Margot Wilkinson-Kaye
Thomas Swetnam
Christopher R. Baisan

Chapter 5.

Borderlands Fire Regimes

Introduction

Fire is a keystone process in most natural, terrestrial ecosystems. The vital role that fire plays in controlling the structure of an ecosystem underscores the need for us to increase our knowledge of past and current fire regimes (Morgan and others 1994). Dendrochronological reconstructions of fire histories provide descriptions of past fire regimes across a range of spatial and temporal scales (Baisan and Swetnam 1995; Swetnam and Betancourt 1991; Swetnam and Dieterich 1985).

The historical fire regimes of the Borderlands ecosystem can be examined across broad spatial scales, from regional to local. Such cross-scale perspectives are needed because local scale patterns were embedded within regional scale patterns. These patterns are summarized by Swetnam and Baisan (1996), who compiled a network of 63 fire-scar chronologies from the Southwestern United States and demonstrated that fire recurrence was highly synchronous across the region and associated with interannual fluctuations in wet and dry conditions. Comparisons of individual fire histories revealed high variability in fire regime properties, such as fire frequency that were due primarily to local-scale influences such as vegetation composition, topography, or historical human impact. Hence, the influence of climatic variability on fire regimes was most evident at the coarse, regional scale, while the influence of other factors was most evident at the fine, local scales.

Climate and Study Area Information

Dendroecological sites in southern Arizona are distributed throughout the basin and range topography that extends from the Colorado Plateau to the Northern Sierra Madre Mountains. The sites are predominantly in upper-elevation, forested areas. These mountain islands, referred to as the Madrean Archipelago, are depicted as forested peaks surrounded by a shore of oak woodlands and a sea of semidesert grasslands. The regional climate is semiarid with a bimodal pattern of precipitation distributed between the summer and winter months.

The typical fire season occurs in the late spring or early summer, prior to the onset of the summer monsoon rain (Baisan and Swetnam 1990; Barrows 1978). High lightning incidence, accumulated dry vegetation, high ambient temperatures, and low relative humidity combine to create optimum fire conditions in a window from about late May to early July.

Regional Fire History Study

Fire-scar based fire history reconstructions for the Borderlands area were compiled from the University of Arizona Laboratory of Tree-Ring Research's database (Swetnam and Baisan 1996), and descriptive statistics were computed for these chronologies for the period 1700 to 1900 (table 5.1 and fig. 5.1). These fire-scar chronologies have been grouped into five broad forest and woodland types: mixed-conifer (MC), a combination of Douglas-fir, white fir, and pine; ponderosa pine (PIPO); pinyon/juniper (PJ); and oak (OAK). These groups were based on the dominant overstory trees in the sites from which the fire-scarred samples were taken. The Mean Fire Interval (MFI) and the Weibull Median Probability Interval (WMPI) are measures of central tendency of the fire interval. A fire interval is considered the number of

Fish, Paul R.; Fish, Suzanne K.; Madsen, John H. 2006. Prehistory and early history of the Malpai Borderlands: Archaeological synthesis and recommendations. Gen. Tech. Rep. RMRS-GTR-176. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 112 p.

Table 5.1. Site information and fire-interval statistics for fire histories in and around the Borderlands ecosystem.

Number on map	Site	Mountain range	Species[a]	Elevation range in ft	WMPI[b]	Min-max. fireinterval	Standard deviation
1	Lemmon Peak	Sta. Catalina	MC	8,750-8,960	7.9	2–17	4.8
2	Rose Canyon	Sta. Catalina	PIPO/MC	7,000–7,600	7	2–16	3.8
3	Mica Mountain	Rincon	PIPO/MC	6,790–8,530	6	2–13	2.7
4	Josephine Saddle	Santa Rita	Pine/Oak	6,800–7,200	7.9	3–21	4.2
5	Sierra Ajos	Sierra Ajos	Pine/Oak	6,890–7,218	5.1	2–11	2.5
6	Camp Point	Pinaleno	MC	7,546–9,600	8.7	2–26	6.5
7	Peter's Flat	Pinaleno	MC	9,200–9,450	8.9	3–22	5.3
8	Rhylite Canyon, Middle	Chiricahua	PIPO/MC	5,920–6,300	14.2	4–50	11.4
9	Rhyolite Canyon, Upper	Chiricahua	PIPO/MC	6,800–7,000	12.2	4–31	6.7
10	Rhyolite Canyon, Lower	Chiricahua	Pine/Oak	5,600–5,920	8	1–17	4.6
11	Castle Creek	Mogollon Rim	PIPO	8,000–8,200	6.8	1–14	3.3
12	Thomas Creek	Mogollon Rim	MC	8,300–9,200	8.3	1–24	7
13	McKenna Park	Mogollon	PIPO	7,640–7,800	5.5	1–16	4.2
14	Gilita Ridge	Mogollon	PIPO	8,300–8,300	7.2	3–28	6.8
15	Black Mountain	Mogollon	PIPO/MC	8,400–9,300	5	1–20	4.5
16	Langstroth Mesa	Mogollon	PIPO/MC	7,800–8,400	4.5	1–22	3.8
17	Bearwallow	Mogollon	MC	9,000–9,600	14.4	2–32	10.9
18	Narrows	Organ	PIPO/PJ/Oak	7,000–7,300	9.5	3–21	6.5
19	Fillmore Side Canyon 3	Organ	PIPO	7,200–7,800	13.5	4–23	5.6
20	Ice Canyon	Organ	PIPO	7,500–7,800	23.8	7–35	10.8
21	Fillmore Side Canyon 1	Organ	PIPO	7,200–7,500	8.8	2–23	6.2
22	Ledge Site	Organ	PIPO	7,800–7,900	19.7	12–27	5.3
23	Snag Saddle	Organ	PIPO	7,800–8,000	18.7	9–27	8.1
24	Fillmore Side Canyon 2	Organ	PIPO/MC	7,200–,7700	8.7	2–23	7.3
25	Upper Fillmore West	Organ	PIPO/MC	7,800–8,200	3.4	1–23	4.1
26	Animas Peak , North	Animas	PIPO	8,000–8,400	11.9	3–36	11.1
27	Animas Peak, South	Animas	PIPO/MC	8,000–8,100	12.6	2–32	9.3

[a]MC = mixed-conifers, PIPO = ponderosa pine (*Pinus ponderosa*), PJ = pinyon-juniper. These designations refer to the dominant overstory tree species. All fir□

[b]Weibull Median Probability Interval.

years between two successive fire occurrences (Romme and others 1980). The MFI is the average of all fire intervals within a specified area and designated time period (Romme and others 1980). WMPI is the estimated fire interval at which there is approximately a 50 percent probability of a longer or a 50 percent probability of a shorter fire interval occurring as computed by fitting a Weibull type model to the fire interval distribution (Grissino-Mayer 1995).

Swetnam and Baisan (1996) found that in general, historical fire frequencies decreased with increasing elevation and associated forest and woodland types. Fires burned at increasing intervals along the gradient from the lower pinyon-juniper, oak, and ponderosa pine cover types to the higher mixed-conifer sites. However, tremendous variability in fire frequency existed due to unique site characteristics, including topography and especially land-use history. This variability precludes any predictive generalizations of fire regimes based solely on forest or woodland type (as defined) or elevation. There was a tendency for slightly shorter fire intervals in ponderosa pine and mixed-conifer forests than in pure ponderosa pine stands. This may have been due to higher productivity in the more mesic sites that resulted in a more rapid buildup of fuels.

Despite the large variability of fire regimes at local scales, remarkable synchrony in fire events across the Southwestern region occurred during the pre-European settlement era. Swetnam and Baisan (1996) compared large and small regional fire years with a reconstruction of the Palmer Drought Severity Index (PDSI). A regionalized PDSI for the Southwest was computed by averaging 13 grid point time series to a single time series that represents an annual drought magnitude fluctuation from AD 1700 to 1978 (Cook and others 1996). Small fire years (those with few fire-scar sites recording fires) were significantly correlated with years of above-average moisture, and large fire years were significantly correlated with years of below-average moisture. Additionally, there was a lagged relationship between the prior year's

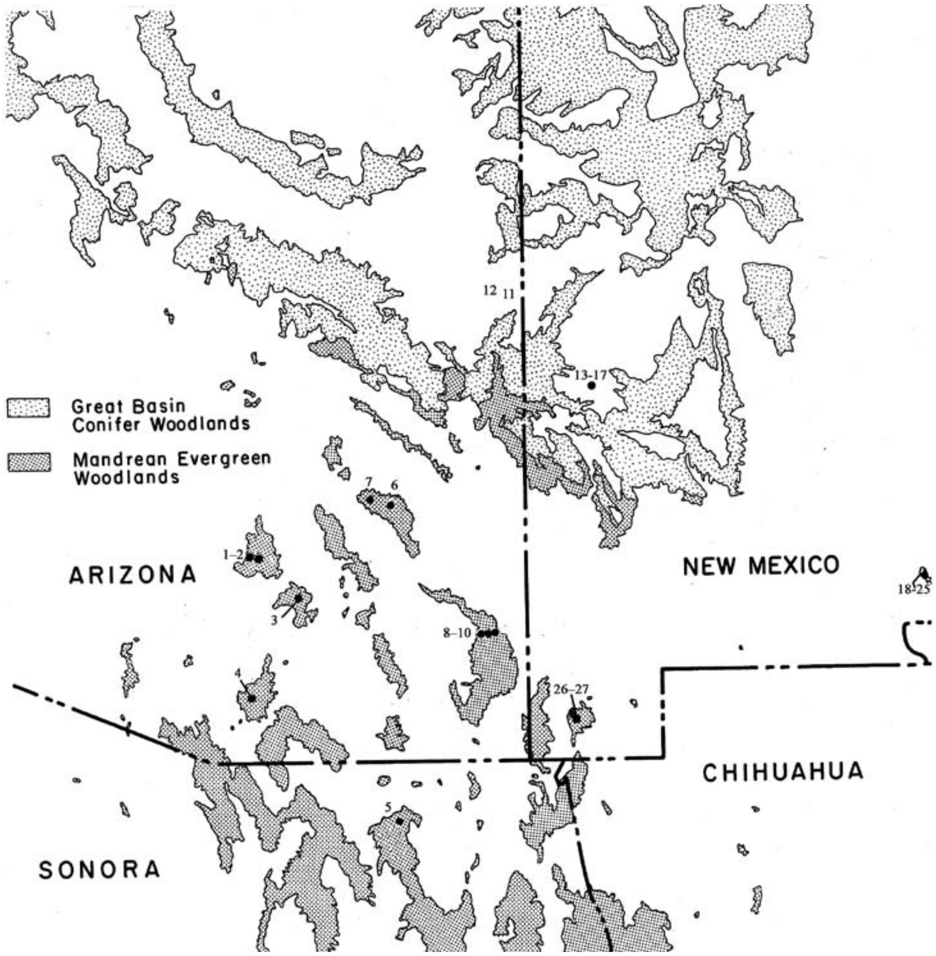

Figure 5.1. Site locations for fire history reconstructions. Numbers relate to information in table 5.1.

climate values and large fire years in many ponderosa pine stands. Large fire years often occurred during drought years that were preceded by 1 to 3 years of above-average moisture conditions. The underlying mechanism behind this lagging relation was attributed to fine fuel (grasses, needles, herbs) buildup during the years of high precipitation. Hence, a severe drought year following 2 or 3 wet years resulted in optimal burning conditions with an abundance of dry fuels. In contrast, comparison of regional fire years in mixed-conifer forests with the PDSI time series showed that large fire years depended only on extremely dry conditions during the fire year itself, with no important prior-year effects of climate. This suggests that fuel production was not limiting, but rather the key factor was dry fuels.

The regional comparison of fire dates reveals that local variations in fire regimes are embedded within large-scale patterns controlled to some extent by climatic variation. Although regional generalizations can be made, local-scale fire histories indicate that topographic, vegetative, and historical land-use characteristics determine the range and variability of fire regimes.

Local Fire History Reconstructions

Six studies from the Borderlands mountain ranges provide examples of variances in fire frequencies due to site-specific characteristics. The variability in fire regimes was associated with variability in vegetation composition, topography, and land-use history. The studies include: Rhyolite Canyon, the Rincon Mountains, the Pinaleno Mountains, and the Huachuca Mountains in southeastern Arizona, the Animas Mountains in southwestern New Mexico, and the Sierra de los Ajos Mountains in northern Mexico. Each study provides information on historical, spatial, and temporal fire patterns in the Borderlands region. When combined, these studies provide a large-scale picture of the role fire played in the area's prehistory.

Rhyolite Canyon

Rhyolite Canyon drains a major watershed in the Chiricahua National Monument, on the northwestern side of the Chiricahua Mountains, Arizona. Mixed-conifer and oak woodlands are found on north-facing slopes and in canyon bottoms of the valleys, and evergreen xerophytic plants of interior chaparral are found on the south-facing slopes. The fire-scarred species used to reconstruct the fire history in Rhyolite Canyon were ponderosa pine (*Pinus ponderosa*), Apache pine (*Pinus engelmannii*), and Chihuahua pine, (*Pinus leophylla* var. *chihuahuana*) Thirty-three samples were used to create the 380-year fire chronology, which was separated into three periods: 1604 to 1801, 1801 to 1851, and 1851 to the beginning of large-scale grazing by livestock and the onset of active fire suppression (Swetnam and others 1992).

The synchrony of fire scars from 1604 to 1801 indicated that fires generally spread throughout the canyon with a Mean Fire Interval (MFI) of 14.6 years and a range of 9 to 22 years. Slightly higher fire frequencies at the upper and lower elevations of the canyon compared to the fire frequency in the middle portion of the canyon suggested that not all fires burned throughout the whole canyon. Lightning likely started many high elevation fires, some of which spread down into the canyon, and grass fires probably also spread from the lower elevation. The regular fire regime found in the 17th and 18th centuries came to an abrupt end in 1801. There was an absence of fire scars in the upper and middle canyon for the next 50 years. This gap from 1801 to 1851 was anomalously long and was unusual compared to most other Southwestern fire history reconstructions in pine forests (Swetnam and Baisan 1996). Swetnam and others (1989) hypothesized that a flood or debris flow within the canyon was responsible for this gap. Tree-ring samples from flood-scarred trees along the canyon bottom support this interpretation.

In the second half of the 19th century the fire frequency exceeded that of the pre-1801 regime. The highest frequency was found in the lower canyon with a MFI of 6.0 years and a range from 3 to 9 years. Swetnam and others (1992) suggest that evidence of Apache occupation during that time may explain the high fire frequency. The possible role of fires ignited by Native Americans is discussed later in this chapter.

The fire history of Rhyolite Canyon was highly variable. The long interval in the early 1800s suggests that geomorphic events (floods and debris flows) may have been important interactions with resettlement fire regimes with Borderlands riparian canyons. Sources of fire ignition and the spread into these canyons include both high elevation conifer forests and low elevation grasslands and woodlands.

Rincon Mountains

The Rincon Mountain Wilderness is within the Saguaro National Monument in southern Arizona. Baisan and Swetnam (1990) combined modern fire and lightning records, analysis of fire-scarred trees, and historical accounts to reconstruct a fire history in the Wilderness area. The study focused on the fire regime of Mica Mountain above 2,134 m (7,000 ft). In the study area the slopes with northern aspects support a mixed-conifer vegetation type. The higher elevation south-facing slopes host a ponderosa pine/southwestern white pine (*P. strobiformus*) community referred to in this study as an "open pine forest" with a grassy understory and a number of small meadows interspersed. Lower elevations with south-facing slopes support pine communities with species of evergreen oak. Forty-nine samples, most from ponderosa pine and southwestern white pine (*Pinus strobiformus*), were used to reconstruct the fire history.

The fire history reconstruction showed that fires were probably large; fire dates recorded by fire-scarred trees were synchronous over the entire Mica Mountain study area, encompassing several thousand hectares. This may be due to the lack of topographic fire barriers within the study area. The MFI for the entire Mica Mountain study area was 6.1 years. The mixed conifer sites had a MFI of 9.9 years. The presence of quaking aspen (*Populus tremuloides*) stands indicates that high-intensity, stand-replacing fires have played a role in the mixed-conifer system. Quaking aspen rapidly colonizes openings in the landscape caused by fires. In the mixed-conifer stands, patchy, high-intensity, stand-replacing fires combined with the frequent low-intensity, surface fires to make a more dynamic fire regime in open pine forest.

In contrast to Mica Mountain, Rincon Peak showed more evidence of large-scale crown fires in mixed-conifer vegetation. Modern ignition records show that Rincon Peak was subject to less frequent, natural ignitions than Mica Mountain. The less frequent ignitions resulted in long periods without fire during which fuels accumulated. When an ignition did occur, the resulting fires were probably larger and more intense. This demonstrates the highly variable nature of fire regimes within a given vegetation type due to site-specific characteristics.

Despite the variation in fire occurrence between the sites, the areas sampled showed a period of no fires lasting at least 10 years in the first half of the 1800s. One area showed a 19-year fire-free interval from 1822 to 1841.

Baisan and Swetnam (1990) compared large fire years with a PDSI reconstruction. Large fire years were often associated with years of moderate drought that, more importantly, had been preceded by 2 to 6 years of above-normal moisture conditions. As previously discussed, this pattern has also been found in a coarser scale analysis of the entire Southwestern region fire history database (Swetnam and Baisan 1996).

The last large fire was in 1886. This abrupt change in fire frequency coincided with the removal of the Apaches from the area and the increased land use by Anglo and Hispanic settlers. Baisan (1990) found no evidence that the fire frequency in the Rincon Mountains was elevated due to fires ignited by the Native Americans. The incidence of lightning ignitions, based on 20th century records, appeared to be high enough to account for the fire frequencies observed in the presettlement period.

Pinaleno Mountains

Mt. Graham in the Pinaleno Mountains in southeastern Arizona is a rich area for investigating multiple and interacting roles of forest disturbance, climate, and land-use history. Ninety fire-scarred samples from two mixed-conifer sites were analyzed for the fire history reconstruction, and 291 samples from adjacent spruce-fir sites were analyzed for stand age structure (Grissino-Mayer and others 1995). The mixed-conifer sites had a MFI of 4.2 years before 1880. This is the shortest mean fire interval yet found in mixed-conifer sites studied in the Southwestern United States and is similar to the MFI commonly documented in presettlement ponderosa pine stands. Historical fires in mixed-conifer stands on Mount Graham are thought to have been low-intensity, surface fires that spread over at least 400 ha due to few topographic barriers. The sharp decline in fire occurrence around 1880 found in the fire-scar record coincided with a rise in grazing in the area.

Based on the stand age-structure of the spruce-fir site and the fire history from the adjacent mixed-conifer site, Grissino-Mayer and others (1995) suggest that a stand-replacing fire burned through the spruce-fir area around 1685. This was a year of widespread fires in the two mixed-conifer sites. Following the fire, Engelmann spruce (*Picea engelmannii*) dominated the stand and corkbark fir (*Abies lasiocarpa* var. *arizonica*) regenerated in smaller numbers. Corkbark fir then experienced a pulse of recruitment in the 1840s. Grissino-Mayer and others (1995) suggest this recruitment may have been partly due to extended drought conditions and the superior ability of corkbark fir to establish in low-light, closed canopy conditions.

Dendroclimatological comparisons between drought and fire occurrence showed a relationship between fire events and severe drought events. These fire events were often preceded by several years of above-average moisture conditions (Baisan and Swetnam 1995; Swetnam and Baisan 1996).

Comparison of the fire history from the mixed-conifer stands and the stand age structure of a spruce-fir stand shows that fires only rarely spread from the mixed-conifer into the spruce-fir forest. Fires in the spruce-fir forests were rare and stand replacing when they did occur. Frequent, low-intensity fires probably maintained the stability of both the mixed-conifer and spruce-fir stands. The frequent surface fires in the mixed conifer probably kept the forest open and parklike, and therefore less susceptible to high- intensity, stand-replacing burns. The proximity of these open mixed-conifer forests may have also preserved the spruce-fir forests for long periods because high-intensity crown fires sweeping up from lower elevations were unlikely to spread through the crowns of the mixed-conifer stand. Conditions have now drastically changed on Mount Graham. Closed canopy forests extend from the pine through the mixed-conifer zone on the mountain, threatening red squirrel habitat and astronomical observatories with catastrophic fire.

Huachuca Mountains

A fire history covering the last five centuries is currently being reconstructed for the area surrounding Pat Scott Peak, located at the boundary between Fort Huachuca Military Base and the Miller Peak Wilderness Area in the Huachuca Mountains in southeastern Arizona (Danzer n.d.). Overstory vegetation of the study area consists mainly of ponderosa pine, southwestern white pine, and Douglas-fir (*Pseudotsuga mensiezii*), with an understory of gambel oak (*Quercus gambelii*) and alligator juniper (*Juniperus deppeana*). The fire chronology is based on fire-scar samples from 33 trees and spans the period from A.D. 1499 through 1993.

The period from 1700 to 1899 was used for analysis of fire frequency because of the limited sample depth prior to 1700 and the lack of recorded fires after 1899. Fire interval statistics were analyzed separately for three periods: 1700 to 1899, 1700 to 1806, and 1807 to 1899. In addition, the fire frequency was calculated for three classes of fires. The first class included all fires that were recorded by the sampled trees. The fire data were then "filtered" by including only those fires that were recorded by less than 10 percent of the trees (interpreted to be small or spatially patchy fires) and by 20 percent of the trees (interpreted as large) (table 5.2). Fire interval statistics indicate that two types of fires were common in the area: small fires burned at an interval near 3 to 6 years, and less frequent, widespread fires burned at intervals from 7 to 9 years.

The effects of landuse on the fire regime of Pat Scott Peak were easily distinguishable by the end of the 19th century. Following 1874 few surface fires occurred, and by 1914 they were completely eliminated. The last

Table 5.2. Mean Fire Interval (MFI) statistics for three periods and three classes of fires at Pat Scott Peak, Huachuca Mountains, southeastern Arizona (Danzer n.d.b).

Class of Fire	MFI 1700 to 1899	MFI 1700 to 1806	MFI 1807 to 1899
All fires recorded	3.2	3.5	2.7
10% filtered	6.5	6.4	6.7
20% filtered	8.5	9.9	7.3

widespread fire occurred in 1899, and may have been due to the excessive buildup of fuels associated with the previous 25-year absence of fires. This drastic decrease in fire frequency was attributed to grazing, logging, and fire suppression activities associated with the growing population of settlers in the area (Danzer n.d.).

Animas Mountains

A fire history reconstruction in the Animas Mountains in New Mexico provides evidence of a mixed surface fire/crown fire disturbance regime for the range (Baisan and Swetnam 1995). The complex topography of the area resulted in a mosaic of plant communities determined largely by elevation and aspect. Coniferous forests are found on northeast-facing slopes and in mesic canyons. The fire history reconstruction in the conifer forests provided a unique insight into the interactions of fuels, vegetation, topography, and land-use history.

A combination of the rough topography, the heterogeneous vegetation, and the limited ignition sources for the Animas range resulted in occasional stand-replacing fires and episodic surface fires in the area. This fire regime was interrupted in the first half of the 20th century when the USDA Forest Service had jurisdiction of the range and practiced active fire suppression. The conifer forests of the Animas Mountains support a fire regime characterized by both frequent, low-intensity fires and occasional stand-replacing fires. Site-specific characteristics have overridden it with a more dynamic, mixed-fire regime.

Sierra de los Ajos Mountains

The Sierra de los Ajos Mountains are in northern Sonora, Mexico. The upper elevations of these mountains support conifer forests. In contrast to the Animas Mountains, the Sierra de los Ajos have a fire regime that is representative of the typical ponderosa pine forest type, with a MFI of 5.4 years. The Sierra de los Ajos have the unique characteristic of a continuous fire history throughout the 20th century. These mountains have not experienced disruptive fire control and intensive grazing characteristic of the mountain ranges north of the United States-Mexican border.

Human Influence on Fire Histories

The four major human influences on natural fire regimes in the Borderlands region in recent centuries have been the use of fire by the Native Americans, livestock grazing, logging and fuelwood harvest, and fire suppression. Although not all of these latter factors were influential upon the fire regimes during the prehistory of the Borderlands, they have all had an effect on our ability to understand the natural role of fire in forested systems.

Lightning versus Human Ignitions

Generally, it is difficult or impossible to completely distinguish between natural and human-caused ignitions in the historical record. Morgan and others (1994: 104) point out that "only the results of fire can be observed, not their causes." The 20th-century records showed that lightning strikes were common in the Borderlands mountain region. In addition, historical records showed that Native Americans used fire on the landscape. These two types of ignitions left identical physical scars on trees. It was thought that one of the only ways to discern between the two types of ignitions was to look at any changes in fire frequency. In some cases this may have been possible. Exceptionally inflated fire frequencies in the 18th century in the Organ Mountains, New Mexico, compounded with historical records documenting the presence of Apaches near the collection sites, and the documentation of the use of fire on the landscape by these Apaches, suggested that the Native Americans may have had an influence on the 18th-century fire regime (Morino, personal communication). Swetnam and others (1989) suggest that high fire frequencies following 1851 may be a result of Native Americans setting fire to the landscape. In other cases, variations in fire frequencies and evidence of fire ignitions by the Native Americans followed no clear pattern (Baisan and Swetnam 1990; Danzer n.d.).

Ignition sources for landscape fires was not a limiting factor in the Southwestern United States. In addition, an ecosystem generally has a particular capacity to burn, which, in the arid Southwest, is primarily determined by fuel amount and fuel moisture conditions. This meant that no matter how frequently the Native Americans ignited fires or how frequently lighting ignitions occurred, fuel had to be present and weather cooperative.

Post-1900 Influences on Fire Regimes

Hispanic and Euro-American settlers began to have an impact on the fire regimes of the Southwestern United States by the end of the 19th century when they brought large numbers of livestock to the area. The intense grazing of the animals in grass-covered areas altered the amounts of fuels available for burning. Logging practices also had an important impact on the composition of the forests, and the logging roads interrupted the connectivity of the forest and the fuels. Active suppression of fires by forest managers, which began in the first half of the 20th century, put an abrupt end to fire occurrence in many natural, forested areas in the United States.

Human impact on fire regimes has taken many forms. Native American use of fire over the landscape may have resulted in inflated fire frequencies. In contrast, grazing, logging, and fire suppression resulted in decreased fire frequencies.

Conclusions

Our review of climate trends from the perspective of tree-ring data from the Borderlands region and the discussion of departures from regional patterns, coupled with fire history preserved in fire-scarred, living trees, snags, and logs, have been the basis of our fire-regime review. Information about ignition sources, fire perimeters, and intensity of fires was not directly recorded. We must look to the Principle of Uniformity and assume that processes that occurred in the past were similar to those that occur now. Current fire behavior shows us how fires may have behaved in the past. This extrapolation, combined with the fire interval information reconstructed in fire histories, allows us to paint a general picture of past fire regime characteristics. In the case of the Borderlands, multiple fire history reconstructions have given us information on the historic fire regime for several of the mountain ranges in the area. The individual studies show the importance of site-specific factors, but general patterns in fire regimes can also be found. Stability in the upper-elevation pine and mixed-conifer forests in the mountain ranges surrounding the Borderlands was maintained by moderate- to low-intensity fires burning at moderate to high frequencies. Cultural influences have been shown to be both variable and site and time specific.