REINTRODUCING FIRE IN PONDEROSA PINE-FIR FORESTS AFTER A CENTURY OF FIRE EXCLUSION

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ABSTRACT

Elimination of the historic pattern of frequent low-intensity fires in Inland West ponderosa pine (*Pinus ponderosa*)-fir (*Abies* spp. and *Pseudotsuga menziesii*) forests has contributed to major ecological disruptions. Today most stands contain thickets of small trees (often firs) and are experiencing insect and disease epidemics as well as catastrophic wildfires. Restoring sustainable forest conditions is complicated by fuel accumulation, poor tree vigor, and profound changes in stand structure.

Existing conditions in many pine-fir forests require partial cutting to: (1) remove sapling and pole size ladder fuels; (2) manipulate species composition to favor ponderosa pine; and (3) reduce overstory density to promote regeneration. Focused cutting allows controlled removal of trees in terms of number, size, species, and location, particularly those that cannot be targeted for removal in a prescribed burn. Harvest cutting also allows trees to be used for forest products, often generating enough income to pay for needed restoration treatments.

Prescribed fire should be introduced after the initial cutting as a more ecologically based disturbance to promote restoration. Properly applied fire removes undesirable small trees, reduces the fuel hazard accentuated by cutting, stimulates herbaceous and shrubby vegetation, and creates nutrient-rich mineral seedbeds favored for seral species regeneration. Fire should be reapplied periodically to manipulate living and dead biomass, and help maintain healthy, resilient forest conditions.

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INTRODUCTION

Historically, the ponderosa pine (*Pinus ponderosa*) forest type covered vast expanses of the western United States. Even after 60 to 80 years of generally successful fire suppression, the pine type occupied an estimated 27 million acres (USDA 1982). Today, the pine-fir forests (*Pinus* sp., *Abies* spp., *Pseudotsuga menziesii*) of the American West are a primary focus of concern about declining forest health (Mutch et al. 1993, American Forests 1995, Phillips 1995). Elimination of the historic pattern of frequent low-intensity fires in these forests has contributed to ecological disruptions that underlie current forest health problems. Until the early 1900's, open stands dominated by large fire-resistant pines were typical. Pines were accompanied in some areas or localities by other fire-dependent species such as western larch (*Larix occidentalis*), lodgepole pine (*P. contorta* var. *latifolia*), Jeffrey pine (*P. jeffreyi*), sugar pine (*P. lambertiana*), black oak (*Quercus kelloggii*), or giant sequoia (*Sequoiadendron giganteum*). In contrast, many current stands support dense thickets of small trees dominated by more shade-tolerant species such as Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), grand fir (*Abies grandis*), white fir (*A. concolor*), and incense-cedar (*Calocedrus decurrens*). As a result of this changed composition, density, and structure, today's stands are experiencing epidemics of insects and disease, as well as high-intensity catastrophic wildfires.

Restoring historic forest conditions is often complicated by accumulations of duff, downed woody material, and understory conifer or "ladder" fuels; poor tree vigor, profound changes in stand structure, and a compositional shift toward dominance by late-successional firs. Returning fire under these conditions could severely injure or kill the overstory pines.

Studies of historical conditions in pine-fir forests have determined that frequent low-intensity fires (typically 7- to 40-year intervals) over the past few millenia were critical for maintaining open stands dominated by pine and associated seral tree and undergrowth species (Arno 1988, Swetnam 1993). Many stands were self-perpetuating in uneven-aged structures due to scattered mortality of individual trees (or small groups) from lightning or bark beetles. The resulting openings were swept by frequent light fires that favored establishment of the most fire-resistant species (White 1985, Arno et al. 1995).

In the late 1800's and early 1900's dramatic changes occurred in many of these forests. Logging selectively removed most of the large pines (and larch, if present), grazing often removed most of the grassy fuels, and fire suppression interrupted the historic fire regime. An abundance of saplings (pine, and then increasingly firs) became established and by the mid-1900's developed into dense stands and thickets of small trees (Weaver 1943, Weaver 1967). Numbers of trees and basal areas (a rough index of tree biomass) per acre increased markedly. By the late 1900's high stand densities had suppressed growth of both small and large trees, contributing to insect and disease epidemics covering millions of acres (American Forests 1992, Mutch et al. 1993).

Similar trends also occurred in unlogged old-growth stands where fire had been excluded (Arno et al. 1995). Increasing dominance by shade-tolerant trees (primarily firs) produced stands differing greatly in composition and structure compared to historic conditions. These forests generally occupy semi-arid environments, and are highly vulnerable to drought and pests when they are overstocked.

Ironically, exclusion of low-intensity fires virtually assures the eventual occurrence of high-intensity fires that kill most trees (including large ones), and may impact soils, watershed, and wildlife habitat values. In 1994, roughly half of the 3 million acres that burned in the western United States was in ponderosa pine forests (pine and pine-fir types), much of it charred by stand-replacement fires. Resulting postfire conditions were even further displaced from historic conditions. Fifteen to 30 years after such severe fires a large accumulation of dead fuels and a dense stand of shrubs and small trees often develops. This postfire condition can burn even more severely in a second wildfire or double burn (Wellner 1970, Barrett and Arno 1982).

As a result of ecological and economic evaluations, natural resource managers are motivated to return ponderosa pine-fir forests to more historical and sustainable structures. Restoration strategies involve use of: 1) silvicultural cutting methods to reduce stand densities and favor retention of desirable trees; 2) fuel removal treatments; and 3) various prescribed burning applications. After these restoration treatments have been implemented, it should be possible to maintain ponderosa pine-fir forests in more sustainable structures using periodic prescribed burning, with or without cutting treatments, depending on management objectives.

Silvicultural Applications

A primary goal of restoration treatments in ponderosa pine-fir forests is to create more open stand structures, thereby increasing tree vigor and reducing vulnerability to insects, disease, and wildfire. An additional goal in some stands is to manipulate existing species composition and site conditions to favor regeneration of ponderosa pine and other shade-intolerant species.

Returning fire into dense stands or those having significant ladder fuels could fatally damage overstory trees. For these reasons, restoring ponderosa pine forests to more healthy and sustainable conditions will generally require some kind of silvicultural cutting. A primary advantage of cutting is that it allows for the controlled removal of specific trees in terms of number, size, species, and location. Cutting trees also allows them to be used for forest products, generating income to offset treatment costs. This is an especially important factor if fire is to be introduced over extensive areas.

Ponderosa pine-fir stands that need some kind of restoration treatment represent a range of conditions. However, two conditions warrant special attention: 1) overstocked second-growth stands, because of their prevalence; and 2) relict old-growth stands which now have dense understories, because of their scarcity and ecological significance.

Before cutting treatments are initiated, general restoration goals need to be established in the form of a target stand or desired future condition. Historical descriptions, old photos, forest inventory records, and field plot data can be collected and analyzed to help determine initial targets for restoration. For example, research plot data can provide density targets for thinning (to improve vigor) and for shelterwood and selection cutting (to secure regeneration) in second-growth ponderosa pine stands (Barrett 1979, Fiedler et al. 1988).

For old-growth forests, early written accounts provide qualitative descriptions of the structure and composition of stands in the ponderosa pine type. For example, Weidman (1921) and Meyer (1934) report that virgin stands in this type were primarily ponderosa pine and many-aged. Tree-ring analyses (Steele and Fiedler 1996) and reconstructions of age-class structure (Arno et al. 1995) in old-growth stands provide a quantitative complement to these earlier descriptive accounts.

Together, these sources provide a framework for establishing density, structural, and species composition goals for overstocked second-growth and declining old-growth stands. They also provide a basis for developing restoration treatments to initiate pine regeneration and guide succession toward the appropriate desired future condition.

Overstocked Second-growth Stands

Density reduction is the primary treatment need in overstocked second-growth stands which commonly range from 120 to 200+ square feet of basal area per acre (28 to 46+ square meters per hectare). Many such stands are still primarily ponderosa pine in the overstory, and young enough to provide a reasonable opportunity for successful restoration. Symptoms of declining vigor in these stands include narrow growth rings in recent years, and scattered pockets of mortality from bark beetle (*Dendroctonus ponderosae*).

Density targets following treatment in even-aged or irregular even-aged stands range from 40 to 80 square feet of reserve basal area per acre (9 to 18 square meters per hectare) (Fiedler 1996). This basal area density range is equivalent to about 120 to 240 8-inch trees per acre (296 to 592 20-centimeter trees per hectare), 50 to 100 12-inch trees per acre (124 to 248 30-centimeter trees per hectare), or 30 to 60 16-inch trees per acre (74 to 148 40-centimeter trees per hectare). Post-treatment basal area targets will typically be on the lower end of this range on drier sites or where regeneration of ponderosa pine is a primary treatment goal, and toward the upper end on better sites, in areas exposed to wind, or where the goal is growth enhancement of reserve trees, rather than regeneration.

The initial cutting leaves the largest and best pines to provide site protection and a well-distributed seed source. While this cutting resembles a shelterwood, it is the first step in a long-term restoration effort to develop uneven-aged stand structures, so is best described as the initial cut in the implementation of the selection system. Future cuttings are planned at 20- to 30-year intervals, with the purpose of reducing stand density and regenerating pine in newly created openings following each entry. The long-term goal is to create and maintain open multi-aged ponderosa pine stands that are resistant to surface fire, and to allow a few overstory trees to reach a very large size, die, and become snags.

Primary goals of the initial cutting in overstocked second-growth are to reduce inter-tree competition and decrease the potential for crown fires. Harvest cutting which leaves 10- to 30-foot (3- to 9-meter) gaps between crowns greatly reduces this potential. If present in large quantities, sapling and small pole "ladder" fuels should also be reduced to limit the potential for surface fires to spread into overstory canopies. Although markets are sporadic, small trees can sometimes be utilized for products (e.g., studs, posts, poles, pulpwood, or firewood). Utilization can help offset the costs of dealing with small trees in some other way, such as slashing and burning on-site. Alternatively, sapling-sized trees can usually be killed with a prescribed broadcast burn following harvest. On sites with large numbers of unwanted understory trees, cutting and hand-pile burning during cool, damp weather may be necessary to protect the residual overstory from fire injury. This treatment would not replace prescribed broadcast burning, but would precede it. Although these procedures can be costly, they are often necessary to offset decades of uncontrolled forest growth and fuel buildup. However, treating the small-tree component is just one part of the comprehensive prescription. Removal of larger trees to reduce density and manipulate species composition in the overstory of overstocked second-growth stands generally results in positive net product revenue for the overall treatment (Fiedler et al. 1997).

Overstocked Old-Growth Stands

The senescent condition of many trees in old-growth stands makes prospects for restoration uncertain. Furthermore, there are no management guidelines to draw on in terms of density targets for restoration. However, recent old-growth reconstructions back to the turn-of-the-century provide a reasonable basis from which to develop post-treatment targets. Work by Covington and Moore (1994) in the Southwest, and Habeck (1994) and Arno et al. (1995) in the Northwest, indicates that pre-1900 stands typically had basal area densities <100 square feet per acre (23 square meters per hectare), whereas many existing stands considerably exceed this density level.

The initial harvest entry into old-growth stands typically involves two kinds of cuttings. Selection cutting in the overstory is aimed at reducing stand basal area to secure regeneration of ponderosa pine, and reducing the composition of Douglas-fir and true firs. Thinning is often needed as well to reduce the density of saplings and poles in the understory. The existing small-tree component is typically dominated by firs, which are especially susceptible to fire, root disease, and defoliation by western spruce budworm (*Choristeneura occidentalis*). Ponderosa pine seedlings and saplings are also occasionally found in the understory. However, because these shade-intolerant trees are growing under a canopy, they are typically etiolated, and therefore do not provide a manageable stand component. Small, suppressed ponderosa pine are commonly infected with comandra rust (*Cronartium comandrae*), as well.

While reserve basal areas of 40 to 60 square feet per acre (9 to 13.5 square meters per hectare) are recommended for young-growth, uneven-aged stands to ensure regeneration of shade-intolerant ponderosa pine (Fiedler et al. 1988), somewhat higher reserve densities can be maintained in old-growth stands. Site utilization is less per square foot (meter) of basal area in larger, older trees than in smaller, younger trees because of the lower ratio of sapwood area to total basal area (Fiedler and Cully 1995, Arno et al. 1997). It follows that stands with a considerable proportion of their basal area in large trees will provide a lesser draw on site resources than stands with the same total density, but with a greater proportion of basal area in smaller trees. For this reason, Stand Density Index (SDI; Reineke 1933) is likely superior to basal area as a measure of density for uneven-aged stands or old-growth stands being considered for restoration, because it adjusts for tree size.

Experience has shown that leave-tree marking results in a superior reserve stand, because the marker focuses on the most desirable trees for retention, at an appropriate spacing. With cut-tree marking, the residual stand is simply comprised of the trees that were not cut (i.e., the leftovers). The reserve basal area target, the most important element in the silvicultural prescription, can typically be achieved in the first entry. Scattered small openings are created in the marking process to promote regeneration of ponderosa pine. In contrast to the traditional marking approach aimed at increasing the uniformity of spacing, occasional groups of old-growth trees are left intact (or nearly so) to maintain the inherently clumpy nature of these stands.

Similar cuttings are planned at 20- to 30-year intervals into the future. The long-term objective is to maintain the old-growth character, perpetuate ponderosa pine, restore historic levels of vigor, and reduce susceptibility to damaging insects and fire.

Not all restoration needs can be met by silvicultural cutting; however, some needs are best addressed (or can only be addressed) by cutting. Furthermore, cutting will generally be the first treatment needed in stands with high density or significant ladder fuels. Silvicultural cuttings followed by compatible prescribed burning treatments comprise an integrated system for initiating the first phase of restoration. Because stands are dynamic, cutting will likely be needed at various intervals into the future to reduce overstory density, create openings to favor regeneration of ponderosa pine, and provide conditions appropriate for prescribed burning.

Finally, it is critical that pretreatment conditions and prescribed cutting treatments be documented, and that the target stand or desired future condition be described in terms of density, structure, and species composition. Only then can progress toward the target be measured and interpreted, and future treatments be altered or refined to better meet long-term restoration objectives.

Prescribed Fire Applications

Prescribed fire and silviculture are complementary parts of an overall restoration plan, because each phase of a restoration effort can only address certain aspects of the stand density or structure or composition problem. The decision to include fire in the overall restoration prescription for a particular site is best made in the process of developing the silvicultural prescription.

Specific fire effects objectives should be established in concert with the silvicultural objectives, so that the proper fire prescription can be developed and applied. There are four common objectives of prescribed burning, several or all of which may be desired effects of a given reintroduction. The first and most common objective is to reduce high levels of accumulated organic matter to lessen the potential for severe wildfire (Mutch et al. 1993). A dilemma arises in that organic matter is an important carbon and inorganic nutrient reserve. However, it is also a forest fuel, and in an environment with a high probability of wildfire because of climate and fuel type, it should be maintained below some hazard threshold. Applied fire is often the most efficient means of reducing and maintaining such fuels at low hazard levels.

A second fire effects objective is to reduce the typically high numbers of seedlings and saplings that contribute to the wildfire hazard, but also impair forest health through competition for limited resources (Habeck 1994). Regeneration cutting and thinning are effective for removing larger trees, but cutting treatments are not practical for eliminating hundreds or thousands of small trees per acre. Prescribed fire is an efficient means of removing most of this undesirable understory conifer layer. However, cutting of sapling or pole-sized trees may be required before burning to break up the continuity of fuels between the small-tree layer and overstory trees. Some trade-offs inevitably occur with the loss of sapling thickets that have value as hiding and thermal cover for wildlife.

A third objective of burning is the reinvigoration of shrubs and herbaceous plants (Wright 1978). These plants were once significant components of the forest undergrowth but have become stressed because of overmaturity and competition with high numbers of trees. After the competition for soil resources and light has been reduced with thinning or regeneration cutting, these plants typically sprout vigorously following top killing and litter removal by fire. Many plants will not respond to either burning or topkilling alone-both are required. Wildlife forage values usually improve dramatically after burning.

A fourth fire effects objective is partial exposure of a mineral soil seedbed, which is generally required for natural regeneration of seral species (Harrington and Kelsey 1979). Mechanical scarification is also an effective means of exposing mineral soil, but this approach displaces the organic layer and may cause compaction. Another advantage of fire for treating seedbeds is that combustion mineralizes organically bound nutrients, often leading to an increase in their availability.

CONCLUSIONS

Fire is a valuable tool for restoring more historic conditions and processes to ponderosa pine-fir forests that previously depended on fire to recycle fuels, control stand density, and maintain seral species compositions. Effective reintroduction of fire under existing density and structural conditions is virtually impossible. Even after initial silvicultural treatment it is challenging. It takes both knowledge and experience to develop and carry out a fire application plan that achieves interrelated and sometimes conflicting objectives (Kilgore and Curtis 1987). For example, while achieving the objective of reducing wildfire hazard, too much fuel may be consumed too quickly, severely injuring already stressed trees (Harrington and Sackett 1992). Conversely, if fire is reintroduced too cautiously, much effort and expense yields little in the way of accomplishment.

The ecological need for reintroducing fire on the landscape is both immediate and immense. Within an operability framework based on accessibility and economics, priorities for treatment should be based on ecological significance (e.g., overstocked stands with stressed old-growth trees), or the potential threat to people or structures (e.g., suburban-wildland interface areas). Given this framework, coordinated silvicultural cutting and prescribed burning treatments provide an integrated system for controlled reintroduction of fire that can also accomplish treatment objectives.

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