

Alternative Ponderosa Pine Restoration Treatments in the Western United States

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Abstract—Compared to presettlement times, many ponderosa pine forests of the United States are now more dense and have greater quantities of fuels. Widespread treatments are needed in these forests to restore ecological integrity and to reduce the risk of uncharacteristically severe fires. Among possible restorative treatments, however, the appropriate balance among cuttings, mechanical fuel treatments, and prescribed fire is often unclear. Resource managers need better information on the effects of alternative practices such as fire and mechanical/manual “fire surrogates.” A group of scientists and land managers has designed an integrated national network of long-term research sites to address this need, with support from the U.S. Joint Fire Science Program. Seven of the 11 sites in the network are in ponderosa pine-dominated Western coniferous forests with low-severity natural fire regimes. The study will assess a wide range of ecological and economic consequences of four alternative restoration treatments: (1) cuttings and mechanical fuel treatments alone; (2) prescribed fire alone; (3) a combination of cuttings, mechanical fuel treatments, and prescribed fire; and (4) untreated controls. The study is long term, with treatments repeated over time. Each site will have at least three replications of the four treatments, applied to treatment units of at least 14 ha in size (including buffer). Where feasible, the replicated units will be supplemented by unreplicated large areas treated similarly to study larger scale ecological and operational issues. A comprehensive set of core variables will be measured at each site, including aspects of fire behavior and fuels, vegetation, wildlife, entomology, pathology, soils, and economics. The core design will allow interdisciplinary analysis at both the site and multisite scales. Investigators at each site will also have the freedom to add treatments and/or response variables to the core design as dictated by local interests, available resources, and expertise.

Introduction

Restoration has become necessary in many ponderosa pine forests of the Western United States. Current forests are denser, more spatially uniform, have more small trees

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and fewer large trees, and have greater quantities of forest fuels than did their presettlement counterparts (Bonnicksen and Stone 1982; Chang 1996; Parker 1984; Parsons and DeBenedetti 1979). Causes of these changes include fire suppression, past livestock grazing and timber harvests, and changes in climate (Arno and others 1997; Parsons and DeBenedetti 1979; Skinner and Chang 1996). These changes have caused a deterioration in forest ecosystem integrity, and an increased probability of large, high-severity wildfires (Dahms and Geils 1997; Patton-Mallory 1997; Stephens 1998; Weatherspoon and Skinner 1996). Reports from the Blue Mountains of Oregon and Washington (Everett 1993), the Columbia River Basin (Quigley and Cole 1997), and the Sierra Nevada Ecosystem Project (SNEP 1996; Weatherspoon and Skinner 1996) have highlighted these problems and have explained the need for large-scale and strategically located thinning (especially of small trees), fuel treatment, and use of prescribed fire. A recent speech by Interior Secretary Babbitt (2000) pointed out that similar problems and the need for similar solutions are now being acknowledged by national policymakers.

The need for widespread use of restorative management practices is clear (for example, Hardy and Arno 1996). Less clear, however, is the appropriate balance among cuttings, mechanical fuel treatments, and prescribed fire (SNEP 1996; Stephens 1998; van Wagtenonk 1996; Weatherspoon 1996). Economic and technical feasibility of various treatments, as well as social and political acceptability, are important considerations in managers' decisions about tools to use. To achieve goals for ecosystem integrity and sustainability, however, we also need better information about the ecological consequences and tradeoffs of alternative restoration practices. The frequent, low- to moderate-severity fires that characterized presettlement disturbance regimes in many of our ponderosa pine forests influenced not only forest structure, composition, and fuels, but also a wide range of other ecosystem components and processes (Agee 1993; Chang 1996). What components or processes are changed or lost, and with what effects, if “fire surrogates” such as cuttings and mechanical fuel treatments are used instead of fire, or in combination with fire? While there is considerable information on the costs and ecological effects of both prescribed fire and thinning treatments in Western forest ecosystems (for example, see Walsted and others 1990), no studies have directly compared these two methods in the same place and at the same time.

Long-term, interdisciplinary research is needed to quantify and compare the consequences and tradeoffs of alternative fire and fire surrogate treatments. Ecological and economic aspects must be included as integral components.

The research should be experimental, rather than retrospective or correlative, to permit stronger inferences about cause-and-effect relationships. Through this research it will be possible to determine which ecosystem functions of fire can be emulated by other means, which may be irreplaceable, and how much restoration will cost society. Such an effort must be collaborative, involving land managers, researchers, and interested public.

A team of scientists and land managers has designed an integrated national network of long-term research sites to address this need, with support from the USDI/USDA Joint Fire Science Program ([http://www.nifc.gov/joint_fire_sci/](http://www.nifc.gov/joint_fire_sci/index.html)

[index.html](http://www.nifc.gov/joint_fire_sci/index.html)). The steering committee (see Acknowledgments) and other participants in this national Fire-Fire Surrogate (FFS) study represent a number of Federal and state agencies, universities, and private entities, as well as a wide range of disciplines and geographic regions. The 5-year study now funded by the Joint Fire Science Program, applies a common experimental design over 13 sites nationally, with each site representing a forest that is at risk of uncharacteristically severe wildfire (Weatherspoon 2000). This paper focuses on the work as applied to eight of the sites in the Western United States, all dominated by ponderosa pine (fig. 1).

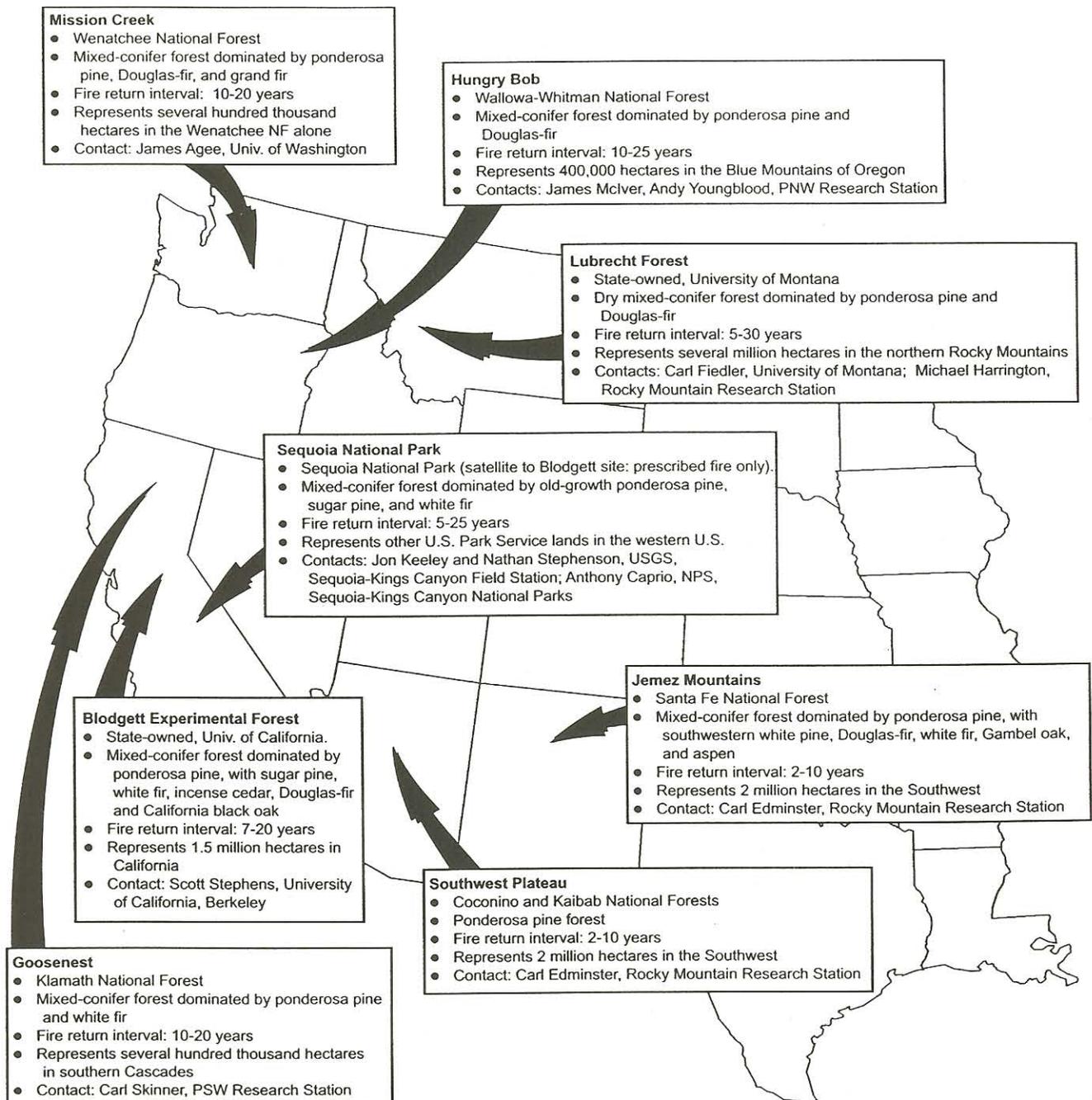


Figure 1—Ponderosa pine-dominated sites of the Fire-Fire Surrogate study.

Objectives

The goal of the study, as it applies to the Western sites, is to quantify the ecological and economic consequences of fire and fire surrogate treatments in ponderosa pine-dominated forests of the Western United States. The primary audience for the study is land managers, the people who make the decisions about which tools are most appropriate to use under different circumstances. Objectives include:

1. **Effects:** Quantify the effects of fire and fire surrogate treatments on a number of critical response variables including (a) fuel and fire behavior, (b) vegetation, (c) soils and forest floor, (d) wildlife, (e) entomology, (f) pathology, and (g) treatment costs and utilization/economics.

2. **Design:** Provide a research design that (a) establishes and maintains the study as an integrated national network of long-term interdisciplinary research sites using a common "core" design, (b) allows each site to be independent for purposes of statistical analysis and modeling, as well as being a component of the national network, and (c) provides flexibility for investigators of each research site to augment—without compromising—the core design to address locally important issues and to exploit expertise and other resources available to local sites.

3. **Models:** Develop and validate models of ecosystem structure and function, and refine recommendations for ecosystem management.

4. **Relationships:** Within the first 5 years of the study, establish cooperative relationships, identify and establish network research sites, collect baseline data, implement initial treatments, document treatment costs, report results, and designate FFS research sites as demonstration areas.

5. **Database:** Develop and maintain an integrated and spatially referenced database to be used to archive data for all network sites, and to allow interdisciplinary and meta-analyses.

6. **Monitoring:** Identify and field test a suite of response variables that are sensitive to the fire and fire surrogate treatments and are technically feasible for use in management contexts.

Research Approach

Experimental Design

The FFS project can best be described as an operational experiment, in which rigorous control is applied to a design meaningful to managers. Thus while the experiment has sufficient replication and control for each site to stand alone statistically, the treatments, variables, and scales have been chosen with the manager in mind. The treatments closely match the options available for managers, the variables chosen for study reflect those of greatest concern to managers, and the scale of the experimental units matches for the most part the sizes of management units typically designed by managers. In addition, the manner in which variables are measured at each site facilitates an integrated analysis of response for the range of variables, thereby providing the kind of information managers need to assess tradeoffs among the treatment options.

Treatments—Study treatments represent various combinations of the most common restoration activities used in forested ecosystems: cutting trees or other vegetation, using prescribed fire, and mechanically treating residues or scarifying the soil. Four study treatments include those that address widely shared concerns about forest health and wildfire hazard, those that deal with environmental concerns, and those most practical from an operational standpoint:

1. Untreated control

2. Prescribed fire only, with periodic reburns

3. Initial and periodic cutting, each time followed by mechanical fuel treatment and/or physical removal of residue

4. Initial and periodic cutting, each time followed by prescribed fire; fire alone also could be used one or more times between cutting intervals

These four treatments also span the range of restoration activities advocated by proponents of "structure restoration" (treatment 3), "process restoration" (treatment 2), or both (treatment 4) (Stephenson 1999).

Cuttings in treatments 3 and 4 will be repeated at intervals appropriate to the forest type and site conditions—for example, every 20 years. Periodic prescribed burns in treatments 2 and 4 will be based on available information about presettlement fire intervals for each research site. Irregular rather than fixed burn intervals are preferable where supported by fire history evidence, as it seems likely that important elements of ecosystem diversity were promoted historically by natural variability in fire intervals (Agee 1993; Skinner and Chang 1996).

We recognize that treatment specifications can encompass considerable variability in both cutting/mechanical and fire treatments that may differentially affect ecological responses of interest. While more precise specifications would reduce treatment variability among sites, such precision is neither feasible or desirable across so diverse an array of sites. The real world of forest ecosystems and resource management would not be well served by such a prescriptive approach. Flexibility in treatment specification does, however, increase the need for: (1) local replication to allow each research site to stand on its own statistically; (2) a specified desired future condition (DFC) for each site to help guide the application of treatments; and (3) careful documentation of treatments actually applied at each research site. We have defined a network-wide minimum standard short-term DFC for the study, based on stand resistance to wildfire:

Each noncontrol treatment shall be designed to achieve stand and fuel conditions such that, if impacted by a head fire under 80th percentile weather conditions, at least 80 percent of the basal area of overstory (dominant and codominant) trees will survive. The definition of 80th percentile weather conditions will be based on an analysis of fire season conditions, calculated for mid-afternoon, over a period of 10 to 20 years at the closest fire weather station. The prescription to implement the treatment will be developed based on fire behavior modeling (for example, FARSITE; Finney 1998) and predicted fire effects. Effects will be predicted using techniques such as FOFEM (First Order Fire Effects Model; Reinhardt and others 1997) and/or other modeling efforts that may include expert opinion.

This standard presumes the retention of a viable residual stand following treatment (clearcutting would not be an acceptable treatment option). The DFC will be well defined and implemented using a specific prescription to ensure consistency among treatment units. Each site DFC will consider management goals appropriate to that site, to stand conditions, and to the expectations of resource managers and other stakeholders. While early treatments may focus on thinning from below, or the equivalent using a series of burns, long-term restoration of historic stand structure will require provisions for recruitment of tree regeneration and development of a sustainable age-class distribution. Although fire hazard reduction will be a continuing emphasis for treatments, in the long run it is expected that stand structure will be increasingly able to accommodate wildfires that occur under the 80th percentile weather conditions.

Assuming the same starting point of stand and fuel conditions, moving toward a given DFC using the fire-only treatment will clearly be much less precise than using cutting treatments. For example, some desired changes in stand structure—for example thinning relatively large trees with fire without doing damage to the overall stand—may not be feasible. However, use of innovative prescriptions, firing techniques, and other methods such as stage burning may, over successive burns, permit considerable progress toward most DFCs using prescribed fire alone.

Replication and Plot Size—So that each site can be analyzed independently, each treatment will be replicated at least three times per site, using either a completely randomized or randomized block design. The core set of four treatments will thus be represented in 12 treatment units at each of the eight ponderosa pine research sites.

Each of the 12 core treatment units at a research site will consist of a 10-ha measurement unit, within which core variables will be measured, surrounded by a 4-ha treated buffer. The 10-ha unit size is a compromise between advantages of smaller units (for example, reduced costs, reduced within-unit variability) and those of larger units (for example, the need to represent natural variability at an operational scale, and the need to accommodate some larger scale ecological responses). The buffer, treated in the same way as the measurement unit it surrounds, will have a width at least equal to the height of a best-site potential tree. A 30-m treated buffer, for example, would bring the total size of the treatment unit to about 14 ha. Site participants will need to determine appropriate separation of treatment units and the nature of treatment in the matrix between units.

We recognize that many aspects of wider ranging wildlife species, bark beetles, and some economic questions can be studied at the 10-ha scale only indirectly—for example, via habitat attributes and modeling methods. Where feasible at a given research site, two additional approaches may help to address larger scale issues: (1) Larger replicated treatment units (for example, larger buffers) can be used, provided that the core 10-ha units are embedded within them and are used for measurement of core response variables. Additional, larger scale variables could then be measured on the larger treatment units. (2) The core 10-ha replicated units can be augmented with much larger (200 to 400 ha or more), generally unreplicated areas nearby treated to the same specifications. These large treatment areas could provide

useful information concerning operational-scale economics and practicability, as well as larger scale ecological responses, especially if linked to the smaller replicated unit via appropriate models.

Response Variables—Ecosystem management requires an understanding of three interacting components: societal expectations and desires, management costs and revenues, and how management activities affect the ecology of whole systems. The social component will be linked to the study through other efforts funded by the Joint Fire Science Program and others. The FFS study is focused on economics and ecology and, because the study is directed toward management, is designed to provide information on how the whole system responds to treatment, such that managers can assess tradeoffs. Because core response variables will be measured at all network sites in a consistent way, we will be able to provide a package of information on how forest ecosystems of this kind respond to management. This is critical in a world where a number of issues are debated simultaneously for every parcel of land. For example, while fuel reduction may lower fire hazard and risk, removing down woody material will also reduce foraging habitat for birds and macroinvertebrate species. Measuring both the extent of fuel reduction and its effect on biodiversity may help identify thresholds that would be useful for fine tuning management to achieve more holistic objectives. In addition, measuring the costs and revenues of fuel reduction provides the kind of information that allows the manager to assess tradeoffs on the application of alternative management tools. Finally, applying this design to eight different sites will provide more robust information to guide management decisions on restoration of ponderosa pine forests.

Several members of our FFS steering committee (see Acknowledgments) have been serving as disciplinary group leaders with responsibility for developing major sets of response variables (table 1). Each group leader has worked with a team of people with appropriate expertise to identify a core set of response variables and measurement protocols to use at all research sites. Their activities also have included cross-group coordination to ensure consistency, compatibility, and nonduplication of data collection efforts. As

Table 1—Disciplinary groups and group leaders.

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| Fire and fuels | Sally Haase, PSW Station, and Bob Vihnanek, PNW Station |
| Vegetation | Jon Keeley, USGS, Sequoia-Kings Canyon National Parks |
| Soils and forest floor/hydrology | Ralph Boerner, Ohio State University |
| Wildlife | Steve Zack, Wildlife Conservation Society |
| Entomology (primarily bark beetles) | Patrick Shea, PSW Station |
| Tree pathology | Bill Orosina, SO Station |
| Treatment costs and utilization/economics | Jamie Barbour, PNW Station |

project implementation proceeds, they will work to ensure that data collection protocols are followed consistently at all the sites. This may include training, oversight of field crews, or other measures as appropriate.

Within-unit sampling of all variables will be keyed to a 50-m square grid of permanent sample points to be established and maintained within each measurement unit. Any number of grid points in a measurement unit may be used for a given variable depending on the nature and appropriate intensity of sampling for that variable. Referencing of all data to the grid, coupled with digital orthophotography, will facilitate spatial, interdisciplinary analysis.

Research Site Locations

Criteria for Site Selection—A network of research sites using a common experimental design has the potential for synergistic output exceeding what could be accomplished by a series of separate, uncoordinated studies. In selecting research sites we have developed and used the set of criteria given in table 2.

Proposed Initial Sites—The proposed initial network comprises 13 sites, each representing a forest with a historically short-interval, low- to moderate-severity fire regime. Eight sites are in Western coniferous forests, ranging from the Pacific Northwest to the Southwest (fig. 1). These sites all share ponderosa pine as an important tree component, but sites vary in composition of other conifers and differ substantially in topography and soil. We recognize that this network of pine sites does not represent all of the geographic localities of Western pine forests that are in need of restoration. However, its composition is a reasonable compromise considering the widespread need for the

information, anticipated availability of funding, and available expertise and commitment. Furthermore, depending on the level of interest and support available, future sites at other localities may be added to the network.

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Table 2—Criteria used in site selection.

1. Site is representative of forests with a historically short-interval, low- to moderate-severity fire regime and a currently high risk of uncharacteristically severe fire.
2. Site is representative of widespread forest conditions (site characteristics, forest type and structure, treatment history) that are in need of, and likely to benefit from, fire or fire surrogate treatments, and in which such treatments are feasible.
3. Site contributes significantly to balancing the overall network in terms of regional representation and/or land ownership type.
4. Partners and cooperators are committed to and capable of participating in the program. This involves several factors, including active support and interest in involvement on the part of partners/cooperators; available land base for the study; ability and willingness of land managers to implement the full suite of experimental treatments successfully within required timeframe, repeat treatments over time as appropriate, commit selected sites for long-term research uses, and document these commitments in amendments to long-term land management plans.
5. On Federal lands, treatment costs are borne by lead agency or partner.
6. Partnerships exist across agencies and with universities, and between researchers and managers.

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