TWENTIETH CENTURY FIRE PATTERNS IN THE GILA/ALDO LEOPOLD WILDERNESS COMPLEX NEW MEXICO AND THE SELWAY-BITTERROOT WILDERNESS AREA IDAHO/MONTANA

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ABSTRACT

We present results from ongoing research into 20th-century fire regimes in two large Rocky Mountain wilderness areas. Fire patterns are represented as digital fire atlases based on archival forest service data. We find that spatial and temporal fire patterns are variable in space and time and related to landscape features, climate, land use history, and changes in fire management strategies. This research provides contextual information to guide fire management in these (and similar) areas in the future.

INTRODUCTION

Federal Wildland Fire Management Policy identifies fire as a critical natural process. It mandates that fire be re-introduced into ecosystems, and recommends that fire be allowed to function as nearly as possible in its natural role to achieve long-term goals of ecosystem health. In order to satisfy the requirements of federal wildland fire policy, fire managers need baseline historical data on the role of fire in specific forest types and on specific landscapes (Kilgore, B. 1985, Morgan, P. et al. 1994, Landres, P. et al. 1999). This historical context is imperative for planning wildfire use at broad spatial and temporal scales, and for identifying areas (or forest types) of special concern. This paper summarizes results from ongoing research into fire regimes in the Gila/Aldo Leopold Wilderness Complex, New Mexico and the Selway-Bitterroot Wilderness Area, Idaho/Montana. The majority of the research described in this paper is contained in Rollins, M. et al. (1999).

Little is known about spatial and temporal patterns of fire regimes in many forest types, and the scarcity of these data limits the understanding of modern fire patterns and landscape response in any historical context. This lack of knowledge also hinders efforts to assess the long-term consequences of fire management strategies that involve both wildfire use and fire suppression (Kauffman, M. et al. 1994, Jensen, M. and Bourgeron., P. 1994). Fire frequency has been documented in many fire history studies (Heinselman, M. 1973, Arno, S. 1980, Swetnam, T. 1993, Swetnam, T. and Baisan, C. 1996), but little is known about fire extent or spatial patterns. Our data, while limited to larger (>50 ha) fires in the 20th-century, encompass two study areas 791,137 ha and 486,673 ha in size, allowing broad spatial and temporal analyses. With mandates for managing federal lands with an ecosystem perspective, spatial information on the range of natural variability (Morgan, P. et al. 1994, Landres, P. et al. 1999) in key ecological processes like fire becomes all the more critical.

A consequence of these management goals is an increasing demand for disturbance history and disturbance ecology information in wilderness areas and elsewhere. Important research questions include: What effects do physical features of landscapes have on fire patterns? Are there different fire frequencies in similar vegetation types at different topographic positions? Is variability over time in the extent and frequency of fires due to climate, fire suppression, or other factors, and are these relationships constant within and between regions? Are late 20th-century fire patterns anomalous? This research seeks answers to these questions.

STUDY AREAS

The Gila/Aldo Leopold Wilderness Complex (GALWC) is a 486,673 ha area in west-central New Mexico (Figure 1). The complex is composed of the Gila Wilderness Area, the Aldo/Leopold Wilderness Area, The Gila Cliff Dwellings National Monument, and some non-wilderness portions of the Gila National Forest. Elevations range from 1300 m near the main stem of the Gila River to 3300 m in the Mogollon Mountains.

Vegetation at the lowest elevations is best characterized as desert scrub. As elevation increases, piñon/oak/juniper woodlands gain dominance. Extensive stands of ponderosa pine are found at middle elevations, with a shift toward Douglas-fir around 2,300 m. At upper elevations, forests are comprised of mixed stands of Englemann spruce, blue spruce, subalpine fir, southwestern white pine, white fir, and aspen.

Fire season in the GALWC begins in April and extends through September. The GALWC is dominated by low-severity surface fire regimes with mixed-severity regimes found at upper elevations (Swetnam, T. and Dieterich, J. 1983, Abolt, R. 1996). The Gila Wilderness Area has the highest level of lightning fire occurrences in the United States with an average of 252 fires per million acres per year (Barrows, J. 1978).

The Selway-Bitterroot Wilderness Area (SBWA) is a 547,370 ha wilderness area in north-central Idaho and west-central Montana (Figure 1). The area is characterized by extremely rugged terrain with broad topographic variation. Portions of the wilderness are found on the Bitterroot, Clearwater, and Nez Perce National Forests.

Figure 1. Study areas

The northwestern portion of the wilderness is distinguished by diverse, Pacific maritime forests with assemblages of western red cedar, western hemlock, western white pine, and Douglas-fir ranging from 500 m to 1500 m. At elevations around 1000 m forests in the central, southern, and eastern portions of the SBWA are dominated by ponderosa pine/Douglas-fir, forests. As elevation increases, these assemblages convert to mixed Douglas-fir/Englemann spruce / grand fir forests followed by subalpine forests containing assemblages of Englemann spruce /subalpine fir with lodgepole pine and whitebark pine dominant on dryer sites and sites with relatively recent disturbance.

Fire season in the SBWA begins in the early summer and extends through September. Fire regimes are mixed, with infrequent, patchy, stand-replacement fire dominant in upper elevation forests and frequent, lower severity, understory fire at lower elevations. Stand replacement fires are dominant across all elevations during seasons with extreme weather (Brown, J. et al. 1994, Barrett, S. and Arno, S. 1991).

METHODS

Twentieth century fire perimeters were obtained in digital form (or digitized) for each area from archival data at the Gila, Clearwater, Bitterroot, and Nez Perce National Forests. Forest Service fire archives were compiled from fire reports or operational fire perimeter maps.

Data for topography and potential vegetation were obtained from the USDA Forest Service Intermountain Fire Sciences Laboratory in Missoula, Montana (Keane, R. et al. 1998, Keane, R. et al. 1999). Topography is represented by two compiled sets of USGS 7.5 minute digital elevation models. From these, we derived elevation, slope, and aspect surfaces using Arc/Info GIS software.

Potential vegetation types 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, S. et al. 1991). Classifications of potential vegetation are based on qualitative and quantitative analysis of geographic location, field data, topography, local productivity, and soil characteristics.

Area burned over time was analyzed for both wilderness areas and reported as proportions of each study area. Area burned and 20th-century fire frequency for each wilderness were summarized by topography and potential vegetation using Arc/Info GIS software. We compared area burned over time with compiled time series Palmer Drought Severity Indices (PDSI) for each wilderness from Cook, E. et al. (1999).

RESULTS

Archival mapped fire perimeters extended from 1909 to 1993 in the GALWC and from 1880 to 1996 in the SBW (Figure 2). Mapped data indicated that 147,356 ha had burned in 232 fires in the GALWC and 474,237 ha in 437 fires 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. Size distributions of fires followed a negative exponential distribution in both wilderness areas. These are similar to size distributions found in other research involving mapped fire perimeters (Minnich, R. 1983, McKelvey, K and Busse, K., 1996, Baker, W. 1989). 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 SBW was 1,153 ha with a minimum of 2 ha and a maximum of 52,223 ha (the largest patch from the 1910 fires). Median fire size was 135 ha.

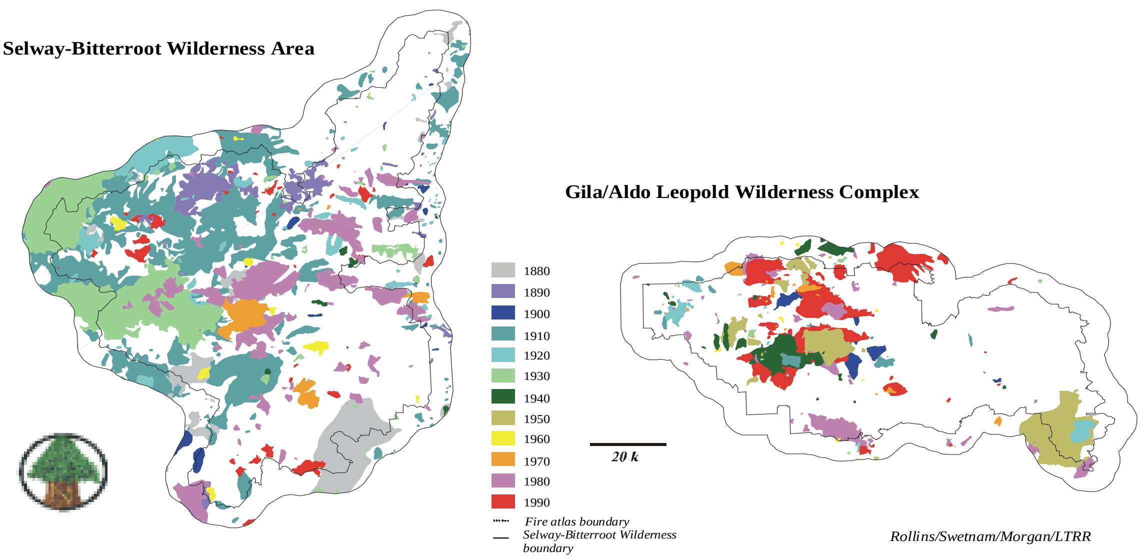

Figure 2. Fire atlases from the Selway-Bitterroot Wilderness Area and Gila/Aldo Leopold Wilderness Complex. Fire years are colored by decade. Data were provided from the Gila, Bitterroot, Clearwater, and Nez Perce National Forests. Figure from Rollins, M. et al. 1999.

Area burned was highly variable from year to year in both wilderness areas with discernible periods of different fire patterns over the 20th-century (Indicated by vertical dotted lines in Figure 4). The size and shape of individual mapped fires over time show evidence of these same periods in each wilderness (Rollins, M. unpublished data).

Graphical analysis of re-burn patterns over the landscape indicate that 20th-century fire frequency is associated with potential vegetation, elevation, slope, and aspect.

The majority of area burned in the GALWC was at mid-elevation ranges, but shifted toward lower elevations from 1980 to 1993 (Figure 3). In the SBWA there was a weak trend from high elevation fires at the beginning of the century to low elevation fires toward the end of the century (Figure 3). Areas with the highest fire frequency in the GALWC were found between 2100 m and 2500 m. In the SBWA, areas with the highest fire frequency were found between 660 m and 1260 m. Areas of highest fire frequency were skewed toward higher slope classes in both wilderness areas. In the GALWC northeastern aspects burned most frequently, while southeast aspects burned less than expected based on the distribution of slope across the landscape. Southeast and southwest aspects burned more frequently in the SBWA. 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; with this relationship grow-

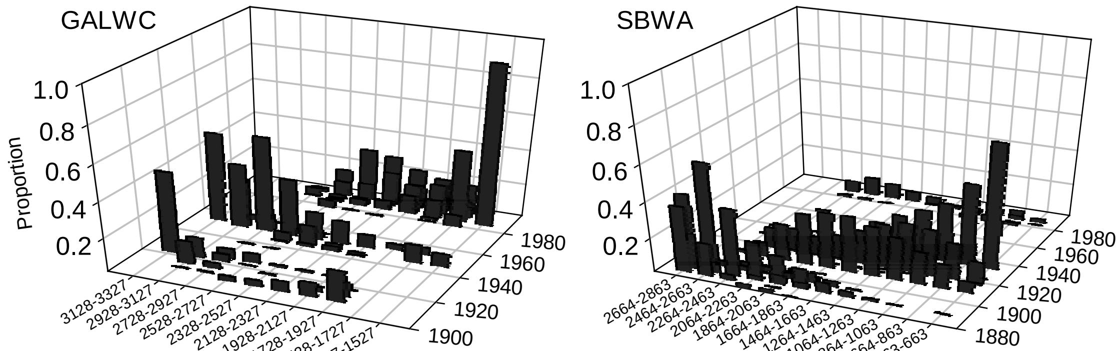

Figure 3. Area burned by elevation, by year for each study area. Areas are plotted as proportions of area burned each year for direct comparison between years. Figure from Rollins, M. et al. 1999.

ing 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 (Figure 4). Chi-square analyses indicate that these patterns are statistically significant.

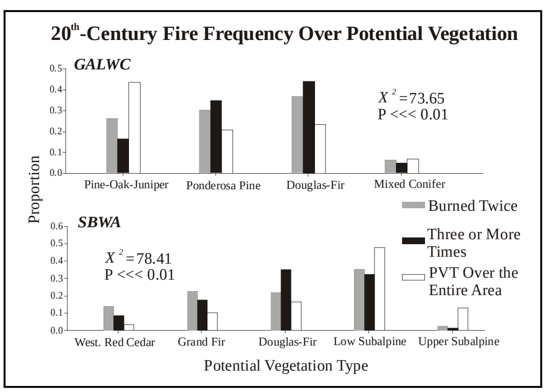

Figure 4. Twentieth century fire frequency over potential vegetation. Values are plotted as proportions of totals for direct comparison. Figure from Rollins, M. et al 1999.

In both wilderness areas the largest fire years corresponded with the years with PDSI below zero (dry conditions, Figure 5). Large fire years, in general, followed periods where conditions were moist. Recent years in the GALWC were an exception, with two of the largest fire years occurring during the wettest years in the 20th-century.

DISCUSSION

Both the GALWC and the SBWA experienced large amounts of fire in the 20th-century. The temporal and spatial patterns of burning may be described both historically and ecologically. Each wilderness area experienced different climate patterns, land-use, and fire suppression over the century.

The 20th-century time-series may be divided into distinct periods in each wilderness (indicated by dashed lines in Figure 5). In the GALWC little area burned from 1909 through 1942 (Figures 2, 3, and 5). Area burned during this time was low compared with estimates of fire extent during the pre-settlement period from Swetnam, T. (1983) and Abolt, R. (1996). This may be the result of a reduction of fine fuels by overgrazing by domestic cattle in the late 19th-century through the early 20th-century (Swetnam, T. and Dieterich, J. 1983, Savage, M. and Swetnam, T. 1990, Abolt, R. 1996). This reduction in fire frequency continues through the present on heavily grazed landscapes (Swetnam, T. and Baisan, C. 1996). At the turn of the century Rixon, T. (1905) reported that the area encompassing the current Gila National Forest was carrying too many sheep and cattle. The levels of grazing were reduced dramatically following the creation of the Gila Wilderness Area in 1924. The continuing decline in area burned after 1935 is clearly due to aggressive fire suppression. Swetnam, T. and Dieterich, J. (1983) report that frequent (10-15 year fire return intervals) fires over 1200 ha were common in the ponderosa pine forests of the Gila Wilderness during the 17th, 18th, and 19th-centuries, and have suggested this as a goal for wildfire use. While some fire sizes were in this range, the number of fires of this size during the 20th-century was relatively low.

PDSI values from 1909 through 1935 were moderate and showed little variability (Figure 5), this may also account for lower area burned. From 1942 through 1958 New Mexico experienced the worst period of prolonged drought since 1580 (Swetnam, T. and Betancourt, J. 1998). This period is associated with a

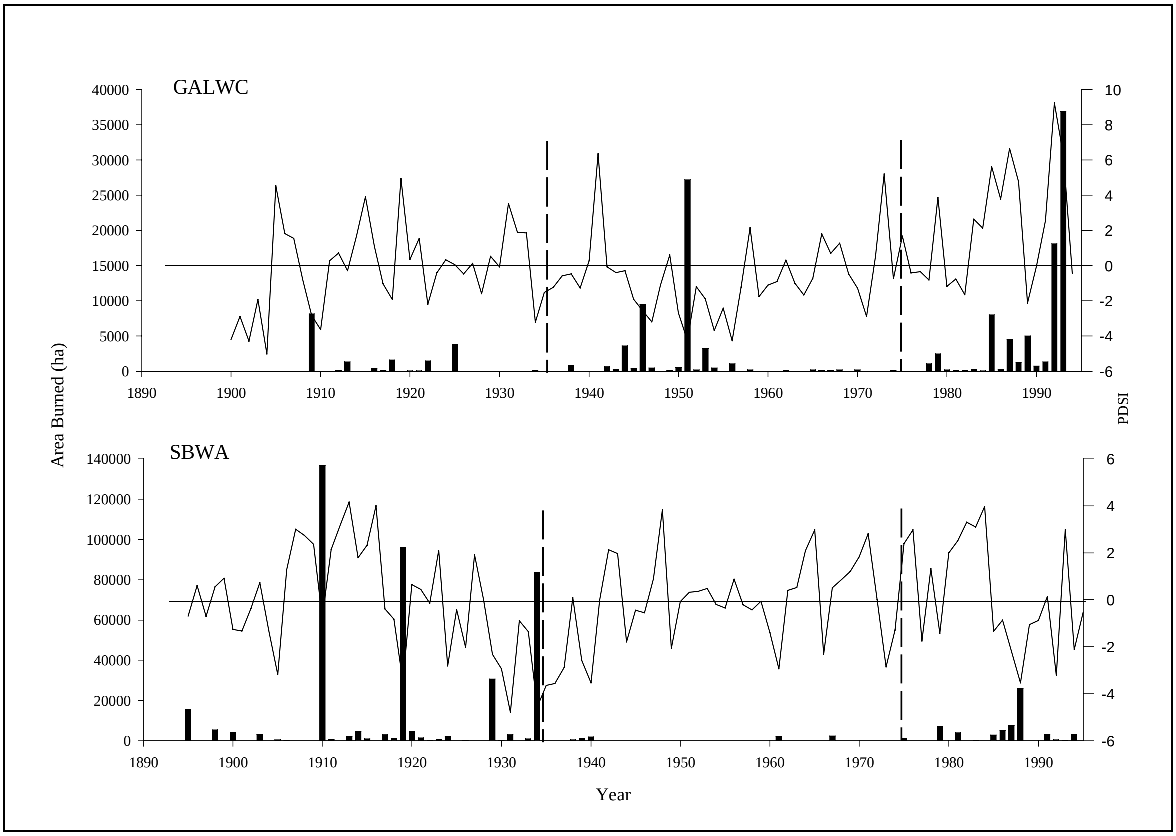

Figure 5. Area burned in each wilderness (bars) plotted over Palmer Drought Severity Index (solid lines). Dashed lines indicate time periods delineated based on levels of fire suppression in each wilderness. Figure from Rollins, M. et al. 1999.

large increase in the amount of burning and size of fires in the GALWC. The 1946, 1951, 1953 and 1956 fire years all are among the largest fire years and correspond with the driest years during the drought. Advances in fire suppression technology were first implemented in the GALWC in 1948 with aerial reconnaissance and suppression operations common by the mid-fifties. Aggressive suppression efforts appear to have reduced the amount and rate of burning in the GALWC from 1958 through 1975. Overall this was a moderately dry period (Figure 5). Since 1975, with the implementation of wildfire use, the amount and rate of burning increased dramatically even though yearly conditions were the wettest in the 20th-century (Figure 5). Area burned in ponderosa pine forests has approached pre-settlement values during recent years, while fire was largely absent at higher elevations. Notable exceptions are the 1995 Sprite Fire and the 1996 Lookout/Langstroth Fire complex that burned in the upper regions of the Mogollon Mountains. These fires were not included in the fire atlas for this paper.

Area burned in the SBWA was high in the late 19th-century and early 20th-century (Figures 2, 3, and 5). These large fires may have been due to ignitions from Native Americans, miners, trappers, or loggers; but the preponderance of evidence indicates that these large fire events were a natural part of fire regimes in the Northern Rocky Mountains (Habeck, J. and Mutch, R. 1973, Arno, S. 1980, Brown, J. et al. 1994, Barrett, S. and Arno, S. 1991, Barrett, S. 1995, Morgan, P. et al. 1995). Unlike the GALWC, grazing was not prevalent in the SBWA. While the east- facing slopes of the Bitterroot Mountains and low-elevation benches along the Selway River experienced moderate grazing from the mid-1800s to the early 1900s, the main portions of the SBWA were so remote that little, if any, grazing occurred. Large fire years early in the 20th-century occur during dry years (Figure 5). Annual area burned in the SBWA was reduced dramatically after 1935, with few mapped fires from 1935 to 1975. This may be due to a lack of personnel for observing remote fire events during World War II, and an extended period of aggressive fire suppression after World War II. After 1950 there were aerial fire depots at Grangeville, Idaho and Missoula, Montana that served as headquarters for smokejumper operations, aerial reconnaissance, and aerial fire retardant application. There is little variability in PDSI from 1935 to 1975 relative to the early 20th-century (Figure 5). Extended periods of drought from 1925 to 1940 and from 1984 to 1992 may be associated with periods of large fire occurrence, especially in moist forest types. The increase in area burned during recent years may be due to extended drought (Figure 5) or the implementation of wildfire use. Fire rotations during recent years remain much longer than fire rotations before 1935 (Rollins, M. unpublished data). As Brown, J. et al (1994) found, much less area has burned recently than earlier in the century, especially at high elevations.

Regional climate has been shown to be related to multi-century fire occurrence in the southwestern United States (Swetnam. T. 1988, Swetnam, T. and Betancourt, J 1990, Swetnam, T. and Betancourt, J. 1998, Grissino-Mayer, H. and Swetnam, T. 1999). Barrett, S. et al. (1997) also suggest that drought and fire episodes may be related in the Northwestern United States. We found this to be true in both wilderness areas. Dettinger et al. (1998) have described a north-south 'seesaw' in precipitation with a pivot centered at 40°N. Instrumental PDSI from the SBWA and GALWC may show this pattern. In the GALWC the large fire years in the 1940s and 1950s corresponded to the lowest, and most sustained PDSI values since the 16th-century (Swetnam, T. and Betancourt, J. 1998). During these years the SBWA showed normal to above average moisture levels (Figure 5). In the SBWA the large fires in 1889, 1919, 1934, and 1988 were all notable drought years. Conversely, the 1910, 1919, the 1980s, and 1990s in the GALWC were quite moist.

There are exceptions to the relationship between drought and area burned. In the GALWC during the 1980s and 1990s PDSI values were relatively high, indicating moist conditions, while area burned was also notably high. This may be explained by the timing of precipitation in the Southwestern United States, and by the implementation of wildfire use. The majority of annual precipitation in the GALWC is generated during either late summer orographic storms generated from moist air masses moving up from the Gulf of Mexico, or frontal storms during winter months. The moist conditions in the eighties and early nineties created favorable conditions for the growth of grasses, herbaceous forbes, and other understory fine fuels. The period from 1975 through the present has had the highest occurrence of El Niño years in the 20th-century, and possibly the last 200 years. The large fire years in these recent years burned almost entirely in mid-elevation ponderosa pine forests during dry springs, and were managed as prescribed natural fires. When these fires moved toward higher elevations they ceased spreading due to moist conditions in upper elevation forests.

Landscape characteristics apparently had a strong effect on 20th-century fire frequency. The analyses presented here will strengthen future modeling efforts to investigate past and potential fire patterns in each wilderness. Potential vegetation, elevation, slope, aspect, and climate all affected local fire frequency. These relationships showed key similarities between wilderness areas.

In the both wilderness areas, ponderosa pine and Douglas-fir potential vegetation types (PVTs) had the highest 20th-century fire frequencies (Figure 4). This supports evidence from Swetnam,T. and Dieterich, J. (1983), Swetnam, T. and Baisan, C. (1996), and Abolt, R. (1996), Barrett, S. and Arno, S. (1991) and Brown, J. et al. (1994) indicating these forest types as having high fire frequencies based on dendroecological evidence of pre-20th-century fire.

In the SBWA shrubfield and western red cedar PVTs all had higher fire frequencies than would be expected with a random distribution (Figure 4). The shrubfield PVT is found on steep hillsides above the Selway and Lochsa Rivers. These shrubfields were thought to have been created and maintained by severe fires in the late 19th and early 20th-centuries (Barrett, S. 1991).

Topography is the most important landscape component in fire behavior (Agee, J., 1993). Elevation, slope, and aspect all affected fire frequency patterns in the GALWC and SBWA. In the GALWC the highest fire frequencies were found between elevations of 2100 m and 2500 m. These elevations have been the focus of much of the Gila National Forest wildfire use programs. Conversely, higher elevations dominated by mixed-conifer forests have burned less frequently than would be expected under a natural fire regime (Abolt 1996). Managing fire in these forests is difficult because fuel loads have accumulated over years without fire, and large, high severity fires are a risk. The majority of fires at these elevations are suppressed, especially if fire weather is extreme. Figure 3 shows that the majority of area burned from 1942 to 1958 is at higher elevations than more recent fire (1980 to 1993). This may be a result of dry conditions during the 1940s and 1950s leading to more severe, stand-replacing fires in mixed-conifer forests during these years. The 1951 McKnight fire was perhaps the most severe fire in the history of the Gila National Forest, and was, until recently, the largest fire on record in the Southwestern

United States. The shift in area burned toward lower elevations between 1980 and 1993 may be due to increased fine fuel production during these wetter years in combination with wildfire use programs implemented by the Gila National Forest. In the SBWA 20th-century fire frequencies are highest between 660 m and 1260 m (Figure 3). High elevation fires are infrequent in the SBWA, and have become rarer with time (Figure 3, Brown, J. et al. 1994). The majority of high elevation fires are suppressed during dry years, which have been common since the mid-1980s. This may be contributing to a decline in whitebark pine forest habitats in the SBWA and surrounding forests (Keane, R. and Arno, S. 1993).

Although elevations with high fire frequencies differed between the two wilderness areas, vegetation communities found at these different elevations are quite similar. Vegetation type has been described as a general indicator of fire regimes (Agee, J. 1993). Elevation may be a local factor that mediates the ignition potential of storms, affects precipitation, and local moisture status.

Both study areas showed higher fire frequencies on steeper slopes. This was expected based on the physics of fire behavior. As flaming fronts move up steeper slopes, radiant heat is emitted closer to available fuels and pre-heats fuels more efficiently. The uphill movement of flaming fronts is aided by convective air currents generated from downslope fire. Uphill pre-heating and convective air currents influence the conversion from low intensity surface fires to high intensity, crown fires. In the GALWC north and northeastern slopes burned more frequently than south-facing slopes. In the SBWA southern slopes burned more often. Aspect and slope influence local moisture status. In general, steeper south-facing slopes are the driest while northeastern slopes are more mesic (Agee 1993). Moisture status, soil condition, and energy balance all contribute to site productivity, leading to variable fuel loads and conditions with topography. In general, north and east-facing slopes are more productive. In the GALWC these slopes may have burned more frequently because fine fuel production was higher and contributed to fire spread. In the SBWA, dominated by mixed and high-severity fires, south-facing slopes may have burned more frequently because higher insolation levels dried larger fuels more thoroughly. Topographic shading and local site productivity may have made discerning fire-aspect relationships quite complex. A combined slope-aspect coverage, or an aspect coverage that includes topographic shading may prove to be a better choice for empirically defining fire-slope-aspect relationships.

CONCLUSION

This paper summarized spatially explicit, time series data for 20th-century fire patterns; and graphically portrayed key relationships between 20th-century fire patterns, topography, vegetation, and climate in two large, Rocky Mountain wilderness ecosystems. The results of this research are a preliminary step toward empirically understanding the complex interactions between landscape characteristics and fire patterns. Fire patterns in each wilderness varied over the period of record with most of the area burned in a few large fire years. Area burned over time appeared to be related to drought status and land-use in both areas. Topography, vegetation, and weather were related to 20th-century fire frequency; with ponderosa pine forests and mid-elevation, warm, dry, steep slopes burning the most frequently. Results were similar to fire regime characteristics in both wilderness areas previously described in dendroecologically based, multi-century fire history research and analysis of 20th-century fires in other areas.

Our research is a first step in developing statistical models of fire regimes in these wilderness areas. We hope to show that broad-scale, comparative studies like these are a valuable way to test for the validity of extrapolating interpretations from landscape-scale modeling. Spatially explicit, empirical evidence of pattern-process relationships will be valuable in future process-based modeling of potential fire regimes with predicted climate change. This 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.

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