Ecosystem-Based Management in the Lodgepole Pine Zone

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Abstract—The significant geographic extent of lodgepole pine (*Pinus contorta*) in the interior West and the large proportion within the mixed-severity fire regime has led to efforts for more ecologically based management of lodgepole pine. New research and demonstration activities are presented that may provide knowledge and techniques to manage lodgepole pine forests in the interior West. First, at the stand and watershed levels, a current application of a suite of restoration treatments to lodgepole pine stands within a watershed in central Montana is discussed. Second, a Bitterroot Ecosystem Management Research Project (BEMRP) study is presented that characterized landscape and patch dynamics in lodgepole pine forests at a coarser spatial resolution. Various landscape metrics for quantification of the range of variation in aerial extent of cover type and structural stage categories were used, and the implications for ecosystem management are discussed.

The subalpine lodgepole pine forest type is estimated to cover about 15 million acres in the western United States and a much larger area (nearly 50 million acres) in western Canada (Lotan and Critchfield 1990). Lodgepole pine is the fourth most extensive timber type west of the Mississippi River and is the third most extensive in the Rocky Mountains. Its range extends from 35° latitude to the Yukon at 65° latitude, and longitudinally from the Pacific coast to the Black Hills of South Dakota. The adaptations of lodgepole pine to severe, stand replacement fire—in particular its serotinous cones—has long been acknowledged. Less well known is that lodgepole pine forests also burned in low- to mixed-severity fire, often creating two-aged stands and variable patterns across the landscape (Agee 1993; Arno 1980; Barrett and others 1991). Numerous studies in the interior Northwest have documented the intricate mosaic patterns of historical fires in lodgepole pine forests (Arno and others 1993; Barrett 1993; Barrett and others 1991). Newer studies are looking more closely at the details of these patterns and their implications for management. These studies are being used as a basis for designing and refining silviculture and prescribed fire treatments in national forests of the Northern Rocky Mountains.

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In the past, clearcutting and broadcast burning of lodgepole pine forests was considered to be economically efficient and conducive to regeneration. These treatments roughly mimic effects of natural, stand-replacement fires. More recently, foresters have recognized that burning irregularly shaped cutting units containing patches of uncut trees, while also creating snags, would far more effectively simulate effects of historical fires. An example of this approach on the Bitterroot National Forest is the Tolan Creek Timber Sale southeast of Darby, Montana, on the Sula Ranger District. Two large harvest blocks of 75 and 125 acres of lodgepole were treated with silviculture systems designed to simulate natural fire patterns. Seedtree reserves were retained in the pure lodgepole pine stands and shelterwoods with reserves were retained in the mixed Douglas-fir (*Pseudotsuga menziesii*)/lodgepole pine stands. Several lessons were learned there, including problems encountered with long skidding distances in such large units and narrow burning windows that made it difficult to accomplish site preparation. An additional, fairly common, result of the constraints of very narrow prescribed burning windows occurs when burning is postponed to the point when fine fuels are gone due to compaction and decay and fuels may need to be augmented to provide sufficient fire intensity to create snags by killing some trees and also to open serotinous cones. In this case, some planting may be required.

Recognition of the extent of the mixed-severity fire regime in lodgepole pine, and the recent success and experience gained from the Tolan Creek Timber Sale, have led to continued efforts toward more ecologically based management of lodgepole pine. In this paper we present new research and demonstration activities that may provide knowledge and techniques to manage lodgepole pine forests in the interior West. First, at the stand and watershed levels, we describe a current application of a suite of restoration treatments to lodgepole pine stands within a watershed in central Montana. Second, we move to a coarser spatial resolution and discuss a BEMRP study, which characterized landscape and patch dynamics in lodgepole pine forests and the implications for ecosystem management.

Restoration in Lodgepole Pine: A Mixed- and High-Severity Fire Regime

A major, watershed-scale research and demonstration study of ecosystem-based treatments in a subalpine lodgepole pine forest is being implemented on the 9,125-acre Tenderfoot Creek Experimental Forest (TCEF) in central

Montana (fig. 1). This study will test the feasibility of an array of management treatments that consider societal needs for wood products while maintaining lodgepole pine forests. The treatments are designed to emulate natural disturbance processes (predominately fire) while avoiding catastrophic-scale disturbances. While not directly funded by, or related to, the Bitterroot Ecosystem Management Research Project (BEMRP), the research and demonstration study at TCEF was deliberately initiated to meet the need for new management techniques for lodgepole pine on the Bitterroot National Forest as well as other areas in the interior Rocky Mountains. A number of attributes of the TCEF were attractive for this study: TCEF is an official Forest Service Experimental Forest, it is not near any significant or sensitive urban areas, it has not experienced any previous management activities (with the significant exception of fire suppression), and it is biophysically similar to common lodgepole pine stands found on the Bitterroot National Forest. Additional ecological attributes of TCEF enhancing its utility for this study included no evidence of mountain pine beetle, very little dwarf mistletoe, and scarce evidence of significant wind events.

Paired watersheds at TCEF have been monitored for several years and will serve as a basis for comparison of water quantity and quality under different cutting and burning treatments. A detailed fire history study and map has been completed that documents a sequence of stand replacement and mixed-severity fires extending back to 1580 (Barrett 1993). Stand-replacing burns occurred at intervals of 100 to over 300 years, with low- or mixed-severity burns often occurring within these intervals. Two-aged stands cover about half the area at TCEF, ranging in size from a few acres to about 1,000 acres.

Experimental treatments at TCEF have been designed to reflect these historical disturbance patterns. The study design for TCEF will integrate observations of on-site treatment response with water yield and water quality data from paired, experimental sub-watersheds that have monitoring flumes. The treatments include silviculture, prescribed fire, and silviculture-with-prescribed fire. The silvicultural system proposed is a two-aged system termed "shelterwood-with-reserves," with two forms of leave tree retention: one with leave trees evenly distributed, and the other with leave trees in a noticeably uneven pattern, suggestive of historical mixed-severity burns. A three-dimensional visualization depicting the two forms of retention is shown in figure 2. About 50 percent of the basal area will be removed. Low intensity underburns will follow in 50 percent of the harvested units. In addition, several large blocks (35 to100 acres) will be treated by mixed-severity underburning with no silvicultural treatments. The suite of treatments will be applied on each of the two, paired sub-watersheds—one with a southern aspect and one with a northern aspect (fig. 3). Immediately adjacent to each treatment sub-watershed is a hydrologically similar sub-watershed used as a no-treatment control.

Snag retention and/or recruitment objectives will be 9 to 15 trees per acre of 9 to 10 inches minimum diameter in three age classes. Changes in amounts of coarse woody debris will be assessed with respect to potential impacts on small mammal densities (Hardy and Reinhardt 1998).

Planning for this extensive study was initiated in 1995, and several Forest Service Research personnel were included as ex officio members of the interdisciplinary planning team assembled by the Lewis and Clark National Forest to accomplish the Environmental Assessment (EA) process required for the project. The EA was completed in 1998 and a final decision notice was issued in early 1999. Construction of approximately 2½ miles of roads will be accomplished in 1999 and harvesting should be completed by fall of 2000. Prescribed burning operations may be executed in 2001, if this aggressive schedule is executed without complications.

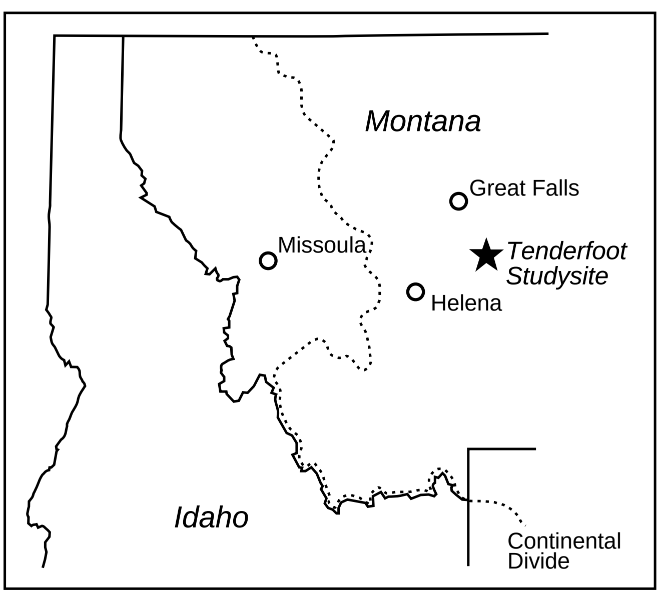

Figure 1—The Tenderfoot Creek study site is a USDA Forest Service Experimental Forest located in the Little Belt Mountain Range in central Montana.

Landscape and Patch Dynamics in Lodgepole Pine Forests: Implications for Ecosystem Management

General characteristics of disturbance regimes can often be described from landscape patch characteristics and dynamics (Hessburg and others, in press a; Forman 1995; Swanson and others 1990). We computed landscape metrics for ten Bitterroot National Forest lodgepole pine landscapes in order to (1) describe general landscape characteristics, (2) quantify a range of variation in these metrics for baseline threshold values, and, most importantly, (3) derive spatial treatment guidelines for harvesting and restoring these ecosystems.

Seven small landscapes on the Bitterroot National Forest (Bitterroot Forest), about 1,483 acres in size and composed primarily of lodgepole pine, were mapped from 1993 aerial photos using the methodology described by Hessburg and others (1998a). Additionally, three larger landscapes (9,884 to 37,065 acres) from the Interior Columbia Basin Ecosystem Management Project (ICBEMP) were mapped at two

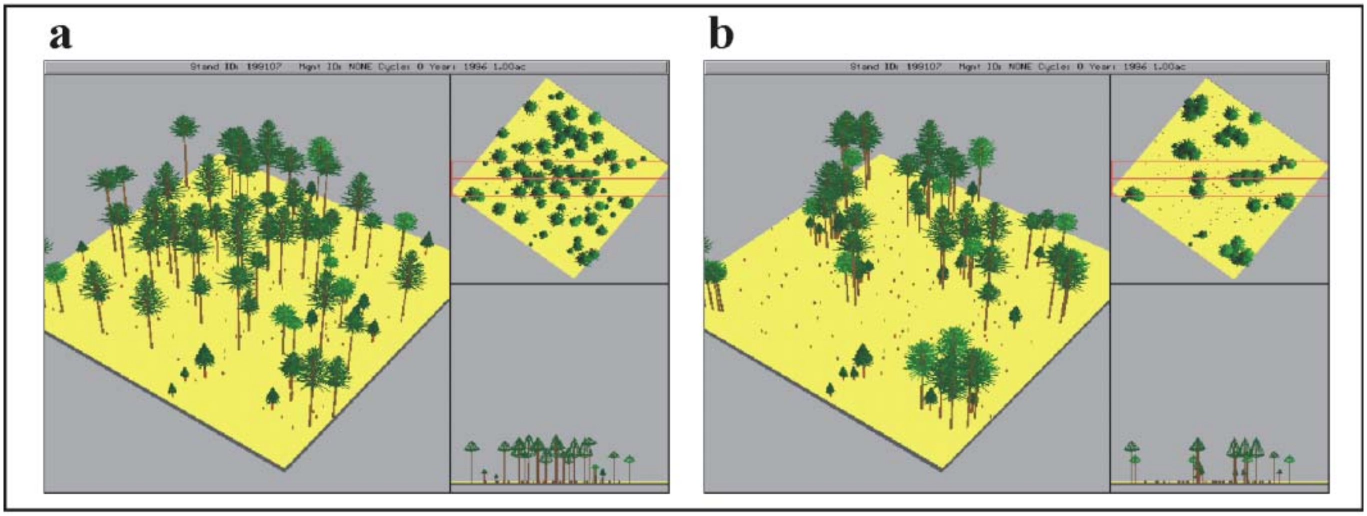

Figure 2—Visualizations depicting two distributions of retention trees: even distribution (a) and clumped distribution (b). Each of the treatments retains the same basal area, stem density, size distribution, and species composition.

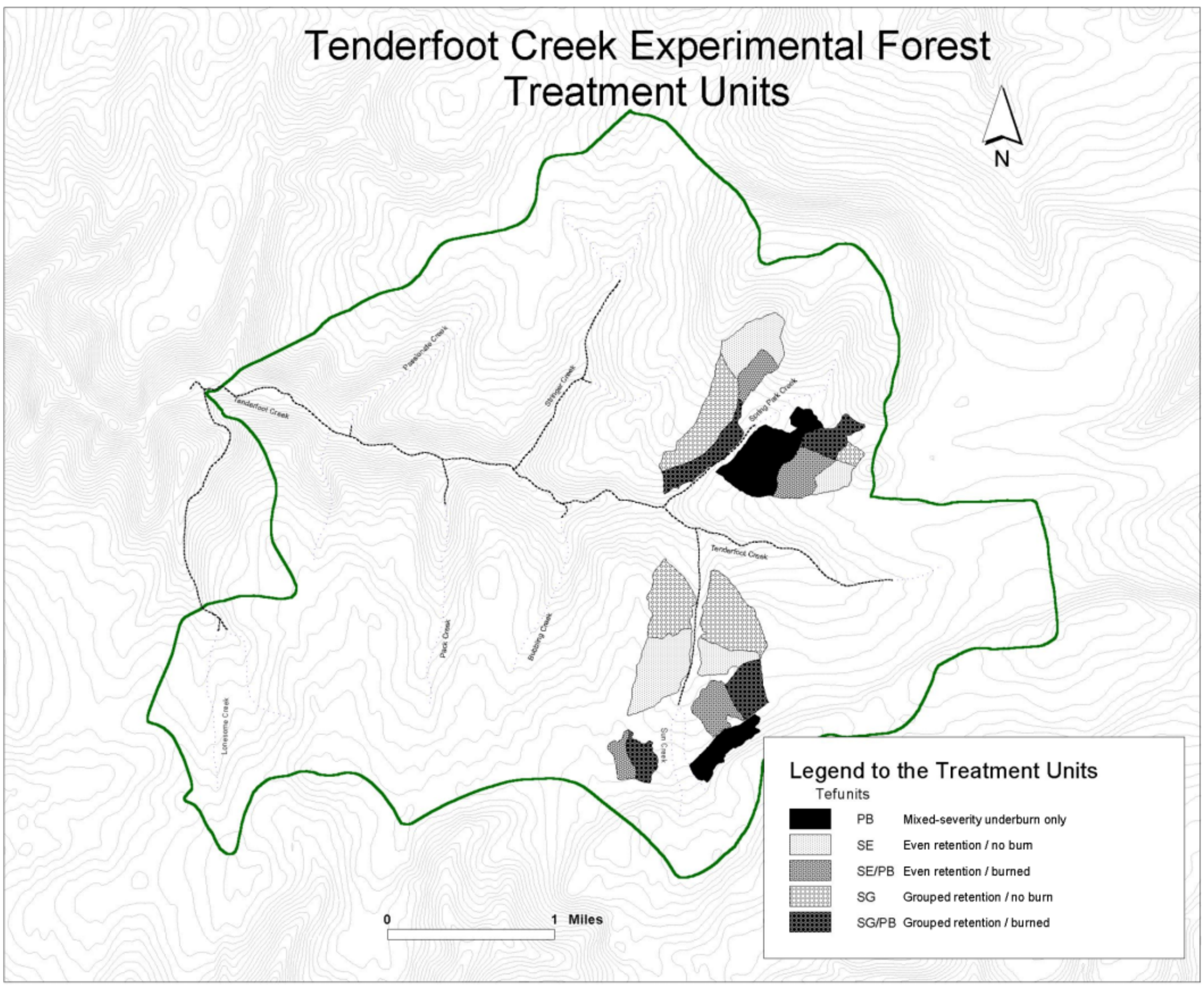

Figure 3—The 18 treatment units are distributed across Sun Creek (north aspect) and Spring Park Creek (south aspect) subwatersheds.

time intervals, 1937 and 1993. General descriptors for each of the ten sites are given in table 1. We then selected the attributes of cover type, structural stage, and canopy cover as the key polygon descriptors for this study. Spatial data layers were created for each landscape and then imported into the FRAGSTATS (McGarigal and others 1995) spatial pattern analysis program to compute the landscape metrics.

A comparison of ICBEMP historical to current landscape metrics reveals some interesting relationships. It appears historical landscapes had less subalpine fir and more pine and nonforest cover types than current landscapes (table 1). These pre-1940's landscapes had more early seral patches in the nonforested and seedling/sapling structural stages. Patches tended to be larger, more irregular, less contagious, and more diverse prior to the 1940's historical landmark (table 2). This is consistent with metrics computed for other current landscapes that have had fire exclusion for long time periods (Keane and others 1999; Hessburg and others, in press b). All current landscapes were heavily weighted toward the later structural stages with over 80 percent of the landscapes being older than seedling/saplings. Estimates of similar landscape metrics by Hessburg and others (1998b) were extremely close to those computed for the Bitterroot National Forest landscapes. They used 132, 6th HUC code watersheds in the east slope of the Cascades—a region quite distant from the Bitterroot valley. This may indicate that fire processes are similar across all landscapes that support lodgepole pine, a concept supported in the fire sciences literature (Heinselman 1981; Peet 1988; Wright 1974).

The most useful patch type or mapping entity to assess depends on management objectives. If management at the species level is required (e.g., return lodgepole to the landscape), then the cover type metrics should be used. We selected the combination of cover type and structural stage because this probably best represents the mosaic produced by fire regimes. The strata for which landscape metrics are shown in table 2 represents the combination of cover type and structural stage.

Table 1—General description of the 10 current and additional 3 historic landscapes employed in the landscape metric evaluation.

Landscape study area	Landscape assessment project	Study area size (ha)	Dominant cover type[a]	Dominant structural stage[a]	Dominant canopy cover[a]
Beaverwoods	BNF	766	Lodgepole pine	Pole	Moderate
Cow Creek	BNF	334	Douglas-fir	Pole	Moderate
Gibbons	BNF	593	Douglas-fir	Small	Moderate
Lick Creek	BNF	667	Douglas-fir	Pole	Low
St. Joe	BNF	476	Subalpine fir	Pole	Low
Sawmill	BNF	276	Subalpine fir	Small	Moderate
Sweeney	BNF	248	Douglas-fir	Small	Moderate
Sweeney-Joe					
Historical	ICRB	4,300	Subalpine fir	Nonforest	Low
Current	ICRB	4,300	Subalpine fir	Small	Low
Roaring Lion					
Historical	ICRB	6,573	Subalpine fir	Nonforest	Low
Current	ICRB	6,573	Subalpine fir	Nonforest	Moderate
Sleeping Child					
Historical	ICRB	14,398	Lodgepole pine	Small	Moderate
Current	ICRB	14,398	Subalpine fir	Small	Moderate

[a]Cover type, structural stage, and canopy cover are based on the most dominant category.

Table 2—Landscape metric evaluation statistics for all ten lodgepole pine landscapes show current and historic conditions (current/historic) for the combination of cover type and structural stage. The Sawmill landscape is presented as an example target landscape.

Landscape Metric[a]	"Target" landscape (Sawmill)	Metric statistics for all 10: Average	Minimum value	Maximum value	Standard error
		current/historic			
LPI (%)	20.3	12.7/14.4	5.6/7.1	24.6/27.2	1.8/6.4
MPS ha)	7.1	21.4/68.5	5.7/34.4	66.6/118.0	6.5/25.3
PSCV (%)	142.5	148.7/209.6	110.1/144.2	236.8/340.1	11.4/65.3

[a]LPI = landscape patch index; MPS = mean patch size; PSCV = patch size coefficient of variation.

Landscape characteristics important to **treatment design** are the size and variability of patches. Therefore, we recommend **mean patch size** (acres), **patch size coefficient of variation** (percent), and **landscape patch index** be used to design treatment units (table 2). **Mean patch size** (MPS) statistics provide a *target* patch size. In our study, the MPS for current landscapes (15 to 163 acres) was much lower than MPS computed for historical landscapes (84 to 291 acres). The **patch size coefficient of variation** (PSCV) can guide the manager as to the sideboards or boundaries in selecting a patch size. Data computed for historical and current landscapes show the PSCV was often much larger than the MPS indicating the wide variation of fire mosaics common on the Bitterroot landscape (table 2). Lastly, **landscape patch index** (LPI)—the maximum percent of the landscape occupied by one patch—provides an indication of the largest patch management activity should create on that landscape. Landscape metrics from an example target watershed (Sawmill) were compared to averages from the Bitterroot study and were found to be within the range of variation of both current and historical landscapes (table 2). On that basis, the largest patch to create on the Bitterroot landscapes would probably be between 20 to 40 percent of the total landscape (table 2).

Conclusions

With the exception of a comprehensive fire history study, the treatments currently being implemented on the Tenderfoot Creek Experimental Forest (TCEF) are an example of management activities designed without the benefit of landscape metrics analyses. In lieu of such metrics, the treatment design at TCEF reflects qualitative assessments of desired "patchiness" and also the desire to emulate the historical patterns of natural disturbance.

In contrast, spatial metrics provide a method of assessing the landscape structure and composition of individual watersheds prior to treatment to determine harvest or burn parameters, although the high variability between and across landscapes makes a "one-size-fits-all" set of recommendations nearly impossible. These data have shown that a target landscape, such as the Sawmill watershed used in this example, can be identified and that landscape metrics such as those shown here (MPS, PSCV, LPI) can be used to prescribe a desired condition for which management activities may be designed and implemented. However, data from this analysis are not suitable for computing frequency of treatment activity or fire rotation and are therefore somewhat limited in their use for design of treatment prescriptions in the absence of other information. Treatment scheduling in time and space is a complex and demanding task that must account for wildfire events, global climate change, management activities in parts of the landscape and in other ecosystems, and the current socio-political climate.

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