in the warm-dry Recent Douglas-fir and Recent Grand Fir groups and a lower degree of change in the warmest-driest portion of the Ponderosa Pine group and the cooler and moister Persistent Shade Tolerant group.

Hagmann et al. (2013 and 2014) report historical forest structure and composition recorded by 1920s timber inventories on the Klamath Indian Reservation (now part of the Fremont-Winema National Forest) and the Warm Springs Indian Reservation (north of the Deschutes National Forest). Inventories encompassed a wide range of forest types from xeric pine to moist mixed conifer. In both study areas and in all forest types, they found significantly lower historical forest densities and a higher proportion of ponderosa pine and large trees than currently present. 1920s stand basal areas were only marginally higher in moister sites and structure and composition of ponderosa pine and mixed conifer sites were quite similar. They hypothesize that frequent fire across a range of forest types tended to equalize forest density across the landscape.

Heyerdahl et al. (2008, 2002, and 2001) provide fire histories of four sites spanning the length of the Blue Mountains from near the Washington border to the southern Blue Mountains. They investigated both bottom-up (local differences in topography) and top-down (climate) controls on fire pattern by contrasting within and between study site fire variation. Fire frequency and seasonality differed between northern and southern study sites, and between mesic sites compared to dry sites, providing evidence of a top-down control on fire regimes. Fire pattern differed within sites, providing evidence of bottom-up topographic controls, except at the southernmost site located within the MNF.

Perhaps the most frequently cited and influential study of historical eastern Oregon forest dynamics is Hessburg et al.’s 2007 study of patch dynamics using historical (circa 1930s) photography in 38 randomly selected subwatersheds in eastern Oregon and eastern Washington (none of these watersheds were located in the southern Blue Mountains). Hessburg identified “highly variable mixed severity fire as the prevailing fire process” that resulted in a “complex patchwork of fire regimes and patch sizes.”

Baker and Williams 2015, Williams and Baker 2012, and Baker 2012 use Government Land Office (GLO) records from the late 19th century to infer historical density, composition, and characteristic disturbance processes across ~300-400,000 ha study areas on the east slope of the Cascades and the northern Blue Mountains. They claim that less than 40% of the Blue Mountains study area and less than 24% of the east Cascades study area consisted of low-density, pine dominated forests that experienced frequent fire at the end of the 19th century. Other studies demonstrate that Baker and Williams consistently overestimate forest density using information from GLO surveys and their work has been criticized for unsupported inferences about fire severity (Stephens et al. 2015, Hagmann et al. 2014, Fulé et al. 2014).

Conclusions

Moist mixed conifer forests are a subset of mixed conifer forests. The BMFP needs to determine:

- What forests on the MNF are moist mixed conifer forests.
- How moist mixed conifer forests differ from other forest types.
- If management of moist mixed conifer should differ from management of other forest types, and if so, how?

Existing forest typologies may be useful for answering these questions. For instance, ILAP maps of moist grand fir or existing models of the cool/moist plant association group (PAG) could be considered moist mixed conifer.

With the exception of Baker's work, there is a consensus in the scientific literature that mixed conifer forests are significant departed from historical conditions. Although moist mixed conifer forests are not clearly defined by the scientific literature, with the exception of Baker's work, there is nothing in the literature that suggests that moister and more productive mixed conifer sites are not also departed from historical conditions and should not also be considered for active management.

Much of the scientific literature indicates that both mixed conifer and moist mixed conifer forests are strongly influenced by mixed severity fire that creates a mosaic of structurally and compositionally diverse patches of different sizes. The BMFP should seek to determine to what extent moist mixed conifer forests on the MNF were influenced, or will be influenced in the future, by low, mixed or high severity fire and whether coherent patch dynamics are a desired future condition.

Much of the scientific literature indicates that complex topography plays a strong role in shaping moist mixed conifer forests and mixed severity fire regimes. The BMFP should seek to determine to what extent topography influences moist mixed conifer forests and to what extent topography can be used to guide management.

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