

Twentieth-Century Fire Patterns in the Selway-Bitterroot Wilderness Area, Idaho/Montana, and the Gila/Aldo Leopold Wilderness Complex, New Mexico

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Abstract—Twentieth century fire patterns were analyzed for two large, disparate wilderness areas in the Rocky Mountains. Spatial and temporal patterns of fires were represented as GIS-based digital fire atlases compiled from archival Forest Service data. We find that spatial and temporal fire patterns are related to landscape features and changes in land use. The rate and extent of burning are interpreted in the context of changing fire management strategies in each wilderness area. This research provides contextual information to guide fire management in these (and similar) areas in the future and forms the basis for future research involving the empirical definition of fire regimes based on spatially explicit time-series of fire occurrence.

Large wilderness areas may be viewed as natural laboratories for studying patterns and processes in ecosystems virtually uninfluenced by human activity. They provide the opportunity to understand basic ecological principles (Parsons and Graber 1991) and to define benchmark or control areas for gauging how nonwilderness systems have been affected by human land use (Christensen and others 1996). A library of empirical studies of pattern-process interactions is crucial for understanding the relative effects of landscape patterns on ecosystem processes (Turner and others 1995), and wilderness research is a crucial component. The need for spatial and temporal research into fire regimes is particularly critical in light of predicted climate change (Price and Rind 1994; Running and Nemani 1991; Ryan 1991). This research is one of the few (if not the only) specific examples of using broad spatial databases and 20th century fire perimeter data in two disparate regions to determine relationships between landscape attributes and ecosystem processes. Comparison between two regions yields a measure of the generality of interpretations and allows observation of fire-landscape-climate relationships that may occur at regional scales.

In: Cole, David N.; McCool, Stephen F.; Borrie, William T.; O'Loughlin, Jennifer, comps. 2000. Wilderness science in a time of change conference—Volume 5: Wilderness ecosystems, threats, and management; 1999 May 23–27; Missoula, MT. Proceedings RMRS-P-15-VOL-5. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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The objectives of our research were to characterize the interrelationships among fire, topography, and vegetation across two major Rocky Mountain Wilderness ecosystems: the Selway-Bitterroot Wilderness Area in Idaho and Montana and the Gila/Aldo Leopold Wilderness Complex in New Mexico. Comparing results between two distinct regions, the northern and southern Rocky Mountains, provides a regional perspective. Fire-climate relationships may be studied at these scales. Differences and similarities in our results enable us to determine whether fire-landscape relationships are determined by constraints at local or regional scales. This paper describes the acquisition and compilation of GIS databases for each wilderness area, a graphical analysis of spatial and temporal fire patterns, and a comparison of patterns found in each wilderness.

Study Areas

The Gila/Aldo Leopold Wilderness Complex (GALWC) is a 486,673-ha area in west-central New Mexico. The complex is composed of the Gila Wilderness Area, the Aldo/Leopold Wilderness Area, the Gila Cliff Dwellings National Monument and some nonwilderness portions of the Gila National Forest. The GALWC encompasses the headwaters of the Gila River, the Mogollon Mountains and the Black Range, 70 km north of Silver City, New Mexico. The Gila Wilderness portion of the study area is topographically diverse, with deep, narrow river canyons, flat mesa tops and steep mountains. Elevations range from 1,300 m near the main stem of the Gila River to 3,300 m on top of the Mogollon Mountains. The Aldo Leopold Wilderness Area is rugged, with elevations ranging from 1,500 m near the Mimbres River to 2,900 m on McKnight Mountain in the Black Range.

Broad valleys of desert scrub (*Ceanothus*, *Artemisia*, and *Yucca* sp.) are found at the lowest elevations. As elevation increases, piñon/juniper woodlands (*Pinus edulis*, *Juniperus deppeana*, and *J. monosperma*, and *Quercus* sp.) gain dominance. Extensive stands of ponderosa pine (*Pinus ponderosa*) mixed with Douglas-fir (*Pseudotsuga menziesii*) are found at middle elevations. At upper elevations, forests are comprised of mixed Englemann's spruce, subalpine fir (*Abies lasiocarpa*) (var. *arizonica*), Southwestern white pine (*Pinus strobiformis*), white fir (*Abies concolor*) and aspen (*Populus tremuloides*).

Fire season in the GALWC begins as early as April and may extend through September. Spring conditions are

usually dry, with thunderstorm activity increasing in June and July. The GALWC is dominated by low-severity surface fire regimes. Higher mortality, mixed-severity fire regimes are found at upper elevations (Abolt 1996, Swetnam and Dieterich 1983). During dry seasons, fire behavior can be extreme, with lethal fire common across all elevations. The Gila/Aldo Leopold Wilderness Complex has the highest number of lightning-ignited fires in the nation, with an average of 252 fires per million acres (404,687 ha) protected per year (Barrows 1978).

The Selway-Bitterroot Wilderness Area (SBWA) in Idaho and Montana is a 547,370-ha wilderness area; second in size (in the conterminous United States) only to the adjacent Frank Church-River of No Return Wilderness in Idaho. The area is characterized by extremely rugged terrain with broad topographic variation. Portions of the SBWA are found in the Bitterroot, Clearwater and Nez Perce National Forests. The northwest portion of the wilderness is characterized by Pacific maritime forests with assemblages of western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), western white pine (*Pinus monticola*) and Douglas-fir ranging from 500 m to 1,500 m. As elevation increases, mesic and mixed conifer forests dominate, with assemblages of Douglas-fir/Englemann's spruce (*Picea engelmannii*) /grand fir (*Abies grandis*) found on moist sites and ponderosa pine, while Douglas-fir and western larch (*Larix occidentalis*) forests occupy dryer sites. Subalpine forests make up the largest portion of the Wilderness, characterized by assemblages of Englemann's spruce/subalpine fir (*Abies lasiocarpa*) with lodgepole pine (*Pinus contorta*) dominant on drier sites and stands with more recent disturbance. Many of these lodgepole pine stands are extensive and have homogenous stand structure and ages. The highest subalpine sites are characterized by mixed whitebark pine (*Pinus albicaulis*)/alpine larch (*Larix lyallii*) forests.

Large thunderstorms are frequent in the SBWA, with a peak in activity during the early summer. Fire season in the SBWA begins in the early summer and extends through September. Fire regimes are mixed, with patchy stand-replacement fire dominant in upper elevation forests (70% of the SBWA) and lower severity, understory fire at lower elevations. Stand-replacement fires are dominant across all elevations during seasons with extreme fire weather (Barrett and Arno 1991, Brown and others 1994).

Methods

Twentieth-century fire perimeters were obtained in digital form (or digitized) from archival fire data at the Gila, Bitterroot, Clearwater and Nez Perce National Forests. Archives were compiled from old fire reports or operational fire perimeter maps. Using Arc/Info GIS software, digitized fire perimeters were organized by year, then compiled (using the Arc/Info 'Regions' data architecture) as separate fire atlases for each wilderness. These atlases were subset to a 5 k buffer around each wilderness boundary. The individual fire years for each area were converted to 30 m binomial raster grids using Arc/Grid. These layers were added together to create continuous surface models of fire frequency for each wilderness area.

Data for topography and vegetation were available from the USDA Forest Service Intermountain Fire Sciences Laboratory in Missoula, Montana (see Keane and others 1998; Keane and others 1999). Elevation was represented by two compiled sets of 7.5 minute USGS digital elevation models for the study areas. Slope and aspect surfaces for each study area were derived using the Arc/Grid commands SLOPE and ASPECT. Potential vegetation types (PVTs) were used to characterize the forests of each study area. Potential vegetation is a means of classifying biophysical characteristics of a site using the vegetation that would be present in the absence of disturbance (Cooper and others 1991). Classifications of potential vegetation were based on qualitative and quantitative analysis of geographic location, existing vegetation, field data, topography, local productivity and soil characteristics. GIS layers for vegetation and topography were subset to the extent of the fire atlases.

Different time periods for each wilderness area were delimited by different fire management strategies (see dashed lines in fig. 2). Area burned over time for both wilderness areas was plotted, then reported as proportions of each study area for each time period. Natural fire rotations for pre-suppression, suppression and prescribed fire periods were calculated. Distributions of 20th century fire frequency were summarized by topography and potential vegetation for each wilderness using Arc/Info GIS software.

Results

Fire perimeter data extended from 1909 to 1993 in the GALWC and from 1880 to 1996 in the SBWA. Mapped data indicated that 147,356 ha had burned in 232 fires in the GALWC and 474,237 ha in 437 fires in the SBWA. In the GALWC, 1909, 1946, 1951, 1985, 1992 and 1993 were the largest years, with 71% of the total area burned during these years. In the SBWA 1889, 1910, 1919, 1929, 1934 and 1988 were the largest years, accounting for 72% of the total area burned. Data from the SBWA show an almost total lack of mapped fire from 1935 through 1979. Mean mapped fire size in the GALWC was 637 ha, with a minimum of 2 ha and a maximum of 19,446 ha (the 1951 McKnight Fire). Median fire size was 88 ha. Mean fire size in the SBWA was 1,153 ha, with a minimum of 2 ha and a maximum of 52,223 ha (the 1910 Moose Creek fire). Median fire size was 135 ha. Perimeters from the two largest fire years are shown in figure 1.

Time periods related to different fire management strategies are indicated by vertical dotted lines in figure 2. Fire rotations for each of these time periods are summarized in table 1. Graphical analyses of re-burn patterns over the landscape indicate that 20th century fire frequency was associated with potential vegetation, elevation, slope and aspect.

Areas with the highest fire frequencies in the GALWC were found between 2,250 m and 2,525 m. In the SBWA, areas with the highest fire frequencies were found between 600 m and 1,760 m (fig. 3). Areas of highest fire frequency were skewed toward higher slopes in both wilderness areas. In the GALWC, northeast aspects burned most frequently, while southeast aspects burned less than expected based on the distribution of slope across the study area. Southeast and southwest aspects burned more frequently in the SBWA.

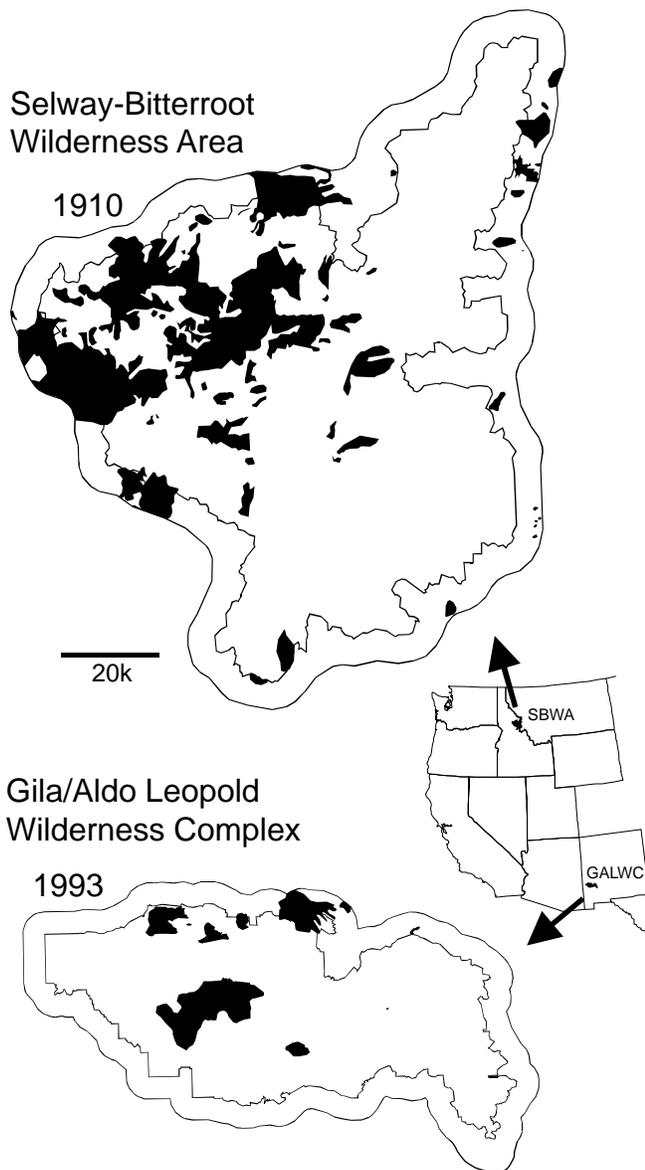


Figure 1—Perimeters from the two largest fire years in each wilderness area.

Quantitative descriptions of these relationships will be reported elsewhere.

In the GALWC, areas that had burned multiple times were more likely to be in Douglas-fir or ponderosa pine potential vegetation types. This relationship grew stronger as fire frequency increased. In the SBWA, areas that had burned two or more times were more often found in shrubfields, western red cedar or Douglas-fir potential vegetation types (fig. 4). It is important to note that ponderosa pine forests are included in the Douglas-fir PVT in the SBWA. Chi-square analyses indicated that these patterns were statistically significant.

Discussion

Each wilderness experienced large amounts of fire in the 20th century. The time-series of area burned may be divided

Table 1—Fire rotations for time periods delineated by different fire suppression levels in each study area.

Time period	Area burned (ha)	Percent of study area burned	Natural fire rotation (years)
Selway-Bitterroot Wilderness			
1880-1935	482,030	60.9	92
1936-1974	9,622	1.2	3,206
1975-1994	58,427	7.4	271
Gila/Aldo Leopold Wilderness Complex			
1880-1946	32,601	6.7	552
1947-1974	34,742	7.1	406
1975-1993	80,424	16.5	114
Selway-Bitterroot Wilderness			
1880-1935			
Gila/Aldo Leopold Wilderness Complex			
1880-1946			

into distinct periods in each wilderness, indicated by dashed lines in figure 2. Changes in fire frequency and area burned over time are attributable to land-use and fire suppression in each area. Fire suppression in each wilderness has taken place since the early 20th century. Large numbers of forest rangers and conscripted miners in the SBWA fought the great fires of 1910 (Habeck 1972; Moore 1996; Pyne 1982). Fires in the early 20th century were also fought by miners, loggers and forest rangers in the GALWC. In the mid-20th century, fire suppression technologies improved with the implementation of smokejumper and aerial retardant operations, a direct result of technologies improved during World War II (Pyne 1982). Aerial fire depots began operation in the late 1940s in Grangeville, Idaho, Missoula, Montana and Silver City, New Mexico. From the late 1940s through the mid-1970s, fires in both wilderness areas were suppressed rapidly and aggressively. Each wilderness area implemented prescribed natural fire management in the mid-1970s and both areas are currently considered to have the most advanced, broad-scale wildfire use programs in the United States.

In the GALWC, grazing was the main land use at the turn of the century. High levels of grazing are thought to have reduced the area burned, by reducing fine fuels, across the Gila National Forest from the mid-1800s through 1929 (Savage and Swetnam 1990, table 1), when grazing was reduced sharply in the forest reserve. Large fires during the mid-1940s and '50s correspond with a period of severe drought in the southwestern United States (Swetnam and Betancourt 1998). The absence of fire from the mid-1950s through the mid-1970s is probably due to aggressive fire suppression by the Gila National Forest. Area burned in the SBWA was quite high in the late 19th century and early 20th century (table 1). Grazing was never a prevalent land-use in the SBWA, unlike the GALWC. The main portions of the SBWA were so remote that little if any grazing occurred. Analyses of the relationships between area burned in each wilderness and time series reconstructions of drought may be found in Rollins and others 1999. Natural fire rotations in recent years are much shorter than rotations during the modern-suppression period (table 1). While this indicates

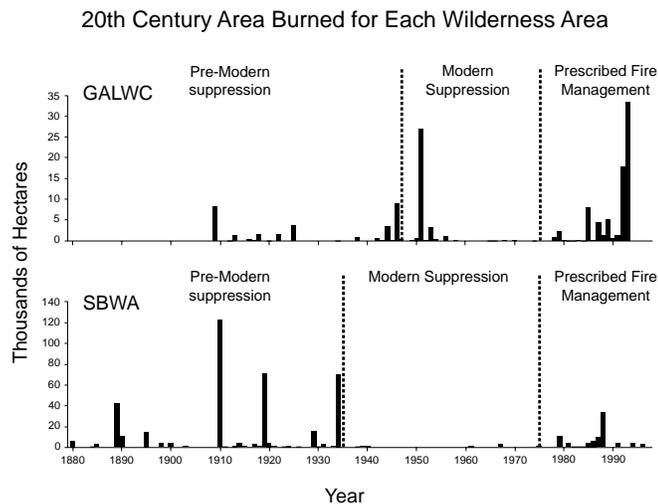


Figure 2—Area burned over time in each wilderness. Dashed lines indicate time periods delineated based on different fire management strategies.

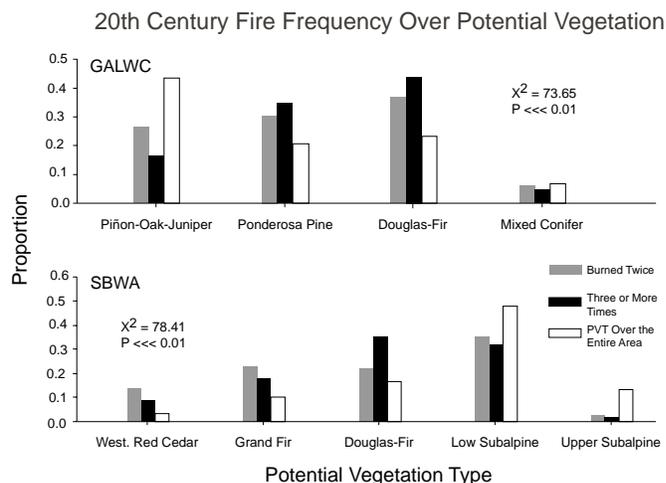


Figure 4—Distributions of areas that burned three or more times (7,020 ha in the Gila/Aldo Leopold Wilderness Complex and 7,472 in the Selway-Bitterroot Wilderness Area) by potential vegetation type. Areas are plotted as proportions of totals for direct comparison.

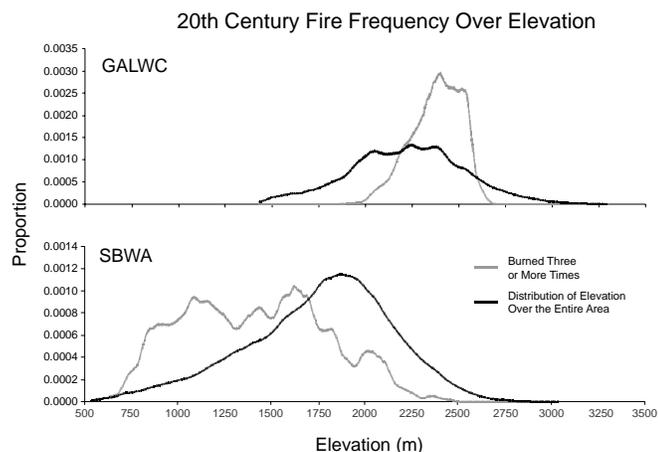


Figure 3—Distributions of areas that burned three or more times (7,020 ha in the Gila/Aldo Leopold Wilderness Complex and 7,472 in the Selway-Bitterroot Wilderness Area) over elevation. Areas are plotted as proportions of totals for direct comparison.

that wildfire use programs are successful to some degree, there are forest types where fire rotations remain much longer than pre-settlement estimates (Rollins and others, in preparation).

Topography and vegetation apparently had a strong effect on 20th century fire frequencies. In both wilderness areas, ponderosa pine and Douglas-fir PVTs had the highest 20th century fire frequencies (fig. 3). This supports evidence from Swetnam and Dieterich (1983) and Swetnam and Baisan (1996) that indicates these forest types had the highest fire frequencies, based on dendroecological evidence of pre-20th century fire. Open, ‘parklike’ ponderosa pine stands are common in both wilderness areas. These stands are maintained by frequent, low-severity fires that prune lower branches and suppress the growth of woody understory vegetation.

Elevation, slope and aspect are all important landscape-scale factors that determine fire patterns over landscapes. Our analyses show that elevation, slope and aspect affected 20th century fire frequency in both wilderness areas. In the GALWC, the highest fire frequencies were found between elevations of 2,250 m and 2,525 m (fig. 3). At these elevations, forests were dominated by ponderosa pine stands that historically showed high frequencies of large, low-severity fire events (Abolt 1996; Swetnam and Dieterich 1983). These forests have been the focus of much of the Gila National Forest’s prescribed natural fire management. In the SBWA, 20th century fire frequencies are highest between 600 m and 1,760 m. These elevations correspond with forests dominated by combinations of ponderosa pine and Douglas-fir and have been shown to exhibit high fire frequencies historically (Barrett and Arno 1991; Brown and others 1994). Both wilderness areas showed higher fire frequencies on steeper slopes. Steeper slopes cause fire to spread faster (Agee 1993). The uphill movement of flaming fronts is aided by more efficient radiant heat transfer and convective air currents generated from downslope fire. In the GALWC, northern and northeastern aspects showed higher fire frequencies than would be expected based on the distribution of aspect across the landscape. South and southeastern aspects had higher fire frequencies in the SBWA.

These results support working hypotheses that during ‘climatically average’ fire years, fire regimes in the southern Rocky Mountains are dominated by spatial distribution of fuel structure and composition, while in the northern Rocky Mountains climate (at least levels of solar insolation) constrains fire patterns during years with average weather. These hypotheses will be described in an upcoming journal article. Future research will concentrate on incorporating data for existing vegetation and climate variables, along with the variables described in this paper, into regression-based models of potential fire frequency. These surfaces of potential fire frequency will be valuable for evaluating fire management strategies based on the restoration of fire as an

ecosystem process in Rocky Mountain forests. The results of this research are a preliminary step toward quantitatively determining the complex relationships between landscape characteristics and fire patterns.

Fire regimes over the last millennia have shaped the forests of the Rocky Mountains. Large wilderness areas, like the Gila/Aldo Leopold Wilderness Complex and the Selway-Bitterroot Wilderness Area, remain the only areas where evidence of this long-term series of disturbance and recovery may be found. Our research is a first step in developing statistical models of fire regimes in these wilderness areas. Understanding of ecosystem dynamics and response to change is needed to understand what determines the distribution, extent and location of fires and to guide decisions about forest management. Globally, large wilderness ecosystems are rare, and getting rarer. In the face of rapid, broad-scale landscape change, knowledge and predictability of ecosystem function are imperative.

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